

Automated Instructional Design and Development

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Abstract: This paper identifies some of the requirements for an intelligent computer-based multi-media interactive instructional development and delivery system. We have illustrated the following:

Instructional design principles can be built-into intelligent design and development tools for use by subject matter experts.

Intelligent instructional development tools can significantly reduce the development delivery ratio.

Intelligent instructional development tools can empower subject matter experts for better instructional design of multi-media computer-based interactive instruction.

Introduction

What are the problems?

- Trained instructional developers are in short supply.
- ISD, especially for computer-based multi-media interactive instruction, is too labor intensive usually requiring more than 200 hours of development for a single hour of instruction.
- ISD is not adequate for computer-based multi-media interactive instructional development. It provides little guidance for interaction and it does not specify an adequate syntax for knowledge representation

What is the challenge?

- Reduce the development to delivery ratio by at least an order of magnitude -- from 200:1 to 20:1.
- Provide tools that empower subject matter experts to do effective computer-based multi-media interactive instructional development without requiring them to have extensive training in instructional design or authoring systems.

What is a possible solution?

Develop an intelligent instructional design environment with the following important features:

- It includes a built-in instructional design advisor.

- It provides guided knowledge acquisition (subject matter analysis).
- It automates much of the instructional development.
- It allows the user to override prescribed solutions.

This paper will describe and demonstrate the attempts of the Utah State University Department of Instructional Technology ID₂ research group to develop ID Expert™, an intelligent computer-based multi-media instructional development system.

Instructional transactions with built-in instructional design

The Gagné assumption

There are different kinds of knowledge and skill and each type of knowledge and skill requires unique conditions for learning. (Gagné 1985).

Learned performance is a function of engaging the learner in instructional interactions (conditions) which are appropriate for a given type of knowledge.

An instructional transaction shell is a computer program that encapsulates the conditions for a given type of knowledge or skill. An instructional system can use an instructional transaction shell over and over to teach different topics, and even different subject matter domains, providing the type of knowledge being taught is the same.

The computer program assumption

A computer program is an algorithm plus data. An algorithm is a procedure for performing some symbol manipulation task. Data are the symbols manipulated by a computer algorithm. Computer algorithms gain their power by being reusable. The computer uses the same algorithm over and over with different data.

An instructional transaction shell is a computer program that encapsulates the conditions for a given type of knowledge. We assume that an instructional transaction shell is an algorithm. We assume that we can decouple the subject matter (knowledge) to be taught from the strategy required to teach this knowledge. We assume that the subject matter to be taught is the symbols manipulated by the computer and represents the data part of the computer program. Therefore, we can use a given instructional transaction shell (computer algorithm) over and over to teach different knowledge (data).

What is a transaction?

An instructional transaction is a mutual, dynamic, real-time give-and-take between an instructional system and a student in which there is an exchange of information. An instructional transaction is an instructional algorithm that is a pattern of all of the learner interactions required to enable the acquisition of a particular kind of knowledge or skill. An instructional transaction shell is a computer program that promotes a particular set of learner interactions and that we can reuse it for different content topics providing these topics require the same kind of knowledge. An instructional transaction supports different kinds of instructional interactions including presentation, exploration, practice, and assessment.

Characteristics of an Identify transaction

We have described a number of classes of instructional transactions including identify, execute, interpret, classify, generalize, judge, decide, and transfer (Merrill, Jones & Li, 1992). We describe here some of the characteristics of an identify transaction.

We modeled an identify or naming transaction on paired associate learning from learning psychology. It enables the learner to acquire the ability to name, locate and describe parts of an entity. It encapsulates the following learning principles:

The system presents the learner one member of a pair (A, B) and asks the student to locate, recognize or recall the other member of the pair. Adequate learning has not occurred until when given A the learner can provide B, or when given B the learner can provide A for every pair in the learning task.

Adequate learning has not occurred until the learner can identify without delay one member of a pair when the system presents the pairs in random order.

Chunking the pairs to be learned into meaningful groups each of which include only a few pairs facilitates adequate learning.

Demonstration of an Identify transaction



Figure 1 Learner interface and sample lesson for ID Expert™

ID Expert™ is an instructional design tool that facilitates the development and delivery of computer-based interactive multi-media instructional materials. This system attempts to implement the instructional principles just described.

Figure 1 illustrates the student interface of ID Expert configured to teach a geography lesson on the countries of Europe. As the lesson opens the system displays a map of Europe and plays the following audio message:

"Welcome to European Countries. To begin select presentation, exploration or practice from the learn-by menu. We hope you enjoy learning about Europe."

The learn-by menu is a pull-down menu that, for this lesson, shows 3 selections: presentation, exploration, and practice. In this lesson, when the learner clicks on presentation, the system randomly selects a country, highlights its outline on the map, and waits for the learner to click the mouse on the country. When the learner clicks, the system displays the name of the country. When the learner clicks on the name, the system displays a brief description of the country. When the learner clicks on the description, the system presents a brief multi-media demonstration related to the country. In this lesson the system displays a text message and a short video clip describing a feature of the country. The system repeats this name, description, and multi-media demonstration for each country. The learner can stop the presentation whenever he or she wishes.

