A classification scheme for learner-computer interaction

Barney Dalgarno
Charles Sturt University

Efforts are underway to develop learning resource repositories to allow reuse of learning resources. However, a barrier to the effective reuse of such resources is the lack of ability to easily locate resources appropriate for a particular learning situation within these repositories. Various metadata standards have been proposed to allow the characteristics of learning resources to be described and consequently to allow effective searching. However, it is generally accepted that these standards do not provide enough detail about the pedagogical aspects of the way in which a particular learning object is intended to be used. It is argued in this paper that the learner computer interactions potentially facilitated by the resource are an important element of a pedagogical description. Consequently, this paper proposes a classification scheme for learner computer interaction, suitable for inclusion within learning objects standards. The classification scheme includes three dimensions: cognitive task, input technique and system response.

Keywords: learning objects, learner computer interaction

Introduction

There are a number of efforts underway to develop the organisational and technological infrastructure required for reusable learning resource banks or repositories (see for example Brownfield and Oliver, 2003; Oliver, 2001; Harper, Oliver and Agostinho, 2001). There is potential for huge savings in the cost of educational development through reuse of resources in this way, especially in the tertiary education sector where learning resources for the same fundamental concepts are developed by thousands of academics throughout the world (Downes, 2001). One of the important prerequisites for widespread reuse of learning resources is a common standard for classifying the 'learning objects' that make up a repository, enabling them to be tagged with 'metadata' for automatic retrieval (Boyle and Cook, 2001).

There are now a number of learning object metadata standards, including the Dublin Core Education Working Group draft proposal (Dublin Core Metadata Initiative Education Working Group, 2000), the IMS Learning Resource Meta-data Specification (IMS Global Learning Consortium, 2004) and the IEEE Learning Object Metadata specification (IEEE Learning Technology Standards Committee, 2004). According to Boyle and Cook (2001) a crucial limitation of the current standards is that they they lack a sufficiently fine grained classification for the pedagogical characteristics of the learning objects. Ip and Morrison (2001) also emphasise the importance of identifying the types of human computer interactivity possible with a learning object, to separate those resources that can be explored using a standard tool such as a web browser, and those that have software components embedded within them.

This paper proposes a classification scheme for learner computer interaction, suitable for use within learning object metadata standards. The proposed classification scheme is intended to address some of the limitations of the existing standards by encompassing both the pedagogical and user interface aspects of the interaction. The proposed scheme is intended to encompass the learner computer interactions that occur in all types of interactive learning resources, including those delivered online and on CD ROM and those intended for K-12 education, higher education, and workplace training.

The proposed scheme is particularly suitable for classifying learning objects which go beyond the delivery of content and are intended to enable or facilitate the completion of learning activities. According to constructivist theories of learning, it is through the learner's activity that learning outcomes are achieved, and therefore the particular types of activity that could be facilitated by a resource are an important aspect of the learning design (Dalgarno, 2001; Jonassen, 1991). The proposed classification scheme encompasses both cognitive and behavioural aspects of the learner's activity. It is important to emphasise, however, that the scheme focuses on learner computer interaction not human to human interaction facilitated by a computer. Although most online learning resources include mechanisms for communicating either synchronously or asynchronously with teachers and other learners, this type of interaction is outside the scope of the proposed classification scheme.

The paper begins with a discussion of the model of learner computer interaction on which the classification scheme is based, followed by a discussion of the limitations of the existing learning object metadata standards. The proposed scheme is then described and explained along with the process used to develop it, which included iteratively testing and modifying the scheme while applying it to 20 different learning resources. A summary of the results of this testing process is provided. Finally a discussion of how the scheme could be used as a basis for modifications to the learning object metadata standards is provided.

Learner computer interaction

One approach to devising a classification scheme for learner computer interaction, would be to observe or log learners as they use computer assisted learning resources, and record their actions and the corresponding system responses with a view to developing a series of categories for each of these aspects of interaction. Learner actions might include selecting hypertext links, searching for text, and visiting particular web addresses. System responses might include displaying text, playing a video or carrying out a calculation and displaying the results. Kennedy (2004) refers to interactivity characterised by learner and system actions as 'functional interactivity'. He argues that the learner's cognitive processes are an important element of the interaction and should be central to any model of learner computer interaction. He refers to interactivity characterised by cognitive processing in addition to learner and system action as 'cognitive interactivity'. The model on which the proposed classification scheme is based incorporates a conception of interactivity consistent with Kennedy's cognitive interactivity.

