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Final curriculum report

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Authors: [Lysanne Post, Pengyue Guo, Nadira Saab & Wilfried Admiraal]
Reviewer(s): [Gerd Kortuem & Antonius Camara]
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D4.5 Final Curriculum Report

Summary

In the IoT Rapid Proto Labs, students learning labs have been implemented as part of course curricula on IoT. In these learning labs, students work on authentic tasks, either problem-oriented or product-oriented, to enhance both their domains-specific skills and knowledge as well as generic competences of collaboration, communication, problem solving, critical thinking and creativity. Project they have worked on include, for example, an Internet-connected wheelchair, smart waste bins, intelligent IoT device for pest detection in precision agriculture and cafeteria queue monitoring. Designing an interdisciplinary IoT curriculum poses different challenges than designing a regular (IoT) curriculum. It involves collaboration with other – possibly international – higher educational institutions and business to bring different disciplines and perspectives together within one course. In the IoT Rapid-Proto Labs project, teachers encountered such challenges. Therefore, a set of guidelines has been created based on more general instructional design model of group learning activities (GLAID; De Hei, Strijbos, Sjoer, & Admiraal, 2016). These guidelines include elements of learning goals, tasks and activities, assessment and support. Some curriculum examples are provided.

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1 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. In the IoT Rapid Proto Labs project, student labs have been designed, implemented, evaluated and redesigned in order to get more insight into how to design student learning labs in higher education. Before going into what we learned about how to design these curricula with student learning labs, we first review competences students can acquire in online student learning labs in higher education.

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2 Competences addressed in online student learning labs

In most studies, students evaluate students' learning outcomes of online learning labs in terms students' domain-specific competences and not in terms of generic student competence. However, many authors do point out that generic competences are relevant for learning in student labs as can be seen in Table 1. By far, the most addressed competences are *collaboration* and *communication*. Other competences that are addressed are *problem-solving*, *planning*, *reflection*, *critical thinking*, *creativity*, *presenting*, and *autonomy*. In most studies that address collaboration or communication, the student labs involve group work. The studies that address collaboration describe it as a competence that is highly relevant for both hands-on labs and online or remote labs. Collaboration among students is sometimes realized by working in the lab from the same computer. In other studies, an online lab environment allows multiple students to be logged in to the same experiment at the same time. Communication is often described as critical for collaboration and is usually realized by a chat option in the online lab environment. The other competences addressed in the studies on student learning labs are not related to group work of the students.

Table 2.1. Generic competences in online student learning labs

Authors	Collaboration	Communication	Problem solving	Planning	Reflection	Critical thinking	Creativity	Presenting	Autonomy
Azad (2007)	X			X					X
Broisin et al. (2017)	X	X							
Corter et al. (2007)	X	X							
De Jong et al. (2014)	X	X		X	X			X	
Duro et al. (2008)			X						
Geaney & O'Mahony (2016			X						
Jara et al. (2011)	X								
Lang et al. (2007)					X				
Lehlou et al. (2009)	X								
Luthon & Larroque (2015)	X	X							
Malaric et al. (2008)	X								
Nedic (2013)	X	X							
Nedic & Machotka (2007)	X	X							
Nickerson et al. (2007)	X	X							
Soares et al. (2014)	X	X							
Tho & Yeung (2016)	X	X	X	X		X	X		
Tirado-Morueta et al. (2018)		X							
Total	13	10	3	3	2	1	1	1	1

Collaboration is understood to be very important for learning in online student labs and effective communication is critical for successful collaboration. Not surprisingly, studies emphasizing these two competences often report labs in which students work in groups. Collaboration and communication are two very important competences to consider in designing authentic learning environments in STEM higher education.

Other, more general literature about competences might help us to determine which competences are most relevant for learning in student learning labs. The report "Digital skills for life and work" of UNESCO and Intel Government and Education (2017) provides an overview of many frameworks of digital competences and summarizes them. The report describes, among others, generic digital skills. In line with our findings it presents digital communication and collaboration as important competences. The report also describes higher-level cognitive skills, including not only domain-specific (programming) skills, but also 21CS. Collaboration, communication, problem solving, critical thinking, and creativity are the 21CS that are described in the overview by UNESCO and Intel Government and Education (2017; https://en.unesco.org/news/new-broadband-commission-report-highlights-emerging-global-skills-gap), which are also addressed in the reviewed studies (see Table 1).

In sum, five generic competences are addressed in most online student labs and refer to generic 21CS: Collaboration, communication, problem solving, critical thinking, and creativity. Both these generic competences and competences specific for the STEM domain (e.g., particular designing, programming and prototyping skills) can be developed and improved by 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. It is a challenge to develop design principles for students' learning labs, preferably supported by meaningful technology, in such as a way that they promote the five core competences of collaboration, communication, problem solving, critical thinking and creativity.

3 Implications for the 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

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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 (Sawyer, 2008) 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).