In this lesson, when the learner selects exploration from the learn-by menu, the system presents the names of all the countries simultaneously. When the learner clicks on a name, the system highlights the country's outline on the map, displays the text description of the country, and displays the multi-media presentation related to the country. The learner can explore the countries in any order and as many times as desired.

In this lesson, when the learner selects practice from the learn-by menu, the system selects a country at random and highlights its outline on the map. It then presents a response dialog box directing the learner to type the name of the country. If the learner is correct, the system presents a "right" message. If the learner is incorrect, the system presents a "try again" message for the first error, and a "wrong" message for the second error and then presents the correct answer.

The system then displays a selection response dialog box directing the learner to select the description corresponding to the country. If the learner is correct, the system presents a "right" message. If the learner is incorrect, the system presents a "try again" message for the first error, and a "wrong" message for the second error and then presents the correct description.

The system then presents a multi-media selection response dialog box (see figure 2) directing the learner to select the multi-media presentation corresponding to the country. The learner can view a multi-media demonstration by clicking the view button. Again the learner has 2 tries to select the correct demonstration. The learner repeats this pattern of response for each country. In this lesson, the learner can abort practice at any time.



Figure 2 Learner response dialog for selecting a multi-media presentation

The above demonstration is not unusual. An instructional designer could have created this lesson using any of a number of available authoring systems. The unique feature of this presentation is that the user (author) did not create any of the interactions; ID Expert automatically created the presentation, exploration and practice interactions. The user merely supplied the subject matter to be taught.

A knowledge base -- uncoupled subject matter

Knowledge representation

We previously stated the assumption that subject matter can be decoupled from instructional strategy and that knowledge (subject matter content) is the data manipulated by an instructional algorithm (instructional transaction).

We assume that the system can represent knowledge and skill from different subject matter domains using a common syntax or knowledge structure. We assume that the user can detach this knowledge structure from the instructional transactions required to teach this knowledge to a learner. We further assume that the user can detach the resources (multi-media representations including text, graphics, video, and audio) from the knowledge that they portray. We have previously described an *elaborated frame network* knowledge representation system (Jones, Li & Merrill, 1990).

Engaging the learner with an appropriate type of knowledge structure and appropriate representations of the knowledge or skill to be acquired facilitate learned performance.

Entity knowledge

In an elaborated frame network we have identified three types of knowledge objects: entities, activities, and processes. An identify instructional transaction is appropriate for teaching the parts, location of the parts, and descriptions of the parts of an entity. An entity knowledge object is a device, object, person, creature, place or symbol. An entity knowledge object consists of several slots (knowledge elements) including a manifestation, a name, a location, a description and a demonstration. The system represents each of these knowledge elements by multi-media resources. The system usually represents a manifestation by a graphic that illustrates the entity or part of an entity. The system manifests some entities by other forms of multi-media representation including audio, video, and text. The system usually represents the name by a text string or an audio name. It represents the description by text or an audio description. The demonstration can be any multi-media representation including text, graphic, audio, or video.

A given knowledge object can have more than one manifestation or demonstration. The user can attach the same knowledge object to different multi-media representations.

Demonstration of ID Expert -- linking in new knowledge

ID Expert™ enables the user (subject matter expert) to couple and uncouple knowledge from a given transaction by the click of a button. The knowledge exists in a knowledge base separate from the instruction enabling the user to couple, uncouple and reuse the knowledge without any additional development effort.

Figure 3 illustrates the knowledge base interface for ID Expert™.

