Implementing a Reuse Strategy Across Multiple Domains

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Abstract

This paper addresses some of the critical organizational issues that should be considered when implementing enterprise reference models and architectures, and how these specifically affect VV&A and reusability of data and/or content. Two specific domains are described in the context of one general organizational transition model to demonstrate commonality. The Process-Based Modeling and Simulation, and Training and Education domains have benefited significantly from understanding and leveraging operating models from other domains. As organizations move toward knowledge management (aka the collection, classification, storage and retrieval of "knowledge objects") VV&A will increase in importance and must be addressed through new standards, tools, and workflow rules. The operating model to implement a reuse strategy is remarkably consistent across many domains.

Introduction

Verification, Validation, and Accreditation (VV&A), has been one of the most difficult areas to fully implement in the modeling and simulation arena. Even with HLA providing a more fully defined architecture and standards for building simulation objects within the virtual and constructive simulation domain, the number of formally approved simulation models in the DoD Modeling and Simulation Resource Repository (MSRR) are relatively limited. Two of the major VV&A obstacles are the cost to conduct VV&A and model knowledge. Depending on how accurate the simulation model needs to be, the cost of fully validating and verifying the model can cost more than the initial model development. System dynamics textbooks document twelve (12) validation and verification tests that range from model sensitivity, structure assessment, behavior reproduction, extreme conditions, and surprise behavior [Sterman, 2000]. Although many subject matter experts are comfortable with conceptually validating model construction and data elements, it is much more complex and difficult to understand and verify the model syntax, algorithms, behavior, and nested logic.

Within the realm of Process-Based Modeling and Simulation (PBM&S), typically discrete-event and continuous simulation, there are a multitude of Commercial-Off-The-Shelf (COTS) simulation development tools, each having their own terminology, model construction rules, and output formats. Most of the information collected and resulting models from these tools is used once and lost for future reference. Subject matter experts can usually perform conceptual model validation, but find model verification extremely difficult unless they understand the modeling tool syntax, algorithms, model development constructs and rules. In the absence of this knowledge, model verification is too often left to the developer who may be too close to the model to easily see errors and may have made erroneous assumptions about actual operations that were modeled [Aust, Dunlap, & Frye, 2002].

VV&A has become an even more critical and difficult task with today's emphasis on "enterprise" solutions for less cost, which must then be balanced against the dynamic environment of quickly evolving and changing technology. The same reuse and interoperability objectives that resulted in the High Level Architecture have been applied by the Department of Defense Advanced Distributed Learning (ADL) program to develop a common reference model (the Shareable Content Object Reference Model or SCORM) for the management of learning objects and/or content. These architectures, reference models and systems provide the capability to create, store, and retrieve content for reuse to reduce cost, decrease development times, and improve concurrency and configuration management of content across the enterprise. However, lessons learned in the PBM&S and Training and Education domains have demonstrated that, while the architectural framework is a solid foundation, organizational issues that arise during implementation of these high-level models may result in very limited return on investment if not properly addressed.

This paper will address some of the critical organizational issues that should be addressed when implementing enterprise reference models and architectures, and how these specifically affect VV&A and reusability of data and/or content. Specifically, this paper will describe common operating models and organizational issues across the domains of Process-Based Modeling and Simulation, and Training and Education, and how different communities of practice can benefit from understanding and leveraging each other's operating models.

Process-Based M&S Domain

The 1990s provided new challenges within the Department of Defense (DoD); resources were dwindling, yet there was more demanding operational requirements for more technical capability than ever before. Modeling and simulation seemed an optimal solution to this dichotomy of limited resources versus expanding requirements, but would only provide the long-term benefits with substantial change.

"*... it was clear that if these simulated environments were going to be used in the future, they, too, needed to be developed in a more cost-effective way. No longer was it affordable to develop a new simulation to address each new problem. Investments in simulators to support development alone were no longer tolerated; these costly items needed to be put to work supporting training and mission rehearsal. It was no longer acceptable for multiple organizations to create simulations of similar systems. To be useful, the authorities on those systems had to invest their time to ensure that the simulations provided an acceptable representation of the systems. Often the largest expense of developing simulations was the hidden costs: understanding the system characteristics and validating the simulation, that is, ensuring that the simulation reflected the system characteristics. These costs needed to be managed.*" [Kuhl, Weatherly, and Dahmann, 1999].

