Vocabulary Considerations for the Experience API (xAPI)

By the ADL Technical Team

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(send questions or feedback to: xapi-vocabulary@adlnet.gov)

About ADL

The Advanced Distributed Learning (ADL) Initiative collaborates with government, industry, and academia to research, develop, and implement learning technology specifications and standards. Since its inception, the ADL Initiative has fostered the development, dissemination, and maintenance of guidelines, tools, methodologies, and policies for the cost-effective use of advanced distributed learning resource sharing across DoD, other Federal agencies, and the private sector. ADL has also supported research and documentation of the capabilities, limitations, costs, benefits, and effectiveness of advanced distributed learning.

Executive Summary

While sharing data across organizational boundaries is a goal for the Experience API (xAPI), the initial efforts have been primarily focused on structural interoperability. This focus was necessary to ease the integration of learning experience data from different sources. However, during the past few years little progress has been made in regards to consistently interpreting meaning from xAPI data. Meanwhile, Linked Data has emerged as the de facto standard for sharing semantic data on the web. As a result, there are now a growing number of publicly available vocabulary datasets as well as Linked Data-consuming applications, repositories, and registries that provide value-added ontology and metadata capabilities for organizing and sharing information. However, there are currently no established practices of embracing Linked Data principles or resources for the development, discoverability, and management of xAPI vocabularies and their potentially powerful ontology components. By leveraging Linked Data as the foundation for xAPI vocabularies, Communities of Practice (CoP) could fundamentally improve the quality and semantic interoperability of xAPI data by allowing the vocabulary metadata to match schemas and interlink previously unrelated datasets. In other words, controlled vocabularies and metadata for xAPI, if linked, could provide the semantic glue needed to make xAPI data become more expressive and reusable.

The goal of this paper is to identify considerations for xAPI controlled vocabularies and present them to the xAPI community for public comment. The intent is that the community will work together on how to best address these considerations both for today and for the future versions of xAPI. Resources and guidelines that can improve the semantic interoperability of and collaboration on xAPI vocabularies are required. This paper is not intended to be an exhaustive analysis of solutions. Rather, it is an initial exploration into the some of the development, discoverability, and management challenges that might be considered in the

xAPI community's impending efforts to align xAPI vocabularies with best practices and standards.

Background

The Advanced Distributed Learning (ADL) Initiative has a reputable history for efficiency by collaborating on and utilizing existing standards. When the Sharable Content Object Reference Model (SCORM) specification was developed, a pragmatic approach was taken to research and build upon on the successful work of the AICC, IEEE, IMS, and other standards activities to create a robust reference model. Likewise, the xAPI itself is heavily based on work derived from the Activity Streams 1.0 Specification (2012).

In the 0.95 version of the xAPI, core verbs and activity types were removed from the specification. Since then, the specification has recommended that implementers adopt community-defined vocabularies in favor of creating their own. However, communities only recently (late 2014) began converging and working on domain-specific vocabularies through the ADL-facilitated CoP groups. In addition, through discussion forums and group mailing lists the xAPI community has identified the need for alignment with best practices and models based on Linked Data and machine-readable vocabularies. Rather than create an original information model explicitly for xAPI controlled vocabularies, the xAPI community should first determine which existing standards, specifications, and practices are relevant and have the most potential for successful adoption by the global xAPI community.

Problem Definition

Useful learning analytics require consistent approaches to describing domain-specific concepts, which in turn require formalized vocabulary practices to be followed by Communities of Practice (CoPs). The Experience API (xAPI) specification (ADL, 2014) vaguely requires CoPs to create controlled vocabularies for verbs, provide human-readable descriptions of their intended usage, and make these accessible at an International Resource Identifier (IRI) location. Additional considerations of ontology relationships, vocabulary management, discoverability, and reuse could significantly impact interoperability, but none of these are currently being addressed. Achieving true interoperability requires a focus not just on the interoperability of data but also of the communities. ADL recently began facilitating the congregation of CoPs and providing basic options for documenting verb and activity terms, but discovered this guidance was not sufficient. Proven vocabulary practices that can improve the interoperability of and collaboration on xAPI vocabularies are greatly needed. There are entirely too many options for the creation and publishing of vocabulary datasets alone. Today, there are several standards, formats, and varying technical approaches available for vocabulary development. It is not feasible for CoPs to organically converge and easily address these considerations independently without guidance or community acceptance of best practices. A unified direction, process, and governance strategy for xAPI vocabularies has not been established, but is desperately needed for the long-term success and overall maturity of both the structural and semantic interoperability of the xAPI.

In addition to structural data interoperability (the ability of two or more applications or agents to exchange information), semantic interoperability is needed to automatically interpret the information exchanged meaningfully and accurately in order to produce useful and consistent results. Currently, xAPI vocabularies don't utilize a common information exchange reference model or schema to make semantic interoperability possible. In addition, there are currently no documented requirements for the semantic validation of xAPI data or legitimate processes to discover and reuse existing vocabularies. Therefore, the xAPI is conjectured to be at high risk of producing inadvertent vocabulary data silos and semantic interoperability problems that could hinder both humans and machines from sharing and optimally understanding xAPI data.

While initially investigating the vocabulary landscape, a number of formats, standards, tools, and systems have already been discovered. However, most of these require a deeper understanding of the concepts and terminology pertaining to ontology-related work and semantic data concepts. It is beyond the scope of this paper to provide in-depth coverage of these concepts and terminology, but some of them must at least be briefly discussed early on for improved readability and understanding of this paper. More formal and lengthy descriptions of the concepts and terminology are provided in Appendix A.

Controlled Vocabularies, Taxonomies, and Ontologies

The main reason for suggesting some form of vocabulary control in the xAPI specification is to achieve consistency in the description, storage, and retrieval of xAPI verb data. However, when implementing vocabulary control there are two fundamental challenges with natural language as stated in ANSI/NISO Z39.19-2005 (2010):

1. Two or more terms can be used to represent a single concept
2. Two or more words that have the same spelling can represent different concepts

In order to address these types of semantic differences that inherently arise in natural language exchanges between people, vocabulary development best practices should be followed. According to W3C (n.d.), vocabulary development best practices involve classifying the terms that can be used in a particular domain, characterizing possible relationships, and defining the constraints when using those terms. These practices usually involve challenging work around defining and curating the various terms, synonyms, hyponyms, and other related terminology that might be preferred within a CoP. Therefore, vocabulary development has the potential to turn into very complex ontology work. Not surprisingly, the terms vocabulary and ontology are often used interchangeably. A common practice in the taxonomy profession is to use the term "ontology" only for more complex and formal collections of terms and their relationships, while a controlled vocabulary is used for general domain agreement of terms.

