Full Stack Web Development: A Project-Based Learning Course Prepares Students for Industry 4.0

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Full Stack Web Development: A Project-Based Learning Course Prepares Students for Industry 4.0

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In 2016, we launched a graduate-undergraduate course titled *Full Stack Web Development* at in the Enterprise Systems Modeling Laboratory (ESML), Faculty of Industrial Engineering and Management, Technion, Israel Institute of Technology. The course aims to teach basics of Model-Based Systems Engineering (MBSE), system modeling, and developing complex Web applications to support requirements of the emerging Industry 4.0 wave. Initiated in Germany, Industry 4.0, the fourth industrial revolution, is closely related to the Internet of Things (IoT), Cyber Physical Systems (CPSs), information and communications technology (ICT), Enterprise Architecture (EA), and Enterprise Integration (EI) (Lu, Y. 2017). In Industry 4.0, enterprises and companies of all sizes are expected to work collaboratively using common standards to develop, produce and evolve ever more sophisticated products, services, and systems. These combine hardware and software that are increasingly intertwined and versatile, making the systems complex, in turn mandating that they be modeled and simulated in detail before they are built and fielded.

We review the various pedagogical aspects of the course and how the combination of novel pedagogical elements prepares students for the new era of Industry 4.0, the dawn of which we are now witnessing.

The course is taught in a Project-Based Learning (PBL) approach in a real-world-like agile software development environment, characteristic of a high-tech startup companies. PBL organizes learning around projects, fostering active, social, and self-learning techniques alongside design and creation of teamwork artifacts. Through active learning, teams work towards solving real-world problems (Dori & Silva, 2010). Skills emphasized by PBL include project management, systems thinking, effective communication, and collaborative work. These skills are sought after by prospective Industry 4.0 employers, so they are critical to students' success in the modern workforce and in studies for graduate degrees. Projects performed in PBL courses should be based on challenging research questions, so students can gain full experience of design, investigative activities, and decision making. They should give students the opportunity to work relatively autonomously over extended periods of time, culminating in realistic products or presentations (Jones, Rasmussen, & Moffitt, 1997; Thomas, 1999). Useful students' projects connect activities with underlying conceptual knowledge that the student is expected to gain (Barron, Schwartz, Vye, Moore, Petrosino, Zech, Bransford, & The Cognition and Technology Group at Vanderbilt, 1998, p. 274). While designing the *Full Stack Web Development* course, we wanted to integrate meaningful, complex, real-world problems into the PBL basis of the course. To this end, we selected as project topics real features from *OPCloud*, a Web-based framework we are developing, which implements Object-Process Methodology, OPM (Dori, 1995; 2016), ISO 19450:2015

International Standard. OPCloud is designed to model and simulate Industry 4.0 systems, so the projects assigned to the students relate to domains that include IoT, CPS, and ICT. For example, a team of students designed and implemented an interface between OPCloud and MATLAB to enhance OPM conceptual modeling with computational capabilities. Another team developed an option for collaborative modeling in OPCloud, a feature that one of the ESML industrial partners specifically asked to be developed.

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