MEAT: An Authoring Tool for Generating Adaptable Learning Resources

Yen-Hung Kuo and Yueh-Min Huang
Department of Engineering Science, National Cheng Kung University, No.1, University Road, Tainan City, Taiwan
Tel: +886-6-2757575 ext. 63336 // Fax: +886-6-2766549 // keh@easylearn.org // huang@mail.ncku.edu.tw

ABSTRACT

Mobile learning (m-learning) is a new trend in the e-learning field. The learning services in m-learning environments are supported by fundamental functions, especially the content and assessment services, which need an authoring tool to rapidly generate adaptable learning resources. To fulfill the imperious demand, this study proposes an authoring tool named Mobile E-learning Authoring Tool (MEAT) to produce adaptable learning contents and test items. In addition, the visualized course organization tool has also been provided to teachers to organize their teaching courses. All functionalities of the MEAT are designed according to the teachers’ feedback and their technological learning needs. To evaluate the MEAT, we have conducted an extensive comparison between the MEAT and other (adaptation) content authoring tools. The result indicates the MEAT is the only tool, which can produce adaptable contents and test items while supporting learning standard. In addition to technical comparison, the qualitative feedbacks from teachers and students are also shown in the evaluation section, and result points out the advantages and shortcomings of the MEAT. According to our findings, we have summarized some design principles for readers who are interested in designing e-learning applications. It hopes our precious experiences can inspire readers to develop more valuable learning tools.

Keywords
Adaptable learning materials, Adaptable test items, Authoring tool, Learning map design, Mobile learning

Introduction

Owing to the proliferation of e-learning, the content production becomes a great deal, which aims at satisfying the learning demands of distance learners. In addition, with advances of mobile technology, the learning demands may also come from mobile devices, and that increases the complexity and difficulty of the content production. To deal with the diversified demands, an authoring tool is needed by content creators to produce adaptable learning resources. To fulfill the imperious demand, an authoring tool named Mobile E-learning Authoring Tool (MEAT) was conceived in this work; for it contains adaptable content and test item generation abilities, user-friendly learning design functions, and intuitional GUIs. Except for advantages hereinbefore, the produced contents of MEAT are Sharable Content Object Reference Model (SCORM) conformable learning objects, which have high interoperability and reusability, and a Learning Map Design Tool has also been provided by MEAT to assist teachers with systematically organizing of their course structures in the SCORM Sequencing and Navigation (SN) form (ADL, 2006).

In 2005, Simon et al. summarized three authoring types of adaptable content generation approach, which are introduced in following (Simon et al., 2005).

- **Multiple Authoring**: The Multiple Authoring generates multiple versions of content to fit each specific electronic device used by learners to access course content. Contents which are generated by the Multiple Authoring approach have better exchangeability among learning platforms as well as higher management costs.
- **Single Authoring**: The Single Authoring provides a single source code implementation of the user interface that is valid for all devices. In addition, it is a feasible way to generate adaptable learning content, but its functionalities and design usually depend on the supported markup language interpretation.
- **Flexible Authoring**: The Flexible Authoring freely combines the Multiple Authoring and the Single Authoring technologies to produce adaptable learning materials. With the Flexible Authoring, content creators can create truly adaptable content by taking into account a wide variety of different factors and circumstances.

In this work, authors have implemented the Flexible Authoring approach in the MEAT, including the Multiple Authoring approach in the content authoring functionalities and the test item generation functionalities handled through the use of the Single Authoring. Based on such an implementation, the content creators can design fully interoperable custom creations without markup language restrictions. Since the format of test items is fixed, the Single Authoring method is used for test item generation functionalities, allowing items to be easily reorganized and
reducing maintenance costs. The contents and test items produced by MEAT are the adaptable learning materials, which can be learned by learners with any device at anytime and anywhere, and that is why the MEAT could contribute to m-learning field.

In this study, authors intend to share the experience of the MEAT development, which consists of technical aspect issues and encountered problems of engagement. An extensive comparison with other authoring tools and the academic evaluations were also conducted in this article to reveal the usability of the MEAT. Based on our findings, we have summarized a series of authoring tool design guideline, and we hope these valuable experiences can help other developers in mobile learning area.

Mobile E-learning Authoring Tool

There are three major roles that must play in the authoring environment to produce the learning content. These are learning designer, programmer, and artist. In the authoring environment, the learning designer bases on the goal of instruction to select a proper way to design the learning scenario and content, and the productions of this phase of development are usually limited to descriptive text. The programmer is then providing technical support according to the requirements of the content and scenario, and several software components and tools are produced along with this production phase. Meanwhile, the artist focuses on embellishing the learning interface by using appropriate images and layout designs. Subsequently, all productions in previous phases are well organized as the learning contents (organization of the content structure), which also further be arranged in a fitting manner based on the learning designer’s previous experiences (organization of the course structure, such as SN). While the learning contents being conducted on Learning Management System (LMS), the formative assessments are also utilized to determine the current state of the learner’s understanding. The assessment result then can be treated as the useful feedback for content evolution and refinement. The entire instructional content development process can also refer to rapid prototyping supported by ADDIE (Analyze, Design, Develop, Implement, and Evaluate) model (Molenda, 2003). Most often, teachers fill all three roles in the authoring environment. The great advantage of the MEAT is taking care of the most complicated technological functions for teachers. Consequently, the MEAT frees up teachers’ precious time, which can then be devoted to content improvement or other tasks. The functionalities of the MEAT are shown in Figure 1, and details will be introduced in following sub-sections.

