Conceptual Model Learning Objects and Design Recommendations for Small Screens

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ABSTRACT
This article presents recommendations for the design of conceptual models for applications via handheld devices such as personal digital assistants and some mobile phones. The recommendations were developed over a number of years through experience that involves design of conceptual models, and applications of these multimedia representations with students in schools and higher education. Three sets of design recommendations are discussed: design presentation of conceptual models, small screen design, and design in relation to specific learning uses. These recommendations should prove useful to designers of multimedia resources and professionals engaged in instructional uses of these representations. The article calls for researchers to pay more attention to the design of conceptual models and other forms of multimedia resources and their instructional uses.

Keywords
Design, Conceptual models, Learning objects, Multimedia learning, Handhelds, M-learning

Introduction
A conceptual model is a particular kind of a learning object (see Churchill, 2007). It is an interactive and visual representation designed to depict a concept or a number of connected concepts, and support conceptual learning through multimedia and processes of manipulation and interrogation of represented properties and relationships. Emerging handheld technologies (portable digital assistants and some mobile phones) are equipped with multimedia capabilities that enable delivery of conceptual models. If appropriately designed for the context of use, conceptual models can be effectively delivered to a variety of learning environments via this technology.

This article presents recommendations on three aspects of conceptual model design for applications via handheld technology: presentation of conceptual models, small screen design, and design in relation to specific learning uses. These recommendations were developed over a number of years of experience designing conceptual models and applications of these multimedia representations with students in schools and higher education. The paper lists and expands on these recommendations, and provides brief background information on how these were explicated. The paper also attempts to substantiate the presented arguments through reference to an example of a conceptual model. However, readers should not expect detailed descriptions of data collection and analysis in this paper. Detailed reports on a study of various sets of recommendations have been presented elsewhere (e.g., Churchill & Hedberg, 2008b). Overall, the paper provides information that could be useful to designers of multimedia resources and professionals engaged in instructional uses of these representations, and calls for researchers to pay more attention to design as it relates to instructional uses of conceptual models.

A simple example of a conceptual model is presented in Figure 1. This conceptual model displays a concept of a triangle and its associated properties and relationships. It allows students to manipulate the base and height of the triangle by dragging corresponding sliders. Manipulating either of the two parameters of the triangle (base or height) by dragging the sliders will result in an immediate update of the display: the triangle will be redrawn in a corresponding size, and the numerical information regarding associated parameters (such as the value of the hypotenuse) will be updated. This conceptual model can be reused for different purposes and with different groups of students. For example, lower grade students could use it to explore the properties of a right-angled triangle, while more senior students might explore properties such as Pythagorean theorems and basic trigonometric functions (sine and cosine).

The current literature lacks specific recommendations for the design of conceptual models for applications via small screens of handheld technology. This paper introduces a set of recommendations for such design. These recommendations integrate three sets of independently developed guidelines: (a) design for presentation, (b) design for small screen and (c) design for learning uses. The recommendations reported in the article will contribute to the
literature, and are useful to designers of educational multimedia, teachers involved in uses of conceptual models in instruction, and researchers interested in the effect of design possibilities on multimedia learning.

Figure 1: “Explore Triangle” conceptual model learning object (from Churchill & Hedberg, 2008b)

The rest of the article is organized into three main sections. The first provides theoretical background relevant to idea of a conceptual model and its application. The next section presents various design recommendations. Finally, there is discussion of a conceptual model designed in line with these recommendations.

Key Concepts and Issues

The idea of concept has been the subject of a philosophical debate and has influenced the work of well-known figures such as Kant, Vygotsky, Piaget, and others interested in understanding forms of knowledge and how these develop in individuals (see Berger, 2005, Hartnack, 1968, Turner, 1975). Concepts in a school curriculum can be understood as components of knowledge that learners need to construct in order to engage with specific disciplinary issues, solve problems and further learn. Anderson and Krathwohl (2001) propose a model for curriculum planning that divides content knowledge into four categories: factual, conceptual, procedural and metacognitive. Similarly, in the instructional design community, Merrill (1983) introduces Component Display Theory (CDT) and classifies knowledge into concepts, facts, procedures and principles. Overall, learning should not simply include remembering of facts but also development of conceptual knowledge. Conceptual models, when appropriately designed, might serve as useful tools to support conceptual learning (Bruner, Goodnow, & Austin, 1967). The key idea behind the conceptual model as presented in this article is that concepts from curriculum content can be represented through digital representations specifically designed to support conceptual learning.

