

A Taxonomy to Aid Acquisition of Simulation-Based Learning Systems

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ABSTRACT

Simulations are increasingly being used for education and training a range of skills, including convoy driving, flying aircraft, repairing vehicles, and performing surgery. At the same time, the Sharable Content Object Reference Model (SCORM) is now required as the standard for U.S. Department of Defense Interactive Multimedia Instruction (IMI). Simulation-Based Learning Systems (SBLs) are being developed that combine SCORM IMI for knowledge acquisition with simulations for experiential learning. The design of SBLs requires weighing a range of issues, each with risks and benefits, to achieve a cost-effective result for a specific set of education or training requirements. However, different education and training requirements lead to different SBL designs with different issues.

This paper describes a taxonomy that was developed to characterize different classes of SBL designs and to identify design issues associated with each class. The taxonomy identifies each class of SBL by a set of discriminators, which are grouped into three categories:

- System functionality discriminators (describe how the SBL controls the simulation, provides the training content, and presents student assessments)
- Human computer interface discriminators (describe how the student and the instructor interact with the system)
- System environment discriminators (describe the location and ownership of simulation and learning management system assets, including servers, student and instructor client machines, and the network connecting these components).

This paper presents SBL design issues, including risks and benefits, in the context of the six quality metrics—interoperability, accessibility, adaptability, reusability, durability, and maintainability—developed by the Advanced Distributed Learning consortium for the SCORM standard. Examples of SBLs presented to the standards group are characterized using the taxonomy.

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INTRODUCTION

Simulations are increasingly being used for education and training a range of skills, including: convoy driving, flying aircraft, repairing vehicles, and performing surgery. At the same time, the Sharable Content Object Reference Model (SCORM) is now required as the standard for U.S. Department of Defense (DoD) Interactive Multimedia Instruction (IMI) (DoD, 2006). Simulation-Based Learning Systems (SBLs) are being developed that combine SCORM IMI for knowledge acquisition with simulations for experiential learning. The design of SBLs requires weighing a range of issues, each with risks and benefits, to achieve a cost-effective result for a specific set of education or training requirements. However, different education and training requirements lead to different SBL designs with different issues.

SIMULATION-BASED LEARNING SYSTEMS

SBLs use simulations as an integral part of the learning experience. The simulation component of an SBL can provide a safe, cost-effective environment for the student to practice their skills while learning by doing. The SCORM component of an SBL can increase the effectiveness of the experiential learning by:

- Providing supporting IMI (such as familiarization with equipment controls and indicators, or reading the steps of a procedure from a manual)
- Determining the sequence of learning experiences, interleaving didactic IMI lessons and simulation scenarios
- Using both simulation information and IMI tests to assess student performance (often through mechanisms like After Action Reviews [AARs]).

Simulation-Based Learning Systems Components

The taxonomy follows the SCORM model and assumes the following elements of an underlying architecture (shown in Figure 1):

- **The students who are interacting with the SBLs in order to learn:** For individual training, there is no interaction between the students either directly or through the SBLs. For collective training, the SBLs provides methods for the students to interact with each other.
- **A user interface that is presenting information to the student user**
- **A simulation system that is computing the consequences of the student's actions in the context of the learning event**
- **An instructor who may or may not be interacting synchronously with the student.** If the instructor is operating asynchronously, then the learning management system (LMS) is responsible for sequencing the student learning experiences and for providing real-time feedback to the student.
- **An LMS that can serve up learning events to the student user.**

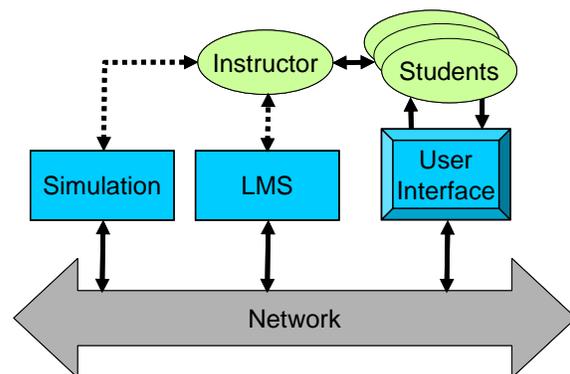


Figure 1. Components of an SBL

Lessons Learned From Standards Activities

This paper presents lessons learned about the risks and benefits of SBL designs gained through the efforts of an ongoing IEEE study of potential standards for SBLs (Dargue, Smith, Morris, & Frank, 2006). In February 2006, the IEEE Learning Technologies Standards Committee (LTSC) and the Simulation Interoperability Standards Organization (SISO) initiated a study group to determine if standards could

