1909 Conference
109th Conference - Nashville, Tennessee - November 16 & 17, 2023

Session IX: CAD/Graphics/Manufacturing

Paper 17. Establishing an Ecosystem for Open-source Educational Computer Aided Design (CAD) Models

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The International Technology and Engineering Educators Association (ITEEA) *Engineering by Design* curriculum is currently taught by more than 5,000 technology and engineering education teachers. This curriculum is designed to enable educators to implement the Standards for Technological and Engineering Literacy (STEL) which emphasizes the relationship between technology (broadly defined) and engineering design and problem solving.

This curriculum is reviewed and updated on an on-going basis to reflect evolving technological capabilities in schools. During the past decade, K-12 schools have established makerspaces with 3D printers, digital die cutters, and other fabrication tools. Digital fabrication technologies and inexpensive microcontrollers have made open-source hardware designs that can be fabricated in schools feasible. Open-source hardware is the hardware equivalent of open-source software. The designs for open hardware are freely shared, enabling others to replicate and revise the objects.

Figure 1. Enrique Galindo (AMTE President), Kelly Dooley (ITEEA CEO), Andrea Borowczak (ASTE President), and David Slykhuis (NTLS Chair) announce the launch of the CAD Library

ITEEA has joined its peer teacher education associations such as the Association for Science Teacher Education (ASTE) and the Association of Mathematics Teacher Educators (AMTE) to facilitate use of open-source hardware in schools. In support of this effort, ITEEA, ASTE, and AMTE jointly announced the launch of the first peer-reviewed *Educational CAD Model Library* at the 24th National Technology Leadership Summit (NTLS), held at the headquarters of the National Education Association in Washington, D.C. on September 14, 2023. This work is supported by a National Science Foundation Pathways to Open-Source Ecosystems (POSE) Phase I grant (#2229627, Bull, G., P.I.; 2022-2024)

The *CAD Library* is the first peer-reviewed library of educational objects. Each association assumes responsibility for reviewing objects in its discipline. The review process involves two steps:

1. Each object must be replicated by someone other than the developer. Often this may be someone other than a teacher, such as a high school engineering student working with a teacher, a local Fab Lab collaborating with a school, or a collaborator working in a makerspace in a nearby university.

2. After the object has been successfully fabricated, with any revisions to the CAD files or assembly instructions required for successful replication, another teacher will pilot the instructional materials as part of the peer review process. This process is used to revise instructional supports (such as lesson plans, videos, etc.) as required to ensure that students are able to reach the overarching objectives connected to the relevant standards.

Once the review process consisting of (1) successful replication and (2) classroom use has been completed with revisions made as needed, the object is then published in the *CAD Library*.

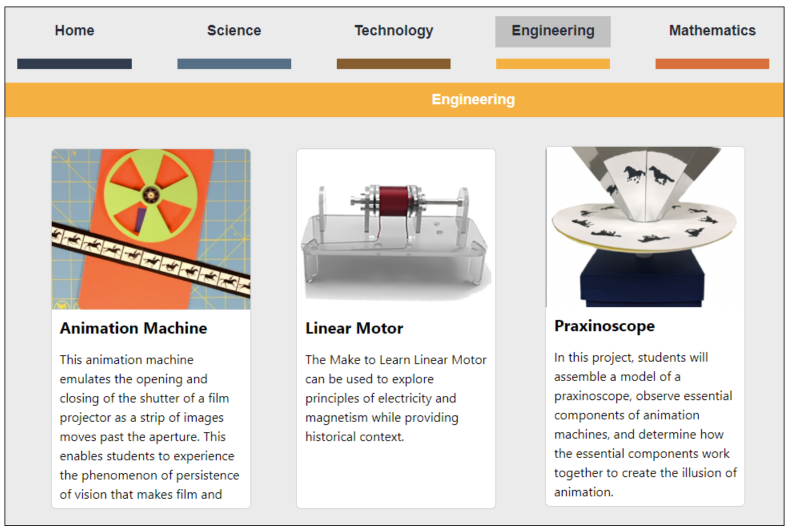

Figure 2. Educational CAD Model Library (www.CADlibrary.org)

There are many existing repositories of CAD models, but models in these repositories may not always print as intended.

Figure 3. CAD models may not always print as intended.

Replication by someone other than the developer can identify issues that would be frustrating for a teacher attempting to fabricate the object. The replication process includes assembly of the object in instances that involve multiple components.

