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Developing a Mission for the National Education Network: The Challenge of Seamless Access

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Developing a Mission for the National Education Network: The Challenge of Seamless Access

The National Library of Education (NLE) recently created the National Education Network (NEN). This article explores the potential mission of the NEN in light of the emerging global learning infrastructure made possible by the Internet. Given the NEN membership of Internet-based collection holders of educational resources, the article develops a five-part framework for exploring the nature of education information provision in a networked digital environment. It examines a number of government sponsored and private sector initiatives that stand as exemplars of the elements of the framework. Once defined, the framework provides the mechanism for framing a policy-based mission for the NEN in which it advocates for education information collections, educates its constituents in terms of the emerging education object economy, and promotes collective dissemination of information regarding the digital learning infrastructure.

INTRODUCTION

The Clinton administration has been a driving force in the adoption and use of the Internet in federal agencies. Few agencies have been more affected by this executive push for government information on the Internet than the U.S. Department of Education. Over the past six years, policy directives have led to a concerted effort on the part of the Department to adopt the Internet as an essential device in serving the information needs of the public. For example, in an April 18, 1997 memorandum, President Clinton directed all federal agencies to identify educational resources and to make them available over the Internet:

> "Over the next 3 months, you should determine what resources you can make available that would enrich the Internet as a tool for teaching and learning, and produce and make available a new or expanded version of your service within 6 months."[2]

The memorandum then charges the Department of Education with the coordination of these activities:

> "The Department of Education will also be responsible for chairing an interagency working group to coordinate this initiative to ensure that the agency-created material is of high quality, is easily accessible, and promotes awareness of Internet-based educational resources among teachers, parents, and students."

One result of the deliberations of the interagency working group is the Federal Resources for Educational Excellence (FREE) initiative.[3] FREE seeks to identify educational resources across government agencies and to provide easy web-based access to those resources. However, the FREE initiative is only one part of larger national and international efforts to make education information widely and easily available by means of the global Internet. This article focuses on another specific policy mandate to introduce the larger context of policy initiatives promoting education information accessibility—the creation of a cooperative network to support the National Library of Education.[4]

For the past year, the National Library of Education (NLE) has facilitated the formation of an organization called the National Education Network (NEN) as part of the Library's efforts to broaden the impact and collaboration of education information providers. Still in its formative stages, the NEN has gone from initial conceptualization to foundation building. However, as it enters into its final formative stages, it still lacks a coherent mission and purpose. Membership remains unresolved as to the NEN's core activities. In this article, we advocate for an expansive mission for the NEN.

While the NLE is the driving force behind the NEN both financially and organizationally, the Library's future role with NEN remains unclear—is it a member, a host, or a parent? The formative role played by the Library is the result of its founding legislation in the *Goals 2000: Educate America Act*[5] The Library is required to seek cooperation in the

functions it performs with its own resources, and to promote the use of information technology for networking and cooperation.

At the first meeting of NEN, there was considerable confusion regarding its mission.[6] The confusion centered on whether the assembled body was the NEN, merely a formative group that would create the NEN, or a set of advisors to the NLE. As noted earlier, there was also confusion over NLE's role within the organization. In this article, we seek to clarify the potential role of the NEN in the context of the emerging digital learning infrastructure.

We begin with a scenario that provides a relatively modest picture of the digital information space that will support teachers and learners in the near future. The scenario is followed by a brief enumeration of key factors in the development of seamless end-user access to education information on the Internet. We then propose a framework for analyzing the various components of network-based information systems in the digital learning environment. We conclude by framing a mission for NEN within the context of the proposed framework.