![Figure 1: The functionalities of MEAT](image)

Transformation functions

From the content authoring aspect, material transformation is an essential preprocessing work that aligns different formatted materials to predefined formats. In our case, the accepted image format is JPEG, and the multimedia audio...
and video files are transformed to streaming. In this work, we have expended the most effort on transforming slide-typed lectures, which happens to be the most popular electronic teaching medium in universities. We transformed each slide to a JPEG image without preserving the animations on the slide. This not only captures the snapshots of slide but also extracts all slide texts, which enables the system to automatically generate a preview of information of the slide for students. Using the preview information, students can get an abstract of the slide, and they can then decide whether or not it is worth studying according to their demands.

Figure 2: Synchronized adaptable learning content on different devices. Notice that the images in mobile devices support the zoom in/out function for students to check details of images (see the leftmost two images of Fig. 2c)
Synchronization functions

According to Dual Coding Theory (Tan et al., 2003), learning efficiency is enhanced by engaging both visual and verbal learning, and therefore, to synchronize multimedia and static learning materials is an important task. The Synchronization functions consist of a tool set to assist teachers to synchronize streaming (audio and video) and static learning materials (slides, web pages, FLASH), and for any synchronized learning object, its static materials would automatically play according to the associated time stamps of streaming. Figure 2 shows the synchronized adaptable learning content in different devices.

Figure 3: The snapshot of Post Synchronization in MEAT

Figure 4: The conceptual and virtual mapping of Extensible Time Stamp Indexing Model
Based on the synchronization types, the synchronization functions provided by MEAT can be classified into two categories: the Post Synchronization and the Real-time Synchronization. The two types of synchronization are similar and their main difference is the streaming sources. In Post Synchronization, streaming is sourced from pre-recorded audio/video, and during the synchronization process the teacher can search the stream to find a specific scene for synchronizing. This capacity to undertake a direct search in audio or video stream speeds up the synchronizing progress because there is not a 1:1 ratio between streaming time and the time needed for synchronization. In our experience, to synchronize a one hour lecture stream takes only about 10 minutes. Figure 3 shows the snapshot of Post Synchronization. Differing from Post Synchronization, Real-time Synchronization records the teacher’s lecture as a video stream when synchronizing. Since Real-time Synchronization course is continuous, it takes 1:1 time to produce the lecture video, which is the limitation of Real-time Synchronization. Nevertheless, the Real-time Synchronization still advances in teaching in classroom where teacher can teach while doing the Real-time Synchronization. After the class, the learning content is produced and ready for students. This efficient process indirectly improves students’ learning efficiency, thereby fulfilling the purpose of “Rapid e-Learning” (Archibald, 2005).

To precisely associate static materials with the correct time stamps of streaming is one of the major tasks in Synchronization phase. This study adopts the XML (Extensible Markup Language) (W3C, 2006) and XSLT (Extensible Stylesheet Language Transformations) (W3C, 1999) to implement an Extensible Time Stamp Indexing Model for instantly associating the static material with the correct streaming time stamp, in which users can add additional information with respect to static materials. Next paragraph defines the Extensible Time Stamp Indexing Model and explains how it works from an abstract conceptual perspective.

Let $M$ be an Extensible Time Stamp Indexing Model, which is characterized by a set of triplet $T = \{t_1, t_2, \ldots, t_n\}$, where $n$ is associated with the number of registered time stamps and $t$ is a set of meta-information of a specific time duration of given time flow $F (|F| = \text{length of streaming or time flow})$. For any triplet $t = \{id, s, e\}$, where the $id$ is an unique ordinal identification in $T$, the time stamp $s$ is a time index associated to a beginning of time duration, and the extension $e$ is a profile object, which collects a set of user-defined information to describe the corresponding static learning material, e.g. title and file location. It denotes the time duration of $t_i$ as $d_i$, where $d_i \subseteq F$. If $\mid T \mid = n$, the time duration $d_i (i = \{1, 2, \ldots, n-1\})$ can be distinguished by $(t_i[s] - t_i[s])$ and the last time duration of $d_n$ can be obtained by $(|F| - t_n[s])$. Given two time durations $d_i$ and $d_j$, where $i \neq j$, then $d_i \cap d_j = \phi$. Moreover, $\bigcup_{i=1 \text{ to } n} d_i \leq |F|$, because there is no restriction on $(t_i[s] = \text{beginning of } F)$. Figure 4 shows how to map the conceptual Extensible Time Stamp Indexing Model to virtual one. Considering Figure 4, the left hand side shows the conceptual Extensible Time Stamp Indexing Model, where each block presents a triplet $t$ with respect to certain time duration of $F$. Subsequently, the right hand side of Figure 4 is a virtual xml file, which presents the mapping result of conceptual view. Notice that the real implementation of Extensible Time Stamp Indexing Model is similar to the Virtual view of Figure 4, but some differences exist between them, e.g., tag names are different and the model structure is not exactly equal.

