IoT Proto Labs: Cross-border Multidisciplinary Learning Labs in Higher Education

Wilfried ADMIRAAL
Leiden University

Lysanne POST
Leiden University

Pengyue GUO
Leiden University

Nadira SAAB
Leiden University

Sari MAKINEN
Haaga-Helia University of Applied Sciences

Ohto RAINIO
Haaga-Helia University of Applied Sciences

Johanna VUORI
Haaga-Helia University of Applied Sciences

Jacky BOURGEOIS
Delft University of Technology

Gerd KORTUEM
Delft University of Technology

Gerard DANFORD
Haaga-Helia University of Applied Sciences

Abstract: Student labs are one promising way to cope with changing requirements from the labor market in the domain of Science, Technology, Engineering and Mathematics (STEM), but also to keep the field up to date, to start innovations and to advance the STEM domain as such. In these labs, students work together in small groups imitating professional practice of design and technology workers. More insights are needed how to design student labs. In order to effectively enhanced generic competences, such as collaboration, communication, problem solving, critical thinking, and creativity, student labs should be designed as authentic productive learning environments based on three design principles: 1) Realistic, complex task situations, 2) Multidisciplinarity, and 3) Social interaction. IoT Rapid Proto Labs are examples of such student labs, in which cross-border multidisciplinary teams of students, teachers (coaches), and practitioners jointly develop solutions to challenging IoT applications (Internet-connected objects), add value for enterprises, and strengthen the employability, creativity and career prospects of students.

Keywords: Student labs, Authentic learning, Higher education, Science, Technology, Engineering and Mathematics (STEM)

Introduction

Lack of skilled labor in the domain of Science, Technology, Engineering and Mathematics (STEM) is one of the main obstacles to EU economic growth in the coming years. In the period of 2015-2025, a growth in demand of STEM jobs of 8% is expected, compared to 3% for all occupations, leading to persistent shortages in terms of 700,000 job vacancies a year. University level education in the STEM domain is expected to provide future workers with a wide-range of technical skills and competences as well as an ability to understand and apply high level maths, science and other theory (Lucena, Downey, Jesiek, & Elber, 2008). Yet, at a time when there has been unprecedented attention around the need to increase training and recruitment, 'Computer Science' and 'Engineering and Technology' have the highest 'subject-specific' attrition rates in the UK university system (The Telegraph, 2017). Not only do the expected shortages create challenges for educational programs that prepare prospective professionals. Industries and businesses in the STEM domain form a dynamic, constantly changing field, which requires new skills from the professionals working in the field. These new skills are not only important to cope with these changing requirements, but also to keep the field up to date, to start innovations and to advance the domain as such.

These expected shortages and predicted changes means that prospective professionals in the STEM domain are required to develop a broad range of skills such as creativity, innovation skills, performance skills, critical thinking, problem-solving strategies, and self-regulation skills. As the range and complexity of these skills is so comprehensive that any one individual is unlikely to have them all, nor to have developed them all to the same high degree, prospective professionals should acquire communication, interaction and collaboration skills as well. All these skills are commonly referred to as 21Century Skills (21CS): cognitive, affective, motor and regulative skills that enable individuals and groups to face complex task situations effectively and efficiently. These 21CS are important to enable future workers to continuously adapt to and anticipate on what the profession, the labor market and society in general ask for.

Both these generic competences (i.e. 21 CS) and competences specific for the STEM domain (e.g., particular designing, programming and prototyping skills) require different educational setups compared to tradition teacher-centered ways of learning. One promising way and commonly used in design and technology studies is the use of student labs, which are small groups of student working together on solving authentic problems and producing solutions within a limited time period, imitating professional practice of design and technology workers. These student labs can provide an optimal learning environment to prepare students as future workers building on two main principles. First, these labs can be designed as authentic learning environments that simulate qualities of the –future- workplaces. Second, these labs can enhance particular student competences the labor market requires, in terms of both generic competences and competences specific for the STEM domain. Generally, three main types of student labs can be distinguished: 1) physical labs in which students learn and work together sharing the same location and time, 2) online labs in which students synchronously and a-synchronously learn and work together sharing the same virtual environment and 3) remote labs in which students control equipment in a lab from a distance. Often blends of the three main lab types are used. More insights are needed in what competences student labs in the STEM domain address and what the implications would be for the design of student labs.