A SCENARIO

> ***The following occurs in a single interface:*** A primary school teacher has several students with Attention Deficit Disorder (ADD) in her history class and wants to include activities in her lesson planning that will meet their specific needs. She also wants materials that will meet state and local academic standards. She searches the Internet using a simple query language that identifies the kind of information she is seeking. From the ERIC database, she finds several documents and journal articles—all immediately available in full text. The same search query also discovers a number of activities, lesson plans, computer simulations, and other instructional software designed for use in a history class with ADD students. All of these materials are available electronically—some are from freely accessible repositories and others are available on approval from online

publishers. All of them have been mapped to the state's academic standards. Still uneasy about her understanding of certain aspects of ADD and her use of the discovered materials in her classroom, the teacher seeks expert advice by expressing her remaining questions and concerns to the network. Intelligence in the network routes her question to a human expert in ADD who, through online dialogue, puts to rest the teacher's final concerns. The school's curriculum committee reviews and approves the final package. Once approved, course management software available to the teacher's desktop helps to integrate the new materials into her course materials. Two self-enabled modules selected from the repositories of publishers automatically establish the means for micro-payments based on student use of the modules. The approved package is made available over the network to the teacher's students. Student performance is automatically entered into student records through the course management software.

Today, public and private sector developments in the infrastructure and use of the Internet are turning this scenario into a reality. Key factors in developing seamless end-user access to education information on the Internet include:

- **Structured Data:** Documents on the Internet are becoming more richly structured in order to support reliable information access and other processing functions. There is a movement away from flat HTML files with tags that indicate appearance toward tags capable of denoting deep structure. In the past year, HTML 4.0 refined the functionality of meta tags allowing for richer metadata to be stored within an HTML file. Further, with the acceptance of the eXtensible Markup Language (XML) standard, it is now possible to store structural and semantic data in web-based objects. This data can be used to improve retrieval an interchange. Lastly, this year has seen great advances in database technologies. Large-scale relational database management systems are incorporating Internet technologies such as XML, Java and cascading style sheets. This in turn has lead to more web sites that have database cores in place of static file systems of HTML pages.

- **Information Standards:** While standards have always played a role in education information and the Internet, a new wave is leading to greater interoperability among objects. This wave can be seen in distributed programming standards such as CORBA, DCOM and Java. Metadata standards (semantic representations of educational resources, transactions, and people) flowing from the work on structured data are also emerging as means of control in a distributed, document and transaction rich information environment. Standards promoting security and interoperability will be fundamental to the development of "trusted systems"[7]

- **Networked Information Discovery and Retrieval (NIDR):** The Internet represents a significant shift away from large, centralized collections of documents with powerful retrieval engines (such as a traditional library's online public access catalog or the large databases of full-text materials such as Lexis/Nexis) to frequently smaller, massively distributed collections. Metadata is being used to improve resource discovery and retrieval across such domains, to control collections of documents in repositories, to enhance interoperability among software modules, and to provide mechanisms for enforcing use restrictions and other intellectual property rights.

- **Education Object Economy (EOE):** The private sector is rapidly positioning itself to play major roles in an emerging economy in educational objects on the Internet. Initiatives such as EDUCASE's National Learning Infrastructure Initiative (NLII)[8] and the European Union Commission's ARIADNE project[9] signal partnerships among private sector commercial providers of educational resources, major educational institutions, and professional organizations to encourage development of the EOE. As a result, a new emphasis on markets and profit is emerging that will stand beside the culture of cooperation and collaboration that has characterized the domain of educational resources on the Internet in the past. This influx of interest and capital on the part of the private sector has led to shorter production cycles, higher production values, and different rules of collaboration. The recent signing into law of the *Digital Millenium Copyright Ac*t[10] partially paves the way for the full development of the EOE by providing legal protections against both circumventing

technical mechanisms protecting copyright interests in digital works and tampering with intellectual property rights information.

All of these developments have lead to a rapid growth in the number and variety of players in education information. Today's alphabet soup of initiatives and organizations stand as a testament to a new interest in a digital environment of networked education information resources and services.

In such an active and evolving world, there is a great chance for duplication of effort. There is also the real possibility that NEN will simply become yet another set of letters in an already crowded roster of acronyms. The question must be asked: "Why form yet another organization when there is already plenty of work being done?" In order to avoid duplication and to attempt to answer this question of NEN's potentially unique contribution, a framework is needed to identify gaps and needs in the education information domain.