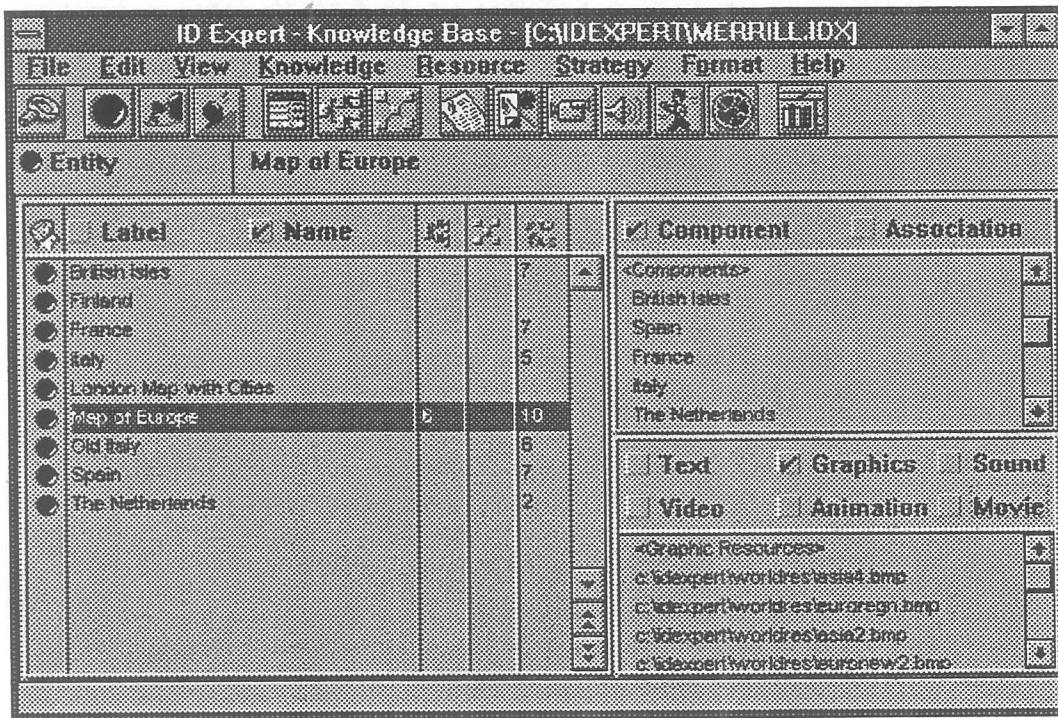


Figure 3 Knowledge Base interface for ID Expert™.

The left panel of the dialog lists each of the knowledge objects in the knowledge base in alphabetical order. In our illustration the focus knowledge object is the "Map of Europe". The user has selected this knowledge object in the left panel. Its full name appears in the upper right panel under the icon bar. The upper right panel shows the components of the selected knowledge object. The components of an entity are parts. In this knowledge base the focus knowledge is a "Map of Europe", its components are the countries to be taught: British Isles, Spain, France, Italy, The Netherlands, etc. The lower right panel shows multi-media resources attached to the selected knowledge object. The second item "c:\idexpert\worldres\europregn.bmp" is the map of Europe used in the illustrated lesson. The user may select other resources when this knowledge object is used in other lessons.

To attach an existing knowledge object to our focus knowledge and hence to our lesson is very easy. Finland appears in our knowledge base but it is not attached to our focus knowledge. To include Finland in our lesson, the user clicks on the focus knowledge (Map of Europe) in the left panel to select it and then selects Edit Component Information from the knowledge menu.

The system displays the component dialog to the user (see Figure 4). The user puts the pointer in the panel where the new component (the country of Finland) is be linked and clicks the right mouse button. A pop-up menu appears. The user selects the Link Component option. A selection dialog lists all the appropriate components in the knowledge base. If the user has already created the knowledge object (Finland), then it appears in the knowledge base. By merely clicking on its name, the user attaches Finland to the focus knowledge object (Map of Europe). The next time the system presents the lesson, it includes the new component (Finland).

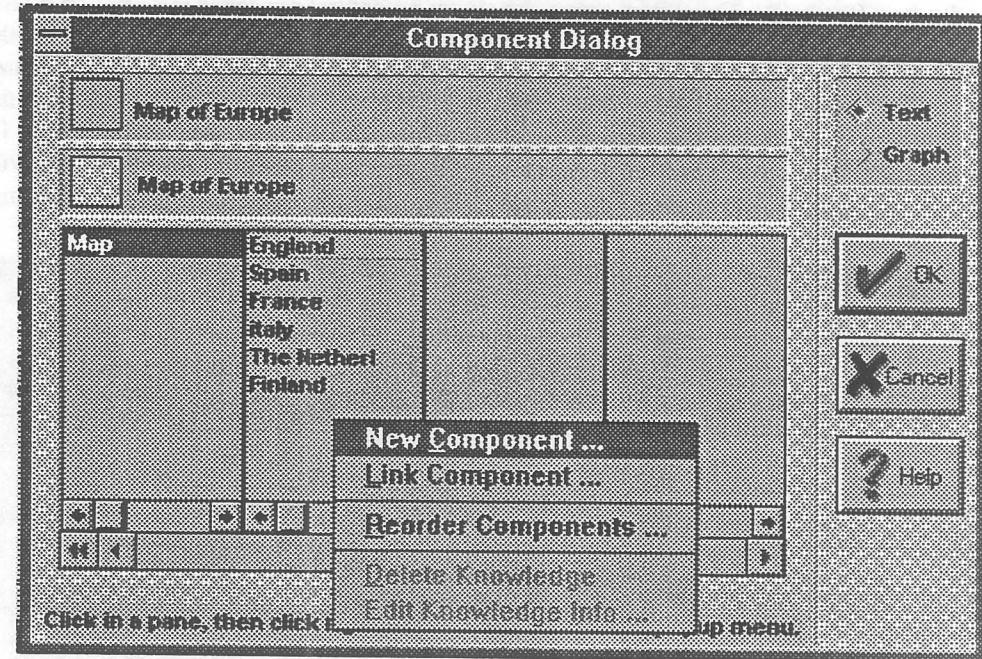


Figure 4 Edit Components dialog for linking components to a knowledge object.