In the current study, a newly developed design of learning labs (the IoT Rapid Proto labs) in higher education is discussed, which aims at developing and improving students' 21CS and preparing students as future workers.

Design of Student Learning Labs in Higher Education

Developments in theories of effective learning and teaching reflect shifts from behaviorism to cognitivism to situationism (Day & Goldstone, 2012; Putnam & Borko, 2000). Lave (1988) challenged traditional views of learning and teaching by stating that new knowledge is constructed in the course of understanding and participating in new situations, a process generally referred to as "situated learning", with an emphasis of the social and interactive nature of learning. Taking a situated approach on teaching and learning helps to advance to design robust interventions in higher education practice. The creation of knowledge and skills is a continuous but not always linear process. It involves actively researching and experiencing reality as well as experimenting, which means building up experience goes with making errors. Skill formation is a social activity determined by the context and the way in which groups of people share knowledge and experiences. Learners build up knowledge that is linked to concrete applications, contexts and cultures. It requires the construction of practices and apprenticeship (Lave & Wenger, 1991).

In student learning labs, these perspectives of situated learning are combined. In these learning environments, the boundaries between formal and informal learning are fuzzy to engage students in meaningful, collaborative and authentic learning situations, where learners meet each other and workers in the field. Student learning labs require authentic productive learning environments shaped by:

1) *Realistic, complex task situations*, which give scope for the participant's initiative and exploration via divergent assignments, global guidelines and global criteria. The complexity requires interaction with other disciplines and between learners. These learning situations are 'hybrid', in which school-based learning and workplace experiences are closely connected.

2) *Multidisciplinarity*, as the real-life problems and challenges to cope with are not compartmentalized into clear-cut disciplines (Heijnen, 2015). Most suitable for the present project seems what they call *pragmatic interdisciplinarity*: an outcome centered approach that involves envisioning an effective and workable final product and back-filling through strategic selection of disciplinary inputs from the STEAM domain.

3) *Social interaction*, as learners need to apply and build up multiple skills and expertise, reinforced by mutual interaction and cooperation. The most important forms of creativity are joint cooperative activities of complex networks of skilled individuals. Social interaction is a crucial element of authentic productive learning environments, as it enables participants to operate as a learning community in which various forms of expertise, experiences and skills are shared (Wenger, 1998; 2009).

Implementation of Student Learning Labs in Higher Education: IoT Rapid Proto Labs

IoT Rapid Proto labs are blended (virtual as well as real), user-driven, and authentic productive learning environments in which distributed multidisciplinary groups of five to then higher education students (from three European countries) collaborate on solving ill-structured problems. These students attend these blended multi-disciplinary learning and work environments as part of their bachelor or master program in the domains of Industrial design, Engineering and Technology. Throughout the discovery, design, develop and test process, student teams are continually supported by HEd teachers combining the roles of coach, guide and instructor. These labs are open environments, with flexible start and end dates, international virtual as well as local face-to-face interaction and collaboration, and dynamic boundaries between participants, and allowing both linear and nonlinear learning and work curves. The labs are also supported by a Project Arena (web-platform) which enables them to effectively collaborate on rapid-prototyping of IoT products/services. The Project Arena also stimulates the flow of knowledge and innovation between higher education, enterprises and other stakeholders. Each IoT Rapid Proto-Lab student-centered team will rapidly set-up, trial and test an innovative IoT solution for their SME/Start-up client. Technology regularly used in higher education support the learning and work processes of the lab participants, building on open-source learning platforms such as Moodle and open source collaborative writing tools, screen sharing, video conferencing, mind mapping and chat, as well as hard ware such as Whiteboards, tablets, smart phones and 3D printers.