However, whereas Kennedy's model includes a very broad element 'cognitive processes', the model used in this paper includes instead a slightly narrower element, 'cognitive task', which encapsulates the specific task that the learner is trying to carry out at any given time, and which provides the motivation behind their actions. The inclusion of this element in the model allows an action like selecting a hypertext link, carried out while exploring a set of information pages, to be differentiated from selecting a hypertext link in order ro choose an answer to a multiple choice question. Cognitive tasks might include, for example, exploring a simulation, completing a multiple choice quiz or attending to feedback. The model used in this paper is illustrated in Figure 1.

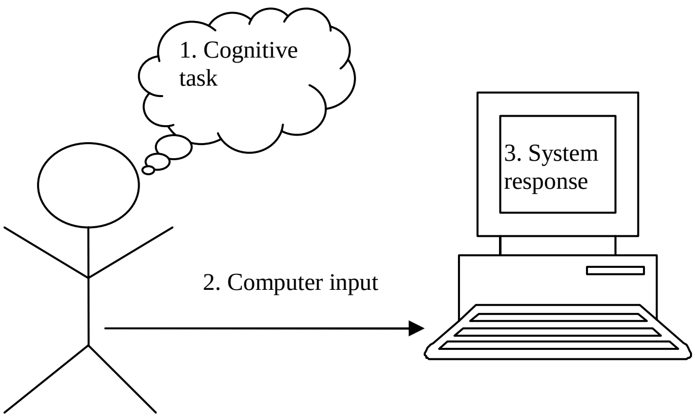

Figure 1: Proposed model of learner computer interaction

The proposed classification scheme is based on this model and includes a series of categories of cognitive task, input technique and system response. Before describing the scheme, the degree to which the learning object metadata standards incorporate these aspects of learner computer interaction is discussed.

Learning object metadata standards

As discussed above, there are three learning object metadata standards: the Dublin Core Education Working Group draft proposal (Dublin Core Metadata Initiative Education Working Group, 2000), the IMS Learning Resource Meta-data Specification (IMS Global Learning Consortium, 2004) and the IEEE Learning Object Metadata (LOM) specification (IEEE Learning Technology Standards Committee, 2004). The IMS specification and Dublin Core proposal are both essentially based on the IEEE LOM specification, without adding any additional pedagogical or user interface attributes. Consequently, the degree to which the IEEE LOM specification incorporates the aspects of learner computer interaction described above, will be discussed here.

The IEEE LOM specification (draft 6.4) consists of a series of data elements, divided up into the following nine categories:

- General
- Lifecycle
- Meta-Metadata
- Technical
- Educational
- Rights
- Relation
- Annotation
- Classification.

The Educational category includes three data elements related to learner computer interaction: Interactivity Type, Learning Resource Type and Interactivity Level. The Interactivity Type can be either *active*, *expositive* or *mixed*. The Learning Resource Type can be either *exercise*, *simulation*, *questionnaire*, *diagram*, *figure*, *graph*, *index*, *slide*, *table*, *narrative text*, *exam*, *experiment*, *problem statement*, *self assessment*, or *lecture*. The Interactivity Level can be either *very low*, *low*, *medium*, *high* or *very high*.

The interactivity type alone does not describe very much about the nature of the interaction. For example, there is a broad range of cognitive and user interface activities that could be carried out by the learner while using an *active* resource. The learning resource type provides some suggestion of the types of interaction that might be facilitated by the resource. However, resource types such as simulation, exercise, or exam might include a wide range of different interactions. The interactivity level would seem to be of limited use, as it implies that interactivity is a single dimensional, linear property. Numerous researchers have demonstrated that interactivity is a complex, multi-dimensional concept (see for example Sims, 2000).

It can be argued, then, that the categories within the IEEE LOM, and related learning object metadata standards, do not provide sufficient detail about the learner computer interactions within a learning resource. This conclusion is consistent with that of a number of researchers who have attempted to apply the standard (see, for example, Aghostino, Bennett and Harper, 2004). The following section describes the proposed classification scheme which attempts to address this limitation.

The proposed classification scheme

As discussed earlier, this scheme is based on a model of learner computer interaction that incorporates the learner's cognitive task, the input technique used to carry out this task and the system response that occurs. Specifically, under the proposed scheme a learner computer interaction will be classified using a single category of cognitive task, a list of the categories of input technique involved and a list of the categories of system response involved. This allows for the fact that a learner computer interaction may involve a series of interface commands and a series of system responses.