![Image](https://example.com/image.png)

**Figure 5:** The Seek algorithm

```plaintext
Input: $p$ is a time point;
      $T = \{t_1, t_2, \ldots, t_n\}$ is a set of triplet.
Output: A triplet $t$, which duration includes $p$.

Algorithm Seek($p, T$)
1. if $t_i[s] \geq p$
2. return $t_i$ /*out of range*/
3. if $t_i[s] \leq p$
4. return $t_i$
5. for $i \leftarrow 1$ to $n-1$
6. if $t_i[s] \leq p$ and $t_i[s] > p$
7. return $t_i$
```

Generally speaking, when playing the learning streaming, the static materials would be displayed accordingly. However, in online asynchronous learning, the students usually seek the streaming for a specific purpose (seeking
inconsistency) and navigate directly to a certain material by skipping previous lectures (skipping inconsistency). These behaviors usually create inconsistency between the streaming and the static materials, and therefore a remedial operation is required to correct this. To correct the skipping inconsistency is relatively easy, as it can be corrected by setting the navigated material as the present one. Furthermore, the seeking inconsistency can be corrected by Seek algorithm (see Figure 5). In Seek algorithm, the input $p$ is the new seeking time point, $T$ is the set of triplet of $M$, and the output is the correct triplet $t$, which satisfies $t[x] \leq p < t[x] + d$, where $d$ is the duration of $t$ ($t$’s duration includes $p$). The only non-trivial step is steps 5-7, which consist of an iteration to locate correct triplet $t$.

**Packaging functions**

The Packaging function is composed of three sub-functions: The Mobile Content Translation Module, The Metadata Editing Tool, and the SCORM Packaging Module. Following paragraphs will introduce how these three sub-functions cooperate to perform packaging task.

The Mobile Content Translation Module is responsible for generating mobile content according to the imported learning materials. In particular, the Mobile Content Translation Module analyzes the structure of learning materials and reconstructs a similar structure in mobile web pages. In order to deal with the image resizing work, the Mobile Content Translation Module also invokes Transformation Function to size down the images for rebuilding learning materials in a mobile manner. Following that, the Metadata Editing Tool provides a logical view of metadata for teachers to describe the (mobile) learning content, and the SCORM Packing Module then packaging the metadata file for producing a SCORM-compliant learning object. Hereinafter we summarize the selected parameters used to generate content for mobile devices.

- **Descriptive text**: The title and main text are extracted from slides and they are then presented on mobile devices by clear text-based form. It enables learners to read them by their preferred devices without taking into account the resolution issue.

- **Layout structure**: In addition to descriptive text, the original text layout structure (the nest structure, such as items and sub-items) is also reproduced into mobile-based content. Text items usually have the group relationships among themselves, and this parameter keeps the relationships in mobile content for illustrating the original meanings designed by creators.

- **Memorandum**: Memoranda are often added into slides as the detailed annotations or supplements for reminding instructors of important concepts in slides. Since the descriptions of memorandum are relevant to slide, they are also extracted from slides to mobile content.

- **Sequence of slide**: Based on the sequence of slide, the MEAT generates one index page (see the leftmost pictures of Figures 2b and 2c) to organize the mobile content. In addition, the page head and foot of each mobile content page has been added the hyperlink for navigating to next, index, and previous pages (see Figures 2b and 2c). Consequently, mobile learner can traverse among mobile contents via minimum clicks.

- **Snapshots of slide**: All snapshots of slides are generated and downsized to mobile manner. Owning to the main texts of slides has been extracted, the purpose of these snapshots are to provide the figured concepts (such as trend of a curve and so on) instead of the descriptive concepts.

The interoperability and reusability of learning object that conforms to the SCORM standard would be improved, and following the standard substantially reduces the cost of learning content reproduction. In order to conform to the standard, teachers have to fill in the fields of content metadata with the correct information. If the fields are not filled in correctly, the advantages of the standard are lost with the need to go through a lengthy authoring step. In actuality, with regards to early versions of MEAT, which only provided the complete SCORM metadata filling form (see Figure 6a), there was a feedback from teachers indicating that the metadata filling work was too lengthy, and consequently there were few teachers who filled it in. It has been noted that people tend to perceive what they are motivated to perceive – that which has either intrinsic or extrinsic value (Bruner, 1966). If Bruner is correct, we can assume that teachers did not complete the filling task because of costs associated with filling the enormous metadata fields exceeding the benefits of that, and the scale of the filling work obviously has to be reduced. To this end, we summarized the key fields from complete SCORM metadata according the necessary fields defined in SCORM (see Figure 6b). Henceforth, if a teacher does not want to fill in the complete metadata, she can have the alternative of filling in the summary one, and the change result in teachers’ appreciations.
Assistant functions

There are two assistant functions in the MEAT to help teachers accomplish further instructional tasks. The first is the Test Item Design Tool, which allows teachers to design test items for evaluating students’ statuses, and the second is the Learning Map Design Tool, which provides an intuitive interface for teachers to organize their teaching courses and test items. Details of the two functions are shown in following paragraphs.

The primary purpose of assessment is to provide teachers with an objective view of students’ status, and to enable teachers to determine whether or not students have sufficient proficiency to move on to the next level of learning (Tan et al., 2003). In addition, assessment results can also provide the valuable feedback to the teacher for indicating...
the suitability of the instructional style. Figure 7 shows the interface of the Test Item Design Tool, which supports the generation of types of adaptable (single authoring) multimedia test items such as true-false questions, multiple-choice, multi-select, blank-filling, and short-answer questions. These adaptable multimedia test items could be imported into the item bank of a learning platform, and the teacher could choose a set of items to be used as a test sheet for performing online and mobile based formative/summative assessments over the Internet. Figure 8 shows an adaptable multimedia test item on some different learning devices.