IoT Rapid Proto Labs work on research challenges as well as assignment from SMEs or a network of SMEs. The research challenges deal with part-products, processes and tools that support and facilitate solutions for problems brought in by SMEs (e.g., embedded electronics, software efficiency, robotics control and vision). Through a newly developed portal, SMEs or networks of SMEs can provide two types of assignments:

1. Problem-oriented assignment: the SME presents problems they do not know how to solve and lab participants try to find a solution, and

2. Product-oriented assignment: the SME presents an idea or a product and the lab participants to address its development with an inter-disciplinary approach.

The labs can work on, for example, integration or adaptation of existing technologies, market and product analysis, industrial design, product design, and use experience. This combination of working on research challenges and authentic SME problems and issues create an innovative research-industry collaboration, with co-creation and interactions in communities of students and users. IoT Rapid Proto Labs, remotely networked, support participants with different skills and experiences to share competences and collaborate to find out IoT solutions (see Figure 1). In Table 1, three examples of authentic task for IoT Rapid Proto Labs are summarized.

SME

User-Driven Projects

DISCIPLINES

Connected
student labs

INTERNET OF THINGS

Industrial design, Engineering,

Finland, Italy,
Netherlands

Smart prototypes, products and

PEDAGOGY

Lab

Multidisciplinary

Authentic Learning
Environment

TEACHER DEVELOPMENT

STUDENT DEEPER LEARNING

Coaching Skills

Arena

Tools

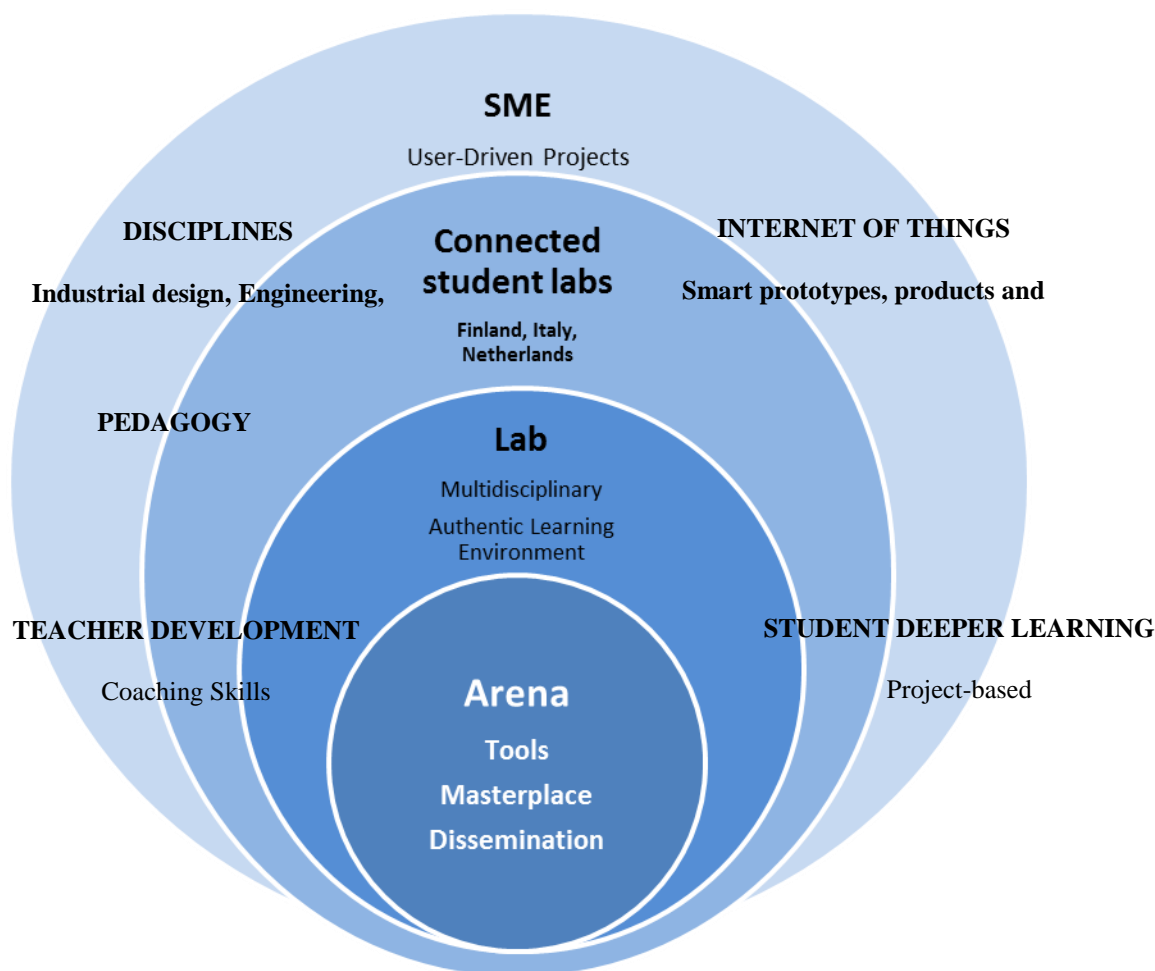Masterplace

Dissemination

Project-based

Figure 1. Design of IoT rapid proto labs

Concluding Remarks

IoT Rapid Proto Labs are examples of student-learning labs in higher education in the STEM domain developing and improving cross-border, multidisciplinary collaboration, communication and problem solving. In addition to hardware and software tools for design and testing prototypes, various tools for student collaboration and collaborative learning are used supporting sharing files, screens and posts, editing documents, design, presentations and drawings and communication through email, video- and audio conferencing, instant messaging, online discussion, and live chatting (c.f., Al-Sammarraie & Saeed, 2018). These forms of collaborative learning in authentic productive learning environments might offer as effective ways to prepare students as future workers in the STEM domain.

Table 1. Three examples of authentic tasks of the IoT rapid proto labs

1. Smart ski boots	2. Wearable devices for affective computing	3. Smart devices for wheelchair user well-being