The categories of cognitive task encompass tasks able to be carried out within computer assisted learning resources consistent with contemporary theories of learning, including resources identified as being consistent with the various interpretations of constructivism (see, for example, Dalgarno, 2001). The input technique is the observable action carried out by the learner as they interact with the computer. The system response categories encompass both the processing carried out by the computer and the output that appears as a result. In developing the classification scheme, a decision had to be made whether to group processing and output together or to have them as separate categories. From the perspective of the user of an online learning resource, the processing that the computer carries out and the output generated are very closely intertwined, because the processing is invisible to the user until output occurs. Consequently, for simplicity, these two aspects of learner computer interaction have been grouped together. Fourteen categories of cognitive task are proposed, along with 15 categories of input technique and 11 categories of system response. Table 1 lists and explains the categories of cognitive task, Table 2 lists and explains the categories of input technique and Table 3 lists and explains the categories of system response.

The classification scheme was developed using an iterative process of theoretical postulation and empirical exploration. Specifically, the initial version of the scheme was used to classify a series of learning resources, which led to modifications to the scheme, followed by further classifications and so on. In all, 20 learning resources, covering a diverse range of knowledge domains and pedagogical approaches, were classified as part of the process of arriving at the final classification scheme. A summary of the results of this empirical evaluation of the scheme are presented in the next section.

Testing the classification scheme

The proposed scheme was initially developed through a process of theoretical analysis, drawing on related classification schemes in the literature. The initial version was then applied to a series of 20 learning resources, encompassing a range of resource types and learning domains. As part of this process new categories were added to the classification scheme and the new version of the scheme was then reapplied to each resource.

In applying the scheme, the expected cognitive tasks were first identified and described and then the input techniques and system responses associated with each were identified. Due to space limitations, only a summary of this application of the scheme is presented here (see Table 4). This summary provides only a list of the categories of cognitive task, input technique and system response, for each resource, without specifying which input techniques and system responses were associated with each cognitive task. The implications of using a more fine grained application of the scheme versus this summary approach are discussed in the next section.

Subsequent to the testing process, additional minor refinements to the scheme were made, with the inclusion of the 15th category of input technique, mouse rollovers, the combining of the previously separate buttons and icons categories, and the separating of the check boxes and radio buttons category from the button category. The summary presented in Table 4 uses the earlier version of the scheme and thus there are minor differences between the input technique categories in this table and in the latest version of the scheme presented in this paper.

Applying the classification scheme to learning objects

Recalling that the IEEE LOM consists of a series of data elements divided into categories, one approach to incorporating the proposed classification scheme into the standard would be to add three additional data elements to the educational category, called cognitive tasks, input techniques and system response techniques. These could contain a list of the classes of task, input and response possible with the learning object. This approach would allow for reasonably quick tagging by the developer, and would allow summary information such as that presented in Table 4 to be specified but would not provide a complete description of the individual learner computer interactions possible using the resource. An alternative approach would be to use a data element called interactions (again within the educational category) containing a list of interaction data elements, where each interaction data element contained a single data entity called *cognitive task*, and a series of data entities called input technique and system *response technique*.