Models have been described as powerful tools for learning, and their educational use has been described as model-centered learning and instruction (e.g., Seel, 2003, Gibbons, 2008). Lesh and Doerr (2003) define a model as a conceptual system “consisting of elements, relations, operations, and rules governing interactions” that are used to “construct, describe, or explain the behavior of other system(s)” (p. 10). For Dawson (2004), a model is “an artifact that can be mapped onto a phenomenon” and that is “easier to understand than the phenomenon being modeled” (p. 6). Johnson and Lesh (2003) more specifically discuss technology-based representational models and suggest that these models can be used for communicating, modeling, describing, or experimenting with other system(s). For
Johnson and Lesh (2003), key characteristics of technology-based models are that they are interactive and involve the use of more than one type of representational media. Norman (1983) uses the term ‘conceptual model’ and refers to it as a representation of a target system designed to serve as a tool for understanding or teaching. Mayer (1989) also describes a conceptual model as a representation designed for teaching and learning purposes, and writes that such a representation “highlights the major objects and actions in a system as well as the causal relations among them” (p.43).

Today’s technology enables design of conceptual models in multimedia form. This form is predominantly interactive (e.g. sliders, buttons, hot-spots, text-entry and other interactive features of a screen) and visual (e.g., diagrams, illustrations, pictures, videos, effects and animations). It can also contain other modalities such as text and audio. This idea of a conceptual model as visual and interactive multimedia representation is influenced by theoretical work such as: external multimedia representations (Schnotz & Lowe, 2003), dynamic visualization (Ploetzner & Lowe, 2004), information visualization (Bederson & Shneiderman, 2003), visual explanations and envisioning information (Tuft, 1990; Tufte, 1997; Tufte, 2001), visual and multimedia displays and conceptual models (Mayer, 1989; Mayer 2003), conceptual models (Norman, 1983), multiple representations (van Someren, 1998), modality and multimodality (De Jong et al. 1998; van Someren et al. 1998) and pedagogical models (Fraser, 1999). Overall, the literature suggests that technology creates opportunity for design and application of conceptual models and other forms of multimedia representations that can effectively support teaching and learning (e.g., De Jong et al., 1998; Fraser, 1999; Norman, 1983; Johnson & Lesh, 2003; van Someren, 1998). It is also suggested that learning with these representations is supported through activation of certain cognitive processes such as mind modeling and linking between internal representations (e.g., Churchill, 2008a; Seel, 2003; Mayer, 1989; Mayer, 2003).

The Cognitive Theory of Multimedia Learning (Mayer, 2001; Mayer, 2005) provides some useful ideas for the design of conceptual models and other forms of representations for educational purposes. In terms of this theory, learning is a sense-making activity in which a student actively builds a coherent mental representation from presented pictures and words, and the teacher is a guide who assists the student’s sense-making process. Visually and words are processed through different channels, passing into the working memory through sensory memory. Through processing of the material in the working memory, and by drawing upon their prior knowledge, students develop verbal and pictorial models (mental models) that are further integrated into coherent knowledge (cognitive schema) in long-term memory. Multimedia supports students to pay attention to relevant information, selecting words and pictures, organizing these in mental models and integrating them with prior knowledge into coherent knowledge constructed in long-term memory. Mayer and his collaborators provide a number of principles as guides for the design of representations for multimedia learning (Ayers & Sweller, 2004; Fletcher, & Tobias, 2005; Low & Sweller, 2005; Mayer, 2001; Mayer, 2005; Sweller, 2005):

- **Multimedia principle** (a representation for multimedia learning should integrate visual and verbal information, not verbal alone);
- **Principles for managing essential processing**: segmenting (multimedia messages should be presented in student-paced segments), pre-training (names and characteristics of main concepts should be familiar to students) and modality (words should be spoken rather than written);
- **Principles for reducing extraneous processing**: coherence (extraneous material should be excluded), signaling (cues should be used to highlight the organization of the essential material), redundancy (the same information should not be presented in more than one format), spatial contiguity (words and pictures should be physically integrated), and temporal contiguity (words and pictures should be temporally integrated); and
- **Principles for multimedia learning based on social cues**: personalization (words should be presented in conversational style), voice (narration should be in a standard-accented human voice) and image (it is not necessary to include a speaker’s image on the screen).

Although these multimedia learning principles suggest some useful ideas for conceptual model design, a more specific set of recommendations is required, not only for design purposes, but also to inform teachers regarding the effective instructional uses of these representations. Attention needs to be given to learning as a cognitive activity in which a student builds a coherent mental representation from the presented material. Further, a learning task should trigger these cognitive processes through conceptually demanding acts where learners use multimedia material as a means to achieving an outcome.

