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Establishing a Peer Review System for Open-Source Educational CAD Models

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Since the advent of affordable fabrication technologies such as 3D printers, many schools have established maker spaces. The educational effectiveness of fabrication tools in K-12 maker spaces is facilitated by access to useful Computer-Assisted Design (CAD) models and associated instructional supports. The launch of Educational Fabrication & Design provides a site for peer review and publication of CAD models designed for K-12 education. Upon acceptance, articles will be published with a link to a corresponding model in an educational CAD Model Repository.

During the past decade, many K-12 schools have established maker spaces with 3D printers, digital die cutters, and other fabrication tools (Bull et al., 2014; Chan & Blikstein, 2018; Martin, 2015; Song, 2018).

Digital design and fabrication, with its emphasis on modeling and visualization, provides opportunities for deeper student learning in content areas (Bevan, 2017; Bull et al., 2014; Eisenberg & Buechley, 2008). Effective student engagement with tools for design and fabrication of physical objects also has direct connections with workforce development, including manufacturing.

Manufacturing and its associated supply chain accounts for more than a third of all goods and services. The sector is currently the fourth largest employer in the United States, with over 12.5 million workers and an average salary of $57,000 **(**Bureau of Labor Statistics, 2018**)**. However, lack of qualified workers leaves more than 20% of new job openings unfilled **(**Boston Consulting Group, 2013; Rattner, 2017).

The educational effectiveness of fabrication tools in K-12 maker spaces is enhanced by access to useful Computer-Assisted Design (CAD) models and associated instructional supports for teachers. Carefully designed CAD models and associated instructional materials can enable teachers to make effective use of maker spaces in K-12 school (Bull et al., 2018; Corum & Garofalo, 2018; Standish, 2017).

There are multiple ways in which well-designed CAD models can enhance instruction in schools. The National Council of Teachers of Mathematics (NCTM, 2000) standards recommended using representation of concepts in a variety of ways that include physical models and apparatus. The National Science Teachers Association (National Research Council, 2012) standards recommended that students learn science using practical experiences to make lessons relevant. The CAD model for a kit such as an electric motor can enable students to construct a working mechanism and incorporate it in a mechanism of their own design. Instructionally relevant CAD models can also provide scaffolding for students' remixed designs.

Development of effective instructional CAD models, like creation of textbooks or other educational products, can require significant time and expertise. Many K-12 schools do not have the staff time or expertise to fully develop, pilot, and assess the efficacy of such materials. Other instructional materials such as textbooks are carefully reviewed prior to use in schools. Existing repositories of CAD models (at sites such as Thingiverse, Instructables, etc.) do not have objective external review systems that ensure that the models can be easily fabricated and that they can be used to address educational objectives effectively.

We are, therefore, pleased to announce that a new section of the *CITE Journal*, the Educational Fabrication & Design (ED&F) section, is being established, beginning with this issue. ED&F has been established to provide a mechanism for peer review of CAD models and publication of associated partitioner-based manuscripts describing instructional use of models submitted for review. Articles may address instructionally relevant elements such as (a) educational objectives, (b) prior instances of use of related models and historical connections, (c) design considerations and challenges, (d) fabrication and assembly instructions, (e) recommendations for revision and remixing, (f) explanation of ways in which students will demonstrate their understanding, and (g) description of pilot use in a K-12 classroom. Additional materials such as instructional videos can also be submitted. Each article should be accompanied by a corresponding open-source education CAD model, which will be made available in an Educational CAD Model Repository upon acceptance of the article for publication.

The *CITE Journal* is currently sponsored by five professional associations: Association of Mathematics Teacher Educators, Association for Science Teacher Education, National Council for the Social Studies College and University Faculty Assembly, English Language Arts Teacher Educators, and Society for Information Technology and Teacher Education. We are pleased to announce that the International Technology and Engineering Education Association (ITEEA) will join these associations as a sponsor of ED&F.

The following criteria for review have been developed to provide a sense of the elements that might be considered during review of open-source CAD models and associated articles submitted for review. These criteria will be refined by the editors and staff of the *CITE Journal* as experience is gained in review of open-source educational CAD models and associated manuscripts describing their use.

Fabrication Criteria

- Can the CAD Model be fabricated without issues? (2)
- If assembly is required, can the artifact be assembled without difficulty by students at the grade level for which it is intended?
- Are clear instructions provided?

Educational Criteria

- Are clear learning objectives provided?
- Do support materials describe how students will be able to show their understanding?
- Is there appropriate alignment with standards in the subject area (mathemathics, science, engineering, etc.) relevant to the intended use of the model? Are assessment items provided that can be used to evaluate learning outcomes?
- Are the instructional support materials provided for the teacher clear and usable?

Other Review Criteria (applied where appropriate)

- Are there provisions or options for students to remix a model or modify it?
- Is there a way to craft the model by hand (without technologies)?
- Does use of this model build resilience and encourage persistence among students?

- Is there a historical connection with the model?
- Are there cross-curricular connections?

Implementation of these strategies will be achieved through collaboration across education associations representing the *CITE Journal* sections. These associations have successfully collaborated for more than 20 years as members of the National Technology Leadership Summit (NTLS) coalition.

ITEEA plans to identify potential contributors through its network of teachers who use its acclaimed *Engineering by Design* curriculum. Currently, more than 5,000 K-12 technology and engineering teachers and more than 50,000 students use this curriculum, building design challenges related to the initiative directly into the curriculum so that substantial numbers of users engage with this effort.

The Fab Foundation, a nonprofit organization that emerged from MIT's Center for Bits and Atoms, will engage the users in its network of more than 2,000 digital fabrication facilities in this process and feature information about the initiative at its annual conference. EduFab, a related nonprofit educational organization that grew out of the Fab Foundation, will actively support the project with pilot implementations in its network of more than 300 school systems.

The *CITE Journal* was established in 2000 through an NTLS initiative. The current initiative is a natural extension of the prior work of the NTLS consortium, lying at the intersection of the review system developed for the online peer-reviewed journal and the prior work of consortium members in maker spaces.

The widespread availability of design and fabrication tools in K-12 makerspaces offers the potential to create new objects and remix existing designs. Remixing of carefully reviewed CAD models will develop visualization skills crucial to important areas of academic development. It will also help democratize this area, leading to broader participation in fields that make use of 3D design skills. This broader participation will also encourage students to enter science, technology, engineering, and mathematics fields that require use of these skills.

We invite comments and recommendations regarding extensions and refinement of the methods described here. Selected commentaries will be published with a link to this overview.

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