From this realization came the High Level Architecture (HLA), a disciplined approach that specifies development of component-based distributed simulations to allow reuse of defense simulations in different applications. This architecture has predominately been applied to DoD virtual and constructive simulation development efforts.

The Process Based M&S Catalyst

Process-based modeling and simulation (like discrete-event or continuous simulation) is quickly becoming a popular technology for computing potential Return on Investment (ROI) for planned information technology implementation and process improvement. Dr. Profozich (1998) describes this dynamic environment and predicts simulation modeling to become one of the essential tools in ERP implementation, supply chain applications, and any major process improvement endeavor. However, there are a multitude of Commercial Off The Shelf (COTS) process-based simulation tools to choose from, and most are not interoperable with each other. As the popularity of this technology grows, industry desires to "hook" models together to form larger, enterprise models to examine and improve things like supply-chain issues. If the existing models were developed in different tools, with no forethought for future interoperability, an enterprise approach usually requires a significant amount of rework and expense.

VV&A Problem: Limited Structure

"Conceptual validation should be the foundation for simulation credibility. Validation of results from simulation testing and use can determine how well the simulation performs for specific test cases, but without validation of the concepts and algorithms of the simulation, one has no basis for judgment about how well the simulation can be expected to perform for any other conditions" [Pace, 1998]. Historically, Process-Based Modeling and Simulation (PBM&S) development has been applied to only segments of an enterprise and often development was more of an art than a science. This was not a significant problem in the manufacturing environment, where PBM&S was traditionally applied, model validation was relatively easy, and simulation efforts were limited to specific areas with no requirement for reusability. However, developing enterprise simulation decision support in a service industry involves processes that are not tangible products on a product line, business rules that are not clearly defined, and model validation is extremely difficult. "Simulation of customer service processes presents a unique challenge because both the flow objects and resources are humans. Humans have much more complex and unpredictable behavior than products, documents, equipment or vehicles" [Tumay, 1996].

Although many computer simulation applications define operating rules on how to create an event, resource, or entity in the application, they usually allow great flexibility in how the model is constructed and allow the modeler to define many user-specific parameters, algorithms, and distributions. With recent improvements in hardware and software capability, there are many cost-effective computer simulation tools available in the market, some even built on existing flow chart tools that are familiar to many managers. This means simulation modeling and analysis is no longer limited to only industrial engineers that have been educated in rigorous development concepts, but is now openly used by many others without the benefit of strong development theory. The flexibility in constructing computer simulation models, combined with the lack of rigorous development techniques, creates large inconsistencies in simulation model development and makes VV&A more difficult than ever before.

The best solution to this problem, from a user's perspective, may be to develop and enforce interoperability standards similar to HLA. This type of solution will most likely evolve over time, but will take significant effort and time to gain agreement on standards, motivate vendors to comply, and develop interoperable tools/models. HLA wielded more leverage with vendors because it was born in a marketplace that involved large contracts that were primarily dependent on one very large customer, the Department of Defense. Even with the leverage of a limited number of buyers and providers at hand, HLA still took years to define, communicate, and implement. Process-based simulation software vendors are not in the same kind of market. The large demand for their tools allows vendors the latitude to develop stand-alone applications at a sizeable profit. In fact, many vendors see a distinct advantage in delaying interoperability because they can convince organizations to standardize on their software, tools, and consultants for all model development. Until the user community unites, defines standards, and forces vendors to comply, we are left with many process-simulation tools that are not interoperable and more importantly, a large volume of knowledge that is boxed into a wide variety of tools and terms of reference that limit future discovery or reuse [Aust, Dunlap, & Frye, 2002].

Terms of Reference - Common Model Elements

Even though many of the current COTS tools and resulting models are not interoperable, there are still ways to improve VV&A and gain reuse between process-based simulation models in the short-term by focusing on the model data, algorithms and business rules that controlled the simulation models. Similar to a math model report from live or constructive simulations, a standard conceptual validation report can be created with common simulation data elements independent of software application or modeling techniques.