If the user wants to detach a given component from the focus knowledge object and hence from the lesson, then the user again clicks on the focus knowledge to select it and selects the Edit Components command from the knowledge menu (see Figure 4). The system displays the component dialog. The user clicks on the component to be removed to select it, clicks on the right mouse button with the pointer in the components panel causing the pop-up menu to appear, and then selects Delete Knowledge from the pop-up menu. There are two levels of delete. The user can detach the knowledge from the focus knowledge thus eliminating it from the lesson, but it can still remain unattached in the knowledge base for use another day. The user can also completely remove the knowledge object from the knowledge base.

Demonstration of ID Expert -- creating new knowledge

ID Expert™ enables the user (subject matter expert) to easily create a new knowledge object independent from the transaction(s) that will use this knowledge object. ID Expert enables the user to link one or several resource configurations to the knowledge object. We will demonstrate the creation of a new knowledge object using ID Expert™. The system includes the capability to call up multi-media editors to select, create or edit resources for attachment to a knowledge object. The user can create knowledge objects once and can then reuse them as often as necessary. Once created the user can link the knowledge object to a transaction without any

requirement to modify the existing transaction shell. The user can use the same knowledge object in different transactions. Because a knowledge object can have multiple resource configurations its appearance to the student may be completely different when the user reuses it in another transaction.

To create a new knowledge object is very easy. Suppose that we want to add Switzerland to our lesson. The user (author) selects "New Entity" from the knowledge menu or clicks on the new entity icon (the ball). The system shows the author an entity knowledge information dialog (Figure 5). The user types in the name of country (Switzerland), and a description of the country. If the user anticipates using a constructed response for the description, then the user clicks on the key words button. A key words dialog enables the user to specify key words that the system will use in evaluating the learner's response. The answer processing algorithm of ID Expert supports logical AND and OR connections between key words. It also allows for wild card letters and approximate spelling. ID Expert will teach the lesson even if the user does not provide key words.

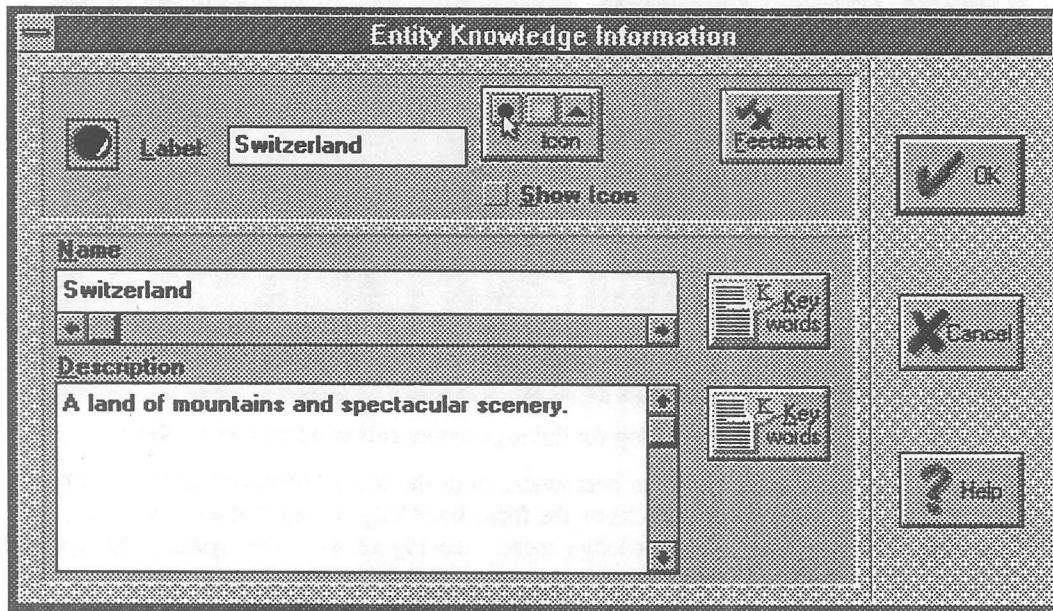


Figure 5 New entity knowledge information dialog.

To attach (link) the new component (the country Switzerland) to the focus knowledge (the map of Europe) the user selects "Edit Component Information" from the knowledge menu. The component dialog box (see Figure 4) shows all of the components of the focus knowledge. Clicking the right hand mouse button while the mouse is in the panel showing where the user wishes to add the component knowledge, causes the pop-up menu to appear. The user selects Link Component from the pop-up menu. The system shows the user a list of all the entity knowledge objects in the system. Switzerland now appears in the list. The user merely clicks on Switzerland to add it as a component of the Map of Europe. The user could have added the new knowledge object (the country Switzerland) directly to the focus knowledge (the map of Europe) by selecting New Component from the pop-up menu. The system would then display the entity knowledge information dialog (Figure 5) and would automatically link the new component to the focus knowledge.

The knowledge object contains the name and description of our new country but does not include a multi-media demonstration. If we want to also include a multi-media demonstration then we must link resources to our new knowledge object (country). The user clicks on the new knowledge object (Switzerland) in the left panel of the knowledge base interface (see Figure 3) and then selects Assign Resources from the Resource menu. The system displays the assign resources dialog to the user (Figure 6). From the Assign Resources dialog the user can select previously created multi-media resources or create new resources. To attach a resource the user clicks on the appropriate button corresponding to the type of resource to be selected or created. A resource dialog (see figure 7) then enables the user to search for an existing resource, edit a resource, preview a resource, or open the original resource editor to create a new resource.