A conceptual model should be used in context of a learning task (see Churchill & Hedberg 2008a). For Foo, Ho and Hedberg (2005), learning task design should be the central task for a teacher when planning lessons. Such tasks
might take the task-form of troubleshooting, strategic performance analysis, case study, design challenge or resolving a dilemma (for more detailed classification of problem types, see Jonassen, 2000). Mayer, Dow and Mayer (2003) suggest that a task should present students with a conceptually demanding question that requires deep processing of the presented material and the development of self-explanations. Alternatively, a conceptual model can be used as an aid to a teacher’s presentation or to engage students in discussion about the presented properties and relationships. Post learning, a conceptual model can be provided for students to support their homework, assignments, preparation for tests and independent learning activities. When developing computer-based instructional material, instructional designers might use a conceptual model as a media object to be integrated in their overall design product: e.g., a conceptual model can be used as supportive or just-in-time information in learning designs based on the 4C/ID-Model (see van Merriënboer, Clark, & de Croock, 2002).

Emerging handheld technology (e.g., portable digital assistants and mobile phones) opens a spectrum of opportunities for the support of teaching and learning. Attewell (2005) claimed that as the number of such devices increases globally, this technology is becoming part of “digital life” for many individuals. These tools may assist learners “to access Internet resources and run experiments in the field, capture, store and manage everyday events as images and sounds, and communicate and share the material with colleagues and experts throughout the world” (Sharples, Corlett & Westmancott, 2002, p. 222). For Luchini, Quintana and Soloway (2004), the key benefit of handheld technology is as a powerful personal device that “provides access to tools and information within the context of learning activities” (p. 135). Studies reported a variety of situations for the use of handheld devices in teaching and learning: during classes, enabling teachers and students to share files (Ray, 2002) and allowing students to ask anonymous questions, answer polls and give teachers feedback (Ratto et al., 2003); for delivery of coursework and quizzes and as an intelligent tutoring system (Kazi, 2005); for dissemination of information and collection of data during field trips (So, 2004); as a tool that supports students’ inquiries (Sharples et al., 2002; Clyde, 2004); in computer-supported collaborative learning (Roscelle & Pea, 2002; Zurita & Nussbaum, 2004); as personal technology for lifelong learning (Sharples, 2000); as support for more flexible modes of assessment (Vogel, Kennedy & Kwok, 2007); and to assist disadvantaged young adults to improve literacy and numeracy skills (Attewell, 2005).

One important affordance of this technology is as a ‘multimedia-access tool’ (see Churchill & Churchill, 2008b). A variety of multimedia resources can be delivered using this technology (e.g., e-books, web pages, presentations, interactive resources, audio files and video segments). These resources can be accessed any time, anywhere, by connecting to the Internet using 3G mobile telephony network or WiFi, from the memory of the device or storage card if the resources were previously downloaded, or through synchronization of a handheld device with a computer. However, merely moving resources from a computer to a handheld device might not lead to effective learning. Resources for use via handheld devices must be designed with certain design principles in mind.

Conceptual models might be effective resources for handheld technology, as these can be made available to students in a variety of situations, anytime and anywhere via such technologies (Churchill, 2008b; Churchill, Kennedy, Flint & Cotton, 2010). Designing and implementing conceptual models via handheld technology might open possibilities for its more effective use in teaching and learning. However, this requires an understanding of effective design for presentation via the small screens of handhelds, and the ways in which a conceptual model might support learning when delivered via this technology in learning contexts such as educational fieldwork.

**Design Recommendations**

This section of the paper discusses recommendations for conceptual model design for small screens. These recommendations were developed over a number of years through experience that involves reviews and design of conceptual models, and applications of these with students in schools and higher education.

**Design for Presentation**

The first set of recommendations informs the design of content, screen and interface elements of a conceptual model. These recommendations were developed through a review of a number of conceptual models (some of these conceptual models are available at http://www.learnactivity.com/lo/ or through a repository at http://risal.cite.hku.hk). Two experienced instructional designers assisted the author in the review. Each of the three
reviewers described features and characteristics of the reviewed conceptual models through reference to the criteria based on the relevant issues from the Cognitive Theory of Multimedia Learning, as follows:

- **Multimedia principle** -- What is the predominant mode of representation for the essential content of this conceptual model (e.g., visual, textual, animation, auditory)?

- **Principles for managing essential processing (navigation)** -- Describe characteristic structure and navigation (e.g., single or multiple screen, user-paced or automatic, hierarchical or linear navigation, physically and temporally integration of modes).