Software is also tested for objects that incorporate microcontrollers. For example, we are currently adapting the OpenFlexure 3D-printed microscope (https://openflexure.org/) for use in schools. This microscope incorporates a microcontroller that is used to control the stepper motors that adjust the focus of the microscope.

Figure 4. An open-source 3D printed microscope.

The OpenFlexure microscope can capture high resolution medical-grade images and transfer them to the hard disk of a computer. A team of engineering students is in the process of replicating this microscope to ensure that a teacher in a school would be able to follow the fabrication directions and install the software required to operate the microscope.

After the object has been successfully replicated, a teacher who can pilot its use in their classroom is identified by the curator. When an object is published in the *CAD Library*, both instructional resources and a fabrication guide are provided. A faculty member in a teacher education program may also be identified to work with the teacher and support them. Successful use of the *CAD Library* will require establishment of an ecosystem around the library.

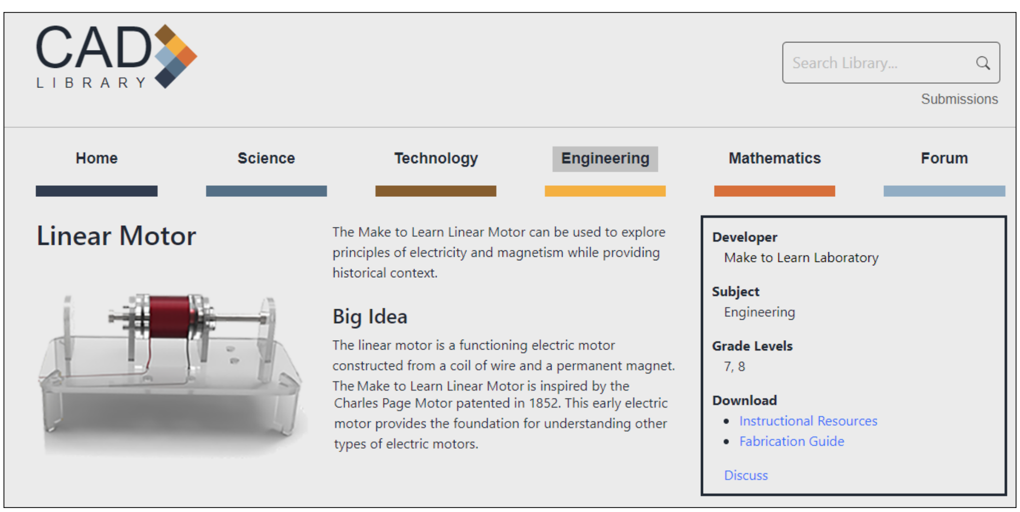

Figure 3. An object published in the CAD Library.

The instruction resources provided include a description of classroom use and related learning outcomes by at least one teacher. Each object also includes a link in a related forum.

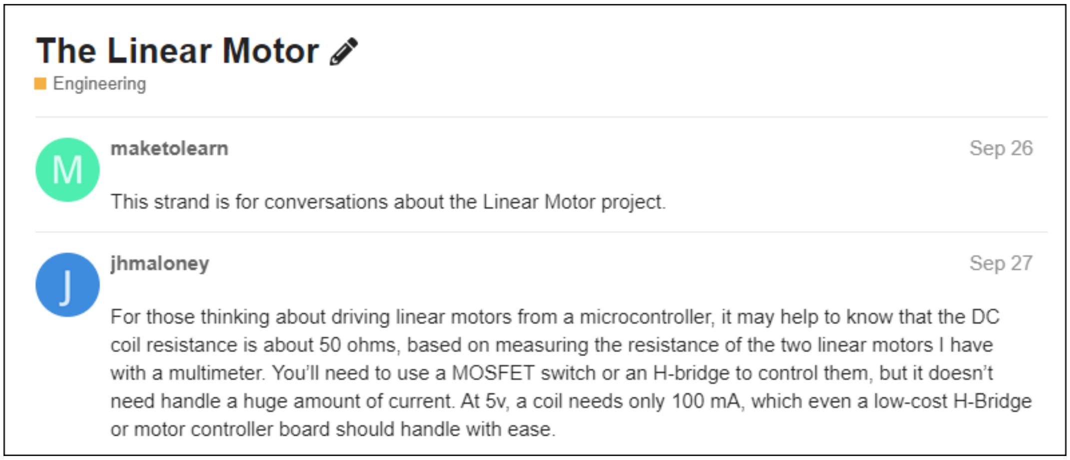

Figure 4. A forum strand linked to the Linear Motor object.