A given knowledge object can have a large number of resources assigned as shown in the right panel of Figure 6. The user can then arrange these resources into different configurations. Hence, a given knowledge object may also have several different resource configurations. When the system presents the knowledge object in one lesson it might use one configuration of resources; when the system uses the knowledge object in another lesson it may have a different configuration of resources. Thus the same knowledge object can appear in many different ways when the system presents it to the learner. In the current illustration, our new component (the country Switzerland) has a demonstration consisting of three components: A piece of text, an audio (wav) file explaining something about the country, and a graphic picture illustrating the mountains.

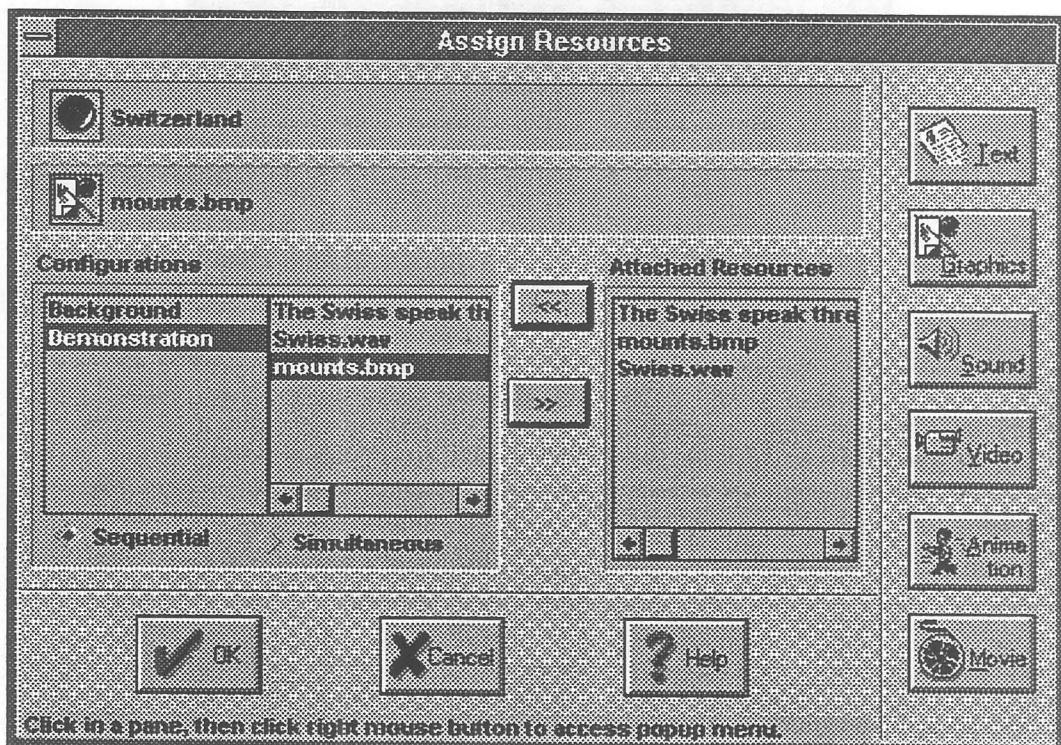


Figure 6 Assign resources dialog.

Except for some formatting of the resources, we have now completed our authoring of a new component of the lesson. The next time the system presents the lesson, it will include a presentation, exploration, and practice interaction for Switzerland. The user did not concern themselves with any of the instructional strategy but merely created a new knowledge object and attached appropriate resources to this object.

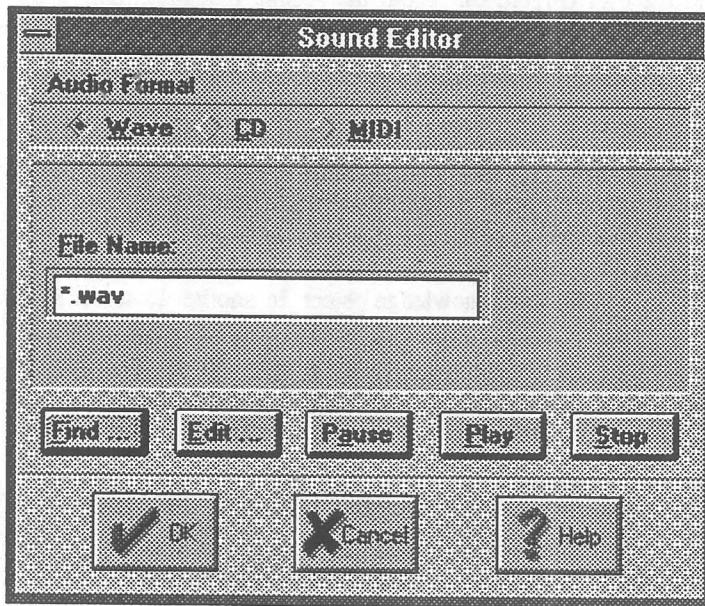


Figure 7 Multi-media resource dialog for sound.