A PROPOSED FRAMEWORK FOR ANALYSIS

We propose an analytic framework that defines the various aspects of education information provision in the context of the global Internet. It consists of five distinct core functions: (1) aggregating, (2) organizing, (3) using, (4) tool building, and (5) policymaking. The first three functions represent the core of the information system infrastructure that connects end-users with needed educational resources. The last two functions may be viewed as enabling functions without which a fully operable system as envisioned in our scenario is not possible. Each of these functions is seen as non-exclusive. Thus, a stakeholder may be placed in several different functional categories depending on the role being played at any given point in time. For example, a digital library (as opposed to a simple digital repository) both collects resources (i.e., aggregates) and organizes those resources for end-user access.

In the following sections of this article, we will first define each of these functions and then discuss a number of the stakeholders and projects that stand as function exemplars.

Aggregating

As we define it here, the function of aggregation is the sole purpose of a network-accessible repository of primary digital objects.[11] At its simplest, a digital repository is what might be called a "bit bucket." The function of aggregating is fulfilled by putting any number of arbitrarily selected digital objects such as text-based documents, software applications, images, multimedia creations, and data sets securely into that network-accessible bucket. As described by Kahn and Wilensky,[13] a digital repository is functionally unconcerned with the file formats of the digital objects it contains and could care less either about possible logical relationships among those objects or how those objects are selected.

As we define it here, the digital repository is merely a warehouse without logical form or end-user purpose. So described, the digital repository can be likened to a storage facility such as Bekins Van & Storage, and like Bekins, the digital repository has simple protocols for "depositing" digital objects in the repository, "accessing" those objects individually, and "disseminating" them. Thus, a digital repository is capable of storing a digital object it is handed, and, when handed a unique identifier or "handle" for that object, the repository can retrieve and disseminate the object to the requesting individual or program.[13] These functions of the digital repository are achieved through what Kahn and Wilensky call "a repository access protocol (RAP), which all repositories must support."

While the aggregating function of the digital repository appears surprisingly simple at first blush, as the EOE emerges, that simplicity will mask substantial complexity embedded in many of the most valuable digital objects accessible over the Internet. These highly valuable objects will be what we call "self-enabled." In other words, they will carry an enabling core of metadata in the form of rights management and processing

information to support the economic micro-transactions fundamental to commerce in digital education objects. Part of the RAP of many digital repositories will be the absolute enforcement of each object's usage rights. One of the principle goals of the *Digital Millenium Copyright Act* is to provide legal protections for the integrity of: (1) the technical mechanisms needed to render these digital objects "self-enabled," and (2) the rights management information needed to restrict the behavior both of the digital repository and the potential end-users of the objects it contains and disseminates. Thus, in fulfilling its aggregating role, the digital repository will become an integral part of what Mark Stefik calls the system of "trusted systems."[14]

In its purest sense, a digital repository with its simple aggregating function is a far cry from our notion of a *traditional* library—even a far cry from our notion of a *digital* library. We posit that a digital repository and a digital library are not coextensive. In fact, digital libraries may frequently be the logical amalgam of resources drawn from across a large number of digital repositories. We additionally posit that, by definition, a digital library includes a broad range of value-added functionality that creates a constituency-based context in the form of organization for access. It is to the definition of this second function of our framework that we now turn.

Organizing

Our discussion of the digital repository above is framed in terms of a pure model with the repository totally lacking any logical organization that would assist an end-user in finding digital resources to meet a specific information need. So, no end-user can ask (query) our pure digital repository with its totally arbitrary aggregation of digital objects for all of its resources on a given topic or that meet specific criteria of any meaningful sort. In short, the pure digital repository contains objects differentiated one from the other only by means of their unique identifiers or handles. Effective end-user access depends on higher-order organizing mechanisms than the simple assignment (but nevertheless complex management) of unique object handles.