be developed to support the interoperability of SCORM content with simulations. The study group has conducted several meetings and collected 23 position papers from various interested parties. These position papers are the primary sources for this paper. Additional lessons learned were extracted from a study of SBLs for endoscopic surgery (Lamata et al., 2006).

The taxonomy of learning systems described here was developed to capture many of the variations in SBLs discussed by this group. The goal was to use the taxonomy to identify potential simulation market segments and the issues related to those segments that could lead to the greatest benefit for initial standards efforts. The taxonomy would also help the study group to understand those types of SBLs that were (and were not) supported by proposed standards. The taxonomy was also a way to document assumptions about the SBL and to understand how those assumptions influenced the issues.

THE SIMULATION-BASED LEARNING SYSTEM TAXONOMY

A Taxonomy as a Decision Aid

A taxonomy can be viewed as a decision tree, where each level in the tree asks a multiple-choice question. The possible answers to that question discriminate the possible branches to the subtree. Figure 2 depicts a question-and-answer path through the taxonomy. The decision nodes with the same colors all have the same question and the same possible answers.

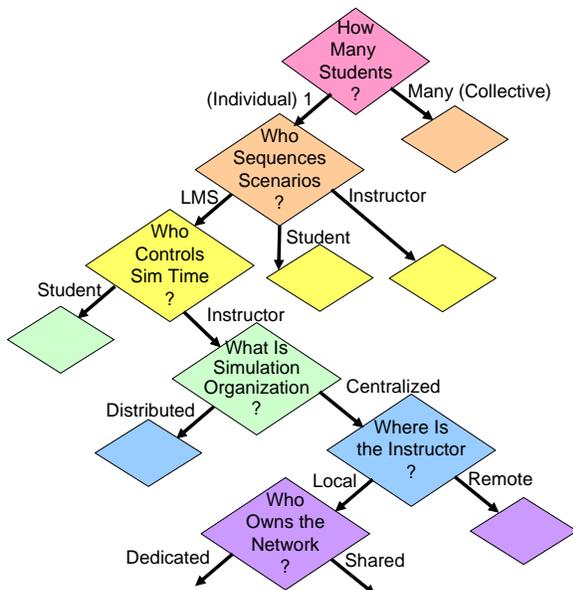


Figure 2. Taxonomy as a Decision Tree

Alternatively, each possible simulation in this taxonomy can be characterized by the values of its discriminators, which serve like keywords for searching a database.

Taxonomy Assumptions

The taxonomy does not discriminate on the basis of the application domain of the SBL. Following the example of the SCORM standard, the IEEE study group wanted to identify the interface needs (and therefore standards opportunities) of SBLs that would be applicable across the widest possible range of applications. The taxonomy is consistent with this philosophy.

Similarly, this taxonomy does not discriminate on the basis of pedagogical approaches, although a specific pedagogical approach may imply decisions about some of the discriminators. Again, SCORM does not specify a pedagogy it supports, and the taxonomy is consistent with this philosophy.

Following the model of SCORM, the taxonomy focuses on the operation of the SBL during education and training and does not consider the lesson development environment. Consistent with this focus, it considers two human roles that can be active during the learning: the student user and the instructor.

Categories of Discriminators

The discriminators used in this taxonomy are based in part on the work of Maier and Grossler (2000), who propose three categories of discriminators for a simulation taxonomy: underlying model, human computer interface, and functionality.

Because this taxonomy is focused on SCORM-simulation interfaces, the underlying model category was combined with the functionality category and used to capture information about pedagogical and application domain issues. However, a third category of system environment has been added to the taxonomy to capture discriminators that characterize the location and ownership of resources needed to implement the SBL. Thus, the three categories of discriminators used in this taxonomy are:

- System functionality
- Human computer interface (HCI)
- System environment.