Automated instructional design -- parametized interactions

Parameters

Instructional transactions can carry out their responsibilities (interactions with the students) in a number of different ways. A set of parameters controls instructional transactions and determines how they carry out their interactions. Changing the value of an instructional parameter changes the way that this instructional transaction interacts with the student. The user can change the parameter values or the system can automatically change the parameter values based on built-in rules for effective instruction.

The way a particular instructional transaction carries out its responsibilities is a function of the characteristics of the learners being served, the subject matter domain (knowledge) being taught, and the instructional environment in which the instruction is occurring. An instructional designer must adjust the parameters of an instructional transaction to best accommodate particular learners, learning tasks, and learning environments. An intelligent system, given information about learners, learning tasks, and learning environments can use its internal rules to automatically adjust the parameters of an instructional transaction to best accommodate particular learners, learning tasks, or learning environments.

Demonstration of instructional parameters

Instructional parameters control ID Expert™. Figure 8 is the Identify Transaction practice parameter dialog. The user selects the element to be presented to the learner by clicking the check boxes in the left panel of the dialog. The user selects the response elements (the information to be supplied by the learner) by clicking the check boxes in the right panel of the dialog. Sequence can be either "simultaneous" or "sequential". Simultaneous requires the learner to engage in each type of practice (recall the name, recognize the description, and select the correct demonstration) for each part (country) before responding to the next part (country). Sequential would require the learner to name each part (country) first, then to recognize the description for each part (country), and then to select the demonstration corresponding to each part (country). The "Allow user to abort practice" check box, the "Mastery Criterion" and "# of retries to reach criterion" parameters are self explanatory.

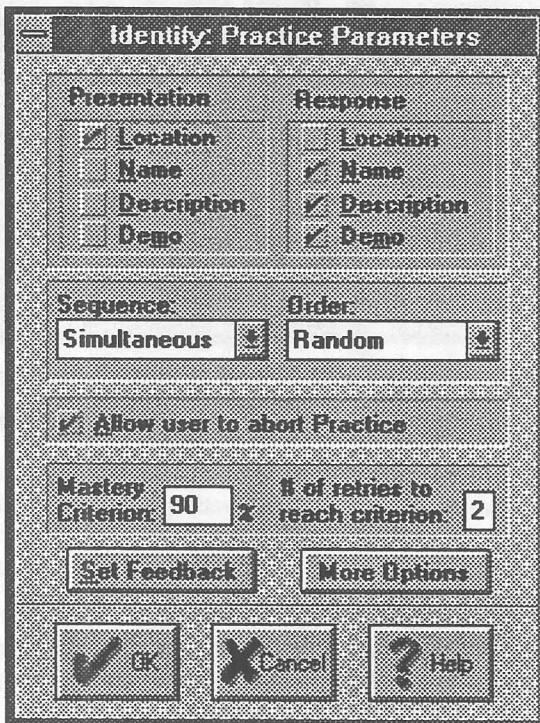


Figure 8 Practice parameters for Identify Transaction

Figure 9 illustrates additional response parameters for identify practice. The system can time the responses or it can "wait for user input". Responses can be recall (type the answer) or recognize (multiple choice).

The parameter settings illustrated are those used for the practice in the sample lesson described in the section "Demonstration of an Identify Transaction" above.

The practice can be easily reconfigured by merely clicking on the check boxes to change the parameters. Suppose that the desired practice is for the learner to merely point to the country shown the name within 3 seconds. The user (instructional designer) clicks the check box for name in the first panel (Figure 8) and clicks the box for location in the second panel. The user

clicks the "Wait for [] seconds" box for Location Response Time and types in the value 3 (Figure 9). The system will modify the next enactment of the practice to correspond to this parameter change.