All process-based simulation-modeling efforts really do have common elements. Something moves through the model to be processed, usually called an entity, discrete events are defined for processing, specific resources may be required to process the entity (like people or machines), and miscellaneous parameters are defined to make the model behave properly. Once these common elements were identified, we developed the structure for a conceptual validation report with generic naming conventions.

Although we are not creating truly interoperable simulation models like HLA, we knew we could gain substantial benefit from High-Level Architecture (HLA) concepts and structured modeling approaches used throughout organizations like the Navy Modeling and Simulation Management Office. We used the HLA Object Model Template (OMT) as the foundation for defining many of the terms in the conceptual validation report. Process-based models have data elements similar to parameters, attributes, routings, and specific ways to define relationships throughout the model. The foundation of model element commonality in conjunction with the structure from the OMT provided the framework for the standard conceptual validation.

The conceptual validation report is composed of five major sections, many of which relate to data elements in other sections of the report (reference figure 1). The first section describes all entities and their associated attributes to include name, availability, travel speed, cost, arrival amount and frequency, and source information. The second section defines all resources and their associated attributes to include name, quantity, availability, cost, and source information. The third section defines all model parameters, i.e. any user or software defined variable or attribute used to manipulate model behavior. The fourth section describes any operating rules defined within the model, to include name, brief description, operating rule syntax, and required parameters. The fifth section defines all model Units of Behavior (UOB). These are all discrete-events defined for the model, which may include activities, locations, routings, waiting lines, etc. Associated attributes include name, availability, capacity, processing time, cost, entities processed, required resources, operating rules, and source information [Aust, & Dunalp, 2000].

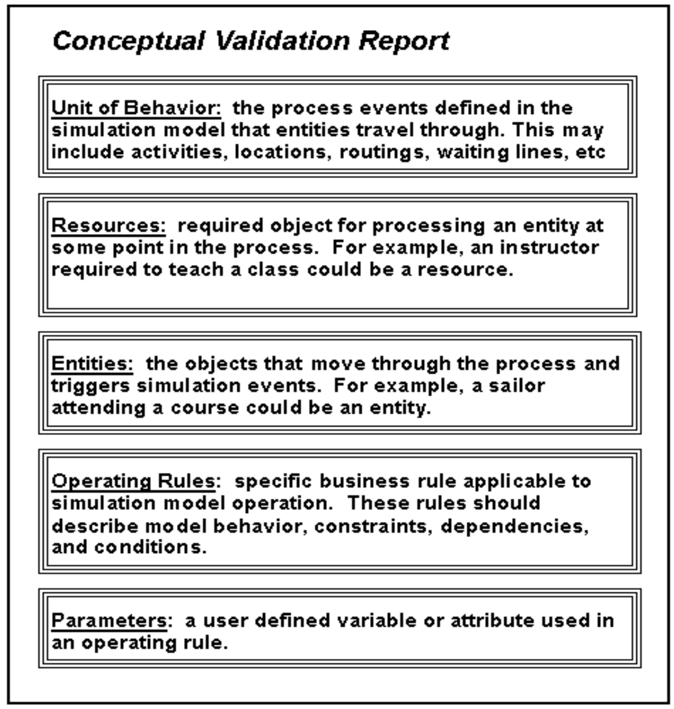

Figure 1: Conceptual Validation Report

Helping the Modeler - BMSRC Tool

The conceptual validation report defined a common language and standard validation report that was independent of PBM&S tool used. This provided the avenue to understand a simulation model and it's associated components without learning the application in which it was developed. This was great for the subject matter experts and VV&A personnel, but required an extraordinary amount of work outside the model software for the modeler to translate the model data into the common terms and report via existing tools like Microsoft Word or Excel. Without tools to make this data entry less labor intensive, and a compelling business case to do it, the idea of a generic report with a reuse structure to support VV&A seemed almost counterproductive.

