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Metadata Standards for Educational Objects

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An Educational CAD Model Library (CAD Library) is being developed by collaborating educational associations affiliated with the National Technology Leadership Summit coalition. The CAD Library's Curators' Council has developed descriptive metadata fields that will be associated with each educational object published in the library. These fields are designed to facilitate search and discovery of objects by teachers who are increasingly well positioned to use these objects in their instruction due to the increasing presence of school-based makerspaces and the 3D printers, digital die cutters, and other fabrication tools. The publication of these metadata standards makes them available to the members of the educational associations participating in the development of the CAD Library and to other relevant stakeholders for feedback to inform ongoing revisions.

Our vision is for every K-12 student to have educationally effective hands-on learning experiences at every grade level. The advent of affordable fabrication technologies has led to the establishment of makerspaces in schools that can facilitate hands-on learning. The educational effectiveness of fabrication tools in K-12 makerspaces requires access to useful computer-assisted design (CAD) models and associated instructional supports for teachers.

To realize this vision of educationally effective hands-on learning experiences in schools, we are collectively developing an ecosystem to support educational manufacturing in schools. An Educational CAD Model Library (CAD Library) is a key component of this ecosystem. The CAD Library is designed to provide teachers with peer-reviewed educational objects that can be used to address instructional objectives. A more complete description of the CAD Library is available in the companion article, "Establishing an Educational CAD Model Ecosystem," published in *CITE Journal* (Bull et al., 2023).

In the same way that journals serve as an engine to generate, validate, and disseminate scientific knowledge, we intend that *the peer-reviewed CAD Library will serve as an engine to generate, validate, and disseminate educational objects*. This process requires metadata and a classification system that not only makes objects discoverable but also encourages invention of new educational objects. In addition to metadata that describes subject, topic, grade level, and educational standards addressed, educational objects can be organized with respect to complexity and function.

A vibrant ecosystem of model creation and use in K-12 education requires the means to make pedagogically effective educational objects discoverable by teachers who have little time to investigate the details of numerous objects to find one suitable for their instruction. Effective educational objects can only be made discoverable if there are succinct descriptions (i.e., metadata) of the pedagogical goals to which the objects can contribute. These descriptions must be in terms recognized and understood by the teachers – not only by the academic researchers curating the objects.

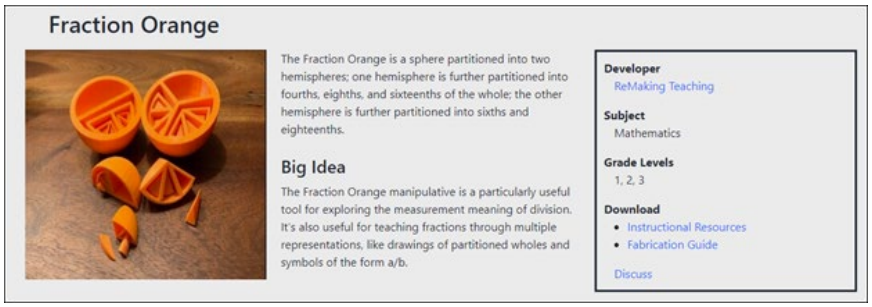
A repository designed specifically for scholarly objects has been developed to house the CAD Library. The Dataverse software (https://dataverse.org/about) is open-source data repository software developed at Harvard University (King, 2007). Objects in the CAD Library are housed in an instance of the Dataverse software managed by the University of Virginia Library. The University's Repository Librarian provides leadership and oversight of the University of Virginia Dataverse, including the CAD Library. An application interface (API) is used to retrieve objects and associated information from the back-end repository (i.e., the CAD Library Dataverse) and display them in a user-friendly format. The web address "CADLibrary.org" has been secured for the CAD Library.

The Dataverse software has existing metadata fields designed for general use with any scholarly repository of objects. In cases in which these built-in fields match descriptors of CAD Library fields, the existing metadata fields have been incorporated into the CAD Library. In addition, a new

block of metadata fields specific to the CAD Library has been incorporated into the University of Virginia Dataverse.

CAD Library curators serve in a role that is analogous to the role of editors of a journal. In consultation with the University of Virginia Repository Librarian, the curators of the CAD Library have identified metadata fields designed to facilitate search and discovery of educational objects. In the remainder of this article, we provide the current draft of metadata fields for the CAD Library. The purpose of this article is to provide this draft as a means of securing input from stakeholders to inform further revisions. The example object in Figure 1 will be used as an illustrative point of reference in relation to the metadata fields that follow.

Figure 1
Fraction Orange: Example of an Educational Object



1. *Name of Object ("Title" field in CAD Library Dataverse) – Required*

The *name of object* field is the descriptor assigned by the developer; e.g., *Fraction Orange* in the instance of the example in Figure 1.

2. *Author – Required*

The *author* field refers to the person who designed the object. There is also an optional field under *author* to enter author identifiers (i.e., ORCID, ResearcherID, etc.).

3. *Contact – Required*

The *contact* field includes name, email, and organizational affiliation of the curator entering the data.