A local company manufactures sport equipment and is particularly keen to innovate their line of ski boots. They are interested to innovate their product and add functionalities to attract customers. The company would like to develop a "smart boot" by adding sensing capabilities to it and provide the user with data analyzing of the skiing performance. In this case the project will cope with the search for existing solutions for sport motion analysis (e.g. inertial wearable sensors) and develop a solution which can be integrated within a ski boot and plan how it will be used. The project represents a real-life product development scenario and faces several multidisciplinary problems: - Product design: add-on for boot or integrate it; - Service design: just give the user sensors and data or provide an app and services to track/compare/share data; - Algorithms: which high-level information the system provide to the user; - Design: design of the product, ergonomic, usability, and - Business: existing solutions, market analysis, marketing approach.	Lab participants receive the assignment to study the development of a wearable device for implicit (no user interaction required) recognition of the user's activities and emotional state (affective computing). The device is worn by the user and it is accompanied by a smartphone app. There is a social component with friends connecting through social networks to compare activities and to exchange information/suggestions. The activities of the project include: - Study of requirements and technical specifications; - Development of hardware and software; - Data collection and development of algorithms for motion analysis; - Integration with smartphone app and backend for data storage and processing; - Integration with existing social solutions and development of a platform to share results/progress, and - Design of the product, design of its user experience, user acceptance evaluation.	Health and mobility are important pillars of well-being. Lab participants receive the assignment to design smart products and services for an internet-connected wheelchair using a domain-specific design platform. This platform is composed of standard hardware components only (Arduino, Raspberry Pi, Wi-Fi, Bluetooth, sensor) and communicates with the Data-Centric Design Hub via standards such as HTTP and MQTT. It comes with a step-by-step, get started guideline for designers without previous experience on IoT and a set of examples for sensing, processing and actuating. The platform supports students to inform, rapid-prototype and evaluate their design concepts in three phases: - Discovering: students receive a bare wheelchair to be transformed into a design platform learning about sensors, actuators and communication; - Experiencing: students use the wheelchair to collect and analyze data and try pre-set algorithms to control actuators, and - Designing: students design and prototype a product or service by extending or leveraging the design platform. For more information, see Bourgeois, Liu, Kortuem, and Lomas (2018).