The current explosion of Knowledge Management theory explains it is necessary to not only be able to quickly and easily access the explicit knowledge (i.e. the hard data contained in standardized systems), but it is also crucial to capture and access the tacit knowledge (i.e. information existing in people's heads or "intellectual capital") which is not currently captured in any system [Bennet, 2000]. A growing number of PBM&S efforts are focused on analysis of an organization's operations and usually requires obtaining a large amount of tacit knowledge to build the model properly. This knowledge is then lost in the complicated algorithms built in the model and not captured for reuse.

Analysis efforts typically follow a one-time use case, as illustrated in figure 2. A crisis comes up, a snapshot of the situation is taken, analysis is performed, action is implemented to solve the crisis, the analysis report is placed on the shelf, and it is rarely, if ever referred to again. [Aust & Dunlap, 2000].

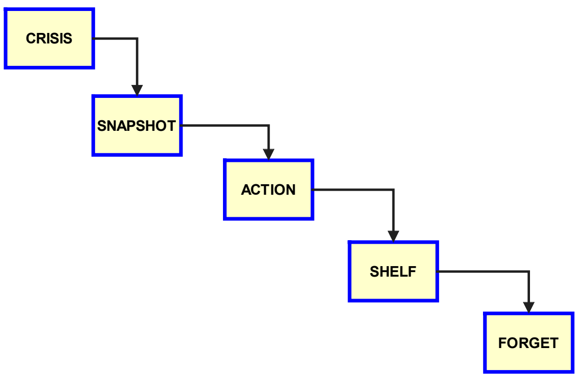

Figure 2: One Time Use Case

Part of the reason for this continual "recreation of the wheel" is because previous analysis efforts are minimally documented, and not stored in accessible locations with adequate description and catalog infrastructure to easily search and retrieve the information. In order to decrease rework and increase future reusability, it is necessary to define how knowledge objects will be classified, tagged, stored, and retrieved at some predefined level of aggregation.

The DoD M&S implementation of HLA addressed the issue of knowledge sharing and data reuse by constructing a web-enabled resource repository where model objects could be submitted, reviewed, validated, and published for reuse by others. In order to reduce the time to document PBM&S models and promote knowledge sharing and reuse, a similar repository made logical sense. The Business Modeling and Simulation Resource Center (BMSRC) was designed to promote a standard model development and VV&A methodology, encourage collaboration between modelers and subject matter experts, expand knowledge sharing, and increase tacit knowledge and data reuse between different models. The BMSRC is currently in its operational validation phase and is undergoing testing with continuous simulation models developed for CNO N81.

New Ways of Doing Business - Structured Workflow

The BMSRC provides structure to the model development process that did not consistently exist otherwise. For example, if model metrics are not clearly defined before data collection begins, too much or too little data, or even worse the wrong data, may be collected. This can be a very expensive oversight that could have been avoided through a structured workflow approach. Many managers who utilize PBM&S tools are not well versed in structured industrial engineering techniques. The templates and workflow rules of the BMSRC were created to help avoid costly mistakes.

For example, the Project Summary template in the BMSRC assists the modeler in firmly defining the model requirements. The modeler must complete this portion before any detailed model data can be entered into the repository. Required information includes project background and scope, the Navy domain in which the effort belongs, the sponsoring organization, who is responsible for maintaining and updating information in the BMSRC, who is responsible for model validation, specific metrics the model will compute to determine return on investment, and other relevant summary information. As the BMSRC becomes populated, users will have the option to apply existing data, i.e. point of contact information, to their models as well, reducing data entry.

The BMSRC also provides collaboration capability. If several modelers are developing separate pieces of the same model, or need to collaborate often as a model is developed, they can easily perform the collaborative tasks even though personnel are not centrally located. This, of course also provides an avenue to conduct interim reviews with users as the models are built to ask questions, clarify issues, or validate an approach (Aust, Dunlap & Frye, 2002].

Anchoring the Change - Policy and Guidance for PBM&S

PBM&S has great potential for improving current operations and providing more robust decision support tools. However, as the technology has improved and become user-friendly, some new problems emerge because there are so many tools to choose from; the tools and resulting models are not interoperable, negating enterprise model assemblies;

and new users are not necessarily educated in disciplined development techniques that lead to costly errors.