These categories and their discriminators are discussed below.

System Functionality Discriminators

The system functionality discriminators identify some application domain and pedagogical decisions that may influence the design of the SBLs. The study group discussions indicated that there are many open issues specific both to the application domains and to the use of simulations for pedagogy. The taxonomy extracts two key decisions:

- Is the system for collective or individual training?
- Who controls the sequencing of the learning events: the LMS or the instructor?

The decision as to whether the system is for collective or individual training has a major impact on how the SBLs can support pedagogy. For example, whether the SBLs is designed for individual or collective training will greatly affect the functionality the SBLs must provide to support AARs. Different human performance measures are needed for individual training and collective training.

The decision between collective and individual training also impacts the management of simulated time, which is one of the HCI discriminators. Good pedagogy requires control over simulated time. For example, if a student is about to commit a life-threatening act, it is often good training to freeze the simulation and provide some didactic instruction (McMaster et al., 2002). This strategy works for individual training, but conflicts with the fairness goals of collective simulations, where maintaining a consistent simulation timeframe across the network of students and simulation servers is critical (King et al., 2007).

The question of who controls the sequencing of the learning events implies multiple design decisions about how the SBLs supports the assessment of the student. Sequencing includes the presentation of AAR materials and the selection of remediation learning events. Sequencing is the primary mechanism for implementing remediation provided by the SCORM 2004 standard (ADL, 2004).

If the instructor is responsible for sequencing the learning events, then the LMS does not make decisions about student performance or select remedial learning experiences. In this case, the SBLs is responsible for providing information that the instructor can use to make assessments and select appropriate remediation. A language is being developed for describing human performance (Haimson & Stacy, 2006) that is a candidate standard. Multiple AAR systems have been developed to provide support for the instructor (e.g., Jensen et al., 2006).

The taxonomy of endoscopic surgery simulations (Lamata et al., 2006) classifies AAR functionality by discriminating among the tools provided to the instructor. It describes learner guidance in terms of procedural guides, visual and tactile cues, and interaction indicators. It describes instructor support in terms of managing features (including support for selecting learning experiences based on the learner's level of expertise) and tutoring tools, such as instructor control of the student's environment or replay of student actions.

If the LMS is responsible for sequencing learning events, then the SBLs needs more extensive assessment functionality. The study group had extensive discussions of assessment frameworks, which emerged as a leading opportunity for standards. Some assessment frameworks are derived from the critical tasks and performance measures specified by the learning institution (Frank et al., 2004), so the simulation results are directly applicable to the student score sheets maintained by the instructor. Other assessment frameworks apply intelligent tutoring techniques (Jensen et al., 2005).

Human Computer Interface Discriminators

The HCI discriminators capture characteristics of the system from the perspective of two key users: the student or learner and the instructor or mentor. The taxonomy focuses on three decisions about the HCI that have significant impact on the architecture:

- **Control over the simulated time:** For example, can a student go back in simulated time, or skip forward to a new point in time?
- **Control over the simulated environment:** This includes particularly the ability to establish the initial conditions for a session or the ability to dynamically alter the environment during the session.
- **Interactivity of the assessment:** The study group sees this as an important distinction between a simulation and an SBLs (Dargue, Smith, Morris, & Frank, 2006).

A key issue relating to the interface is the need for real-time exchange of control between the simulation and the tutoring or scaffolding elements of the learning system. The prevalent method discussed by the study group is sequential handoffs, where the learning system provides didactic information and then cedes control to the simulation. After the simulation is complete, the learning system resumes control to provide the AAR.

One of the position papers (Ostyn, 2006) organizes user interface issues in terms of fidelity along five dimensions: auditory, behavioral, kinesthetic, tactile, and visual. The taxonomy of endoscopic surgery simulations (Lamata et al., 2006) addresses issues related to visual fidelity. It includes a quantitative rollup of detailed fidelity discriminators along three axes:

- Fidelity of the representation of the surgical environment and tools available to the learner
- Fidelity of the mechanical interactions, including collisions, deformations, and even interaction forces
- Fidelity of the representation of pathological behaviors, including modeling of fluids during surgery and the representation of physical aspects of the disease.