According to Hedden (2010), a controlled vocabulary is a restricted list of words or terms used for labeling, indexing, or categorizing information. It is controlled as only the specified terms from the list may be used for the subject or domain area covered by the controlled vocabulary. It is also controlled because there is control over who adds, updates, or removes terms in the list.

The term “taxonomy” is generally referred to as the science of classifying things. It has also been known to commonly describe any basic parent/child hierarchical classification or categorization system. Some taxonomies allow vocabulary terms to have multiple parents (aka poly-hierarchy). This means that if a term appears in multiple places in a taxonomy, then it is referring to the same term. More specifically, if a term has children in one place in a taxonomy, then it has the same children in every other place where it appears. In terms of relevance for xAPI, taxonomy can be more distinctly thought of as vocabulary hierarchy of broader term/narrower terms. This hierarchy can imply a single hierarchical tree, and in some cases it can refer to a collection of term hierarchies intentionally made available for searching or browsing a repository (Hedden, 2010).

In comparison, ontologies often provide more rules and strictness to a controlled vocabulary. People sometimes use the word ontology to imply different things (e.g., glossaries, data dictionaries, taxonomies, schemas, data models, etc.). In a nutshell, an ontology answers the question, “What things can we say exist in a domain, and how do we describe those things that relate to each other?” A formal ontology typically describes the constraints of the concepts and properties in a controlled vocabulary and expresses relationships among terms using some kind of ontology representation language (Pidcock, 2010). CoPs also will often commit to using a specific ontologies exclusively for their domain of interest (Pidcock, 2010). Building a hierarchical taxonomy might be beneficial to the xAPI community to help CoPs better classify terms into groups or “classes” that share similar characteristics. Further, creating a common foundation ontology for xAPI-controlled vocabularies and domain-specific profiles could potentially reveal even more benefits such as, but not limited to, the following:

- Reuse of domain knowledge
- More consistency when describing semantic relationships

- More explicit domain semantics
- Increased compatibility and efficiency when integrating with other domain datasets
- Improved quality of learning data analytics
- More easily exposed structure of information for people or software agents

Vocabulary Development and Standards

In the xAPI specification, there is no requirement to enforce a universal data model to agree on every type of learning activity that can be recorded. Instead, Activity Providers are free to publish different statements about the same activity using their own profiles and vocabularies. This freedom provides great flexibility and resilience, but at the same time can introduce disorderly practices. The establishment of domain-specific controlled vocabularies by each CoP is a gentle, first step in the right direction of following development best practices. Currently, xAPI CoPs are identifying and capturing their terms temporarily using spreadsheets and various other independent tools. The only guidance that has been provided to CoPs is to disambiguate their terms by using Princeton's WordNet (2010) or some other lexical database with semantic validity. However, this is not sufficient, as CoPs are not provided with any further guidance. CoPs require help with discovering and reusing existing vocabularies as well as describing and publishing their terms as a collective vocabulary. Otherwise, mistakes will inevitably be made and duplication of term meanings will likely occur.

Options for vocabulary development include a plethora of different formats, standards, and purposes. As discussed previously, basic vocabulary lists can be enhanced by more complex representations (e.g., controlled vocabulary, taxonomy, ontology). These representations can be serialized in several different yet interchangeable syntax formats. Further, the W3C offers options for describing vocabularies by following practices based on the Resource Description Framework (RDF) such as RDF Schema (RDFS), the Web Ontology Language (OWL), and the Simple Knowledge Organization System (SKOS). In addition, the Dublin Core Metadata Initiative (DCMI) provides metadata design and best practices for providing interoperability for vocabularies of structured data that can be interlinked using RDF. A brief overview of these standards will follow, as it is necessary to understand their potential relevance for xAPI. A comparison table of several relevant standards that were documented as part of this research is provided as a complementary resource in Appendix B.1.

RDF/RDFS, OWL, and SKOS

The RDF version 1.1 consists of a large suite of W3C Recommendations and Working Group Notes, published in 2014. RDF is simply an abstract model for describing resources. A resource is basically anything to which an identifier can be assigned. Similar to xAPI, RDF requires uniform resource identifiers (URIs) and uses a simplified data model to represent everything as statements. It also prescribes a familiar construct in the form of *subject-predicate-object*. However, an RDF triple can be declared as a simple statement in the form of “A is related to B,” as in “verb A has the title B”. For example, an xAPI verb in RDF could simply use “answered” for the label. This is an example of an RDF statement having a human-readable, literal string value and provides little potential for deeper semantic meaning or disambiguation. For all other elements that are not string values, RDF requires URIs from the web, which are machine-readable and if dereferenced, can provide semantic richness. First, imagine the xAPI verb “answered” is identified using a compact namespace prefix for ADL verbs (e.g., @prefix adl: <http://adlnet.gov/expapi/verbs/>), but specifying a synset URI from wordnet would more accurately provide more meaning by using one of the definitions of "answer.” For example, the RDF triple linking “answered” to a WordNet URI could be simply stated as:

adl:answered wordnet:synset <http://wordnet-rdf.princeton.edu/wn31/200637941-v>

URIs are a source of identifiers to denote not only web pages, but also non-digital objects such as people, books, and concepts. In this way, URIs make people, books, and concepts globally referenceable (Baker, Vandenbussche, & Vatant, 2013).

RDF alone does not provide any domain specific terms for describing verbs or classes for things in the world and how they are related (Heath & Bizer, 2011). An extension of RDF, RDFS does provide a basic vocabulary description language, but does not specify relationship types. Rather, it provides a way for a community to define them. This capability of more deeply expressing relationships of classes and their properties by following an ontology approach is often best supported by using both RDFS and OWL, which are actually ontology languages built upon RDF (Heath & Bizer, 2011). Classes are a common ontology component that can represent collections, concepts, or types of objects. RDFS extends the basic RDF syntax by providing additional terms which facilitate the categorization of resources into classes, and which describe how properties are related to those classes. For example, xAPI CoPs could create a vocabulary with verbs that relate to an *assessment* activity profile. They might also define custom properties such as hasType, therefore allowing CoPs to relate RDF descriptions of their interaction types such as multiple choice, matching, drag and drop, etc. The *assessment* class and properties as a profile could then be reused in other xAPI implementations. It is often sufficient to develop vocabularies with only RDFS. However, certain properties from OWL, such as "sameAs," are often used to reveal that two URIs identify the same resource. OWL can also provide more sophisticated representations of relationships of xAPI-controlled vocabularies than RDFS, but it is often more commonly used for computational ontologies and reasoning scenarios (e.g. artificial intelligence agents).