![Figure 7: The snapshot of the Test Item Design Tool](image1)

![Figure 8: The snapshots of adaptable multimedia test item](image2)

(a) Web-based (PC)  
(b) Mobile-based (PDA)

The organization of a meaningful learning map is an important task, one which can be achieved by SN. The SN defines learning activities and corresponding navigations by predefined conditional rules. Moreover, the teachers can design adaptive learning sequencing for students by manipulating the rules, and the students can access appropriate learning materials according to their actual learning level at any given time (ADL, 2006). However, teachers who are not familiar with the SN specification could not perform such task efficiently. In 2005, Chen et al. (Chen et al., 2005) incorporated Petri net into a fuzzy environment to model the learning map visually and transfer the visualized learning map to SN form. Their result indicates that Petri net is a feasible approach to bridge the gap between SN
specification and teachers’ level of expertise. In this work, authors have utilized the Petri net to implement a Learning Map Design Tool to assist instructors with course organizing tasks. Teachers who are interested in designing learning map can easily manipulate the user-friendly drag-and-drop interface of Learning Map Design Tool to organize their courses’ structures (see Figure 9).

Figure 9: The snapshot of the Learning Map Design Tool

Initially, the Petri net was developed by Petri (1962) as a mathematical representation to model the discrete distributed systems. Based on the high-level structure, Petri net can be utilized to present knowledge and complex systems. Moreover, the ease of visualization, one characteristic of Petri net, also facilitates the arrangement of learning objects in learning maps. With concrete perspective, the components of the Petri net are bipartite directed graphs, with two types of nodes: places and transitions. The places formed as circles are utilized to represent learning materials, the transitions formed as bars are registered as assessments with predefined thresholds, and the arcs formed as arrow lines are used to represent the interrelationships among the places and the transitions. In addition, the places in Petri net may associate with a token value to represent current Petri net status, and the token value can also be treated as learner token to trace and record learner’s status, portfolio, and personal profile (Chen et al., 2005). Based on learner token, the Petri net based learning map can then support adaptive learning to learners. Figure 10 shows an example of Petri net which developed by Chen et al. (2005). In Figure 10, a learner is now learning Content A. After completing Content A, if the learner passes the Assessment A, the Content B will then be taught to the learner (solid arrow line represents the static learning path) otherwise the Supplement to Content A will be activated (dotted arrow line registers the alternative learning path). As the result, the learner can acquire adaptive learning materials through the formative assessments and the well-organized learning maps.

Figure 10: An example of Petri nets
Design of manipulation process

The MEAT includes 16 different content authoring processes, 5 different test item generation processes, and 1 learning map design tool, for a total of 22 similar functions on the screen, which overwhelmed most of our pilot group of teachers. The pilot group indicated that about 8 items on a screen at a time is the upper limit. Members of the group also stated that they did not like irrelevant information or components on screen while authoring. A similar idea can be found in cognitive psychology theory, which states that the capability of people’s working memory (short term memory) is limited to between 5 and 9 pieces of information (chunks) being held in the working memory at a time (Tan et al., 2003). To overcome this problem, we have moved in the direction of developing a process, which can locate the system function efficiently and meet the teachers’ technological needs. Our main idea is to group similar functions and to adopt functions’ features as the keys to efficiently locate the proper function. In the first phase, we cluster similar functions into groups. After clustering, the content authoring group includes 16 functions, the test item generation group includes 5 functions, and the course management group has 1 function in it (the Learning Map Design Tool). At the end of the first phase, the test item generation group and the course management group were satisfactory and did not need further modification. In the second phase, we used a two layer learning material selection to locate the appropriate authoring function in the content authoring group. Figure 11 shows the grouped two layer selection process, in which teachers can follow the up to two steps of guidance to easily launch their desired authoring functions.

Evaluations

This section consists of two sub-evaluations, which are utilized to appraise the usability of the MEAT from both technical and academic perspectives. In the first experiment, we have conducted an extensive comparison between our authoring tool and other works in the first evaluation. In the second experiment, we have conducted a case study of nurse education in National Cheng Kung University Hospital in which we have surveyed the teachers and the nurses who involved in the online courses by using questionnaires. In addition, we have also summarized some potential weaknesses of the MEAT in the end of section.

Comparative analysis of authoring tools

To fairly evaluate the proposed tool, we have conducted the critical comparative analysis of authoring tools in this subsection. The qualitative comparison of authoring tools is quite difficult to be conducted in an objective manner. Therefore, only the objective technical criteria are chosen to analyze the comparison. Following part introduces the adopted criteria.
• **WYSIWYG**: The WYSIWYG stands for “What you see is what you get”. This design feature furnishes content creators with an intuitive view to develop their contents. Furthermore, the feature also saves lots of time from troublesome production checking, and the saved time can be further used to enrich learning contents.

• **Multimedia**: This criterion indicates the supported multimedia types of the authoring tool.

• **Content/Test Item Production**: This variable reveals the authoring tool’s ability of learning resource creation. In addition to the production resource types (content and test item), the resource execution environment is also taken into consideration (web/client based resource).

• **Adaptation**: This factor indicates whether the production (content/test item) of the authoring tool is adaptable to accommodate to different learning devices, such as desktop, PDA, cellular phone, and so on.

• **Course Organization**: The course organization function furnishes teachers with organization and management functions to arrange learning resources in a systematic manner. Particularly, suchlike function can assist teachers with producing learning maps or sequencings to learners, and these productions can be further applied to LMS for achieving adaptive learning.

• **Standard**: This variable shows the supported standards of the authoring tool, such as QTI, SCORM, and so on.

• **Client/Web**: This criterion indicates the execution environment of the authoring tool.

• **Purpose**: The design purpose of the authoring tool is determined by this criterion.

To guarantee the quality of the evaluation, eight authoring tools have been selected into this comparison. Since the information technology advances rapidly, only the relevant research works published within the recent five years could be considered as our comparative candidates. As the MEAT is introduced in this article, the other authoring tools and their features are briefly introduced below. Note that not each candidate has a name, and it assigns alphabetical ID to the unnamed candidates for identification.