In order to discuss the abstract function of organizing, we will continue on the same path begun above with the function of aggregating by treating the function of organizing in its purest form—the creation of context. Thus, we view the function of organizing as a process totally distinct from the physical aggregation of digital objects carrying primary content. The organizing function can be likened to the organizational functions of the traditional library—albeit a library that contains only metadata (data about data) and no primary resources. A perfect example of this pure form of organizing is the Gateway to Educational Materials (GEM) discussed in greater depth below which consists totally of searchable descriptions of educational resources stored in digital repositories across the Internet.[15] So described, the organizing function may be viewed as a pure value-added service layered over the digital repository substrate.

We assert that organizing is the act of bringing value for end-users to the various aggregations of digital objects based on a given criterion, or set of criteria. The Internet, standing alone, is merely an arbitrary aggregation of arbitrary aggregations of digital objects. Given a totally arbitrary, and, therefore, chaotic aggregation of digital objects in one or more repositories, organizing is the act of structuring chaos to meet the information-seeking needs of a given constituency. It is the giving of human-perceivable shape to the arbitrary pile of materials in digital repositories across the Internet. In the absence of the organizing function, the digital repository substrate of the Internet will remain nearly useless.

As educational resources on the Internet grow exponentially, their effective retrieval and evaluation becomes increasing difficult. With the current generation of primitive World Wide Web (WWW) search engines such as Lycos, Infoseek, and Excite, it is only possible to search for a known item and then, if found at all, the item is buried in a sea of hundreds of thousands of irrelevant documents. Currently, the kind of precise retrieval of educational resources needed by teachers, students, and parents is not possible with these tools. For example, it is not possible for a teacher to successfully search the WWW for a lesson plan that is: (1) about United States history, (2) intended for use in a 6th grade class including students with ADD, (3) and is designed around a brainstorming teaching

method. It has not been possible to execute such a search on the WWW and retrieve *all* and *only* lesson plans that meet the required criteria.

But, this unfortunate state of affairs is changing through the use of metadata for WWW resources. While the term metadata is relatively new in the circles of people focused on organizing resources for effective retrieval in both the physical and digital worlds, the concept itself is actually old wine in a new (and possibly more sophisticated) bottle. The definition of metadata becomes clear when we look at its classical use in traditional libraries. The library's card catalog (or its digital equivalent) is filled with metadata. Each card or record contains "data about data"—data about some book, data about a sound recording, data about a software program—including data on where to go to retrieve the item described on the card. When we search for items in a traditional library, we search the metadata records that have been carefully designed to help the end user both find a resource and evaluate whether, in terms of that user's information need, it is worth retrieving the resource from the library's shelves.

Around the world, projects are emerging that provide web access to metadata describing educational resources stored in digital repositories. The resources described range from online human experts ("AskA" services[16]) and full courses of study through individual lesson plans and activities to useful software tools and data sets. In addition to the traditional sorts of metadata such as author, title, and subject, these metadata records may contain information about grade level, pedagogical information including teaching and assessment methods, specific learning prerequisites, essential resources necessary to effective use, information about the target audience (e.g., students with attention deficit disorder), and, rights management information. As noted previously, as the EOE emerges, rights management metadata will play an increasingly important role.

The GEM project provides the holders of web-based collections of educational materials with the tools both to catalog their collections by creating metadata labels and to search the collections.[17] In like fashion, the U.S. Department of Education's Cross-Site Indexing

Project uses a metadata-aware version of the web search engine Ultraseek for precise searching of select resources in the Department's online collection.[18] The Department's FREE (Federal Resources for Educational Excellence) project provides structured access to resources residing in a large number federal government repositories while maintaining no primary resources of its own.[19]

Thus, organizing is the act of adding value to a digital repository of primary resources through some point of view. This can be done in the form of a repository selection policy, creation of criteria-based subsets of a repository, a unique aggregation of multiple repositories, and/or creation of selective pointers to educational materials throughout multiple repositories.

Using

Using is the application of education information to an individual end-user context. The using function has two distinct aspects: (1) direct end-user information discovery and retrieval of educational materials through one or more of the mechanisms of organization, and (2) indirect information discover and retrieval performed for the end-user through digital agency. While recognizing the existence of the first aspect of using, we frame the following discussion primarily in terms of the second. Figure 1 illustrates the general context of the using function as it relates to the functions of organizing and aggregating.