In some situations, CoPs may simply want a set of controlled terms without any representation of the relationships to other terms or activities. In these cases, CoPs would not necessarily need to model the domain in the way that the classes and properties are modeled in RDFS and OWL. They might want a simple way to express a parent category or child categories to which terms might be grouped under. The standard used for this situation is SKOS, which provides the ability for a vocabulary to become a structured taxonomy. However, there are really two types of possible SKOS implementations: "basic" and "advanced." In basic SKOS, resources are identified with URIs, labeled in one or more natural languages, semantically related to each other in informal hierarchies, and then aggregated into concept schemes (W3C, 2009). In advanced SKOS, resources allow for mapping across concept schemes and grouping into labeled or ordered collections. In advanced implementations, the SKOS vocabulary itself can be extended to support the needs of a particular CoP or combined with other modeling vocabularies such as OWL (W3C, 2009). However, the intent of implementing SKOS is not to replace controlled vocabularies in their original context, but to allow them to be enhanced and more easily shared, based on a simplified model, enabling wider reuse and better interoperability (W3C, 2009).

DCAM and DCT

The work of the DCMI community is broad and inclusive of many aspects of metadata design, implementation, and best practices. The DCMI Abstract Model (DCAM) is often used as a model for other vocabularies outside of the DCMI. In addition, DCAM is aligned with RDF so that the syntax corresponds to RDF. For example, a resource in DCAM corresponds to the subject of an RDF triple; a predicate in RDF is the same thing as a property in DCAM; and an object in RDF is the same thing as a value in DCAM. While DCAM assumes the existence of classes, it doesn't require that a vocabulary define any classes. The DC Terms (DCT) vocabulary is also intended to be used in combination with terms from other vocabularies.

Vocabulary terms should be persistently and uniquely identified using URIs, but the vocabulary syntax should also leverage one or more predefined vocabulary standards (e.g., RDFS, SKOS, OWL, DCT) for formally describing relationships and providing meaning. In general, it is considered to be a best practice to use well-known ontology and vocabulary standards when developing a new vocabulary. A table of possible properties and metadata elements that could be utilized for the development of a simplified model of xAPI controlled vocabularies are proposed in Appendix B.4.

Vocabulary Discoverability and Reuse

Recent successes in business, commerce, science, and government have revealed that organizations and individuals who choose to openly share data stand to benefit the most (Heath & Bizer, 2011). According to Heath & Bizer (2011), the decision to openly share data also intrinsically reveals the following concerns:

- How to enable discovery of relevant data from available datasets
- How to best provide access to data so it can be reused

Decentralized vocabularies have become a typical scenario today, and service providers have the option to add value to metadata harvested from disparate sources. However, this decentralized and uncoordinated approach also turns these aforementioned concerns into really tough challenges. These challenges are especially relevant for xAPI-controlled vocabularies and the xAPI community. When a CoP is not able to locate an existing vocabulary and must create a new one for their domain or project then how do they make sure others can reuse their vocabulary? In other words, how does the xAPI community minimize duplication of effort as well as reduce the risk of terms produced in one CoP only being usable by that same CoP? In section 4.1.3.2 of the xAPI specification, it states "Activity Providers SHOULD use a corresponding existing Verb whenever possible." Currently, that is rarely possible in the xAPI community. Coincidentally, the practice to reuse existing terms from vocabularies is a key characteristic of following a Linked Data approach. However, the xAPI community is currently lacking both practical guidance as well as the infrastructure to adequately support publishing, discovering, and reusing vocabularies that support Linked Data.

CoPs, Activity Providers, and Learning Record Store (LRS) implementations all would benefit from an inventory of existing xAPI vocabularies in order to prevent duplicative work and consistently improve expressiveness of their data. Currently in xAPI verbs and activities are identified by a URI, but different URIs are not required to be related, accessible, or discoverable in any canonical way. In other words, the xAPI community does not currently follow practices that would allow them to benefit from a dynamic network of Linked Data. Following a Linked Data approach could help improve discoverability and reuse, and in turn, it could also provide the added benefit of helping xAPI data consumers derive deeper insights from the statements because of the strengthened semantic interoperability among LRS implementations. It is beyond the scope of this paper to provide in-depth coverage of Linked Data concepts and terminology, but some of them will be briefly discussed here to understand their importance for discoverability and reuse of xAPI vocabularies.

Linked Data

According to inventor of the World Wide Web, Tim Berners-Lee, there are four key principles of Linked Data (Berners-Lee, 2006):

1. Use URIs to denote things.
2. Use HTTP URIs so that these things can be referred to and looked up (dereferenced) by people and user agents.
3. Provide useful information about the thing when its URI is dereferenced, leveraging standards such as RDF, SPARQL.
4. Include links to other related things (using their URIs) when publishing data on the web.

For more details on some of these concepts and terminology see Appendix A. In Wikipedia (2015), Linked Data is described as a method of structuring data so it can be interlinked and made more useful through semantic queries and shared in a way that it can be automatically read by computers. More formally, Linked Data refers to W3C recommended best practices for exposing and sharing data on the web using RDF. Historically, much of the information accessed over the web has been in the form of HTML content accessed through hyperlinks. Humans and machines both can read HTML, but machines have difficulty interpreting and sharing semantic meaning from it. As a result, Linked Data was established to serve as a map for expressing and sharing how things are connected. Before additional benefits of discoverability and reusability can be realized vocabularies must be first published as open, machine-readable data. Publishing xAPI vocabularies on the web as Linked Data will make it easier for other CoPs, data providers, and LRS implementations to integrate xAPI vocabulary meanings interoperably into other contexts, making that vocabulary data more visible and more reusable.

Vocabulary Publishing and Registries

There is more than one way to publish a vocabulary as Linked Data. Regardless of which approach is used, the approach involves mapping the source data into a set of RDF statements. The statements can then be converted into a wide range of RDF serializations including: RDFa, JSON-LD, Turtle and N-Triples, and RDF/xML (W3C, 2014). Best practices from W3C (2014) further state that vocabularies should be published on the web by using a stable URI and providing an open license. In addition, there are also specific web server configuration options that must be followed if a CoP is publishing and maintaining their vocabulary on the web. Best practices for publishing Linked Data (W3C, 2014) and publishing RDF vocabularies (W3C, 2008) are available and could be further explored by the xAPI community.