Fidelity for equipment maintenance training can be described with a similar approach (McMaster et al., 2002; Evens et al., 2006). In this case, a key issue is providing the environmental realism in a 3D display with appropriate navigation and having the detailed display of the fine print of text in computer monitors or similar read-out devices. Issues related to the representation of test and instrumentation equipment are also important.

System Environment Discriminators

The system environment discriminators capture implications for the system design in terms of characteristics of resources needed to implement the system: clients, servers, and networks. This category of discriminators arose as a way of describing the variability of “wiring diagrams” for simulations presented in the position papers (Hyde, 2006) and also as a way of associating issues and problems that are relevant to one situation, but perhaps not relevant to other situations.

The taxonomy focuses on three aspects of the system environment that significantly impact the architecture:

- Organization of the simulation: centralized or distributed
- Relative location of the instructor and student
- Ownership of the student client machines, simulation servers, and the network.

For High-Level Architecture (HLA) or Distributed Interactive Simulation (DIS) simulations, the simulation is considered distributed in the taxonomy. However, many SBLs have a centralized simulation (Frank et al., 2003; Smith & Dubic, 2006). Distributed simulations communicate over the network and

therefore have to address network performance and access issues.

The relative location of the instructor and the student has a significant effect on the pedagogical functionality required of the SBLs. If the instructor is co-located with the student, then much of the pedagogical work can be provided by the instructor and the SBL functions as a training aid for the student and instructor. This taxonomy assumes that if the student and instructor are co-located, then the instruction will be synchronous. If the instructor is remotely located, then the distinction between synchronous and asynchronous learning has an impact on the functionality required of the SBLs (Arguello et al., 2006). For synchronous learning, the SBLs must provide communication and collaboration tools and the instructor provides much of the pedagogical support. For asynchronous learning, the SBLs must provide the pedagogical support, and the architecture will shift to something closer to an intelligent tutoring system.

Ownership of the student client, the simulation servers, and the network is characterized as either dedicated to the SBLs or shared. Use of shared networks is complicated by security and performance issues that can be avoided with dedicated networks, clients, and servers. Designing SBLs to conform to shared-network protocol standards (such as service-oriented architectures) has potential benefits for the asynchronous upgrade of SBLs components and the supporting software and hardware infrastructure. The use of shared-network protocol standards is a key element of SCORM.

SIMULATION-BASED LEARNING SYSTEM TAXONOMY EXAMPLES

Figure 3 shows a database structure for the taxonomy, where each column specifies a discriminator and each row shows the records of the database (indicated by the references on the right) that are retrieved by using the values of the discriminators in the cells to the left.

Figure 3 shows part of the taxonomy for individual training and provides examples that show the diversity of architectures described in the position papers. These example SBLs represent each answer to each question, although not all combinations are represented. For example, Haynes et al. (2004) describe a system where the scenarios are sequenced by the LMS. McMaster et al. (2002) describe a system where the scenarios are sequenced by the instructor. Similarly, Cooper et al. (2004) describe a system that is downloaded over the Internet, and Waters et al. (2003).