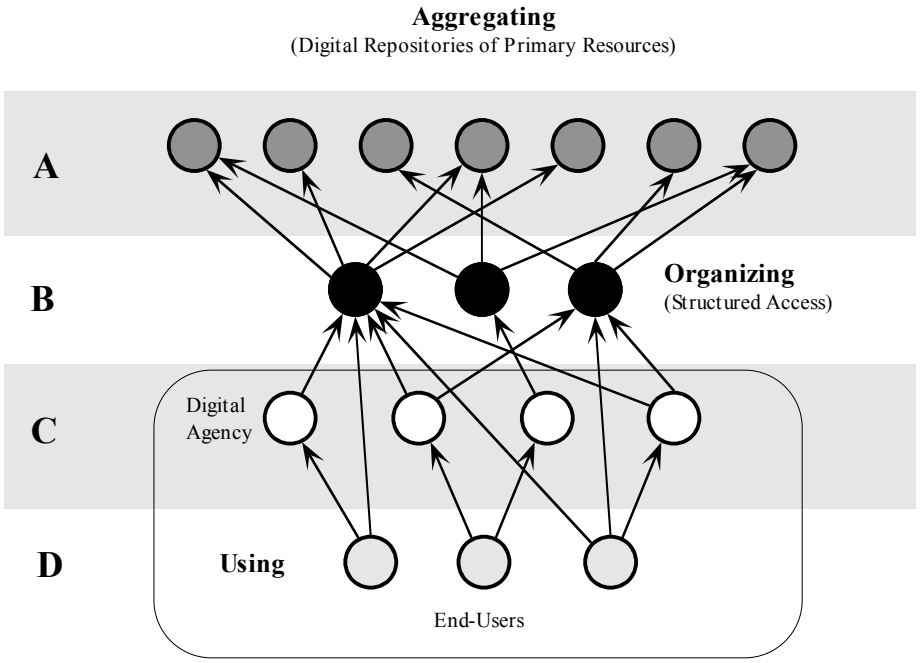

Fig. 1. Aggregating, Organizing and Using Functions

The Figure is divided into zones A through D with zones C and D representing the using function. Zone A represents the digital repositories of primary educational objects. Zone B represents the various organizing mechanisms layered over the digital repository substrate. Zone D represents individual end-users with their specific education-related information needs. Zone C represents a zone of digital agency that, on occasion, functions as mediator between the individual user and the organizing mechanisms. Our concern of the moment is with zone C.

AskERIC's question answering service,[20] as an example of digital agency, uses the ERIC repository and its organizational schemes to meet specific user needs through human-mediated online reference.[21] The AskERIC question answering service has neither a standing publicly accessible repository nor does it engage in the organization of resources. While AskERIC represents a general online question answering service, a growing number of similar services meet the agency needs for question answering expertise in specific knowledge domains. Examples of such services include Ask Shamu,[22] Ask a Scientist,[23] Ask a Volcanologist,[24] and The MAD Scientist Network.[25]

As Figure 1 illustrates, both zones B and C represent layers of mediation between the end-user and the repository of resources. While we note the human-mediated question answering services of zone C, we do not imply that all digital agency will be human-mediated. Purely digital personal agents will provide similar services in the future. Thus, in the future, education information discovery and retrieval for end-users will be both through direct interaction with the zone B organizing mechanisms such as GEM or through some form of digital agency.

The functions of aggregating, organizing and using all have their corollaries in the familiar world of the traditional library. However, on the global Internet, the need for seamless cross-domain access for disparate communities of users means that functions A through C will most frequently be handled as discrete functions managed by discrete agencies. In this way, any single digital repository may have an overlay of any number of separate organizational schemes and structured agency services.