Table 1: Categories of cognitive task

1. Attending to static information	Attending to information might include reading, looking at diagrams, listening to sounds and watching movies. The term static is intended to encompass information that is the same every time it is seen or heard, as distinct from information that is generated dynamically.
2. Controlling media	Typically, the information within a learning resource will be presented using a variety of media forms, each requiring the learner to control the presentation in a particular way. For example, media such as movie or sound clips require the learner to be able to play, pause, and rewind the clip. This does not include the more interactive forms of control that occur within a graphical simulation, for example control over the learner's view position within a 3D environment, as this is covered by category 6.
3. Navigating the system	Navigating the system can involve choosing a content element, choosing a task to be undertaken or browsing through the system looking for information. Corresponding input techniques would normally include clicking on hypertext links, choosing items from menus or clicking on icons or hot spots.
4. Answering questions	There is a range of different types of question that a learner could answer within a learning resource, including simple multiple choice or true/false questions, questions requiring a single word or sentence answer or structured essay questions.
5. Attending to question feedback	Although attending to feedback is a similar task to attending to static information, the fact that the information is displayed in response to the learner's answer to a question changes the cognitive processing involved and consequently, a different category is used for this task. Question feedback might be in the form of text, diagrams, sounds, animations or movies.
6. Exploring a world	The term 'world' is used to refer to graphical and non-graphical simulations or models of real world phenomena, as well as graphical microworlds that allow abstract concepts to be explored. Exploring such a world would typically involve clicking on hot spots or hypertext links, choosing items from menus, or using the arrow keys on the keyboard to navigate through the environment. This category does not include the provision of input that might change the behaviour of the world, as this is covered by categories 8 and 9.
7. Measuring in a world	Some simulations and microworlds allow the learner to carry out measurements or gather data within the environment, which the learner can use to develop their own understanding of the simulated phenomena or concepts.
8. Manipulating a world	This category includes, for example, the making of decisions within a time based simulation or the adjusting of parameters within a simulated model of a system. It does not include the construction of new objects within a graphical simulation or microworld, as this is covered by category 9.
9. Constructing in a world	Within a graphical simulation or microworld, the learner is typically provided with tools to allow them to design, create or construct new entities within the environment.
10. Attending to world changes	The task of attending to changes within a simulated world is a similar task to attending to static information, but the fact that the information is typically the result of actions the learner has undertaken within the environment, changes the nature of the cognitive processing that occurs. This task is also different to the task of attending to feedback, because attending to feedback is likely to result in the learner reflecting on their response to a specific question, whereas the task of attending to world changes is likely to result in the learner adding to, or modifying, their understanding of the phenomena or concepts being simulated.
11. Articulating	According to constructivist theories of learning the process of articulating their current understanding of concepts can help learners to further develop that understanding. Articulation of ideas could take the form of brief text based annotations associated with specific bodies of text within a hypermedia environment. Alternatively, it might consist of longer pieces of writing that sum up the learner's knowledge of a particular domain area at a given time. The articulation might also include diagrams drawn using drawing tools, sounds recorded with a microphone, or even animations or movies developed by the learner.
12. Processing data	Within some knowledge domains, particularly quantitative domains, learners need to make sense of data that they gather in order to understand the phenomena that is the subject of the resource. This data might be gathered as a result of actions within a simulated world, or might simply be presented as static information within a hypermedia environment. Typically, the task of making sense of such data can be made easier by providing tools that allow the learner to carry out simple calculations or more advanced statistical analysis or to create graphs based on the data. Such tools might consist of a calculator, a spreadsheet package, or a graphing tool.
13. Attending to processed data	This category includes attending to the results of data processing either carried out by the learner or carried out by system. In either case, this task is likely to improve the learner's understanding of the phenomena to which the data relates. The nature of the learner's reflection on the quantitative relationships involved differentiates this category from categories 5 and 10.
14. Formatting output	Having articulated their understanding of a particular content domain, the learner will sometimes want to make this information available to others. Typically, they will want to improve the appearance of the information using the formatting tools provided within a word processing or desktop publishing package. This task is quite distinct from the task of articulating the information in the first place.