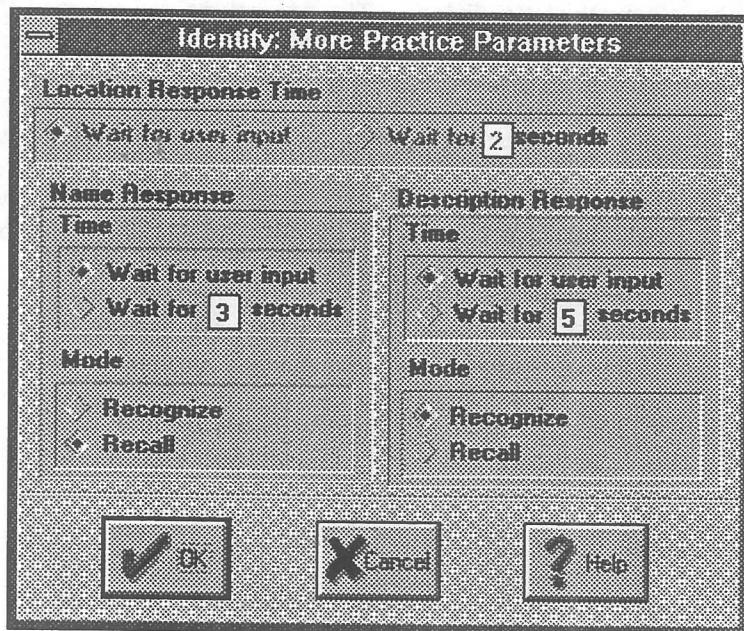


Figure 9 Response parameters for Identify Transaction

Demonstration of automatic configuration based on audience characteristics

ID Expert™ has built-in transaction configuration rules. When by the click of a button the user changes a learner characteristic (such as motivation or experience), the transactions are automatically reconfigured to be more appropriate for learners with these new characteristics. The user can also override this automatic configuration by the click of a button.

Figure 10 is the Audience configuration dialog. The user or instructor can, by means of the pull down menus or radio buttons, select certain learner and task characteristics. Learner variables of motivation can be low or high; and experience can be low or high. The required learning level can be overview, familiarization, basic or mastery. The learning environment may include a job aid. Expert system rules relate these variables to parameter values. Changing an audience configuration variable will automatically change the related parameter values when the user clicks the "Change all strategies" button on this dialog.

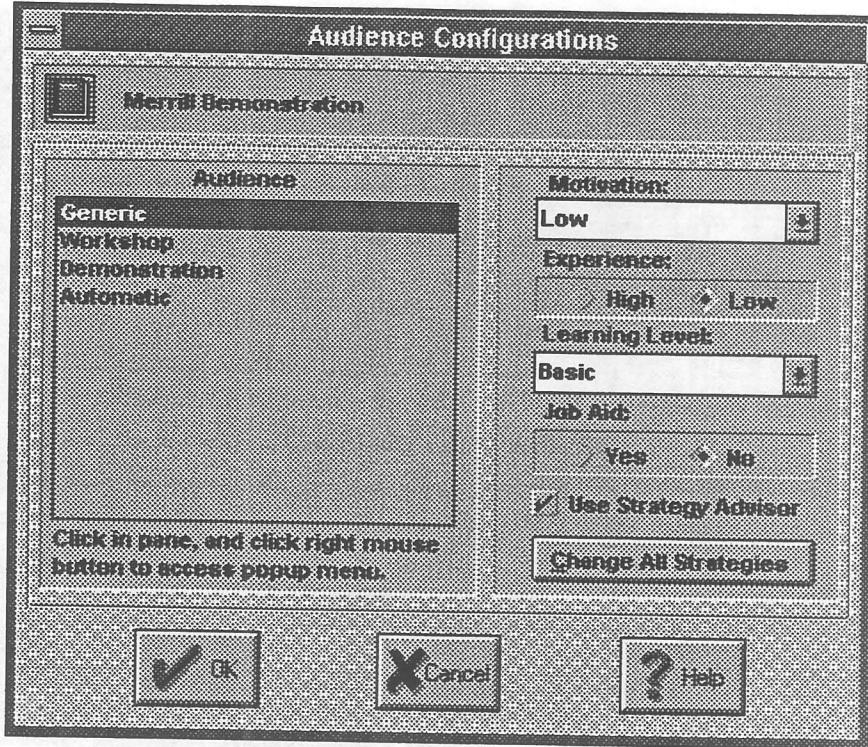


Figure 10 Audience configuration dialog.

Demonstration of reconfiguration based on predefined parameters

ID Expert™ enables the user to save course configurations. By clicking in the audience panel of the audience configuration dialog (Figure 10) the user can define a new audience configuration. The system saves all of the parameter settings adjusted by the user for this particular audience configuration. When the user selects this audience configuration from the pull down menu (Figure 11), the system automatically changes the parameters to those which the user has set for this particular configuration. In other words, the course can be reconfigured by the touch of a button. The user can define as many audiences as desired. Each audience can have a unique configuration of parameters, set either by the automatic expert system rules for audience characteristics, or manually set by the user using the strategy dialogs for lessons, segments, or transactions. With existing systems it is usually necessary to have multiple versions of the course for different audiences. The required development time for multiple courses is very costly. With ID Expert™ such reconfiguration is available at the touch of a button.