- **Principles for managing extraneous processing (interactivity)** -- Describe interactive features used to manipulate the represented concept (e.g., slides, buttons, clickable hot-spots).

- **Principles for reducing extraneous processing** -- How was the extraneous content used (e.g., use of cues to highlight the organization of the essential content)?

Data collected was unitized and sorted by the reviewers into a number of emerging categories, from which the following design recommendations were generated in relation to the presentation of conceptual models:

- **Present information visually** -- In a conceptual model information should be presented predominantly through use of visual elements (e.g., photographs, illustrations, diagrams, graphs, colors, icons and symbols). Sometimes, the same information can be presented in a number of modes simultaneously (e.g., as text, visually and via audio). However, visuals are the central mode of representation and using redundant information should be carefully managed (see redundancy principle [Mayer, 2001]).

- **Design for interaction** -- Relationships should be displayed in interactive ways to allow the user of a conceptual model to manipulate parameters and observe outcomes (e.g., by manipulating sliders, clicking on buttons, or inputting text/numbers). Outcomes of the manipulation can be presented in a single mode or in several modes at the same time (e.g., as a number or a graph).

- **Design a holistic scenario** -- Design elements should be arranged in ways that integrate bits of content into a holistic presentational scenario depicting the concept that is represented. In other words, all areas of the screen need to integrate into a holistic scenario that supports multimedia representation of a concept.

- **Design for a single screen** -- A conceptual model should be most often presented in a single screen, since this allows a student to have a holistic focus on all elements of the required conceptual knowledge. Further, a single screen enables a student to manipulate relationships and properties, and to access outcomes of this manipulation all in one place. At the same time, a single interactive screen can be easily meshed with other media into structures such as web pages.

- **Design for small space** -- The design of a conceptual model should utilize only the screen space necessary to present all the required information, properties, relationships and interactive elements. From the experience of the author, most conceptual models can be designed in a screen space that does not exceed 640 by 480 pixels. This recommendation has two important implications. Firstly, the student concentrates visual attention on a smaller screen area. Secondly, a conceptual model designed for a small screen might later serve as a media object that can be embedded into larger structures such as blog posts, instructional products and PowerPoint slides.

- **Use audio and video only if it they are the only option** -- Audio should only be used if it is effective for a representational purpose or to enhance realism when required (e.g., a specific sound indicating a faulty machine), or to offload cognitive processing from the visual channel (see modality principle [Mayer, 2001]). Similarly, video should only be used when, for example, manipulation of relationships requires different segments from a video to be presented based on the configuration of parameters. Often, content from a video might be presented as several images of the key frames, with short blocks of text explaining each of the frames (which might support temporal contiguity principle [Mayer, 2001]).

- **Use color in moderation** -- In order to clearly present the content, color should be used in moderation. Often, color can be used to connect related information (e.g., connecting a positive numerical value displayed in red with a red bar on a bar graph). Different shades of color can be effectively used, but use of sharply contrasting colors must be avoided. The focus should be on simplicity and clarity of presentation and support for learning, rather than in pursuit of gratuitous artistic beautification of the display.

- **Avoid unnecessary decorative elements** -- Unnecessary decorative elements can add complexity to the representation and result in increased extraneous cognitive load (Mayer, 2001). These should be used in moderation, or not at all. All elements of the display should serve the purpose of representing a concept (or should facilitate this representation) and allow a student to manipulate its properties and explore relationships. In addition, cartoon-like characters should be avoided unless they serve some representational purpose. Many
designers assume that cartoon-like characters will motivate students by making learning fun; however, such graphics are less than productive for learning. For Collins (1996), designers should not assume that fun is a desirable component of presentation, because there is a risk that students might not take such learning seriously; thus, a ‘fun’ presentation might impede learning! Motivation lies in a learning task engaging a student in the use of a conceptual model, rather than in the model itself. A conceptual model is a strategy for effective representation of educationally useful concepts, and unless its display elements support this representation, they should not be included.

- **Design with a single font** -- In order to keep the presentation simple, a single font style should be used (e.g., Arial font in different sizes, shades and styles). The same color fonts can be used to relate pieces of information. Using multiple font types might increase extraneous cognitive load and have a negative effect on learning.

- **Use frames to logically divide the screen area** -- Frames can be useful in dividing the presentation screen into functional and logical areas and groupings. For example, interactive elements such as sliders and buttons can be grouped together in one area of the display, while another area can be used to display output information. Such areas might support visual attention (as a student focuses attention on one framed area at a time) and positively affect the utility of the essential cognitive load required to process information (Mayer, 2001).