In order to enable the discoverability and reuse of vocabularies, it is critical to provide ways to find them by making them available on the web. This can be done by using different approaches, such as leveraging RDF search tools and registries. Controlled vocabularies built for xAPI could be made more discoverable by publishing them as Linked Data through multiple web-accessible, RDF-aware registries. An attempt to create a registry for xAPI has been generously provided by leading members of the xAPI community in the form of a "TinCan" registry, but it doesn't currently promote a Linked Data approach. Further, while the intent of this registry effort is genuine, it has actually exposed confusion and discontinuity among some developers in the xAPI community. The name, ownership, and hosting of this registry inherently implies a former version of xAPI and also now reinforces a proprietary corporate branding, known as TinCan. Appreciation and respect for the creation of the TinCan registry are in order though as it has actually become one of the key drivers for the xAPI community to realize the amount of important vocabulary work that still must be accomplished in order for xAPI to progress and mature. Sharing data, especially when there are multiple CoPs involved, is more attractive if a common language or approach that does not favor any single organization can be agreed upon (Cooper, 2014). The perception of ownership as well as vocabulary governance policies will likely play a significant role in the future success or failure of any xAPI registry effort. Currently, there are several open vocabulary search, publishing, and registry systems readily available to the world that support Linked Data and some of the aforementioned standards such as RDFS, OWL, SKOS, and DCAM. The xAPI community should evaluate if any of these systems (listed in Appendix B.2) could be utilized for xAPI vocabularies. Otherwise, these systems might at least provide new ideas for advancing and transforming the TinCan registry concept into a robust, RDF-aware vocabulary repository and centralized hub for the entire xAPI community.

Vocabulary Management and Governance

While guidance on vocabulary development and discoverability for xAPI are both lacking, so is guidance pertaining to vocabulary management. The learning analytics promised of xAPI also rely heavily on the ability for each Learning Record Store (LRS) to consistently interpret what the verb terms mean (semantic interoperability), which in turn depends on the availability of the controlled vocabulary itself. Currently, the xAPI community has not defined any stable processes or identified best practices for the maintenance of controlled vocabularies. As a result, CoPs are unsure how to publish or manage them. Meanwhile, CoPs have primarily been choosing one of three options for temporarily storing their verbs: spreadsheets, GitHub, and the TinCan registry. However, none of these options are adequate for long-term stability or supporting a true Linked Data/RDF approach that would promote discoverability, reusability, and ultimately semantic interoperability. In fact, the current practices of developing and storing xAPI controlled vocabularies are so fragmented that there is little potential for semantic interoperability to regularly occur. Further research and investigation is warranted for controlled vocabulary management. A listing of possible vocabulary editing and management software solutions is provided in Appendix B.3.

Storage and Ownership

The value of any vocabulary depends on the perceived trust that the vocabulary will remain reliable and accessible over time and that the URIs will be maintained, not sold or simply forgotten (Baker, Vandenbussche, & Vatant, 2013). According to W3C Linked Data Best Practices (2014), vocabularies should only be published by a trusted group or organization. In order for a vocabulary to become a true controlled vocabulary, there should be agreed-upon governance procedures to follow if the list needs to be modified or updated. Given the current immature practices of the xAPI community, should CoPs be trusted to publish and manage their own vocabularies just yet? What happens when the storage locations of vocabularies are a victim of external dependencies, natural disasters, or personnel turnover? Should a governance process be put in place to initially support vocabulary storage and preservation practices of xAPI vocabularies for decades to come? Should the xAPI community follow a centralized or decentralized approach or both? No single organization or company can guarantee that it will be able to preserve a vocabulary or its URI forever. What approaches should be taken to provide redundancy of preserved vocabulary data? The xAPI community does not yet have the answers to any of these questions pertaining to storage and ownership. However, all of these questions and concerns highlight the need for a unified governance strategy, policy, and cooperative agreements on which the xAPI community should definitely engage and collaborate on in the near future.

Persistence and Versioning

According to the W3C (2014), step #5 (Good URIs for Linked Data), a persistence strategy and policy is one of the key building blocks and vital to the success of following a Linked Data approach. Unfortunately, a growing number of vocabularies on the web have been abandoned by their publishers and have broken URIs or obsolete content (Baker, Vandenbussche, & Vatant, 2013). An example of broken URIs has already been discovered within the xAPI community: referencing verbs from the JSON Activity Streams 1.0 vocabulary from 2011. This is likely a result of the Activity Streams vocabulary also not having a defined strategy to address vocabulary storage, persistence, and versioning. This finding is also indicative of other communities' raw and imperfect vocabulary practices. So the xAPI community is not alone, and should see this as an opportunity to put some guidelines in place before xAPI vocabularies become too dispersed, and URIs are broken.

Fortunately, there are options for addressing persistence of vocabulary URIs. The Persistent URL (PURL) concept, PURL.org, allows for URL curation of HTTP URIs on the web. According to the W3C (2014), curation has been defined as "the active involvement of information professionals in the management, including the preservation, of digital data for future use." PURLs provide an address on the World Wide Web that can force a redirection to another valid web resource. If a web resource such as a vocabulary URI changes location (and hence URL), a PURL pointing to it can be updated (W3C, 2014). For secure URLs using HTTPS, the W3C also provides a service called Permanent Identifiers on the web, w3id.org.

A versioning strategy and policy for xAPI controlled vocabularies would also provide a known best practice. There are many options for applying versioning to a vocabulary that can potentially cascade through several layers of granularity though. Versioning practices can be applied at the term and definition level by leveraging existing vocabulary standards and metadata elements such as those provided by the DMCI. More recently, it has become a common practice for vocabularies to even provide descriptions and other metadata about themselves by using one or more emerging standards for this purpose. Some examples include: Asset Description Metadata Schema (ADMS), Vocabulary for Annotating Vocabularies (VANN), and Vocabulary Of A Friend (VOAF) (Baker, Vandenbussche, & Vatant, 2013).

What Others Are Doing: Projects of Interest

While the xAPI community may have different requirements for developing, discovering, and managing vocabulary data it is important to recognize and investigate what other communities are doing (or not doing). The following is a summary of various vocabulary activities and projects that might be of interest to the xAPI community. This summary list is not intended to be exhaustive, but rather it highlights, and in some cases, reinforces many of the considerations and approaches previously identified in this paper.

Open Metadata Registry (OMR) and RDA Registry

The Resource Description and Access (RDA) Steering Committee (RDC), working with the American Library Association Publishing and the Open Metadata Registry (OMR), unveiled the RDA Registry (http://rdaregistry.info) in January 2014. The OMR (http://metadataregistry.org), a National Science Foundation-funded project in active development for more than a decade, is being used by the RDC to manage and generate the RDA vocabularies from multiple sources. The RDA Registry, based on Git, is using GitHub for delivery and GitHub pages for documentation. These services are fed by changes in the OMR, representing a functional upgrade for human and machine users of the RDA Vocabularies. The RDC has embraced semantic versioning principles to make reliable machine-based updating possible for RDA consumers, while allowing the vocabularies to continue to evolve. GitHub recognizes any tag as a release and takes a snapshot of the state of the entire repository at the point in time when the tag was applied. It also makes it possible to reference the snapshot with a specific URI. As RDA becomes a fully multilingual set of vocabularies, several innovative techniques have been developed to manage and serve separate language versions while maintaining linkages of all versions to the RDA canonical URIs.