• **IWiLL** (Kuo et al., 2004): This web-based authoring tool is integrated in the IWiLL learning system, and the aim is to create interactive multimedia contents for English learning. To shorten the content production process, movie clips and subtitles are transformed from DVD to online multimedia database, which allows teachers and content creators to insert multimedia into English learning contents and test items directly. With the supports from the tool, teachers can create content with their preferred design styles, and students can searching relevant contents by importing vocabularies.

• **A** (Simon et al., 2005): The authoring tool supports single authoring for producing adaptable web-based contents. Creators who are interested in authoring by the tool should understand XHTML (Extensible Hyper Text Markup Language). To visualize the XHTML, three device simulators (PDA, smart phone, and WAP phone) have been integrated in the authoring environment for preview.

• **Test Editor** (Romero et al., 2006): The Test Editor is designed for generating adaptable test items by single authoring approach. The generated test items are archived in a XML file, which are reusable and can be interpreted by test engines for assessment. In addition, both the adaptive and the classic linear tests are supported by the test engines.

• **FAÇADE** (Zhan & Kurz, 2005): This tool supports single authoring for adaptable web-based content creation. The FAÇADE framework is a context-aware adaptable tool for single-source web pages. Users with the authoring tool can author with a WYSIWYG graphical user interface, and then the corresponding XHTML for devices will be automatically generated.

• **B** (Wang et al., 2007): This study utilizes web 2.0 technology to design the rich-client authoring environment for creating learning contents which compatible with various e-learning standards without redundant efforts. When authoring with the tool, teachers can directly utilize available learning resources from backend server without pre-downloading into local host, and the index will be automatically made for connecting present authoring and external learning resources.

• **Mobile Author** (Virvou & Alepis, 2005): Mobile Author allows instructors to design mobile Intelligent Tutoring Systems (ITS), which contains mobile contents and test items by both mobile phone and desktop. In addition, each student’s learning behaviors are stored in the long term student model of ITS for adaptive learning.

• **HyCo** (García & García, 2005): The HyCo is an authoring tool introduced to facilitate the composition of hypertext, which are stored as semantic learning objects in backend database. The aim of the HyCo is authoring through a simple and extremely intuitive interface and interaction model. Following that, any teacher with a minimum computer background has the possibility of transforming his/her experience and knowledge into useful and quality hypermedia educational resources.
<table>
<thead>
<tr>
<th>Criteria/Tools</th>
<th>MEAT</th>
<th>IWILL</th>
<th>A</th>
<th>Test Editor</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WYSIWYG</strong></td>
<td>Supported</td>
<td>Supported</td>
<td>Not Supported</td>
<td>Not supported</td>
</tr>
<tr>
<td><strong>Multimedia</strong></td>
<td>PowerPoint</td>
<td>Multimedia</td>
<td>Image</td>
<td>Text</td>
</tr>
<tr>
<td></td>
<td>Web Page</td>
<td>Database</td>
<td>XHTML</td>
<td>Image</td>
</tr>
<tr>
<td></td>
<td>FLASH</td>
<td></td>
<td>VoiceXML</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Audio files</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Video files</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Audio recording</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Video recording</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Content / Test Item Production</strong></td>
<td>Web-based content production / Web-based test item production</td>
<td>Web-based content production / Web-based test item production</td>
<td>Web-based content production / No</td>
<td>No / Client and Web-based test item production</td>
</tr>
<tr>
<td><strong>Adaptation</strong></td>
<td>Flexible Authoring</td>
<td>No</td>
<td>Single Authoring</td>
<td>Single Authoring</td>
</tr>
<tr>
<td></td>
<td>Content (Multiple Authoring)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Test Item (Single Authoring)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Course Organization</strong></td>
<td>Learning Map Design Tool</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Standard</strong></td>
<td>SCORM</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Client/Web</strong></td>
<td>Client</td>
<td>Web</td>
<td>Client</td>
<td>Client</td>
</tr>
<tr>
<td><strong>Purpose</strong></td>
<td>Generation of adaptable learning contents and test items</td>
<td>Generation of English learning contents</td>
<td>Generation of adaptable web-based interfaces</td>
<td>Generation of adaptable test items</td>
</tr>
<tr>
<td><strong>Criteria/Tools</strong></td>
<td>FAÇADE</td>
<td>B</td>
<td>Mobile Author</td>
<td>HyCo</td>
</tr>
<tr>
<td><strong>WYSIWYG</strong></td>
<td>Supported</td>
<td>Not supported</td>
<td>Not supported</td>
<td>Supported</td>
</tr>
<tr>
<td><strong>Multimedia</strong></td>
<td>Images</td>
<td>Learning Object Repository</td>
<td>Text Image</td>
<td>Multimedia database</td>
</tr>
<tr>
<td><strong>Content / Test Item Production</strong></td>
<td>Web-based content production / No</td>
<td>Web-based content production / No</td>
<td>Web-based content production / Web-based test item production</td>
<td>Web-based content production / No</td>
</tr>
<tr>
<td><strong>Adaptation</strong></td>
<td>Single Authoring</td>
<td>No</td>
<td>Single Authoring</td>
<td>No</td>
</tr>
<tr>
<td><strong>Course Organization</strong></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Standard</strong></td>
<td>No</td>
<td>SCORM</td>
<td>No</td>
<td>LOM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IEEE LOM</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>TW LOM</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Client/Web</strong></td>
<td>Client</td>
<td>Web</td>
<td>Web</td>
<td>Web</td>
</tr>
<tr>
<td><strong>Purpose</strong></td>
<td>Creation of adaptable web pages</td>
<td>Generation of general learning contents</td>
<td>Generation of adaptive mobile contents and test items.</td>
<td>Generation of general learning contents</td>
</tr>
</tbody>
</table>

Based on the selected criteria and authoring tools, Table 1 summarizes the comparative analysis result. Among the comparative candidates, only our tool can produce both adaptable learning contents and test items while supporting content exchange standard. In addition, the MEAT is the only tool which provides visualized user-friendly course organization function.