While these presentation recommendations should prove useful, other aspects of design must be considered when presentation is via devices whose screen size and interactions are limited as compared to computers. Furthermore, these recommendations do not provide ideas regarding instructional uses of a conceptual model and therefore, although useful to designers, are of little use to teachers. Applying these recommendations alone will result in a conceptual model design that is not necessarily optimized for instructional use. Further inquiries were conducted in order to develop more comprehensive recommendations which incorporate specific features of design for small screen and learning uses.

**Design for Small Screens**

If appropriately designed for the context, conceptual models can be effectively delivered via technologies including small screen handheld devices (PDAs and some multimedia-enabled mobile phones). The key challenge for the effective delivery of conceptual models is the limited screen sizes of these devices. The current typical dimension of the screen area of a handheld device is about 3.5" (9cm), with a resolution of 320 by 240 pixels. Recent studies have pointed to potential limitations of such screen sizes for effective presentation of information (see Albers & Kim, 2001; Bradley, Haynes & Boyle, 2006; Jones et al., 1999; Jones, Buchanan & Thimbleby, 2003; Kim & Albers, 2001; Lee & Bahn, 2005). Albers and Kim (2001) identify three specific issues that affect user access to information via handheld devices: (a) reading of text on a handheld computer screen is more difficult than on paper, (b) presenting graphical information is limited as regards the size and complexity of image, and (c) interactivity may be compromised due to the lack of keyboard and mouse, while the screen size limits display space for interactive elements. Elsewhere, Kim and Albers (2001) suggest that information design for handhelds must be informed by a new understanding of small screen usability, and the “limited real estate.” Rettig (2002) proposed that designers should storyboard their prototypes on pieces of paper with dimensions that resemble the physical size of the screen of a handheld device. When designing learning objects for use by students on handheld devices, Bradley, Haynes, and Boyle (2006) suggest that although user interactivity does not appear to be affected, screen size continues to present design challenges. These authors report that text legibility and the nature of interactions represented limitations on design possibilities. They suggest that learning objects should be designed for full screen presentation rather than for presentation in a browser window, and recommend greater use of audio over text to compensate for the limited design space.

The author previously engaged in an inquiry to develop a set of design recommendations for small screen presentation (see Churchill & Hedberg, 2008b). In the earlier stage of the study, participants (including a number of school teachers) were engaged in interaction with a number of learning objects via handheld devices (HP iPAQ rw6828 Multimedia Messenger). These learning objects were selected to permit demonstration of various modalities (e.g., text, visuals, audio) and different kinds of interaction (e.g., buttons, hot-spots, sliders, text-entry boxes) in order to facilitate discussion leading to an understanding of possibilities for dealing with the challenges of a small display area. Following the interviews, a few learning objects were progressively (re)designed in consultation with the participating teachers for implementation with students. Students’ use of learning objects was observed and interviews were conducted in an attempt to identify any further issues that should be considered in the effective design of the learning objects. From this inquiry, the author explicates the following recommendations:
• **Design for full-screen presentation** -- Full-screen presentation of a conceptual model increases amount of available space and this appears to create an improved user experience.

• **Design for landscape presentation** – Typically, the screen of a handheld device is presented in portrait layout. The landscape presentation offers more flexibility for design.

• **Minimize scrolling** -- Scrolling should be avoided, or at least minimized.

• **Design for short contacts and task centeredness** -- A conceptual model should be designed such that it enables learning through task-centered information.

• **Design for one-step interaction** -- The design goal for a learning object should be to provide through visualization and interactivity all necessary information with a single display that fits in the screen of the handheld device. Single interactions, such as changing the position of a slider, should result in immediate updates on the screen presented in a way that is perceptually and immediately noticeable by a student in response to an action.

• **Provide zooming facility** -- The display should be enlarged beyond the physical limits of the screen when appropriate. The user should be able to zoom and drag the entire screen in any direction to access hidden areas of the display beyond the physical limits of the screen.

• **Design movable, collapsible, overlapping, semi-transparent interactive panels** -- Utilize floating panels in order to maximize amount of information presented on a display.

Although the two sets of recommendations (design for small screen and design for presentation) address important aspects of design, the critical issue for use of any technology in education is how it can be designed to effectively support learning. The presented design recommendations might be further examined for their impact on learning though methodologies used by the Cognitive Theory of Multimedia Learning researchers. However, this article emphasizes that understanding effective design of conceptual models must also incorporate understanding of how such models are used to support learning tasks. Although the Cognitive Theory of Multimedia Learning provides useful ideas regarding learning from multimedia resources, this article suggests that this theory is incomplete without consideration of learning tasks that require uses of conceptual models and other forms of multimedia representations.