4. *Dataset Description – Required*

The *data description* field allows for the entry of multiple descriptive text boxes. The first *data description* text box should include a brief description of the object that will accompany the object thumbnail image. A second *data description* text box should be used to describe the big idea underlying the lesson.

5. *Key Words*

The *key words* field includes common search terms that teachers might use to identify objects of interest.

6. *Related Work / Article*

This optional field includes links to any other articles or conference proceedings related to the object.

7. *Notes*

The *notes* field is a built-in Dataverse software field that currently is not used for the CAD Library.

8. *Data Creation Date – Required*

This field is not used by the CAD Library but is required by the University of Virginia Dataverse.

9. *Contributor*

The *type* and *name* fields identify the role and name of the curator who managed the review process and accepted the object for publication in the CAD Library.

10. *Depositor*

This field refers to the individual depositing the object in CAD Library Dataverse.

11. *Date – Required*

a. Deposited
b. Published in CAD Library

The *Deposited* metadata field refers to the time that the object is first placed in CAD Library Dataverse and sent out for review. The *Published* field refers to the time that the object is approved for publication and made available to the general public via the website.

12. *Software*

The *software* field contains a list of software used in support of the object.

13. *Digital Object Identifier (DOI)*

A Digital Object Identifier (DOI) is a unique persistent identifier for a dataset implemented with protocols established by the International Standards Organization. A DOI is automatically assigned to every published dataset (object) in the University of Virginia Dataverse. The

attribute of *persistence* means that the link to the digital object can always be accessed unless the object is intentionally deaccessioned. The attribute of *uniqueness* means that the link will only access the specified object. In academic settings, a DOI is typically encountered in the context of the citation for a journal article.

14. *Lesson*

a. *Sample Learning Goals – Required Field*: The *Sample Learning Goals* field describes the learning objective; e.g., "The *Fraction Orange* manipulative is a tool for exploring the measurement meaning of division."

- *Alignment with Content Standards*: The *alignment with content standards* field identifies relevant educational standards addressed: e.g., "CCSS.MATH.CONTENT.6.NS.A.1 Interpret and compute quotients of fractions, and solve word problems involving division of fractions by fractions, e.g., by using visual fraction models and equations to represent the problem." The content standards will also include an associated field that describes the grade level(s) for which the content standard applies.

- *Grade Levels – Required Field*: The *grade levels* field refers to those grade levels from K through 12 for which this object may be used.

- *Discipline and Subdiscipline – Required Field*: The *discipline* field identifies the discipline taught. (In most cases, this corresponds to the area of teacher licensure and accreditation.) The primary discipline in the case of the Fraction Orange would be *mathematics*. The subdiscipline would be *arithmetic*. Multiple *discipline* and *subdiscipline* fields may be added for objects that touch on more than one content area.

Note: The Dataverse software includes a required field named "Subject" that does not include subjects taught in schools such as science, mathematics, and engineering education. Since this field could neither be altered nor used, it is auto-populated with the entry of "Other". However, the field is not used for the CAD Library. Instead, separate fields labeled "Discipline" are provided for CAD Library metadata.

15. *Hardware Specifications*

a. CAD Format: The file type associated with the CAD object; e.g., scalable vector graphic (SVG), stereolithographic (STL),

- Estimated Material Cost (Consumable): The estimated cost (in dollars) of non-reusable material used to create this object.

- Estimated Material Cost (Reusable): The estimated cost (in dollars) of reusable material used to create this object.

- Fabrication Equipment: Equipment needed to fabricate this object (i.e., 3D printer, die cutter, etc.)

- Fabrication Time: The time required to 3D print, laser-cut, etc. the components of the object. Estimated time requirements should be listed to the nearest tenth of an hour. For example, one and one-half hours would be entered as "1.5 hours."

- Assembly Time: The time required to assemble and test the components and install software.

16. *External Contributor*

a. Agency: The name of the institution that developed the object.
b. Identifier: The external URL for where this object is hosted on the external contributor's website.

17. *Provenance*

In science and engineering, a new invention or innovation can serve as an incubator for a series of subsequent inventions. For example, the telegraph served as an incubator that enabled a generation of inventors to learn about electricity and magnetism. This process – in which one innovation inspired a series of related inventions – was a key impetus for the American Industrial Revolution (Hindle, 1983).

Once students understand the foundational principles that underlie a linear motor (for instance), this can lead to discovery and invention (or reinvention) of other objects. The provenance field will make it possible to trace the developmental history of objects and identify ways in which one object can inspire innovation and invention of other objects.

a. Remixed Objects: When an object is remixed, the DOI(s) of the remixed object(s) are listed in this field. This field will provide a sense of objects that spark innovation and invention. This will also ensure that authors of such objects can be made aware of how their innovations are being used and that they receive appropriate credit.

- Object Incorporated into Other Mechanisms: In cases in which an object such as a solenoid or a linear motor has been incorporated into another mechanism, the DOI(s) of the object(s) are listed in this field. This field will offer an indication of objects that often serve as building blocks for the creation of other mechanisms.