From implementation perspective, the authoring tool can be implemented as client-based or web-based tool. With the client-based tool, it has richer and friendlier user interface, and the generation process can be done at local host.
without Internet connection. However, authors with client-based authoring tools usually have to manage the duplicate learning resources both at local host and on LMS, and the external learning material support is also relative weak due to its lack of good integration with LORs (Learning Object Repository) or external (multimedia) backend databases. Opposite to the client-based authoring tool, the web-based authoring tools are usually implemented as a portion or function of entire LMS or LOR. Suchlike integral design allows authoring tool to directly upload its production to databases and also to make links between present design and existing learning resources. Moreover, thanks to advances of Internet and Web 2.0 technologies, web-based authoring tools provide friendlier user interface than before, however some sophisticated functions such like real-time recording are still difficult to implement. The major weakness of web-based authoring tool is that the requisite of Internet accessing. With that, two problems are derived. One is teachers cannot do authoring without Internet connection, and the other is the authoring process would be interrupted by an accidental Internet disconnection. Especially for the latter problem, the tool should provide recovery function to avoid data and status losing. The MEAT is a kind of the client-based authoring tool. While designing the MEAT, we believed that a decent tool must be platform-independent, giving more design flexibility and reliability when teachers authoring with it.

Case study: Nurse education

The MEAT was introduced to facilitate teachers who do not have computer science background to create learning contents and test items with both web and mobile based settings. To reveal the usability of the MEAT, in this subsection we introduce the case study of online nurse education in National Cheng Kung University Hospital (NCKUH).

Since the nurses in NCKUH work with the three-shift workday system, the regular training course is not applicable to this case. However, the nurse training programs and assessment are necessary in hospital, and the assessment result is one of the important criteria of promotion. In this situation, Nurse Department recorded all lectures as VCDs as the asynchronous learning contents for nurses who cannot attend at regular classes. In addition, the Nurse Department has to arrange a proper time to perform nurse assessment. In particular, it is quite difficult to practice assessments since nurses who took the same course may not have the same available time to participate in the examination event. Until two years ago, the Nurse Department of NCKUH decided to choose e-learning as the solution to train and assess nurses. The selected LMS is ANTS (Agent-based navigational training system), which was developed by Jeng et al. (2005), and the MEAT was chosen by Nurse Department as the authoring tool. In the training program, each nurse can choose the courses she needs, and then she can obtain the certifications from Nurse Department if she passed the online assessments. In the nurse training site, all contents and test items are provided by instructors and produced by MEAT. Until now, there are 19 courses and 483 test items available on the ANTS for nurse education.

To reveal the usability of the MEAT, we have surveyed 13 instructors and 583 nurses (students) involved in the training program by questionnaires. Table 2 shows the surveyed results from the instructors. All instructors thought they can easily find out the wanted functions without strenuous training and manual by their side. 61.5% of the instructors believed that synchronization function is easy to manipulate. However, some instructors indicated that there are too many controllable components on the synchronization panel, which let the instructors who first engaged in authoring feel disoriented and fall into the difficulty of information overload (Eppler & Mengis, 2004). All instructors appreciated the summarization of complex SCORM standard and agreed that it is easy to operate the authoring tool through the step-by-step authoring process. In terms of the produced learning contents, teachers thought the web-based contents are better than the mobile-based contents. Nevertheless, they appreciate that the MEAT can produce the acceptable mobile-based contents without paying extra efforts and the productions can be learnt by students in mobile manner. More than half teachers (53.85%) thought the Test Item Design Tool is easy to manipulate. However, some teachers indicated that after several times of engagement, they finally understood the tool can produce different types of test items at a time. We believe there are two reasons to cause this situation: 1) the lack of hints on the test item switch panel and 2) teachers do not need (frequent) switch panel among functions since teachers usually design the same type of test items at a time. Based on the evaluation result of test item, most teachers thought the web-based one is satisfactory (61.55%) but they did not agree that the overall condition of the mobile assessment is good enough for assessing nurses. According to the instructors’ opinions, they mentioned that they worried about that the unstable mobile network may interrupt the assessment progress and the delayed transmission of test items may harm students’ interests. Nevertheless, in terms of rehearsal, instructors still approved
the convenience of mobile-based assessment and they encouraged us to pay more efforts to complete the insufficient parts. In our survey, all instructors did not use the Learning Map Design Tool in their teaching and therefore they cannot judge the academic value in either manipulation or production of Learning Map Design Tool. Their opinions revealed that they did not know what Learning Map Design Tool is and they thought it is not necessary to know when engaging in distance instruction. Finally, even though there is no instructor familiar with all functions of the MEAT, instructors still approved that the MEAT is easy to manipulate and has helpful advantages in e-learning resource production.