**Design for Learning Uses**

The author’s further inquiry developed a third set of recommendations that more specifically address the issue of application of conceptual models via handheld technology in learning contexts. This final set of guidelines complements the design recommendations for presentation and small screens, resulting in a more comprehensive set of guidelines for the design of conceptual models for application via the small screens of handheld technology. On a number of occasions the author engaged with teachers who used conceptual models in instruction and students. Classroom and fieldwork observations, interviews, and review of collected work of students provided data and an informed understanding of the learning uses of conceptual models via handheld devices. These learning uses were classified in emerging categories that became specific recommendations for design (see Table 1 for a list of recommendations and corresponding learning uses).

<table>
<thead>
<tr>
<th>Design for learning uses recommendations</th>
<th>Learning uses of conceptual models identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design for observation</td>
<td>• Aid to observations</td>
</tr>
<tr>
<td></td>
<td>• Tool for linking of theory to the world outside the classroom</td>
</tr>
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<td></td>
<td>• Tool for inquiry</td>
</tr>
<tr>
<td>Design for analytical use</td>
<td>• Analytical tool</td>
</tr>
<tr>
<td>Design for experimentation</td>
<td>• Experimentation environment</td>
</tr>
<tr>
<td></td>
<td>• Tool for generalizing</td>
</tr>
<tr>
<td>Design for thinking</td>
<td>• Environment for articulation of components of knowledge</td>
</tr>
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<td></td>
<td>• External cognitive supplement</td>
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<tr>
<td></td>
<td>• Decision-making tool</td>
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<tr>
<td>Design for reuse</td>
<td>• Preparation tool</td>
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<tr>
<td></td>
<td>• Collaboration tool</td>
</tr>
<tr>
<td></td>
<td>• Reflective tool</td>
</tr>
</tbody>
</table>

*Table 1. Design for learning uses*
The following elaborates on each of these recommendations:

- **Design for observation** -- A conceptual model should be designed such that learners are supported in making links between the real world and the represented properties of a concept. It should be designed such that learners can recognize properties from a real environment in the interface of a conceptual model, as well as the converse. These representations of properties are not simply copies of the real world. Rather, designers should represent reality through illustrations, diagrammatical representations, analogies, metaphors, signs, cues, symbols and icons.

- **Design for analytical use** -- A conceptual model should contain design features that allow learners to input data from the real environment for analytical processing (e.g., a special purpose calculator). Designers should use interactive features (e.g., sliders, dialers, hot spot areas and text input boxes) to enable input of parameters. Outcomes of interactions can be displayed in a variety of formats such as numbers, graphs, audio, verbal/written statements, pictorial representations and animation.

- **Design for experimentation** -- A conceptual model should enable learners to manipulate parameters and properties, and observe changes that result from such manipulations. Also, it might be useful to allow the manipulation of outcomes of analytical use to enable learners to examine how these changes affect related parameters. The changes should be highlighted to provide cues and encourage generalizing. A conceptual model’s design features should allow emergent generalizations to be tested in some way.

- **Design for thinking** -- Designers should incorporate in a conceptual model features that initiate and support thinking. This can be achieved by integrating triggers (e.g., signals and cues) to capture attention and initiate curiosity. Some design ideas from the Cognitive Theories of Multimedia Learning (Mayer, 2001) could be useful as a conceptual guide. For example, a conceptual model design should support the cognitive activities of linking mental models (verbal and visual) developed through interaction with that conceptual model.

- **Design for reuse** -- The design of conceptual models for handheld devices should allow reuse in different environments and activities. For example, reuse might include a classroom presentation, or use by multiple learners as they collaborate. Other applications might require delivery via devices other than handheld, such as a computer, a projector or an interactive white board. The design of a conceptual model needs to consider at least two issues for flexibility of reuse: (a) interactivity should be supported by a variety of devices, and (b) presentation of a conceptual model on a large screen should not cause split attention problems (see Mayer, 2001). In certain cases, it might be useful to provide features that allow data from a conceptual model to be saved in an external file for reuse, or for exchange between collaborating users (e.g., through the Internet or via handheld device connectivity).

These design recommendations and corresponding possibilities for learning uses provide guides for teachers engaged in the planning of instructional uses of a conceptual model. They present possibilities for learning-task-related uses, while at the same time informing designers on ways to ensure that conceptual models effectively support these uses. In the next section of the paper, a case of a conceptual model designed to reflect the three sets of recommendations is discussed. Overall, the intention is to demonstrate the usefulness of the recommendations, and prompt readers to examine if and how these might apply in their own practices.