Acknowledgements

References

Bourgeois, J., Liu, S., Kortuem, G., & Lomas, D. (2018). *Towards a domain-specific design platform for wheelchair user well-being*. Ubi/Comp/ISWC '18 Adjunct, October 8-12, 2018, Singapore. Singapore: ACM.

Day, S. B., & Goldstone, R. L. (2012) The import of knowledge export: Connecting findings and theories of transfer of learning, *Educational Psychologist, 47*(3), 153-176.

Heijnen, E. (2015). *Remixing the art curriculum: How contemporary visual practices inspire authentic art education*. Unpublisjed doctoral dissertation, Radboud Universiteit, Nijmegen.

Lave, J. (1988). *Cognition in practice: mind, mathematics, and culture in everyday life*: New York, NY: Cambridge University Press.

Lave, J., & Wenger, E. (1991). *S`ıtuated learning: Legitimate peripheral participation*. Cambridge, MA: Cambridge University Press.

Lucena, J., Downey, G., Jesiek, B., & Elber, S. (2008). Competencies beyond countries: The reorganization of engineering education in the United States, Europe and Latin America. *Journal of Engineering Education, 97*(4), pp 433-447.

Putnam, R. T., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning?. *Educational Researcher*, 4-15.

The Telegraph. (2017). *University subjects with the highest drop out rate.* Published on 19/1/17. . Available from: http://www.telegraph.co.uk/education/educationpicturegalleries/11002595/University-degree-subjects-with-the-highest-dropout-rates.html?frame=2344255 accessed 19/1/17

Wenger, E. (1998). *Communities of practice: Learning, meaning, and Identity*. Cambridge, UK: Cambridge University Press.

Wenger, E. (2009). A social theory of learning. In K. Illeris (Ed.), *Contemporary theories of learning: Learning theorists in their own words* (pp. 209-218). Abingdon: Routledge.

Author Information

Wilfried Admiraal
Leiden University, Graduate School of Teaching,
Netherlands
Contact e mail:w.f.admiraal@iclon.leidenuniv.nl

Lysanne Post
Leiden University, Willem Einthoven
Kolffpad 1, 2333 BN Leiden
Netherlands

Pengyue Guo
Leiden University, Willem Einthoven
Kolffpad 1, 2333 BN Leiden
Netherlands

Nadira Saab
Leiden University, Willem Einthoven
Kolffpad 1, 2333 BN Leiden
Netherlands

Ohto Rainio
Haaga-Helia University of Applied Sciences
Pajuniityntie 11, 00320 Helsinki
Finland

Sari Makinen
Haaga-Helia University of Applied Sciences
Pajuniityntie 11, 00320 Helsinki
Finland

Jacky Bourgeois
Delft University of Technology,
Mekelweg 5, 2628 CD Delft
Netherlands

Johanna Vuori
Haaga-Helia University of Applied Sciences
Pajuniityntie 11, 00320 Helsinki
Finland

Gerard Danford
Haaga-Helia University of Applied Sciences
Pajuniityntie 11, 00320 Helsinki
Finland

Gerd Kortuem
Delft University of Technology,
Mekelweg 5, 2628 CD Delft
Netherlands