To adequately address these problems requires a common representational framework, common terms of reference, optimum workflow models, top-level policy and guidance to anchor the cultural change sought as a top management objective, and tools that enable the organization to easily adhere to the policy, guidance, and workflow requirements. The Navy training and education community has focused on defining a structured PBM&S development methodology, web-enabled tools, and workflow aids to provide better return on investment. The next critical step will be to define standard procurement guidelines, policy, and direction to completely address the organizational barriers to the PBM&S "knowledge object" reuse strategy to support VV&A.

Reuse is Reuse

Just as the PBM&S community experienced new challenges that forced rethinking current practices, Training and Education content developers have also witnessed a similar model. Multiple domains both within the Department of Defense and commercial industry have a common goal to reduce cost and development time through reusable assets or objects. This could be software assets, simulation objects, or chunks of content (both learning and other).

Eliyahu Goldratt, considered the father of Theory of Constraints, contends the reason we don't see large return on investment in IT solutions is because we neglect to evaluate and change the operating rules that existed before the technology was implemented [Goldratt, 2001]. In other words, we had to create rules to deal with the limitations of not having the technology. However, when we get the technology, we do not evaluate the old operating rules and change them to fit the new technology. These "operating rules" are not typically contained in existing systems, but are tacit knowledge found in the form of work-arounds and other unwritten policy and procedures. This was the case when the PBM&S technology improved and the user-base broadened substantially across new occupational fields, like managers with limited engineering education or experience. The operating rules were not re-evaluated in light of this technology change, and there was no structure to aid this new user-group, who did not have traditional education in disciplined model development techniques, like the previous user-group of engineers. Many failed PBM&S efforts can be traced back to undisciplined model development methodologies, general lack of requirements analysis, and limited VV&A.

Sometimes, even when people know their processes don't fit optimally with the new technology, they cannot conceive of any other way to operate differently. Perhaps they cannot see the forest for the tress, or perhaps they only know the traditional processes they were taught and have not been exposed to anything outside their community of practice. By looking across other domains, we are beginning to see applicability of "operating models" in ways never imagined before.

As organizations move toward knowledge management (aka the collection, classification, storage and retrieval of "knowledge objects") VV&A will increase in importance and must be addressed through new standards, tools, and workflow rules. The operating model to implement a reuse strategy is remarkably consistent across any domain as depicted in figure 3. The Process-Based Modeling and Simulation domain described previously is outlined in green, the general organizational transformation model is outlined in yellow, and the specific actions discussed in the Training and Education domain that follows are outlined in blue.

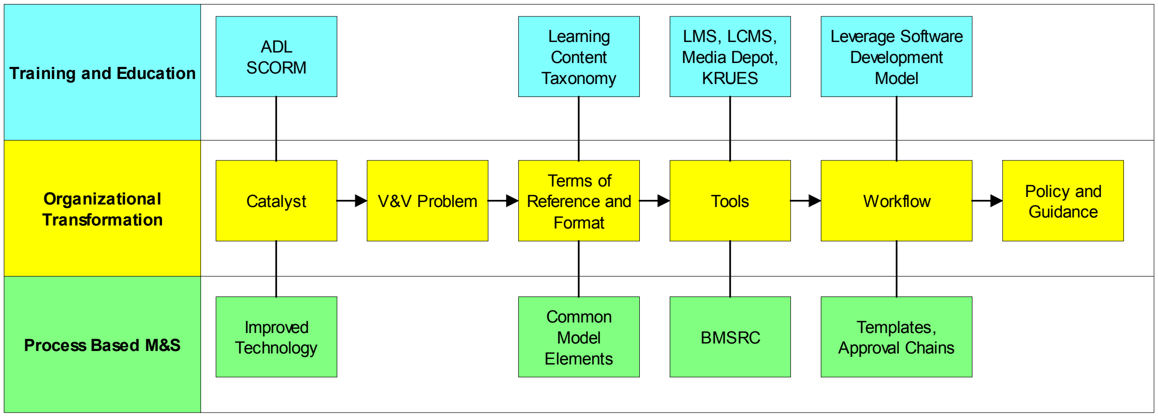

Figure 3: Organizational Transformation Model

The Training and Education Catalyst of SCORM

The Department of Defense (DoD) established the Advanced Distributed Learning (ADL) initiative to develop a DoD-wide strategy for using learning and information technologies to modernize education and training. In order to leverage existing practices, promote the use of technology-based learning and provide a sound economic basis for investment, the ADL initiative has defined high-level requirements for learning content such as content reusability, accessibility, durability and interoperability. The Sharable Content Object Reference Model (SCORM™) defines a reference model for sharable learning content objects that meet ADL high-level requirements. The SCORM is an integrated collection of technical specifications that enable conforming Web-based learning products and learning content to interoperate [ADL, 2002].