Tool Building

In the context of this framework, the tool building function involves the design, development, and deployment of the enabling technologies for aggregating, organizing and using. Tool making is of two fundamental sorts. First, the geographically distributed nature of the domain requires the development of a range of abstract technologies including the standards necessary for the structured representation of digital objects and for cross-domain interoperability. The second sort of tool building involves the development of hard technologies such as the hardware and software necessary to the creation and maintenance of digital repositories, the tools used in their organization, and in the processes of networked information discovery and retrieval. Tools can consist of cataloging modules, search engines or abstract organizational structures such as metadata.

Metadata and Standards Development

In order for the emerging organizing systems to interoperate, they must be based on some level of metadata standardization. Major national and international efforts are under way to create metadata element sets for cross-domain information discovery and retrieval as seen in the Dublin Core Element Set.[26] Recently, the ISO/IEC Joint Technical Committee created Sub-Committee 32, Working Group 2—Metadata which "is responsible for standards that facilitate specification and management of metadata. Use of these standards will enhance the understanding and sharing of data, information and processes to support, for example, interoperability, electronic commerce and component-based development."[27]

The creation of education-specific metadata element sets has been the goal of both a number of government sponsored and private sector initiatives in the United States. The U.S. Department of Education's Gateway to Educational Materials (GEM)[28] provides a good example of the former while the EDUCAUSE-sponsored Instructional Management System (IMS) project[29] is an excellent example of the latter. The Learning Object Metadata Group (LOMG) of the National Institute of Standards and Technology is spearheading a project to bring together collaborators, key individuals, and organizations to develop a metadata standard for learning objects.[30] The work of the IEEE P1484.12 Learning Objects Metadata Working Group[31] is closely paralleling that of IMS.

A number of projects abroad have developed metadata schemes to improve WWW access to educational resources. The Education Network Australia (EdNA)[32] has developed an extensive metadata scheme to facilitate access to educational resources throughout Australia. The ARIADNE project sponsored by the European Union Commission and the Swiss Federal Office for Education and Science is a well-established European metadata effort. In recent months, ARIADNE and IMS have begun to coordinate their metadata development.

The Virtual Reference Desk (VRD) is a federal initiative to create a cooperative digital reference service for the K-12 community.[33] The project was begun by the NLE with support from the White House Office of Science and Technology Policy as part of the

administration's Online Tutoring Initiative.[34] As part of the VRD's mission to connect the disparate "ask an expert" services noted above, the project is creating a metadata scheme called the Question Interchange Profile (QuIP) that allows for the electronic interchange of reference questions among online services. QuIP is a semantic framework consisting of transaction, user, and expert information.

Applications Development

Relying on the metadata and standards-making work, developers are designing the software and hardware tools necessary to the creation and maintenance of a digital learning infrastructure. For example, to support the building of the GEM project's gateway to educational resources known as The Gateway, tools were needed to help collection holders create the metadata necessary to resource discovery and retrieval. Once created, additional tools were needed to "harvest" the GEM metadata and to build a searching and browsing environment for end-users. Major work in the development of tools for creating metadata tools and services is underway with The MetaWeb Project at the Resource Discovery Unit of Australia's Distributed Systems Technology Centre.[35]

The goal of the EDUCAUSE-sponsored IMS project is the creation of a series of standards in areas including metadata and object communications upon which tools can be developed that will prompt growth of the education object economy (EOE). The EOE market will flourish only through the construction of interoperable software modules that an educational institution can assemble as needed. IMS is a clear example of how education information is moving from a niche dominated by public interest, to a market approach.