18. *Object Type*

This field is used to classify objects as (a) static, (2) dynamic, or (3) interactive. All manufactured objects are engineered. Educational objects are a subset of manufactured objects; therefore, connections with fields of engineering can be made. These topics correspond roughly to the

engineering fields of civil engineering, mechanical engineering, and electrical engineering and computer science (Table 1).

Table 1
Type of Object

Category	Static	Dynamic	Interactive
Field	Civil	Mechanical	Electrical / CS
Attributes	No Moving Parts	Moving Mechanisms	Sensors & Actuators

Civil engineering encompasses static structures. Mechanical engineering addresses mechanisms that move. Electrical engineering covers the electrical grid, telegraph networks, and telephone networks. Computer science includes processes that tie all of the foregoing together and make them interactive and interoperable. If these engineering topics are applied to educational objects, these objects can be classified according to whether they are static, dynamic, or interactive.

Packages

In addition to the metadata fields that describe objects and associated resources, the CAD Library Dataverse repository will be used to store zipped folders (known as "packages") of (a) all of the CAD files and instructions needed to fabricate and assemble the object, and (b) instructional resources such as sample tasks and lesson plans that a teacher may need in order to use the object with a class.

1. *Fabrication Guide Package – Required*

The *build details package* includes the information needed to replicate a physical artifact, including the bill of materials, supplies, and equipment required to fabricate the object. In the case of a manufactured product such as a microcontroller or a neodymium magnet (for example), sourcing should also be provided if the object is specialized. Since the cost of materials can change over time, a standard that encompasses broad bands such as "affordable, moderately expensive, and significant cost" may need to be developed. To upload files as a zip file combine t into a zip file. The filename of the instructional package should be of the form, "Fabrication_[Object name]" with "_" used instead of spaces.

a. Bill of Materials (i.e., materials list)
b. CAD Design
c. Assembly Instructions

2. *Instructional Resources Package – Required*

The *instructional resources package* includes descriptions and links to instructional resources that may be available to support instruction. Examples of resources are provided in the list below. The filename of the

instructional package should be of the form, "Instruction_[Object name]" with "_" used instead of spaces.

a. Background Knowledge
b. Sample Lesson Plan
c. Sample Tasks
d. Classroom Explorations
e. Textbook

3. Instruction Videos Package

The *instructional videos package* includes associated video files that are available to support instruction.

Citing and Publishing Objects in the CAD Library

Citation is a crucial element of knowledge generation and dissemination. The CAD Library Curators' Council have collectively agreed upon the following citation format for educational objects:

> Pomponio, E. (2023). *Fraction Orange* [Educational Object]. *Educational CAD Model Library*. Published April 27, 2023. NTLS Coalition. doi:10.18130/V3/JDRILP

The citation for a digital object published in the CAD Library is constructed by combining other metadata fields such as author, title, and the DOI.

The process of publishing an educational object in the CAD Library follows a process that parallels the workflow for a journal. When authors submit an article for review to a journal, the manuscript is sent out to reviewers. Revisions recommended by reviewers are typically incorporated into the manuscript by the author prior to acceptance for publication. The parallel workflow for the CAD Library involves the following steps:

1. Datasets (educational objects) are created and kept in draft (not published) until the review process is complete. The date at which this occurs is documented in the "Deposit" field, along with the name of the Curator who deposited the object.
2. Prior to publication "private URLs" are generated that are sent to reviewers (to give them access to view the metadata and files).
3. Once the reviewers have completed their work, the curator oversees any revisions requested by reviewers.
4. Once revisions are completed, the dataset is published in the CAD Library Dataverse.
5. At that point, the object will appear in the CAD Library, along with the corresponding citation.

In contrast to a journal article, an educational object must first be fabricated and assembled before the teacher can pilot its use in the classroom. In some cases, the teacher may fabricate the object. In other cases, an individual who is not the teacher may fabricate the object. For example, an engineering student might fabricate the object to fulfill an academic requirement or staff or students in a Fabrication Laboratory

(Fab Lab) may fabricate the object in order to gain experience with fabrication techniques.

Fabrication and assembly by an individual who is not the designer will help identify any issues with this process prior to publication. In a separate step, a teacher will then use the object for instruction and provide feedback about instructional effectiveness. Thus, the review process for an educational object encompasses both the process of fabrication and assembly with corresponding correction of any issues with the CAD files or assembly directions and review of instructional effectiveness when used for teaching.

A CAD Library forum provides a site where objects can be discussed with input to authors and developers even after publication. In that sense, publication verifies that the educational object meets a minimum threshold of quality assurance. However, the CAD Library forum provides a mechanism for ongoing refinement, improvement, and development.

Summary

The description of the draft metadata standards developed by the CAD Library curators is provided to familiarize stakeholders and potential authors with these standards and also to provide opportunities for input and feedback for curators to consider in ongoing revisions. This article is designed to accompany the companion article published in volume 23 issue 2 of the journal describing the ecosystem surrounding the CAD Library.

Stakeholders and others who have input can communicate directly with any of the CAD Library curators. The editors of the journal also welcome commentaries for publication with links to this article.

About the Authors

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