JSON Activity Streams 2.0

The JSON Activity Streams Working Group (http://activitystrea.ms) has a draft 2.0 specification that is focused on a new representation that is closely compatible with JSON-LD, but has many serialization and syntax differences. Therefore, it is not defined strictly as a JSON-LD Vocabulary. It is also not backwards compatible with 1.0, therefore, the 1.0 syntax has been completely deprecated. The Activity Streams 1.0 version process for creating a new verb for activity streams was modeled after the microformats process, (http://microformats.org), which is conceptually similar to RDFa, and limited to HTML-based representations. However, by updating the specification to support JSON-LD, it now allows mapping to external vocabularies (e.g. schema.org) and compact IRIs (using prefixes for namespaces). At the time of this writing, the Activity Streams community has a registry (http://activitystrea.ms/registry) of verbs and an activity schema, but it hasn't been updated to support the draft 2.0 specification or any RDF Linked Data approaches. The draft 2.0 version of Activity Streams currently appears to be transitioning to the W3C and focuses on supporting Linked Data as of January, 2015 (http://www.w3.org/TR/activitystreams-core).

The Audubon Core Vocabularies

The Audubon Core is a set of vocabularies that seem follow many best practices and standards of a linked open vocabulary approach. These vocabularies are also part of the Darwin Core Standards developed for and by the Taxonomic Databases Working Group (TDWG), tdwg.org. Their approach is very similar to how the DCMI has documented and implemented their vocabulary properties and terms. In fact, they often mention their adoption of DCAM and other DCMI documentation as their conceptual model. They have created processes, documentation, schemas, vocabularies based on RDF standards, and also provide the communities of practice with an easy way to create new terms based on imported standard vocabularies such as RDFS, SKOS, Dublin Core, and VANN by using semantic mediawiki (semantic-mediawiki.org).

The W3C Government Linked Data (GLD) Working Group

The W3C Government Linked Data (GLD) working group published a W3C Recommendation called the Data Catalog Vocabulary (DCAT) (http://www.w3.org/TR/vocab-dcat) and Project Open Data Metadata Schema (https://project-open-data.cio.gov/v1.1/schema), based on DCAT and JSON-LD. The Project Open Metadata Schema provides a common vocabulary and metadata element nomenclature utilizing existing open vocabulary standards. In addition, they also provide samples, templates, documentation and other resources for their community (https://project-open-data.cio.gov/v1.1/metadata-resources). They are currently using CKAN (http://ckan.org) for publishing and managing data.

The German Competence Centre Interoperable Metadata (KIM) Working Group

This group (https://wiki.dnb.de/display/DINIAGKIM/Titeldaten+Gruppe) and the German hbz (https://www.hbz-nrw.de) promote the re-use of existing vocabularies instead of creating a new ones for every application. They only create new properties or SKOS vocabularies if they can't locate anything from an existing vocabularies that are maintained. They have successfully applied the documentation of vocabulary usage in the form of DCMI application profiles. They key goal of the group is to create application profiles (also called "community profiles" by this group) for publishing library catalogs as Linked Data. They view application profiles as a common foundation vocabulary that pulls together elements from other element sets. They also make it possible for people to fork the application profile on github and to optionally extend it to meet their needs. They specifically use JSON-LD @context as a syntactic mechanism to map short terms to property URIs.

The Call-To-Action

The learning curve to support existing vocabulary standards and a Linked Data approach is tremendous for those unfamiliar with RDF and RDF vocabulary concepts. CoPs have important work to do in identifying pertinent use cases and focusing on harnessing their domain expertise to create useful profiles of xAPI. In the meantime, the xAPI community is living in the “Wild West” where vocabularies are everywhere, yet nowhere. It would be most valuable for the xAPI community to establish a dedicated group to research and prototype vocabulary practices that could be followed. This vocabulary guidance should help define the best practices that can be used to make everyone's life in the xAPI vocabulary lifecycle much easier. There is also a need for a group to oversee policy and governance concerns. Presented below is a list of possible next steps as a result of the development, discoverability, and management considerations provided in this paper.

1. ***Establish an xAPI study / working group focused on Linked Data practices for xAPI vocabularies.*** This group could investigate some of the resources referenced in this paper and any others that are relevant. Initially, the group could start with existing registries and aligning with W3C vocabulary standards, and investigate what other communities are successfully doing. An immediate action might involve updating the existing ADL vocabulary of verbs and activities to be provided as Linked Data by first developing an RDF schema and a RDF vocabulary. The table in Appendix B.4 could be used as a starting point for identifying the properties and other metadata that could be identified and used. Additional considerations for multilingual support as well as "private/closed" vs. linked open vocabularies might also need to be addressed later as group activity progresses and time allows.

2. ***Establish an xAPI governance strategy.*** This group could focus on vocabulary centralization and decentralization options, ownership, and management. This group would generate policy related to the findings of the aforementioned study group focused on best practices for xAPI vocabularies. This group might also help to inform a larger governance body that will address standardization concerns for xAPI. Currently, ADL is the steward of the xAPI specification, but it is possible that stewardship could be transferred to a larger standards body or community-operated activity as various aspects of the xAPI continue to evolve.

3. ***Develop guidance, resources, and documentation***. Documentation of vocabulary usage in the form of application profiles is a commonly adopted practice. Guidance on applying an xAPI vocabulary application profile of properties and metadata, examples, templates and other resources could be created as an outcome of the previous two steps. The ultimate goal as a result of these possible next steps would be to develop a simplified, common vocabulary model and provide consistent practices that any xAPI

stakeholder (e.g., designers, developers, managers, vendors) could easily follow for developing, discovering, and managing xAPI vocabularies.

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Appendices:

Appendix A: Concepts and Terminology

Community of Practice (CoP)

A group, usually connected by a common cause, role or purpose, which operates in a common modality (ADL, 2014).

Controlled Vocabulary

A controlled vocabulary is a restricted, agreed-on list of words or terms developed by a CoP and used for a specific domain of knowledge. The objective of a controlled vocabulary is to ensure consistency in the development and implementation of xAPI statements to avoid ambiguity and ensure the use of consistent language (ADL, 2014).

FOAF (Friend of a Friend)

A descriptive vocabulary expressed using the Resource Description Framework (RDF) and the Web Ontology Language (OWL). FOAF is a machine-readable ontology describing persons, their activities and their relations to other people and objects. Anyone can use FOAF to describe him- or herself. FOAF allows groups of people to describe social networks without the need for a centralized database (Wikipedia, 2015).