The link to the corresponding thread in the forum enables other teachers to provide additional information about their experiences and ways in which they have used the object in their classroom. It also provides a way for a teacher who has a question to correspond with the developer. Each time a post in a forum thread occurs, a notification is sent to the developer of the associated object. This provides a way for the developer to identify potential issues and correct them on an on-going basis.

Teachers and their students will benefit from access to carefully curated models and associated instructional materials. The resulting open-source ecosystem's impact is intended to increase effective use of K-12 makerspaces and lead to broader literacy in design and fabrication.

ITEEA is currently piloting the process of incorporating content from the *CAD Library* in the Engineering by Design curriculum. Invention Laboratories enable students to reconstruct transformational inventions in the Smithsonian's collections organized around the themes of *Sight, Sound, and Motion*. Students are challenged to develop their own unique inventions, using contemporary technologies such as electronic sensors, actuators, and microcontrollers to reinterpret nineteenth century inventions. Each module in the Engineering by Design curriculum consists of a series of learning cycles that culminate in a design challenge. For example, the Animation Lab, accessed through the Engineering section of the *CAD Library*, consists of computer simulations and physical animation machines that guide students through the foundational principles of animation.

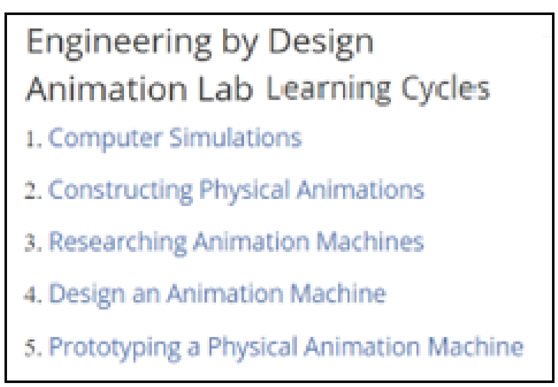

Figure 5. Animation Lab Learning Cycles

The *Animation Machine Laboratory* was piloted in middle school engineering classes in Suffolk, Virginia taught by Debra Shapiro. Students in her classes developed refinements and enhancements that were incorporated into the final version of the instructional materials. After these revisions were incorporated, the object was published in the *CAD Library*.

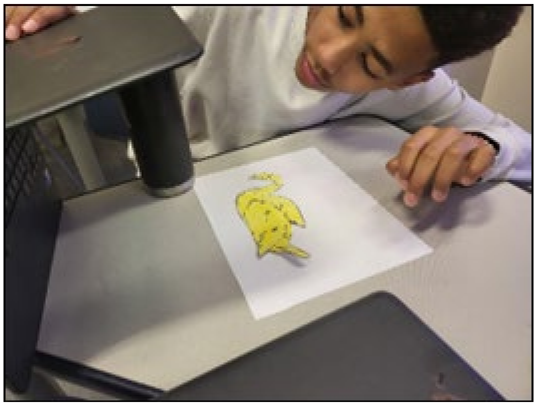

Figure 6. A middle school student developed an enhanced animation method for the module.

Each object published in the *CAD Library* is assigned a Document Object Identifier (DOI) that is unique to that object:

> Bull, G. & Gibson, R. (2023). *Animation Machine* [Educational Object]. *Educational CAD Model Library*. Published September 26, 2023. NTLS Coalition. doi:10.18130/V3/USY827

The predominant use of open hardware in science has been at the postsecondary level (Heradio et al., 2018). Extending the use of open hardware to K-12 schools can increase the range of educational objects available to teachers and generate new, engaging pathways into STEM fields. A peer-reviewed *CAD Library* can facilitate this process.

Authors and developers of open-source CAD models that may be suitable for inclusion in the *CAD Library* are encouraged to submit their designs to the library. Objects submitted for publication in the *CAD Library* must be open source with associated CAD files provided. A description of how the object was used with students should also be provided with evidence of learning outcomes.

Reference

Bull, G., Shapiro, D., Cohen, J., Borowczak, A., Galindo, E., Lassiter, S., & Slykhuis, D. (2023). Establishing an educational CAD model ecosystem. Contemporary Issues in Technology and Teacher Education, 23(3). https://citejournal.org/volume-23/issue-2-23/objects-to-think-with/establishing-an-educational-cad-model-ecosystem