VV&A Problem: Labor Intensive and Expensive

Not unlike the experience with the HLA, many organizations have experienced difficulty in validating products as "SCORM conformant". Using traditional content development models and early releases of the SCORM reference model, the test for "conformance" is typically conducted at the end of course development for the entire course unit. If the course does not meet conformance standards, then the entire course must be reworked to correct the problems. This can be labor intensive and expensive. There remains a higher-level issue of reuse even for those organizations who have successfully produced SCORM conformant courses. The potential for content reuse is greatest in the "chunks" of a course that may be more generically applicable to similar job tasks or learning objectives. This is typically at a level below that of a lesson or chapter. If organizations continue to develop courses as one monolithic unit, the potential for reuse is substantially reduced. However, traditional development processes typically address the development effort as one unit, not smaller chunks to be assembled. Designing verified and valid content for reuse requires a fundamental and revolutionary change in business processes, architectures, instructional strategies, and content development policy, guidance and tools.

Terms of Reference - Operationalizing the SCORM

SCORM gave us the terms of reference and a more standardized vocabulary for learning content reuse. However, just like HLA, the reference model requires a mapping from the concepts down to the implementation level [Flater, 2001]. Specifications that deal with the meta-level were necessary to clearly define the differing levels of knowledge objects, how they would be assembled into larger chunks, the required metadata at each level of the taxonomy, and the required classification schemes. The level of definition of the specification "operationalized" the reuse intent of SCORM by providing the infrastructure for creating, assembling, searching, retrieving, and reusing knowledge objects. Figure 4 depicts a model for developing smaller pieces of content that can be assembled into larger chunks and reused across multiple applications. At each level of the taxonomy, required metadata is defined to more efficiently search and retrieve content. The classification schemes provide additional filtering mechanisms for a greater number of users to find knowledge objects that were created for one purpose, but could also be used for many other purposes.