Table 2: Results of the survey questionnaire from instructors

<table>
<thead>
<tr>
<th>#</th>
<th>Question</th>
<th>Very approvable</th>
<th>Approvable</th>
<th>Neutral</th>
<th>Opposing</th>
<th>Very opposing</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>You can find out correct authoring function without hard practice and manual help.</td>
<td>2</td>
<td>11</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4.15</td>
</tr>
<tr>
<td>2</td>
<td>The engagement of learning content synchronization is easy.</td>
<td>1</td>
<td>7</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>3.54</td>
</tr>
<tr>
<td>3</td>
<td>Comparing to complete SCORM metadata, you prefer to fill in summarized SCORM metadata.</td>
<td>6</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4.46</td>
</tr>
<tr>
<td>4</td>
<td>The step-by-step learning content production process is smooth and easy to follow.</td>
<td>1</td>
<td>12</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4.08</td>
</tr>
<tr>
<td>5</td>
<td>The presentation of produced web-based learning content is satisfactory.</td>
<td>5</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4.38</td>
</tr>
<tr>
<td>7</td>
<td>The presentation of produced mobile-based learning content is satisfactory.</td>
<td>0</td>
<td>10</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3.77</td>
</tr>
<tr>
<td>8</td>
<td>The Test Item Design Tool is easy to manipulate.</td>
<td>1</td>
<td>6</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>3.54</td>
</tr>
<tr>
<td>9</td>
<td>The presentation of produced web-based test item is satisfactory.</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>3.85</td>
</tr>
<tr>
<td>10</td>
<td>The presentation of produced mobile-based test item is satisfactory.</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>53.8%</td>
<td>1.92</td>
</tr>
<tr>
<td>11</td>
<td>The Learning Map Design Tool is easy to manipulate.</td>
<td>0</td>
<td>0</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>The production of Learning Map Design Tool is beneficial to students.</td>
<td>0</td>
<td>0</td>
<td>13</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>From overall point of view, you think that the MEAT is easy to manipulate.</td>
<td>4</td>
<td>9</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4.31</td>
</tr>
<tr>
<td>14</td>
<td>From overall point of view, you think that the MEAT can help you with producing learning resources.</td>
<td>5</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4.38</td>
</tr>
</tbody>
</table>

Table 3 shows the survey results from nurses with regard to the satisfaction of the system. According to the result, most nurses (about 87.23%) approved that the presentation and manipulation of web-based learning and assessment were satisfactory. However, only small portion of nurses (about 6.7%) knew the existence of mobile-based learning site. Based on the small portion of nurses’ opinions, they mentioned that either to browse online learning contents or to engage in online assessment with mobile setting was too expensive even though it is convenient. From overall
point of view, nurses agreed that learning and assessing in e-learning manner were beneficial to them since it frees them from time and space restrictions. Finally, respondents also suggested we allow them to download the mobile version of learning contents from web-based training site. With the downloadable mobile-based contents, the nurses can install them into their cell phone and the nurses can then read the mobile contents without extra Internet connection fee.

Table 3: Results of the survey questionnaire from nurses

<table>
<thead>
<tr>
<th>#</th>
<th>Question</th>
<th>Very approvable</th>
<th>Approvable</th>
<th>Neutral</th>
<th>Opposing</th>
<th>Very opposing</th>
<th>Avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The web-based learning interface, which includes presentation and manipulation, is satisfactory.</td>
<td>63 (10.8%)</td>
<td>488 (83.7%)</td>
<td>31 (5.3%)</td>
<td>1 (0.2%)</td>
<td>0 (0%)</td>
<td>4.05</td>
</tr>
<tr>
<td>2</td>
<td>The mobile-based learning interface, which includes presentation and manipulation, is satisfactory.</td>
<td>0 (0%)</td>
<td>11 (1.9%)</td>
<td>547 (93.8%)</td>
<td>23 (4.0%)</td>
<td>2 (0.3%)</td>
<td>2.97</td>
</tr>
<tr>
<td>3</td>
<td>The web-based assessment interface, which includes presentation and manipulation, is satisfactory.</td>
<td>27 (4.625%)</td>
<td>439 (75.325%)</td>
<td>111 (19.025%)</td>
<td>6 (1.025%)</td>
<td>0 (0%)</td>
<td>3.84</td>
</tr>
<tr>
<td>4</td>
<td>The mobile-based assessment interface, which includes presentation and manipulation, is satisfactory.</td>
<td>0 (0%)</td>
<td>2 (0.3%)</td>
<td>541 (92.8%)</td>
<td>33 (5.7%)</td>
<td>7 (1.2%)</td>
<td>2.92</td>
</tr>
<tr>
<td>5</td>
<td>From overall point of view, you think that learning and examining on the e-learning system benefited you.</td>
<td>40 (6.9%)</td>
<td>519 (89.0%)</td>
<td>24 (4.1%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>4.03</td>
</tr>
</tbody>
</table>

According to the opinions from both teachers and nurses, it reveals the advantages and potential weaknesses of our system. In addition to above results, we summarize the potential drawbacks of the MEAT in the following items, which provide us an explicit direction for further investigation.

- Since the formats of multimedia are arbitrary, the Transformation function cannot properly deal with special cases of file format. For instance, we have encountered a video material with embedded hyperlinks. When playing these types of video, the embedded hyperlinks would automatically open a new browsing window and then navigate to a specific web page.
- The Mobile Content Translation Module supports only slide-typed media translation.
- The MEAT does not integrate with LOR and cannot support direct file upload function.
- Twofold packaged content size is necessary for supporting content re-authoring function. Owing to the materials of the produced learning content are transformed, they cannot be directly used in the re-authoring process. It causes original learning materials have to put into the content package, which increases the size of file and the content preservation cost of the learning platform. We believe the shortcoming would be mitigated when all adopted materials use advanced data formats (e.g. JPEG2000) to allow them to do self-adaptation.
- Teachers cannot customize their content template.
- The language in the complete SCORM metadata is not be translated to Chinese.
- Since the generated adaptable test items are produced by single authoring technology, these adaptable test items can only be executed on learning platforms that support specific markup language interpreting. This restriction would not let us provide a test item preview function to the teacher client.

