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Teaching mechanical design practice in academia

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Abstract

In many research universities, mechanical engineering (ME) curriculum does not include courses that teach ME students essential professional knowledge needed to become a design engineer. Professional know-how is not regarded as an academic topic, although a mechanical designer who will get a job in industry will need to apply this knowledge from his first day. Topics such as selecting mechanical elements (motors, bearings, seals etc.) from a catalog or selecting a proper material or coating for a designed part, are rarely taught even in machine design courses.

We believe that mechanical engineering students should learn practical skills and get basic design experience. To close this gap, we introduced a new “Design and Manufacture Laboratory" for senior ME undergraduate students. The paper describes the laboratory course, students' activities and design projects. The design projects performed in the lab, follow the learned design methodology and include design reviews and appropriate documentation. The designed systems are produced, assembled and tested by each team.

In addition to the learned technical skills, "soft skills" are taught in the lab related to mechanical design that include: team work, self-management, time management, communication skills and presentation skills. These soft skills are an essential tool for every mechanical engineer who starts to work in the global and changing industrial world.

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1. Introduction

In order to prepare mechanical engineering students for industry needs, engineering schools developed courses which focus on engineering practice, such as the Capstone courses [1] and the Learning Factory [2].

Teaching in Mechanical Engineering (ME) departments is focused on engineering science curriculum that does not include practical professional elements. An important customer of engineering education and of ME graduates is industry [3]. Industry expects to obtain engineers with a basic practical experience. The junior engineer should be able to contribute after a short period of time. Industry looks for engineers with essential technical competence in engineering science. Industry can no longer afford an extended training program for the graduates [2]. The result of ignoring practical education, results in a failure to meet industry's needs.

To avoid investment in training and in order to increase productivity, industry looks for engineers with some work experience, at least two to three years in industry. Therefore, it is a challenge for a ME graduate to get his first job without having work experience. A way to avoid this first job entrance-threshold challenge, is to teach the students essential skills of engineering practices [4,5]. Students in research universities understand this limitation, and are interested in getting practical engineering experience [6]. Design projects encourage the students to be active and creative, cope with engineering challenges and get practical experience. In contrast, learning by lectures, which is mainly passive, teaches them to expect the lecturer to provide all required knowledge [7]. As a result of business world globalization, many industrial companies operate in a vibrant and multicultural environment. They realized that engineers that work in the company need, in addition to technical engineering skills, also

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communication skills, team work ability and the understanding of other society cultures. As a result of industry demand, engineering departments started to teach soft skills [8,9,10]. The term "soft skill" in education is quite flexible and has several interpretations. For example, project management course that may be regarded a soft skill course in Computers Engineering department, may be regarded a hard core course in Civil or Industrial Engineering departments [9]. In the laboratory course, in addition to teaching practical technical skills, we also teach "soft skills" such as: team work, communication skills, presentation skills and recently we introduced product design, which is regarded a soft skill in the ME department.

This paper describes the Design and Manufacture Laboratory (D&M Lab) course at the Technion, and includes a description of course format, its contents and students' projects. In order to get feedback from the laboratory course graduates, we conducted a survey and present the results. We asked them about the contribution of the lab experience on their practical design knowledge and whether it had an impact on their performance in their first engineering job

Course description and contents

The goal of the laboratory course is to teach basic mechanical design and practical design knowledge to a small class of 16 students that allows personal guidance and training. The course includes frontal lectures as well as a project done and presented by the students. The project is embedded in the course, it starts in its first week and ends with a built product at the end of the semester.

The objectives of the D&M lab include the following topics:

- Product design methodology – The process of design reviews
- Conceptual design – Development of several solutions to meet given requirements
- Mechanical elements selection from a catalog such as: bearings, fasteners and springs
- Design for manufacture and assembly (DFMA)
- Geometrical & dimensional tolerances
- Manufacturing process selection
- Materials selection – Teach how to select a proper material for a specific application
- Surface finish – Selecting suitable coating and painting
- Teamwork– How to communicate and work together in a project team

Table 1 presents the laboratory course plan, based on a weekly three hour meeting for 13 weeks. Two hours are frontal lectures teaching practical know-how. The third hour is devoted to project tracking and review. The purpose of the frontal lectures is to follow and support the engineering phase of the ongoing project.

Table 1. Laboratory course plan

Week	1ST HOUR (lecturer)	2ND HOUR(lecturer)	3RD HOUR (students)
	Lecture 1	Lecture2	Design Project Event
1	Fastener design	Fastener design	System requirements review (SRR)
2	Bearing design	Bearing design	Brainstorming & concepts
3	Joints	Exact constraint design	Concepts evaluation
4	Production process: Milling	Production process: Turning	Preliminary design
5	Practical mechanical drawings		Preliminary design review (PDR)
6	Practical mechanical drawings		Detailed design
7	Stepper motor & electrical system	Arduino controller	Critical design review (CDR)
8	Measuring instruments	Measuring instruments	Production status
9	Materials selecting	Materials selecting	Production status
10	Thermal treatment	Coating	Programing report
11	DFMA	DFMA	Inspection report
12	Coupling design	Production process: Bending	Integration report
13	Project demonstration & Final report		

2. Students' project

Each semester we propose a design project of a mechanical mechanism that comprises linear and rotating motions. The students have to use existing lab equipment that includes two stepper motors, ball bearings and linear bearings. For a typical project the hardware cost is about $200.

In the last three years the students designed and built the following projects: Two degrees of freedom gimbal shown in Fig 1 (a), "Sine-drawing mechanism" shown in Fig. 1 (b), "Pencil sharpener" shown in Fig 1(c), and "Stamping mechanism" shown in Fig.4.

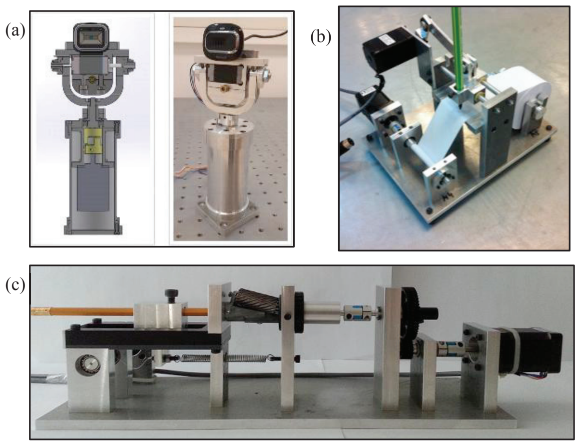

Fig 1. (a) Two DOF gimbal (b) Sine-drawing mechanism (c) Pencil sharpener

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