### A Case of a Conceptual Model Design Based on the Recommendations

In February 2008, the author traveled to Northern Thailand with a group of 72 secondary school students and two of their Geography teachers from Hong Kong. During the trip, the students were required to conduct a study of a river - one of the key topics in the students’ Geography curriculum. This topic includes issues such as how a river changes downstream; how farming and various human settlements influence its changes; obtaining key measurements such as a river’s width, depth, velocity and gradient; and calculating values of other parameters such as discharge and hydraulic radius. During the field trip, the students were equipped with handheld devices - namely, the HP iPAQ rw6828 Multimedia Messenger. This handheld device uses the Windows Mobile operating system. As well as recording collected data and images, the handheld devices were used to access a conceptual model that was designed specifically for use in the context of the students’ filed work. This conceptual model is presented in Figure 2.
The conceptual model contains information about a number of river parameters, enables calculations of river discharge, presents the impact on flow rates caused by the shape of a riverbed, and allows identification of common bedrocks at different locations along the river. Various items of information are presented based on a student’s interaction with the conceptual model. A student can explore issues affecting the river through interaction and manipulation of specific parameters (e.g., how the cross-section of the river changes as its course progresses downstream), and by systematic exploration of specific information (e.g., how the river discharge is calculated based on values of width, depth and velocity).

Prior to the field trip, the teachers displayed the conceptual model via a projector and used it as a visual aid when explaining the key concepts of a river (e.g., depth, velocity, discharge). Once outdoors, the students used the model to support their river study learning task in any way they perceived as useful. After the fieldwork, the conceptual model was useful as a tool that facilitated reflections and writing up of a river case study report in digital form. The students were provided with a PowerPoint template, which they populated with their data, evidence and media from the field, then presented conclusions. During the fieldwork, students used handhelds to store measurements, collect images and capture video, made audio-recorded notes etc, and this information was used as data, evidence and media for the report. The template was also embedded with the conceptual model, along with relevant conceptually challenging questions requiring students to refer to the model when developing their arguments.

Design features of the “River” conceptual model illustrate the usefulness of the recommendations discussed in this article. This is elaborated in Table 2, which links each of the recommendations to some specific feature of the conceptual model. The conceptual model reflects most of the recommendations. It is the author’s intention to further revise the conceptual model in other to improve its design in a way that is fully consistent with all of the recommendations. In particular, revision is required to more closely match recommendations for small screen design. Overall, the author intends to provide sufficient description of recommendations in order to allow readers to examine whether these are useful in their own practices.
<table>
<thead>
<tr>
<th>Recommendations</th>
<th>Design features from the “River” conceptual model (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present information visually</td>
<td>Information in the cm is presented mostly visually (e.g., cross-section of the river and downstream changes). Text is used for buttons, labels, values and instruction.</td>
</tr>
<tr>
<td>Design for interaction</td>
<td>The cm allows a learner to manipulate parameters through sliders (e.g., position on the river). Outcomes of manipulations are presented visually and numerically (e.g., river cross-section and value of discharge).</td>
</tr>
<tr>
<td>Design a holistic scenario</td>
<td>Elements such as cross-section of the river and the river path are arranged in a way that integrates them into a single scenario.</td>
</tr>
<tr>
<td>Design for a single screen</td>
<td>Content of the cm is presented in a single screen.</td>
</tr>
<tr>
<td>Design for small space</td>
<td>The cm is designed for effective presentation in a 320x240 pixel screen area.</td>
</tr>
<tr>
<td>Use audio and video only if it is the only option</td>
<td>No audio or video content is present in the cm. Although audio could add some realism (e.g., water flow), its presence was not necessary.</td>
</tr>
<tr>
<td>Use color in moderation</td>
<td>Color use was limited in the design. Colors include blue, white, black, brown, maroon and green.</td>
</tr>
<tr>
<td>Avoid unnecessary decorative elements</td>
<td>No decorative elements were used in the cm. All elements are related to essential content.</td>
</tr>
<tr>
<td>Design with a single font</td>
<td>Only Arial font was used in the cm.</td>
</tr>
<tr>
<td>Use frames to logically divide the screen area</td>
<td>The screen was divided into functional areas. Top part of the screen presented cross section of the river and its changes. Bottom part of the screen presented related content and interactive elements.</td>
</tr>
<tr>
<td>Design for full-screen presentation</td>
<td>When presented via handheld device the cm is displayed in the full-screen mode.</td>
</tr>
<tr>
<td>Design for landscape presentation</td>
<td>The cm is displayed in landscape mode.</td>
</tr>
<tr>
<td>Minimize scrolling</td>
<td>Content is designed in such a way that scrolling is not required.</td>
</tr>
<tr>
<td>Design for short contacts and task-centeredness</td>
<td>Content is presented visually to maximize amount of information that can be viewed in shortest time. The content displayed, such as numerical values, can support tasks like analyzing real river parameters (e.g., parameters can be configured based on requirements pertaining to the real environment).</td>
</tr>
<tr>
<td>Design for one-step interaction</td>
<td>Any single interaction will result in immediate display on the screen of related information. Outcome of any interaction is immediately noticeable.</td>
</tr>
<tr>
<td>Provide zooming facility</td>
<td>Zooming has not been utilized in the cm. A redesigned version of the cm should contain this facility.</td>
</tr>
<tr>
<td>Design movable, collapsible, overlapping, semi-transparent interactive panels</td>
<td>Content is distributed in four panels, each containing content information and interactive features. Cross-section of the river remains displayed at all stages. The redesigned version of the cm will build further upon this recommendation by including features such as semi-transparent panels.</td>
</tr>
<tr>
<td>Design for observation</td>
<td>Visual elements (e.g., illustrations) are designed in ways that are easily related to reality (e.g., rocks in the river bed or color of water). Also, elements of reality (e.g., farm land) are easily related to visuals in the cm.</td>
</tr>
<tr>
<td>Design for analytical use</td>
<td>Interactive features allow manipulation of parameters and calculation of associated outputs (e.g., changes in the river’s width, depth and velocity will calculate and output value of discharge).</td>
</tr>
<tr>
<td>Design for experimentation</td>
<td>The cm allows a learner to manipulate parameters and experiment with outputs (e.g., how hydraulic radius varies based on changes of the width and the height of the river).</td>
</tr>
<tr>
<td>Design for thinking</td>
<td>Prominent color and objects were used to highlight information such as how velocity is averaged across the river, or to highlight certain manifests in order to lead a learner to query and generalize.</td>
</tr>
<tr>
<td>Design for reuse</td>
<td>The cm is designed with Adobe Flash. It is flexible and easily rescaled to fit larger screens and be displayed via computers and projectors. Interaction used (sliders and clickable spots) is supported across different devices. As a Flash Object, the cm can be embedded in other digital media environments such as PowerPoint slides or blogs.</td>
</tr>
</tbody>
</table>
Conclusion