Table 2: Categories of input technique

1. Typing	This category includes the typing of text or numbers, put does not include the pressing of a single alphabetic or numeric key to carry out a specific action.
2. Valuators	A valuator is a mouse controlled tool allowing a numeric value to be specified.
3. Key pressing	Key pressing involves the pressing of a single key to carry out a specific function, such as an alphabetic or numeric key, a function key or an arrow key. A single key pressed in conjunction with, for example, the shift key or the control key is also included in this category.
4. Pull down menus	Pull down menus are the menus that are normally provided in the menu bar at the top of the screen or window, that unfold downwards when the menu name is selected with the mouse, allowing a single item to be selected. A variation on this type of menu is menus like the *Windows* start menu, which unfold upwards rather than downwards.
5. Menu lists	Menu lists are menus that, rather than needing to be pulled down, consist of a sequence of options that are all visible. The menu items normally consist of a single line of text but can include graphical symbols or icons. Typically an option is chosen by either clicking or double clicking on one of the items.
6. Buttons and icons	Buttons typically appear as a rectangle or oval shape, shaded to look three dimensional, with a small amount of text enclosed. Typically a button is ‘pressed’ by clicking on it with the mouse. An icon is a graphical symbol that represents some task that the learner may carry out or some component of the system that the learner may choose to visit. Typically the learner clicks or double clicks on the icon to cause the desired action to occur. Icons can appear flat on the page, or as part of a button with a three dimensional appearance.
7. Check boxes and radio buttons	Check boxes allow a number of objects in a list to be selected (checked) and radio buttons allow only one object in a list to be selected.
8. Hot spots	A hot spot is a part of a larger image that, when clicked, causes a particular action to occur. Whereas an icon is typically quite small and will sit by itself on the background, hot spots are sometimes quite large and will appear along with a number of other hot spots as part of a larger image. When used as part of a Web page, hot spots are often referred to as image maps.
9. Hypertext	Hypertext links are sequences of text within a larger passage that when clicked cause another passage of text to be shown or some other action to occur. Typically the text that acts as a link will be underlined or shown in a different colour. Web pages make extensive use of hypertext.
10. Scroll bars	Scroll bars provide a method of looking at an area of information bigger than the screen. By using the scroll bars, the position of the screen ‘window’ in relation to the total area of the information can be modified. Typically, the scroll bars, which can be horizontal or vertical, have a button which represents the position of the window, and which can be dragged with the mouse.
11. Media controls	As the learner views movies or listens to recorded sounds, they are typically provided with control tools that allows them to play, pause, and rewind the movie or sound.
12. Selecting	Often in order to carry out an action within a graphical environment the user first needs to select (or highlight) the object or the piece of text on which the action will be carried out. A graphical object can usually be selected by clicking on it, whereas to select a piece of text, the user typically has to drag the mouse pointer across the text with the button down.
13. Dragging	Within a graphical environment, especially an environment that allows the learner to undertake construction tasks, objects on the screen can typically be dragged around with the mouse.
14. Drawing	Drawing within a graphical environment is usually carried out with the mouse, by holding the mouse button down to activate the ‘pen’, and then by dragging the mouse across the screen.
15. Mouse rollovers	Many online resources include icons, buttons or hot spots where some action occurs when the user places the mouse pointer over the area but does not click the mouse button. This is termed a ‘rollover’ effect. Typically the system action will be some form of cue to help the user to predict what will occur if they click on that item. Cues may take the form of short passages of text displayed next to the mouse pointer or colour changes to the button or icon.

This latter more fine grained tagging system provides a more complete representation of the learner computer interactions possible with the resource. Consequently, if learning objects were tagged in this way it would be possible to perform more complex searches of a learning object repository. For example, a lecturer requiring a simulation of a human heart suitable for use in a lecture theatre using a wireless mouse, could search for learning objects with an interaction element with cognitive task category 8, manipulating a world, but excluding those objects containing input technique 1, typing, or 3, key pressing within this interaction element. If the less fine grained tagging system was used, with no grouping of input techniques and system responses with cognitive tasks, and a similar search was carried out, all objects containing any keyboard input would be excluded. Thus, an object that provided a suitable mouse driven simulation of the human heart would be excluded if it used keyboard input elsewhere within it.

Although the more fine grained application of the scheme using the interactions data element with sub-elements would provide advantages when searching a repository, the tagging process would be much more complex and time consuming. This is an important issue. Brownfield and Oliver (2003) and Agostinho et al. (2004) both have reported problems with consistent tagging using the existing standard. Making the process even more complex would seem undesirable. Consequently, more research is required to further investigate the implications of these proposed changes for both creators and users of learning resources.

Table 3: Categories of system response

1. Displaying	Displaying involves responding to navigational input and displaying the element of information that the learner has chosen or that the system has generated.
2. Presenting media	Presenting media includes playing movies, animations and sounds. This might occur under complete system control or with the learner being given controls that allow them to pause, play and rewind the media.
3. Presenting cues	Presenting cues involves the provision of visual or audio cues to help the learner recognise the options available to them. The display of a pull down menu, the change in appearance of a button, hot spot or icon that is clicked, or the highlighting of selected text are all examples of cues.
4. Branching	Branching involves displaying a different section of static information. The information may be in the form of text, graphics or other media, and the branching could occur as the result of user or system control.
5. Assessing answers	Assessing answers is the process of comparing a learner's answer to a question, to the expected answer. Typically this process will be followed by the presentation of static information, or the generation of more complex feedback.
6. Generating feedback	Generating feedback is the process of creating dynamic responses based on a combination of a learner's current action or answer to a question and their past actions. This is a more complex type of feedback than the static information that might normally be presented in response to an answer to a multiple choice question. This type of processing is used a great deal within Intelligent Tutoring Systems, for example.
7. Updating world	Updating a 'world' involves making changes to an internal model of a simulated environment in response to some form of learner input.
8. Generating world	Generating a 'world' involves updating the internal representation of the world by carrying out calculations using a combination of information entered by the user, elapsed time and in some cases randomly generated values.
9. Processing data	Processing data includes carrying out calculations on numeric data as well as producing graphical representations of data.
10. Searching	Searching involves using criteria normally provided by the learner to search for data within some sort of a database.
11. Saving and loading	Information that might be saved to disk or loaded from disk might include a learner's annotations or other articulations, information about which parts of the resource have been visited or which questions have been attempted or the current state in a simulated environment.