User Multiplicity	Who Sequences Scenarios	Who Controls Simulation Time	Simulation Org	Instructor Location WRT Student	Network Ownership	Example Reference
Individual	LMS	Student	Centralized	Local	Shared	
Individual	LMS	Student	Centralized	Local	Dedicated	
Individual	LMS	Student	Centralized	Remote	Shared	(Cooper et al., 2004)
Individual	LMS	Student	Centralized	Remote	Dedicated	
Individual	LMS	Student	Distributed	Local	Shared	
Individual	LMS	Student	Distributed	Local	Dedicated	
Individual	LMS	Student	Distributed	Remote	Shared	(Haynes et al., 2004), (Spaulding,
Individual	LMS	Student	Distributed	Remote	Dedicated	
Individual	LMS	Instructor	Centralized	Local	Shared	
Individual	LMS	Instructor	Centralized	Local	Dedicated	
Individual	LMS	Instructor	Centralized	Remote	Shared	
Individual	LMS	Instructor	Centralized	Remote	Dedicated	
Individual	LMS	Instructor	Distributed	Local	Shared	
Individual	LMS	Instructor	Distributed	Local	Dedicated	
Individual	LMS	Instructor	Distributed	Remote	Shared	
Individual	LMS	Instructor	Distributed	Remote	Dedicated	
Individual	Instructor	Student	Centralized	Local	Shared	
Individual	Instructor	Student	Centralized	Local	Dedicated	(Waters et al., 2003)
Individual	Instructor	Student	Centralized	Remote	Shared	
Individual	Instructor	Student	Centralized	Remote	Dedicated	
Individual	Instructor	Student	Distributed	Local	Shared	
Individual	Instructor	Student	Distributed	Local	Dedicated	
Individual	Instructor	Student	Distributed	Remote	Shared	
Individual	Instructor	Student	Distributed	Remote	Dedicated	
Individual	Instructor	Instructor	Centralized	Local	Shared	(McMaster et al., 2002)
Individual	Instructor	Instructor	Centralized	Local	Dedicated	
Individual	Instructor	Instructor	Centralized	Remote	Shared	
Individual	Instructor	Instructor	Centralized	Remote	Dedicated	
Individual	Instructor	Instructor	Distributed	Local	Shared	
Individual	Instructor	Instructor	Distributed	Local	Dedicated	(Dargue, Biddle, & Perrin, 2006)
Individual	Instructor	Instructor	Distributed	Remote	Shared	
Individual	Instructor	Instructor	Distributed	Remote	Dedicated	(Morris, 2006)

Figure 3. Taxonomy for Simulation-Based Individual Learning Systems

SCORM is designed as a standard for individual instruction. Therefore, SBLs using a SCORM LMS as the primary controlling agent are positioned in the individual branch of the taxonomy shown in Figure 3. The issues of collective training interactions such as team scoring and synchronization of team activities are not addressed by the SCORM standard. However, much of the standards work on simulations has focused on collective training applications.

ADVANCED DISRIBUTED LEARNING QUALITY METRICS AND THE TAXONOMY

The taxonomy provides some insights into the strengths and weaknesses of different SBL architectures with respect to the quality metrics that the Advanced Distributed Learning (ADL) consortium defined for SCORM. The metrics and how they relate to the different discriminators of the taxonomy are discussed in the following paragraphs.

Advanced Distributed Learning Quality Metrics

The ADL Consortium (Marshall & Bray, 2006) has identified the following quality metrics for learning systems, and in particular SCORM:

- **Interoperability:** The ability to take instructional components developed in one system and use them in another system.
- **Accessibility:** The ability to locate and access instructional components from multiple locations and deliver them to other locations.
- **Adaptability:** The ability to change to satisfy differing user needs.
- **Reusability:** The ability to use instructional components in multiple applications, courses, and contexts.
- **Durability:** The ability to withstand technology changes over time without costly redesign, reconfiguration, or recoding.

- **Maintainability:** The ability for distributed learning environments to withstand content evolution and changes without costly redesign, reconfiguration, or recoding.

Quality Implications of Taxonomy Decisions

Interoperability

The integration of SCORM instructional content with simulations implies a new form of interoperability beyond that addressed by the SCORM content or IEEE simulation standards (IEEE, 2007). The focus of study group discussions has been on the communications between the LMS and the simulation.

The taxonomy recognizes different approaches to this communication. The taxonomy discriminates between simulations that are centralized (vs. distributed) and local to the student (vs. local to the LMS or remote). In this case, the simulation can be embedded within a SCORM-compliant Sharable Content Object (SCO), then the simulation engine is the student client and communication between the simulation engine and the LMS is conducted in accordance with existing SCO-to-LMS Computer-Managed Instruction (CMI) standards. In this situation, a separate simulation session is launched for each SCO initiation. This is consistent with browser-based individual training simulations (Wideman & Sims, 2006), where assessment is completely aligned with the SCORM activity-tree structure and the SCORM representation of learning objectives is associated with the activities.

A problem with simulation initialization for each SCO is the associated time delay. This strategy often leads to larger SCOs to minimize the frequency of these delays. An alternative approach is to make the simulation a concurrent process, which is problematic because the SCORM semantics assume that a single SCO is active at any one time, while the simulation may be working with several SCOs.