Conclusions

To sum up this study, we have presented an authoring tool named the Mobile E-learning Authoring Tool (MEAT), which can produce adaptable learning content and test items to support both e-learning and m-learning. In addition, all produced learning contents are conforming to the SCORM standard, which enhances the contents interoperability and reusability. In order to conform to the requirements of the SN, the MEAT also furnishes teachers with a graphical learning map design tool for organizing teaching courses in an appropriate manner.
According to evaluation result, the MEAT is the only tool, which can produce adaptable contents and test items while supporting SCORM standard. Besides, the WYSIWYG feature and intuitive user interface also shorten the creator’s learning curve. Although MEAT does not have external backend databases to support direct resource upload and usage, it still provides a stable and reliable authoring environment for creators to produce satisfactory adaptable learning contents and test items. In the MEAT, the designs of functions and the manipulation process reflect feedbacks received from teachers and in accordance with their technological learning needs. Our evaluation indicates that the teachers are satisfied with the MEAT although there are still some shortcomings to its use. The further direction of this work is to look for ways to mitigate or entirely eliminate these shortcomings and continuously improve our system in accordance with the needs of teachers and learners in an e-learning environment.

Finally, with user’s feedbacks and our experiences of engaging in developing the MEAT, we organize some recommendations for readers who would like to pay efforts to develop authoring applications. We also hope to inspire readers through sharing our investigation experiences.

- **Based on users’ preferences to decide the support multimedia types:** In the past, teachers were based on available tools and technologies to develop their contents and media. Since teachers usually do not like to reproduce old contents with new technologies, authoring tool developers nowadays should take teachers’ preferences of media into consideration to decide the support multimedia types in their developments, especially when the media have been created by teachers with previous technologies.

- **Based on users’ demands to develop functionalities:** Many novel research projects or applications are developed based on positive assumptions, however some of them finally become useless, such like our Learning Map Design Tool. To void suchlike circumstance, it recommends the target tool user should be invited into the developing group as the advisor through entire developing process.

- **To simplify the manipulation interface:** According to the experience of the evolution of the MEAT, we discovered that teachers do not like irrelevant controllable components or information on authoring interface. In addition to redundant information, placing too many controllable objects on interface at a time is not suitable either. With our survey, up to eight objects showing at a time is acceptable.

- **To embellish the manipulation interface:** In the very early version of the MEAT, we adopted the default form of windows components in our interface design. Many opinions from teachers especially who do not have computer science background, indicate that the interface is icy and they do not like to use it. Thereby, there is a recommend to pay more efforts on embellishment, which would bring you unexpected benefits.

- **To simplify the manipulation process:** Based on our experiences, users prefer the simple manipulative action at each authoring stage. In addition, to divide one complex action into several smaller parts and then to serialize them are better ways for teachers to accomplish the original complex task.

- **To build the scaffolding instruction in authoring tools:** The concept of scaffolding was introduced by Bruner (1983), and which provides an explicit strategy for teachers to offer interactive support to learners to bridge the gap between present skill level and next level of skill. Based on the concept, scaffolding instruction can be offered to users when he/she uses certain functionality in the beginning. Besides, the scaffolding instruction can lead users to perform a certain task by a step-by-step guidance, and the guidance would fade when the users familiar with the operation.

- **Component layout principle - from top to bottom and from left to right:** For the case that several manipulative actions have to be done by a specific order on one panel or interface, the better layout principle on interface object is from top to bottom for primary order of objects and then from left to right for secondary order of objects. With such kind of layout, users can follow it to complete a systematic movement.

- **To localize the language toward to target users:** The selection of language on system interface should take account of users from different countries, and it would be the best to set up the language system with which users can choose their native language.

- **To integrate with LOR or backend multimedia database:** The authoring tool integrates with LOR can support direct upload learning object to database and also can utilize available learning resources on server. Such feature can not only simplify the authoring process but also shorten the required time of learning content production.

- **To support e-learning standards:** For reusability and interoperability, the productions of authoring tools should follow e-learning standards such as LOM, QTI, and SCORM.

- **To decrease the control complexity while increasing interactivity of the produced learning resources:** It seems to have conflict between decreasing the control complexity and increasing the interactivity on learning contents at a time. Although it is difficult to take two dimensions into account at a time, there is a successful example such
as Apple iPod (Apple Inc., 2007) utilizing one controllable button to handle all functions. Therefore this is worthy of paying efforts to achieve the goal.

- **To utilize new adaptation technologies to produce learning contents:** In this article, we have mentioned three content adaptation approaches: single authoring, multiple authoring, and flexible authoring. These adaptation methods only focus on producing adaptable web pages, excluding the adaptations of multimedia in the web pages. In order to reach the full adaptation of learning contents (both adaptations of web pages and multimedia are taken into account), the multimedia adaptation technologies should be involved into the content production mechanism. For example, the BSDL (Bitstream Syntax Description Language) was introduced to perform multimedia resource adaptation (Panis et al., 2003).

### Acknowledgements

This work was supported in part by the National Science Council (NSC), Taiwan, ROC, under Grant NSC 95-2221-E-006-307-MY3, NSC 95-2221-E-006-306-MY3, and NSC 96-2524-S-032-001.

### References


Copyright of Journal of Educational Technology & Society is the property of International Forum of Educational Technology & Society (IFETS) and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.