Conclusion

There are significant potential learning benefits from the use of interactive learning resources, but the production costs continually present a barrier to the widespread use of all but the simplest examples. The development of repositories containing reusable learning objects presents the obvious solution to this problem. In fact it could be said that such development is vital to the survival of the fledgling educational multimedia industry. However, if such resource banks are to be any more effective than the huge array of unclassified and irretrievable resources on the Internet today, significant standardisation is required. The IEEE LOM is a significant step in the direction of providing common standards for classifying, and thus retrieving, learning objects, but there are serious limitations in the degree to which it encompasses the pedagogical and user interface characteristics of learning objects.

This paper has proposed a classification scheme for learner computer interaction, suitable for use as a basis for enhancements to the IEEE LOM. It is suggested that such enhancements would allow educational designers and developers to more easily identify the suitability of a learning object to their particular learning situation. However, more work is required to thoroughly investigate the implications of these enhancements to the LOM.

Table 4: Example application of proposed scheme

	Geometer's Sketchpad	Alge Blaster Plus	Bihari Farmer	Investigating Lake Iluka	Gold Fields	Flashback	French Word Torture	The Incredible Machine	Lisp Tutor	Passage to Vietnam	Stella	BioKiosk	Teaching in Context	Sim City	Grolier Multimedia Encyclopaedia	The Intelligent Physics Tutor	Interactive Physics	Understanding the Unobservable	SemNet	Somazone
Cognitive task																				
1. Attending to static information		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X
2. Controlling media				X		X				X		X	X		X			X		X
3. Navigating the system		X	X	X		X	X	X	X	X	X	X	X		X	X	X	X		X
4. Answering questions		X		X		X	X		X							X		X		X
5. Attending to question feedback		X				X	X		X							X		X		
6. Exploring a world	X		X	X	X									X				X		X
7. Measuring in a world	X		X	X													X	X		
8. Manipulating a world	X	X	X		X			X			X			X			X	X		X
9. Constructing in a world	X							X			X			X			X			
10. Attending to world changes	X		X		X			X			X			X			X	X		X
11. Articulating				X									X					X	X	X
12. Processing data	X		X																	X
13. Attending to processed data	X		X																	X
14. Formatting output	X																		X	
Input technique																				
1. Typing		X		X			X		X		X		X		X	X	X	X	X	X
2. Valuators			X											X						
3. Key pressing																				
4. Pull down menus	X										X		X	X	X	X	X		X	
5. Menu lists		X		X		X						X	X		X			X		
6. Buttons	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X		X
7. Icons				X		X		X		X	X	X		X	X		X	X		X
8. Hot spots		X		X	X					X		X		X	X	X		X		X
9. Hypertext				X		X			X											
10. Scroll bars				X		X			X	X	X		X		X	X	X			X
11. Media controls				X		X				X		X	X		X			X		X
12. Selecting	X	X						X			X			X			X		X	
13. Dragging	X		X					X			X			X		X	X	X	X	X
14. Drawing	X										X			X			X	X	X	
System response																				
1. Displaying	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
2. Presenting media				X	X	X				X		X	X	X	X			X		X
3. Presenting cues	X	X	X	X	X						X		X	X	X	X	X	X	X	X
4. Branching		X	X	X	X	X	X	X	X	X	X	X	X	X	X			X		X
5. Assessing answers		X				X	X		X							X		X		
6. Generating feedback									X							X				
7. Updating world	X	X	X		X			X			X			X			X	X		X
8. Generating world	X	X	X		X			X			X			X			X	X		X
9. Processing data	X		X		X						X						X	X		X
10. Searching															X					X
11. Saving and loading				X									X					X	X	X

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