If the simulation is distributed (as is usually the case for HLA simulations) then the taxonomy treats the SBLs as a different branch. In this case, different issues arise, primarily related to the ownership of the network linking the simulation servers and the student client. Several of the position papers discuss the use of HLA for individual instruction (Dargue, Biddle, & Perrin, 2006; Morris, 2006; Marshall & Bray, 2006).

A separate category in the taxonomy is the case where the simulation engine and the LMS are co-located (Smith & Dubic, 2006). This configuration simplifies configuration management in terms of keeping the

versions of the simulation and the IMI content consistent.

Accessibility

For the study group, accessibility was associated with: (1) whether or not the simulation resources were local to (i.e., resident on) the student client computer, and (2) if any of the simulation resources were remote, the extent of the students' access to (and performance of) the network.

Consistent with this approach, the taxonomy identifies ownership of the student client computer as a discriminator. If the client computer is shared with other users, then persistence of student data becomes a design issue with several ramifications. If the data have to be stored outside the client computer, then access to the storage server via the network becomes an issue, because the storage has to be accessible when the student needs it. SCORM LMS standards do not require the amount of storage necessary for saving the state of a large simulation. Shared State Persistence (SSP) provides an extension of SCORM to address this issue (IMS, 2007). The study group has considered models in which storage of student simulation data is provided by a set of servers that is independent of the simulation servers and the LMS (Marshall & Bray, 2006).

If the storage is local to the client computer, then the learning system software on the client has to negotiate the storage space within the constraints imposed by the client computer. This includes the directory path to authorized storage space, which may vary across client computers. Access to the storage may require authorization by the client computer system administrator.

Ownership of the network has significant implications for accessibility, which is why this attribute is a discriminator in the taxonomy. For military units in the field, continuous access to the network by students may not be feasible. Ownership of the network also has security implications that can impede access. In particular, distributed simulations involving classified or sensitive data may not be able to function by using a shared network.

Adaptability

The author interprets this quality measure as referring to the ability of the SBLs to adjust to different levels of expertise of the user through different instructional modes. The study group (Dargue, Smith, Morris, & Frank, 2006) discussed three instructional modes:

- Show Me
- Let Me Try
- Test Me.

A related paper (Whiteford et al., 2003) discusses reuse of a common simulation core with multiple levels of student support for four instructional modes: Familiarize, Acquire (Show Me), Practice (Let Me Try), and Validate (Test Me). The Aircraft Industry Computer-Based Training (CBT) Committee has identified another range of instructional modes for simulations (Hyde, 2006).

The taxonomy addresses aspects of this measure by distinguishing the levels of control that the LMS, the instructor, and the student have over the simulation. The taxonomy considers two forms of control:

- Ability to control which set of simulation initial conditions will be used for the session
- Ability to control time during a simulation session.

The simple sequencing language of SCORM provides a range of options for the LMS to maintain control over initial conditions of a lesson when initializing an SCO. Alternatively, the sequencing language can cede control to the student, and the student can select an SCO with the desired initial conditions.

Control over time is a more complex issue. Many individual training simulations provide methods for the student to control time. For instructors or the LMS to control time means that a real-time feedback system is required. The study group viewed this real-time feedback as a form of assessment, because data reduction of the raw simulation information is not useful for real-time decisions. The real-time nature of this interaction underscores the importance of network performance as an issue, which is related to the network ownership discriminator of the taxonomy.

Reusability

From the standards point of view, reusability can be enhanced through standardized interfaces between different components of the SBLs. These interfaces will allow the learning system architect to “mix and match” components. The most clear-cut example of reusability for SBLs is the potential for updating the informational content of the SCORM IMI while the simulation content remains fixed.

Brooks and Jesukiewicz (2006) describe methods for interleaving IMI to make context-specific data reusable. This strategy may also apply to SBLs where IMI is used to make specific simulation models reusable for different learning objectives.

The study group (Dargue, Smith, Morris, & Frank, 2006) identified two key interfaces to allow a

simulation core to be reused for multiple instructional purposes: the initial conditions of a simulation session and the assessment methods. For SBLs where the simulation sessions are aligned with the SCOs, SCORM provides a parameter mechanism for launching an SCO that can be used to select initial conditions. The consensus of the study group is that reuse of a simulation core to support different assessment goals is not well understood. There is ongoing research in this area (Frank et al., 2004; Haimson & Stacy, 2006).