IRIs

The uniqueness of objects and verbs are dictated by full International Resource Identifiers (IRIs). IRIs are similar to URIs and URLs, which may be more familiar to web developers, but an IRI can use international characters (Wikipedia, 2015).

JSON-LD (JavaScript Object Notation- Linked Data)

A lightweight Linked Data format and full serialization of RDF. It is easy for humans to read and write, and correspondingly represents an instance of an RDF data model. It is primarily intended to be a way to use Linked Data in web-based programming environments, to build interoperable web services, and to store Linked Data in JSON-based storage engines (W3C, 2015).

Learning Record Store (LRS)

A system that stores xAPI learning data. This data is available for retrieval by other systems that create reports, perform analytics, and generally create meaning out of the raw data stored in the LRS in the form of statements. It is important to understand that an LRS is not a learning-management system (LMS), and it is not a replacement for an LMS, though some LMS products support LRS functionality (ADL, 2014).

Linked Data

Describes a method of publishing structured data so that it can be interlinked and become more useful through semantic queries. More specifically, Wikipedia defines Linked Data as "a term used to describe a recommended best practice for exposing, sharing, and connecting pieces of data, information, and knowledge on the Semantic web using URIs and RDF" (Wikipedia, 2015).

Namespace

URIs are most appropriate choice for uniquely identifying resources for machines and humans. However, long URIs are tough to read by humans. One approach is to use a shortcut known as a namespace. A namespace is context for an identifier such as a URI. Namespace URIs in RDF are used to distinguish between properties with the same name. Names in a namespace cannot have more than one meaning; that is, different meanings cannot share the same name in the same namespace. A namespace is also called a context because the same name in different namespaces can have different meanings, each one appropriate for its namespace. Names in a namespace can represent objects as well as concepts (Wikipedia, 2015). The term "namespace" on its own does not have a well-defined meaning in the context of RDF, but is sometimes informally used to mean “namespace IRI” or “RDF vocabulary” (W3C, 2014).

Ontology

From Hedden (2010): An ontology is set of concepts with attributes and relationships between the various concepts that contain various meanings, all to define a domain of knowledge, and is expressed in a format that is machine-readable. Certain applications of ontologies, as used in artificial intelligence or biomedical informatics, may define a domain of knowledge through terms and relationships as the end goal, rather than being used for any tagging. In the area of taxonomies and information science, however, an ontology can be seen as a more complex type of thesaurus, in which instead of having simply “related term” relationships, there are various customized relationship pairs that contain specific meaning, such as “owns” and a reciprocal “is owned by.” An ontology helps to enables reuse of domain knowledge.

Resource Description Framework (RDF)

A collection of RDF statements intrinsically represents a labeled, directed multi-graph. As such, an RDF-based data model is more naturally suited to certain kinds of knowledge representation than the relational model and other ontological models. The RDF data model is similar to classic conceptual modeling approaches such as entity–relationship or class diagrams, as it is based upon the idea of making statements about web resources in the form of subject–predicate–object expressions. RDF/XML is sometimes misleadingly called simply “RDF” because it was introduced among the other W3C specifications defining RDF and it was historically the first W3C standard RDF serialization format. However, it is important to distinguish the RDF/XML format from the abstract RDF model itself. Although the RDF/XML format is still in use, other RDF serializations are now preferred by many RDF users (e.g., RDFa, JSON-LD), both because they are more human-friendly, and because some RDF graphs are not representable in RDF/XML due to restrictions on the syntax of XML (Wikipedia, 2015).

RDF Schema (Resource Description Framework Schema)

A set of classes with certain properties using the RDF extensible knowledge representation language, providing basic elements for the description of ontologies, otherwise called RDF vocabularies, intended to structure RDF resources. These resources can be saved in a triplestore to reach them with the SPARQL query language (Wikipedia, 2015).

Simple Knowledge Organization System (SKOS)

SKOS provides a standard way to represent knowledge organization systems using RDF. SKOS provides a model for expressing the basic structure and content of concept schemes such as thesauri, classification schemes, subject heading lists, taxonomies, folksonomies, and other similar types of controlled vocabulary. It may be used on its own, or in combination with formal knowledge representation languages such as the Web Ontology language (OWL).

SPARQL (SPARQL Protocol and RDF Query Language)

The de facto RDF query language that is able to retrieve and manipulate data stored in RDF format. SPARQL allows for a query to consist of triple patterns, and query data that can loosely be called "key-value" data (RDF data). The entire database is thus a set of "subject-predicate-object" triples, and is analogous to NoSQL databases' usage of the term "document-key-value" (Wikipedia, 2015).

Taxonomy

The word taxonomy generally means the science of classifying things. It is no longer strictly referred to as a science but rather as a kind of controlled vocabulary that has a hierarchical classification or categorization system. A more recent usage of the term refers to multiple controlled vocabularies used for a specific domain or purpose. The terms from each controlled vocabulary may or may not be arranged in a hierarchy, and they may or may not have complex relationships between each other (Hedden, 2010).

Triple

A triple is a data entity composed of a subject-predicate-object. The subject denotes the resource, and the predicate denotes traits or aspects of the resource and expresses a relationship between the subject and the object (Wikipedia, 2015).

URI

URI stands for Uniform Resource Identifier. URIs are text identifiers that serve as a "name" for a "thing," but it is a name which is defined formally enough to be managed by a machine. A URL should be globally unique and persistent, but there is no way to guarantee or enforce this. In the early days of the Internet, resources were exclusively referred to by URLs (Uniform Resource Locators) and there was an expectation that a URL could be used to locate and retrieve an electronic document by means of http. However, over time it became accepted that identifiers could refer to non-retrievable resources as well. The broader term URI came into use to represent an identifier for any kind of resource, including non-information resources (TDWG, 2014). The URI syntax consists of a URI scheme name (such as "http," "ftp," "mailto," "crid," or "file") followed by a colon character, and then by a scheme-specific part (Wikipedia, 2015).

Web Ontology Language (OWL)

OWL is a representation language for authoring ontologies, knowledge bases, and vocabularies. OWL2 was the latest version announced in 2009. OWL is characterized by formal semantics and built as a full semantic extension of RDF (Wikipedia, 2015).

