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Digital design and 3D printing in technology teacher education

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Abstract

This paper reports changes in the Technion technology/mechanics teacher education courses aimed to enhance students' knowledge and skills in teaching digital design and manufacturing. The two major changes are: (1) equipping the departmental laboratory of technology with modern computer aided design software tools (Creo, Mathcad) and 3D printer, and (2) upgrading the courses to meet the conceive-design-implement-operate (CDIO) approach. Our ongoing study indicates that the CDIO approach can be applied to balance learning pedagogical fundamentals, training technological skills, and teaching practice. The study provides indications that learning activities in the courses facilitate development of visual literacy skills.

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1. Introduction

The need for people capable to develop solutions for problems of the modern technologically oriented world is constantly increasing. It requires the incorporation of technology education in high school curricula as an inseparable element of present-day education, and as preparation for technological and scientific careers [1].

The educational system in Israel offers studies of different technological disciplines, four of which are defined science-rich subjects, including mechanical engineering [2]. Other three are electronics, computer science, and science and engineering. The technology/mechanics track at the Technion Department of Education in Technology and Science is the only authorized university undergraduate program in Israel for training teachers of the subject.

The Technion has recently come up with the Views program which calls upon undergraduates and graduates from all faculties to study for an additional B.Sc. in Science and Technology Education, and offers them full scholarships. Many Technion students and graduates have joined the program. As a result the Department and the technology/mechanics track have upgraded the infrastructure and curricula to meet the associated challenges in research and education.

In this effort we address the challenges noted in the OECD review of technology education in Israel [3]: To manage and deliver technology education programs with more extensive involvement of employers and social partners, enhance the role of workplace training, promote further studies and labor market insertion, and direct teachers to maintain up-to-date industry knowledge.

- The departmental Laboratory of Technology plays a key role in the technology education research and teacher training: The Laboratory serves a ground for experiential learning through design, building, and operating instructional engineering systems.
- The Laboratory is a venue for presentations, discussions, and meetings of the research group.
- Laboratory activities with engineering systems are included in all technology education courses. Some of these courses are open for students majoring in science and mathematics education and for students from other departments.

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- Some of the courses are based on project-based education, in which the assignments require the design and construction of an engineering system and development of an instructional unit, using the system as a teaching aid.

In this paper we report changes in the technology-mechanics teacher education courses aimed to enhance students' knowledge and skills in teaching digital design and manufacturing: Equipping the departmental laboratory of technology education with modern computer-aided design software tools (Creo, Mathcad) and 3D printer, and upgrading the course curricula based on the conceive-design-implement-operate (CDIO) approach. We also present indications of our ongoing study that the CDIO contributes to creating the balance of learning pedagogical fundamentals, training technological skills, and teaching practice. The study also indicates that learning activities in the courses facilitate development of visual literacy skills.

In the next sections of the paper we discuss the concept of visual literacy, present the laboratory of technology education, characterize the students, present our case studies and summarize their findings.

2. Visual literacy

Visual literacy is a key component of the technological literacy and its development is one of the main goals of technology education. The ITEEA standard for technological literacy emphasizes the importance of the ability to understand meaning through visual means, to create visual content and to deliver concepts in visual means [4]. Specifically in the technology education, the standard states that "students should be introduced to the importance of design, of visualizing objects, of translating ideas into sketches…"

Debes [5] defines visual literacy as "a group of vision-competencies a human being can develop by seeing and at the same time having and integrating other sensory experiences. The development of these competencies is fundamental to normal human learning." Debes discusses the perceptual aspect of visual literacy (VL). According to him, a visually literate person should be able to "discriminate and interpret visible actions, objects, symbols". He also points out the communicational aspect of VL: "the visually literate person is able to communicate with others", using visible items.

Subsequent researchers added the creative aspect of VL, considering the triad of perception, creation and communication. Brill, Kim and Branch [6] define VL as "the group of acquired competencies for interpreting and composing visible messages". The authors relate these competences to the creation of static and dynamic objects.

Ausburn and Ausburn [7] define VL as "a group of skills which enable an individual to understand and use visuals to intentionally communicating with others". Newman [8] defines VL as "a set of abilities that enables an individual to effectively find, interpret, evaluate, use, and create images and visual media". He defines the visually literate person as "both a critical consumer of visual media and a competent contributor to a body of shared knowledge and culture."

Felten [9] notes that VL is embedded in cultural context. For his definition VL is "the ability to understand, produce and use culturally significant images, objects, and visible actions."

Park et al. [10] note the fundamental role of visual reasoning in graphical design and define it as the composition of visual analysis, visual synthesis and modeling which account for seeing, imagining and drawing. Delahunty et al. [11] claim that the focus of graphical education moves from exercise in using drawing tools and software to development of graphical competencies for technology education and practice, "from being graphically literate to graphically capable".

As noted by Koch and Sanders [12], extended research found that spatial visualization ability is a predictor of success in a computer aided design course. However, it has not been verified that such course can foster the development of visualization skills. The study of Ha and Fang [13] showed that practice in manipulating physical objects and their computer graphic models can affect students' spatial skills.

Our study makes the next step in this direction. We hypothesize that learning practice in which students design computer graphics models and physically embody them through 3D printing can foster the development of visual literacy skills.

3. Technology education laboratory

The laboratory was set up in 2002 and was originally equipped with instructional engineering systems that were advanced for the time, such as robot manipulators, a milling machine, and construction kits. Today this equipment is outdated and needs to be updated. We make the update with support and collaboration of PTC, with careful consideration of specific needs as well as space and staff limitations of the teacher education lab. The software and hardware systems that have been adopted and serve to support the upgrade of our courses are: Creo computer aided design software and Mathcad mathematical calculation software (both provided by PTC), and a 3D printer.

Creo is a parametric CAD software which supports all design phases, from sketching and conceptualizing to detailed design and manufacturing [14]. The software is used by mechanical engineers worldwide. Creo provides a rich environment for learning by design. It provides a wide range of design tools for experiential learning and fosters creativity. The parametric paradigm, the principles of parametric modeling that are essential in the industry are of great potential in education; they foster systematic thinking and planning when solving engineering problems. To support use of Creo for education, the special student edition is provided for free-download.

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