Durability

Durability refers to the ability of the learning system to adapt to changes in the learning system technology, such as changes in server and client computer hardware, operating systems, and middleware, as well as changes to the network technology. The durability of the system is closely related to the ownership discriminators of the taxonomy. If the SBLs is designed for a specific configuration of the computer platforms and network, then the system is much less likely to be durable in its ability to adapt to equipment and network upgrades.

Maintainability

The maintainability of the system is related to the ease with which the system can adapt to changes in the instructional content. This is a complex issue that is not easily addressed by standards that cut across knowledge domains. Because this aspect is closely related to the content domain, it is not addressed by the taxonomy.

LESSONS LEARNED

The lessons learned to date by the study group have been in identifying a set of issues that are relevant to the use of standards. Many of these same issues are significant to the acquisition of a single SBLs.

Ownership Is a Significant Discriminator

Ownership of servers, clients, and networks is a significant discriminator for learning system architectures and is a factor in several of the ADL quality metrics. If the SBLs requires servers that are not owned by the SBLs, then standards are needed to ensure that appropriate simulation services will be available when they are needed for specific training sessions. Shared resources are either a significant risk or require active scheduling, which will require standards to allow the SBLs to negotiate the services.

Standards Are Needed to Provide Persistent State

The requirement for persistent state is an issue for SBLs that is related to the network, client, and server ownership discriminators of the taxonomy, because an SBL will be very restricted in what and how much it can store on a computer that it does not own. Therefore, in situations where the student client computers are shared, there is an emphasis on pushing the persistent state storage back onto the LMS. However, an LMS serving large numbers of students may have difficulty providing the level of storage needed for large-scale simulations. Shared State Persistence (SSP) is a candidate standard being considered as an addition to SCORM.

The study group is considering alternative methods for storing simulation state, including a separate SBL component (Marshall & Bray, 2006). Such a distinct component will require standards for interfaces with the LMS and the simulation components of an SBL.

Assessment Is an Opportunity for Standards Development

Assessment standards for SBLs are needed because assessment is a requirement that is unique to education and training systems as compared with other simulation applications. The current study group approach is that assessment should be considered a separate configuration item with standard interfaces to both the simulation engine and the LMS. Assessment standards for SBLs face a challenge in meeting the ADL quality metric for reusability because assessment is context specific. The assessment standards will have to take into account the context to be reusable across different contexts.

Assessment standards also face a challenge with respect to the ADL quality metric of adaptability. This metric requires that the SBLs adapt to strengths and weaknesses of the individual student. This may require that the assessment adapt to the student, or that the assessment provide the information needed for the instructor or the LMS to adapt the remediation to the student.

Standards Are Needed for Simulation Initialization

Like assessment, standards for initialization of simulations are needed to achieve the ADL quality metric of reusability because the initialization is context specific. There are several efforts to define simulation initialization standards in the IEEE HLA and DIS communities (Dargue, Smith, Morris, & Frank, 2006).

Simulation initialization is also relevant to the ADL quality metric of adaptability, because the LMS should be able to choose the right sequence of simulation scenarios for a particular student by varying the initial conditions. In this case, the initial conditions are a separate asset from the simulation itself.

CONCLUSIONS

The taxonomy provides a framework for discriminating among a wide range of SBLs. Contributions to the IEEE study group displayed a wide range of applications of SBLs, including grade-school education, military training, medicine, aviation, and business. The SBLs described to the study group included examples in each category of answers to the discriminator questions.

Different categories of SBLs will benefit from different standards. The most common opportunity for standards development is in the area of assessment. The study group recommends that an assessment component be considered. The interfaces between this component and the simulation and LMS components are key opportunities for standards, particularly in situations where these components are distributed across a network.

The taxonomy is a useful framework because different categories of SBLs have different risks and different benefits, which can be expressed in terms of ADL quality metrics. Understanding the risks and benefits of different classes of SBLs, in turn, can influence the acquisition choices for a single SBL.

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