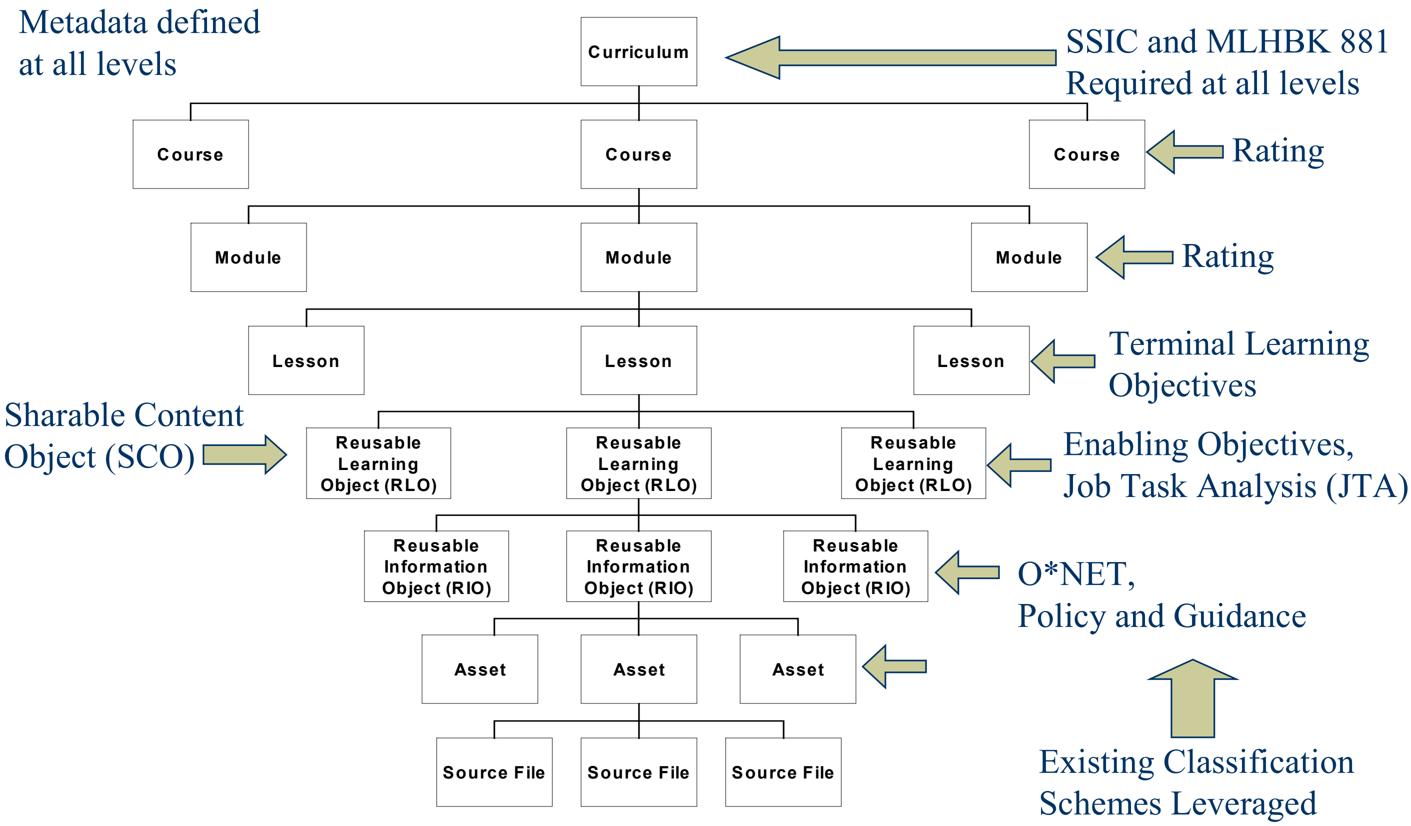

Figure 4: Learning Content Taxonomy

Helping the Contributor - Content Development and Tagging Tools

Technology in the learning space is quickly evolving to provide new and robust capability. The number of tools available to create, store, manage, search, and retrieve content both in the learning space and in the knowledge management space are growing in number daily. Within the Department of the Navy we have GOTS and COTS tools that provide Learning Management System (LMS), Learning Content Management System (LCMS), Media Development, and Sharable Content Object (SCO) development, and Knowledge Management (KM) capability.

Once an operational definition of the SCORM was developed by various organizations in the Navy, it became evident that the increase in workload to tag information and organize it into conformant "chunks" could become too difficult and expensive. Several organizations developed custom tools (e.g. media tagging and ingest tool, SCO production tools) to help the content contributors provide reusable content. Although each current tool provides some unique capabilities with regard to reuse and SCORM implementation, emerging tools are providing more robust capability that will eliminate the need for multiple tools in the future. These tools provide an avenue to reuse content in ways that would have been difficult without the technology. However, the iterative "knowledge object" design or "chunking" of content directly conflicts with traditional business processes for content development that are based on serial development techniques. The drive toward a reuse strategy forced the training and education community to rethink their workflow model.

New Ways of Doing Business - Another New Workflow Model

Although SCORM provides a solid framework for content reusability, this framework requires a mapping down to the implementation level within each DoD agency to fully gain intended reusability benefits. As described before, organizations can develop SCORM conformant courses as one unit and completely neglect the opportunity for reuse at lower levels. Traditional processes for developing a course follow a very sequential process. One such commonly known linear model is ADDIE, which stands for Analyze, Design, Development, Implement, and Evaluate. Traditionally, a large amount of time is spent in each of these sequential phases planning, analyzing, and developing the entire course. This process traditionally produces one large object (the course) that is then validated and tested for SCORM compliance in the context of LMS interoperability. If the course is not found to be compliant, it is labor intensive to make modifications after the fact, because they must be applied to the entire course. Although there is merit in designing the entire course as one unit, fostering a uniform design philosophy, the exhaustive analysis, research, and design that precede course development, and the potential rework required if the course unit is not SCORM conformant is counterproductive to the intended return on investment of reusability, which is most likely at a much smaller level.