POLICYMAKING

The last function of the proposed framework is policymaking. In their discussion of a potential global learning infrastructure, Twigg and Miloff identify a number of public policy challenges relevant to this discussion.[36] Among those challenges are the need to

foster a climate of change in which the "[g]overnment … help[s] educational institutions, the private sector, and the public understand the need for a new learning vision and the critical role that a digital learning infrastructure will play." Second, the government should "[f]acilitate the creation and management of new market forces"—i.e., the government should facilitate the creation and management of the emerging education object economy. And, third, the government should "[f]acilitate the establishment of technical standards." Such standards will be "[c]ritical to a successful digital infrastructure—and to truly unleashing market capabilities—is establishing agreed-to standards for telecommunications, file formats, and security, that enable high interoperability among instructional materials. Government can facilitate dialogue among colleges, educational publishers, and software and telecommunications companies." From the preceding discussion work such as that of the IEEE Learning Technology Standards Committee and the National Institute of Standards and Technology's Learning Object Metadata Group, we see that efforts at standards development are well underway. With projects such as GEM and IMS in the United States and ARIADNE in Europe, efforts to deploy the tools necessary to the digital learning infrastructure are also underway. Whether there is a national policy informing and unifying these efforts is another matter.

In this article, we have seen several examples of federal policy in action through initiatives such as the Department of Education's VRD, GEM, and AskERIC projects. EDUCAUSE's IMS represents policy development efforts by a consortium of government, for-profit, and not-for-profit groups. In many instances, these policies seek radically different goals. Whereas federal efforts have been geared towards supporting and improving traditional educational institutions (particularly K-12 public education), EDUCAUSE's NLII seeks to contain costs through the development of new technology approaches often centered on distance and disintermediated solutions. The irony is that while both have different aims, both are utilizing similar approaches to the technology infrastructure.

PROPOSED ROLE FOR NATIONAL EDUCATION NETWORK

Using the framework defined above, we now turn to the task at hand—proposing a role and mission for the National Education Network (NEN). The NEN is an organization or cooperative of education information resource and service providers. In the framework, they represent the aggregating and organizing functions. Ironically, however, this group has been largely inactive in the standardization and tool making efforts of the Internet. Burdened with legacy technologies and an overwhelming influx of new materials to be made available, these organizations have had little time or resources to look beyond their aggregating and organizing functions.

Given these facts and the need for NEN members to play a significant role in the emerging global learning infrastructure, we propose the following mission for NEN:

> The NEN is a policymaking organization that identifies, promotes, and shapes relevant tools for the digital learning infrastructure and promotes seamless access to education information through quality services.

This mission would have the NEN act as a bridge between the aggregators and organizers of education information and tool builders and services. Figure 2 illustrates the relationship.

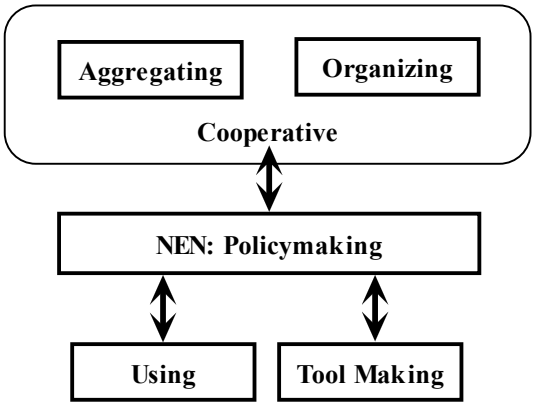

Fig. 2. National Education Network Mission

The focus of NEN should be on the exploration and shaping of the tool building function from a collection holder perspective. The heart of the organization should be advocacy for education information collections, education of its constituents in terms of the emerging education object economy and its enabling technologies, and collective dissemination of information. The proposed mission also implies a logical connection with the National Library of Education's role as tool builder.

CONCLUSION

As the Internet continues to evolve and the federal agencies responses to policy mandates change, questions will emerge: What is the role of the federal government in an education information environment that is moving toward an education object economy? As new market-based options become available to support how America uses information to educate, what responsibilities to support such options should the federal government assume? What are the consequences for the U.S. Department of Education building an infrastructure that can both support existing public education as well as bypass it?

The framework presented in this article has implications well beyond the U.S. Department of Education and the education industry. Training and the delivery of training resources are issues that permeate government and industry. Metadata and emerging standards of educational objects will effect how tomorrow's workforce equips itself for an information-based economy.

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4. National Library of Education (http://www.ed.gov/NLE/).

5. *Goals 2000: Educate America Act*, Pub. L. 103-227 (1994).