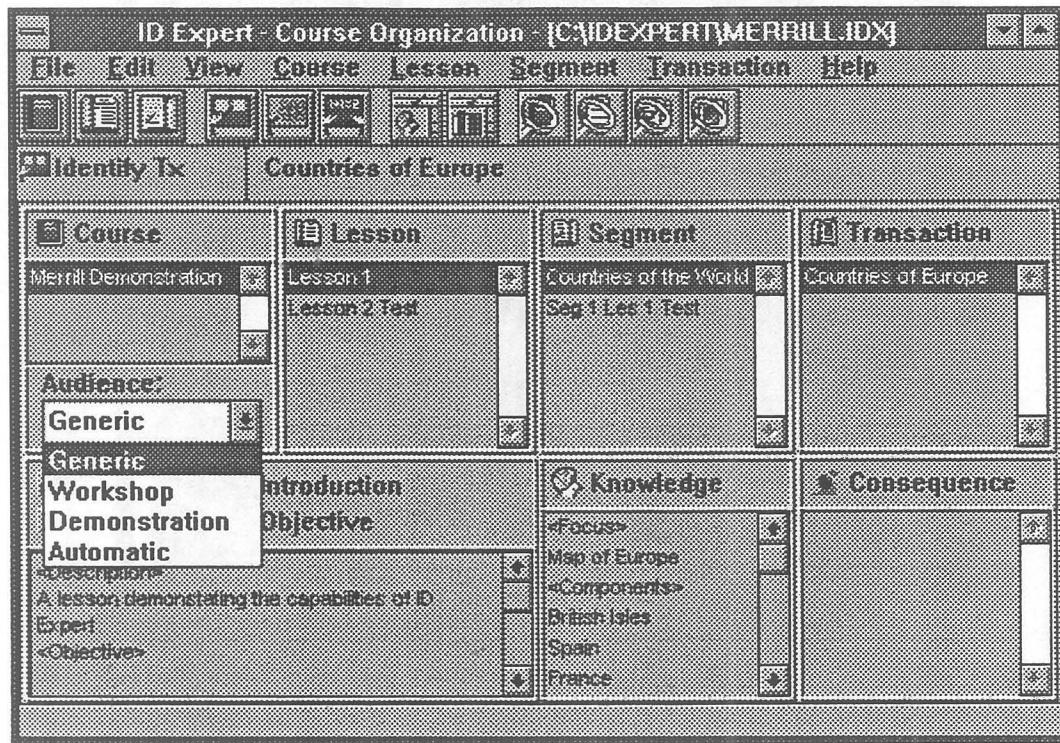


Figure 11 Course reconfiguration at the touch of a button.

Automated instructional design – interaction selection and sequence

A transaction manager

Most instructional designers consider learning goals or objectives as a fundamental task of ISD. However, if the user specifies the knowledge using a known knowledge structure (such as an elaborated frame network), then an intelligent system can contain rules for automatically generating the goals that are possible for a given body of subject matter knowledge. If the knowledge structure contains interconnections between knowledge objects, and these interconnections are for known relationships, then an intelligent system can contain rules for automatically generating lesson and segment sequences appropriate for the knowledge to be taught.

A transaction manager has two responsibilities: first, to assign and sequence knowledge objects to lessons and segments; and second, to assign parameter values to configure the transactions and interactions to best meet the needs of particular learners, learning tasks, and learning environments.

Automated objectives

When the system knows the type of knowledge object and the elements of the knowledge object, then the system also knows what instructional objectives are possible. The system can generate statements of these objectives and the user can select from the possible objectives those which are appropriate for a given course or lesson.

For example, if the knowledge object is a process, then the following objectives represent the range of skill that a student can acquire with regard to this process:

- Recognize and name the events of the process.
- Recognize a correct demonstration of each event in the process
- Predict which events of the process will or will not occur under different conditions.
- Predict which events of the process will or will not occur under different faulted conditions.

If the user has not yet specified appropriate knowledge, it is still possible for an intelligent system to generate a list of possible objectives. When the user selects the desired objectives from the possible objectives, then the system can guide the user to specify the knowledge objects and knowledge elements that are required to instruct these objectives.

Automatic selection and sequence of lessons

If the knowledge base contains appropriate elaboration of knowledge objects, then the system can use its algorithms to select and sequence appropriate segments for a lesson and appropriate transactions for a segment. An elaborated frame network includes specified elaborations of knowledge objects. Every process owns event components; every activity owns step components; and every entity owns part components. Every process is owned by an entity and is defined as changing the properties of an entity. Every activity is owned by an entity and the execution of the activity changes a property of this entity. The elaborated frame network specifies these association links, and the properties involved. The internal rules of the system define a segment to teach a process that includes the following transactions: a transaction to enable the learner to identify the parts of the entity involved in the process; a transaction to enable the learner to enact each of the activities owned by the entity; a transaction to enable the learner to interpret the events of the process.

Automatic selection and sequence of strategies

Built-in strategy rules enable the system to configure the transactions selected by assigning appropriate values to the transaction parameters. Some of these parameters include the following: *transaction levels* ranging from providing information about the process, a demonstration of the process, to allowing the learner to manipulate property values and see effects in a simulation of the process. Other parameters are *Transaction sequence* including an integrated presentation (the system completes the presentation for each transaction prior to exploration, prior to practice, and prior to assessment); a segregated presentation (the system completes each transaction prior to enacting of the next transaction); and learner control of transaction sequence (the system lists the name of each transaction in a learn-about menu that enables the learner to select the transactions in any order). *Interaction sequence* includes a standard sequence (presentation, practice, assessment); a remedial sequence (assessment or practice first, followed by presentation or exploration of content not at the criterion level); and learner control (the system lists the interaction modes on a learn-by menu). Built-in rules automatically configure each of these strategy parameters; however, when the user judges the resulting instruction to be inappropriate, the user can access these parameters and override the built-in rules.

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