Since most content development models in the training and education community of practice are similar in nature, it made sense to look "outside the box", or better yet, across another domain for an alternate operating model that precipitated reuse. The domain of software development had a development model that shortened development time, increase reusability, and provide more flexibility. In the 1980's, the software industry shortened linear development projects through the creation of flexible and extensible code. By using reusable components of code, or "objects", developers could meet shorter timelines and obtain better results because the need for testing and quality assurance on previously tested and accepted code was greatly reduced. Likewise, by focusing on initial design and creating smaller units of content, they could be linked and reused through a database system. The software industry's model of Rapid Application Development (RAD) is gaining momentum within the training and education area as an alternative model for instructional designers to gain the benefits of collaborative and iterative development without sacrificing solid instructional development concepts. [Outstart, 2002]

Anchoring the Change - Policy and Guidance for Content Development

To firmly anchor this change in content development requires associated policy and guidance outlining measures for success and direction for implementation. The SCORM provided the reference model, and the Navy education and training community has drafted several specifications outlining content packaging and submission guidelines, which describes the learning content taxonomy and associated metadata and classification schemes; e-learning content technical specifications; and reusable learning object development guidelines. These policy documents are crucial to the forward direction of the Navy education and training community, but have not evolved quickly. As in any new area, you must first fully understand the new technology, operating models, and future direction before concrete guidance can be developed. The change in the training and education area was a radical one that required not only a technical shift, but a cultural shift as well.

Conclusion

As technology matures, it is imperative that we continually assess the organizational issues that will help or hinder or progress toward future capabilities. This entails a comprehensive analysis of the catalysts, resulting problems in terms of reference and general understanding of the change, the necessary tools to make the change easier, workflow and process improvement changes, and policy and guidance to anchor the cultural change. All of these organizational issues are interdependent and can significantly hinder improvement efforts if not adequately addressed.

In the PBM&S domain, the catalyst for change was the sudden increase in the number of user-friendly applications. This technology improvement allowed a whole new class of developer to begin building and using simulation models for analysis than previously. However, this technology improvement by itself did not necessarily provide more return on investment across the enterprise. In fact, sometimes it caused less productivity when an erroneous model was built and used for decisions that resulted in unpredicted consequences. Unfortunately, a substantial amount of money has been spent on the development of many models that were never even used. The most predominant cause of little return on investment is because of poor requirements analysis, poor model construction, and limited VV&A. However, the technology has been very successful in the manufacturing industry for many years and has the potential to provide large return on investment for many domains if implemented correctly. This implementation in today's environment requires attention be given to structuring sound development methodologies for novice modelers; tools to assist in development, VV&A, and model reuse; and analysis of the most optimum operating model supported with policy and guidance.

In the Training and Education content development domain, the catalyst was the disruptive technology of content management and the SCORM that emphasized content reusability to reduce cost and increase productivity. The technology and DoD SCORM reference model by themselves did not affect the increase in productivity originally envisioned and will not until the SCORM is fully operationalized by the Services and attention is directed to the tools, the workflow, and the detailed specifications required to change how curriculum is developed.

The centerpiece of reuse, whether we are referring to knowledge objects, content, or source code requires a coherent and deliberate plan that accomplishes the following:

1. Define the reuse objectives that provide the metrics for verification and validation
2. Establish common terms of reference, standardize vocabularies, and develop appropriate standards
3. Develop tools to help content contributors cost-effectively supply content in the desired format
4. Reengineer business processes and implement workflow tools to improve efficiency
5. Develop, publish, and audit compliance with policy, guidance, and standards.

While the process and order of events noted in this paper imply a serial process, many of the steps are worked in parallel. VV&A will grow in importance in the knowledge economy. How do we know the information object is valid? Who approved it? How did it get in the system in the first place? When does it expire? Is it relevant to something else? Reuse is inherent in the VV&A process. The raw technology for reuse is readily available, however the organizational readiness to identify a coherent reuse strategy that addresses all of the issues identified in this paper is the key to success.

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