Appendix B: Tables

B.1. Table Comparison of Relevant Vocabulary Standards

Name	Started	Latest	URL	Relevancy
ANSI/NISO Z39.19-2005 (R2010) **Guidelines for the Construction, Format, and Management of Monolingual Controlled Vocabularies**	1974	2010	http://www.niso.org	• Guidelines are applicable to the general monolingual development of controlled vocabularies for pre-coordinated retrieval systems • Addresses the format of terms: single word vs. multiword; grammatical forms of terms; variations in spelling; compound terms; and equivalence, associative, and semantic relationships
Dublin Core Abstract Model (DCAM)	2002	2013	http://dublincore.org/documents/abstract-model/	• Generic information model and does not assume any particular encoding syntax • Specifies components and constructs used for DC Metadata • Builds on RDF, RDFS • Intended to bridge linked data graphs with metadata records

Dublin Core Metadata Terms (DCT)	2000	2012	http://dublincore.org/documents/dcmi-terms/	• Authoritative specification of metadata terms • Also published as RFC 5013, ANSI/NISO Z39.85-2007, and ISO15836 • Offers four levels of interoperability with Level 2 and higher intended for formal RDF semantic interoperability • Builds on semantics and notions from RDF
Web Ontology Language (OWL)	2002	2012	http://www.w3.org/TR/owl2-overview/	• Ontology language intended to represent complex conceptual structures • Semantic markup language for publishing and sharing ontologies on the web • Intended for knowledge representation and reasoning • An OWL ontology is a RDF document
Resource Description Framework Schema (RDFS) 1.1	1999	2014	http://www.w3.org/TR/rdf-schema/	• General purpose language for representing information on the web • Interoperable format for taxonomies • Conceptually relevant in terms of describing resources and giving them persistent identifiers • Has an extension for a vocabulary description language (RDFS), but does not get into specifics such as term relationship types
Simple Knowledge Organization System (SKOS)	2004	2009	http://www.w3.org/2009/08/skos-reference/skos.html	• Common data model for sharing and linking knowledge organization systems via the web • Built upon RDF and RDFS (actual implementation of RDF) • Enables easy publication and use of linked data vocabularies • Not intended for formal ontologies

				• Allows for reuse and sharing of concepts/classes and their descriptions • Allows for linking between concepts from different contexts • Extensible and can be combined with other modeling vocabularies

B.2. Table of Vocabulary Search & Registry Services

Vocabulary Search & Registry Services	Features	URL
CKAN Datahub	• Largest dataset registry for open datasets in general and linked open data of all types	http://datahub.io
Falcons	• Semantic web search engine • Search based on RDF documents • Exposes objects, concepts, classes, and properties • Possibly useful, but appears to be an older service/resource	http://ws.nju.edu.cn/falcons/
Linked Open Vocabularies (LOV)	• Registry that gathers all types of quality vocabularies based on Linked Data standards such as RDFS/OWL. • Full text search feature over 469 vocabularies as of Jan 2015, 46.000+ terms, 462 agents (creators, contributors, publishers) • Optional use of tags instead of hierarchical categories • Over 470 vocabularies currently hosted • Recently re-engineered/new architecture released January 2015	http://lov.okfn.org/dataset/lov/

Meta-Bridge	• A registry of different metadata schemas • Focused on RDFS property and class vocabularies • Hosted in Japan, but can be translated	https://metabridge.jp
Open Metadata Registry	• Tool for consumers and developers of controlled vocabularies • One of the first production deployments of SKOS • Originally funded by the National Science Foundation (NSF) and built to support the National Science Digital Library (NSDL), but open to all • Provides a way to identify, declare, and publish metadata schemas, controlled vocabularies, and application profiles	http://metadataregistry.org

B.3. Table of Vocabulary Frameworks, Editors, and Managers

Vocabulary Software	Description/Features	**URL**
Callimachus	• Editor for creating Linked Data Applications	http://callimachusproject.org/
Fluent Editor	• Ontology editor that uses controlled natural language/English • Allows user to enter RDF statements and automatically generates OWL • Windows only • Uses a subset of standard English to reduce ambiguity problems in full English • Supports OWL2	http://www.cognitum.eu/semantics/FluentEditor/

	● Free for Academia & researchers	
Jena (Apache)	● Open Source Java framework for RDF and semantic applications	http://jena.apache.org/
OntoWiki	● User interface for managing classes, properties, relationships ● LD server and LD client ● Can create wiki pages using markdown	http://aksw.org/Projects/OntoWiki.html
Parrot	● RIF and RDF Ontologies documentation Tool ● Eclipse plugin (Java)	https://bitbucket.org/fundacionctic/parrot/wiki/Home
Open Semantic Framework (OSF)	● Open source framework/software stack for supporting the hosting and management of semantic vocabularies ● Intended to be installed and operated per organization	http://opensemanticframework.org
Semantic MediaWiki	● Open source extension to MediaWiki (powers wikipedia) ● Turns wiki solution into a Linked Data-based collaborative knowledge management system or vocabulary manager ● Exposes content in RDF; based on RDFS and SKOS	http://semantic-mediawiki.org
Sindice	● Platform for building applications on top of collected RDF data ● Offers search, querying, and export of data using specialized APIs and tools	http://sindice.com
SKOS Editor	● Plugin for Protege ● Allows creation of thesauri or vocabularies represented in SKOS	https://code.google.com/p/skoseditor/

SKOSMOS	• Provides services for accessing controlled vocabularies	https://github.com/NatLibFi/Skosmos
TemaTres	• Vocabulary server that enables sharing and reuse of controlled vocabularies • Supports multilingual vocabularies and hierarchical thesauri • Collaborative thesauri development	http://www.vocabularyserver.com
Protégé / Web Protégé	• Open source • Standards compliant • Collaborative editor • Full change tracking and revisions • Supports multiple import/export options	http://webprotege.stanford.edu
TopBraid	• Suite of commercial products for composing, editing, managing, and publishing vocabularies • Implements RDF, RDFS, OWL, and SPARQL	http://www.topquadrant.com/products/

B.4. Possible Properties & Metadata for xAPI Controlled Vocabularies

Property	Namespace Abbrieviation	Namespace URI	Example	Notes
Term Label	rdfs:label	http://www.w3.org/2000/01/rdf-schema#	"answered"@en	-Literal text string value the identified term -Equivalent to dublin core “title”
Term Title	dc:title	http://purl.org/dc/terms/title	"answered"@en	-Literal text string value the identified term -Equivalent to RDFS “label”
Preferred Term	skos:prefLabel	http://www.w3.org/2009/08/skos-reference/skos.html#prefLabel	"answered"@en	- Intended to be used as human-readable label -Instance of owl:AnnotationProperty