6. The first meeting of the NEN was under the name USEIN (United States Educational Information Network). The name was subsequently changed to the National Education Network (NEN).

7. See Mark Stefik "Letting Loose the Light: Igniting Commerce in Electronic Publication," in *Internet Dreams: Archetypes, Myths, and Metaphors*. (Cambridge, MA: MIT Press, 1996) 219-253.

8. See Carol A. Twigg, *The NLII Vision: Implications for Systems and States*. [Online] Available: http://www.educause.edu/nlii/keydocs/publicpolicy.html, 1997; see also, Twigg, "The Changing Definition of Learning," *Educom Review*. 29 (4): 23-25 (1994); Twigg, "The Need for a National Learning Infrastructure," *Educom Review*. 29 (5): 17-20, 1994; Twigg, "Navigating the Transition," *Educom Review*. 29(6): 21-24, 1994; Twigg, *Academic Productivity: The Case for Instructional Software.* 1996 (http://www.educause.edu/nlii/keydocs/broadmoor.html).

9. Alliance of Remote Instructional Authoring and Distribution Networks for Europe (ARIADNE) (http://ariadne.unil.ch/).

10. *Digital Millenium Copyright Act*, Pub .L. No. 105-304 (1998).

11. The term "primary" is used here to denote that the object contains information that the end user wishes to retrieve and use. Thus, a digital repository of primary materials can be contrasted with a digital repository of secondary materials such as metadata.

12. Robert Kahn and Robert Wilensky. *A Framework for Distributed Digital Object Services*. 1995 (http://www.cnri.reston.va.us/home/cstr/arch/k-w.html).

13. "A highly reliable distributed system of handle servers is maintained as part of the infrastructure. These servers map handles to network resources at which the corresponding digital objects are available." Ibid. See also the Corporation for National Research Initiatives' "handle" system (http://www.handle.net/).

14. Stefik "Letting Loose the Light."

15. Our use of the term "repository" in this case is different from the pure form described earlier in the body of this text. Many of the repositories pointed to through GEM metadata also perform organizing functions of their own, and, therefore are both repositories of digital objects *and* organizers of their own digital objects.

16. AskA Services are human-intermediated reference services that serve the K-12 community such as "Ask-A-Volcanologist" and "Ask-A-Space Scientist")

17. Web-based tools developed by the GEM project are available from the GEM Developers Workbench at http://geminfo.org/Workbench/.

18. Cross-Site Indexing Project search engine is available at http://search.ed.gov/csi/.

19. Federal Resources for Educational Excellence (FREE) (http://www.ed.gov/free/).

20. AskERIC (http://www.askeric.org/).

21. While AskERIC does run a web site with a large collection of materials, this example considers only the e-mail based question/answering service.

22. Ask Shamu (http://www.seaworld.org/ask_shamu/asintro.html).

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27. *Metadata Working Group: Document Register* (http://www.metadata.aihw.gov.au/document/brisres.html).

28. GEM Gateway (http://www.TheGateway.org).

29. Instructional Management Systems (IMS) (http://www.imsproject.org/).

30. National Institute of Standards and Technology's Learning Object Metadata Group (LOMG) (http://sdct-ntsrv2.ncsl.nist.gov/metadata/).

31. IEEE P1484.12 Learning Objects Metadata Working Group (http://www.manta.ieee.org/p1484/wg-c.htm).

32. Education Network Australia (EdNA)(http://www.edna.edu.au/EdNA/).

33. Virtual Reference Desk (VRD) (http://www.vrd.org/).

34. White House. *Vice President Gore praises union efforts to connect 700 of the nation's poorest schools to the Internet.* April 28, 1998 (http://library.whitehouse.gov/PressReleases.cgi?date=0&briefing=1).

35. Distributed Systems Technology Centre (DSTC) (http://www.dstc.edu.au/); Resource Discovery Unit (RDU) (http://www.dstc.edu.au/RDU/); The MetaWeb Project (http://www.dstc.edu.au/RDU/MetaWeb/).

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