Contemporary research on technology in teaching and learning pays insufficient attention to the design of educationally useful multimedia representations and their roles in learning experiences. Even existing discussions about learning objects are over concerned with defining what a learning object is, rather than examining effective models for design and their uses. Work reported in this article attempts to contribute in this direction and emphasize the importance of multimedia resources as tools for conceptual learning. The article builds on previous work that defined learning objects and their specific forms (see Churchill, 2007) and expands to detail aspects of design that are perceived as important.

Basically, a conceptual model is a strategy for the design of educationally useful digital material that supports conceptual learning. Effectively designed conceptual models can be provided to teachers to integrate them in their teaching, to students for uses in their independent learning activities, or to instructional designers to use as media objects for integration in larger structures such as computer-based instructional packages. This article more specifically describes aspects of designs of conceptual models for learning applications via handheld technology. Three sets of design recommendations are discussed and it is proposed that these be integrated into a framework for the design of conceptual models. The recommendations cover design for presentation, small screens, and learning uses. An attempt is made to demonstrate their usefulness through presenting a case of a conceptual model designed according to the recommendations. The three sets of recommendations should be considered when designing conceptual models for application via small screens of handheld devices and might also inform planning of their instructional uses. The three sets of recommendations are diagrammatically represented in Figure 3.

Figure 3. Recommendations for design of conceptual models for small screens

It is the contention of this article that it is important to recognize two processes related to conceptual models: the process of designing conceptual models, and that of designing learning tasks with the intention of them being used and reused by students. The recommendations are applicable in both processes, and thus could prove useful to designers who develop conceptual models, and to teachers who plan to use conceptual models in their instruction.

Multimedia designers, teachers and instructional designers are invited to consider the application of the recommendations in their practices. In addition, researchers should examine the effects of the design recommendations on learning outcomes in disciplines where conceptual models might be useful (e.g., science, engineering or mathematics). The author is currently engaged in further study to investigate forms of cognitive residues and associated mind processes when these residues are used. It is hoped that such investigation will lead to
further refining of conceptual model design recommendations and provide outcomes that challenge, revise or further extend theoretical works such as Cognitive Theory of Multimedia Learning (Mayer, 2001) and Cognitive Load Theory (Sweller, 1994).

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References