				-Can be used to further clarify preference over RDFS “label” or dublin core “title”
Related	skos:related	http://www.w3.org/2009/08/skos-reference/skos.html#related	<http://adlnet.gov/expapi/activities/question/>	- Used to assert an associative link between two SKOS concepts
Definition	skos:definition	http://www.w3.org/2004/02/skos/core#definition	"answer (respond to a signal)"@en	-A statement or formal explanation of the meaning of a concept
Description	dcterms:description	http://purl.org/dc/elements/1.1/description	"answer (respond to a signal)"@en	-A free-text account account of the resource -This could be used instead of defining a custom xAPI property for “usage”
Type	rdf:type	http://www.w3.org/2000/01/rdf-schema#	<http://adlnet.gov/xapi/vocabulary-schema/verb>	- An instance of rdf:Property that is used to state that a resource is an instance of a class -This is a sample URI if xAPI community created a verb class as part of a schema for vocabularies
Source	dc:source	http://purl.org/dc/terms/source	<http://adlnet.gov/expapi/verbs/answered/>	-A related resource from which the described resource is derived
Vocabulary Source (RDF)	rdfs:isDefinedBy	http://www.w3.org/2000/01/rdf-schema#	<http://wordnet-rdf.princeton.edu/wn31/200721514-v.rdf>	-Used to indicate a resource defining the subject resource -This property may be used to indicate an RDF vocabulary in which a resource is described
Vocabulary Source URI	rdfs:seeAlso	http://www.w3.org/2000/01/rdf-schema#	<http://wordnetweb.princeton.edu/perl/webwn?o2=&o0=1&o8=1&o1=1&o7=&o5=&o9=&o6=&o3=&o4=&s=answered&i=1&h=00110000000000#c >	-Used to indicate a resource that might provide additional information about the subject resource
Usage Intent	xapi:usage	http://adlnet.gov/xapi/vocabulary-schema/	“Used to record a learner's action of	-This could be a custom property created as part

			answering a specific question."@en	of an xAPI schema -This would be used to express the intended usage and would add further context
Creator	dc:creator	http://purl.org/dc/elements/1.1/creator	"ADL Initiative."@en	-name of a person, an organization, or a service that created the resource
Maker	foaf:maker	http://xmlns.com/foaf/0.1/maker	<http://www.adlnet.gov>	-The agent that created this vocabulary - dc:creator is used only for simple textual names; maker cold be used to indicate the URI of the creator, rather than risk confusing creators with their names
Term Status	vs:term_status	http://www.w3.org/2003/06/sw-vocab-status/ns#	"stable"@en	-Used to indicate the status of a term -Possible values are: stable/unstable/testing/archaic
Example	skos:example	http://www.w3.org/2004/02/skos/core#		-Could be plain text, hypertext, or an image; -Could be a definition, information about the scope of a concept, editorial information, or any other type of information -Might be useful for pointing to an example of the term being used in an xAPI statement
Comment	rdfs:comment	http://www.w3.org/2000/01/rdf-schema#		-A textual comment to helps clarify the meaning of a class and properties -This could be used instead of defining a custom xAPI property for "usage"
Date	dcterms:date	http://purl.org/dc/terms/date	2015-01-05T08:15:30-05:00	-Used to express date information at any level of granularity
Issued	dcterms:issued	http://purl.org/dc/terms/issued	2015-01-05	-Date of formal publication -Refines dcterms:date

Modified	dcterms:modified	http://purl.org/dc/terms/modified	2015-01-06	-Date when resource changed -Refines dcterms:date
Relation	dcterms:relation	http://purl.org/dc/terms/relation	<http://adlnet.gov/expapi/verbs/answered/>	-Related resource -Intended to be non-literal (e.g., URI)
Replaces	dcterms:replaces	http://purl.org/dc/terms/hasversion/replaces	<http://adlnet.gov/expapi/verbs/answered/>	-Resource that is supplanted, displaced, or superseded by the described resource -Refines dcterms:relation

Appendix C: Resources (For Consideration)

Activity Streams 2.0: http://www.w3.org/TR/activitystreams-core/

Beginner's Guide to RDF: https://code.google.com/p/tdwg-rdf/wiki/Beginners

Best Practices for Publishing Linked Data: http://www.w3.org/TR/ld-bp/

Best Practices for Publishing RDF Vocabularies: http://www.w3.org/TR/swbp-vocab-pub/

Cool URIs for the Semantic Web: http://www.w3.org/TR/cooluris/

Data Catalog Vocabulary (DCAT): http://www.w3.org/TR/vocab-dcat/

Data on the Web Best Practices & Requirements: http://www.w3.org/TR/dwbp/

Dublin Core Application Profiles: http://dublincore.org/documents/profile-guidelines/

Dublin Core Metadata Terms: http://dublincore.org/documents/dcmi-terms/

Dublin Core Metadata Registry: http://dcmi.kc.tsukuba.ac.jp/dcregistry/

Dublin Core Alignment with Schema.org:
http://wiki.dublincore.org/index.php/Schema.org_Alignment

How to Publish Linked Data on the Web:
http://wifo5-03.informatik.uni-mannheim.de/bizer/pub/LinkedDataTutorial/

Intro to RDF: https://github.com/JoshData/rdfabout/blob/gh-pages/intro-to-rdf.md#

JSON-LD (JSON Linked Data): http://json-ld.org

JSON-LD 1.0: http://www.w3.org/TR/json-ld/

Lexical Model for Ontologies (LEMON): http://lemon-model.net/

Linked Data: http://linkeddata.org

Linked Data Book: http://linkeddatabook.com/

Linked Data Glossary: http://www.w3.org/TR/ld-glossary/

Linked Data Platform: http://www.w3.org/TR/ldp/

Linked Data Validator: http://validator.linkeddata.org/

Linked Education Catalog: http://data.linkededucation.org/

Linked Open Vocabularies: http://lov.okfn.org/dataset/lov/

Metadata Recommendations for Linked Open Data Vocabularies:
http://lov.okfn.org/Recommendations_Vocabulary_Design.pdf

Namespace Lookup for RDF Developers: http://prefix.cc

OWL Primer: http://www.w3.org/TR/owl-primer/

Project Open Metadata Schema v1.1: https://project-open-data.cio.gov/v1.1/schema/

Persistent Uniform Resource Locators (PURLs): http://purl.org

RDF Translator: http://rdf-translator.appspot.com/

Simple Knowledge Organization System (SKOS):
http://www.w3.org/2009/08/skos-reference/skos.html

SKOS JSON-LD Profile: http://gbv.github.io/jskos/jskos.html#json-ld-context

Style Guideliens for Naming and Labeling Ontologies:
http://dcevents.dublincore.org/index.php/IntConf/dc-2011/paper/download/47/15

Ten Rules for Persistent URIs: http://philarcher.org/diary/2013/uripersistence/

Online Learning and Linked Data – Lessons Learned and Best Practices:
http://www.euclid-project.eu/events/online-learning-and-linked-data-www2014

W3C Data Activity: http://www.w3.org/2013/data/

Web-based Visualization of Ontologies (WebVOWL):
http://vowl.visualdataweb.org/webvowl.html

WordNet RDF: http://wordnet-rdf.princeton.edu/

Vocabulary of a Friend (VOAF): http://purl.org/vocommons/voaf