In the IoT Rapid Proto labs projects, students attend these authentic productive learning 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. Students 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). Two types of assignments are implemented to enhance student learning:

1. Problem-oriented assignment: the SME (or a proxy) presents problems they do not know how to solve and students try to find a solution, and
2. Product-oriented assignment: the SME (or a proxy) presents an idea or a product and the students work on 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. Assignments students worked on in the IoT Rapid Proto Labs projects included (see also https://www.rapidprotolabs.eu/projects/):

- Autonomous last-mile mail delivery
- Smart waste bin
- Internet-connected wheelchair
- Cafetaria queue monitoring
- Reducing noise at Intensive Care Units
- Self-organizing display
- Virtual Nature
- Swarm of drones monitor air quality
- Intelligent IoT device for pest detection in precision agriculture
- IoT-powered flower pot
- Gamified dental brace
- Dementia patient monitoring
- Preventing COVID-19 contagion in industrial environments through anonymous contact tracing

4 How to design an interdisciplinary IoT curriculum?

The student learning labs mentioned above are part of courses on IoT implemented and evaluated in the Rapid Proto Labs project. For IoT courses in which students create IoT prototypes, it is recommendable to create an authentic learning environment. This way, students learn to act as semi-professionals in the real world. Interdisciplinarity is an important aspect of authentic learning, because besides creating a real prototype by programming, it is also likely to involve design and business aspects.

Designing an interdisciplinary IoT curriculum poses different challenges than designing a regular (IoT) curriculum. It involves collaboration with other – possibly international – higher educational institutions and business to bring different disciplines and perspectives together within one course. In the IoT Rapid-Proto Labs project, teachers encountered such challenges. Therefore, we created a set of guidelines based on more general instructional design model of group learning activities (GLAID; De Hei.Strijbos, Sjoer, & Admiraal, 2016). This model is based on the ADDIE - a general model commonly used for instructional design- and include a series of design steps (see Table 2). These guidelines are presented below and provide a step-by-step plan for any teacher who wants to design an interdisciplinary IoT curriculum.

Table 4.1. Design components and possible design decisions of the GLAID framework (De Hei et al., 2016).

Step 1: Analyze	Determine Student characteristics Determine Teachers' characteristics Determine Curriculum characteristics Determine Collaborative premise Determine Global goals		
Step 2: Design	**Interaction** *Declarative and procedural (domain) knowledge* *Social and metacognitive activities*	**Learning objectives and outcomes** *Goal setting* *Content of learning*	**Assessment** *Means* *Criteria*
Step 3: Develop			
Step 3a: *Develop Instructional Strategies*	**Task characteristics** *Kind of activities* *Phases/sequencing* *Duration and frequency of group meetings* *Performance control*	**Structuring** *A priori* *During GLA* *Reflection and evaluation*	**Guidance** *Executor* *Teachers' role* *Communication mode* *Duration and timing*
Step 3b *Develop Logistics*	**Group constellation** *Number of groups and group size* *Heterogeneous or homogeneous* *Group duration*	**Facilities** *Learning resources* *Technology resources* *Space and time*	
Step 4: Implement	Monitoring the instructional process		
Step 5: Evaluate	Evaluating the processes and outcomes		

4.1 Course title

Naturally, the course needs a title. Be clear and concise.

4.2 General introduction to the course

Provide a general idea of what the course is about.
Things to consider:

- Introduce the relevant concepts (e.g., sensors/actuators, embedded programming, micro controllers, power consumption, MQTT protocol, edge devices, data hubs).
- Use this section to introduce the interdisciplinary, collaborative, side of the course and which parties are involved.

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4.3 Level and (time) investment

This section should provide a clear overview of the level of the course and the workload in terms of time and course credits.

IoT can be taught on very different levels and from very different aspects, at least the following:

1. You can teach the very basic sensor-level technologies for software engineering bachelor students after they have taken their first basic programming courses. This would be for example a course about programming with Arduino + sensors.
2. You can teach a basic IoT-technical architecture course to students halfway their software engineering bachelor studies. This could address issues like sending and receiving data with the microcontroller + sensors to/from a data hub, MQTT protocol, edge computing.
3. You can teach an advanced IoT Enterprise architecture course to advanced bachelor or master level students. This course would address issues like how to design a system with potentially tens of thousands of sensors and millions of data transactions per second.
4. You could teach advanced supporting technologies related to IoT, like advanced embedded programming, data analysis, machine learning, or IoT platforms to advanced bachelor or master level students.
5. You can give a general introduction to the business cases and problems IoT can help solve on any level and to students with virtually any background.

Regarding time investment for students, all of these example courses could be around 5 ECTS. The time investment for running any course depends partly on the number of students the course is designed for. If the course can be run by one teacher to some tens of students, then example course 1 can be taught as a project-based course where the teacher guides the students to third party online material and helps them solve their technical problems while building their own little IoT experiment. If example course 1 would need to scale to hundreds of students, then you would need more readymade material that the students can follow in a more structured manner on their own. Example course 5 could be a simple lecture-based course with a traditional exam. Example courses 2-4 would consist of lecture and exercise elements.

Things to consider:

- Level (e.g., Bachelor, Master, first-year).
- Course credits (in ECTS).
- Duration of the course (in weeks).
- Workload per week:
    - Number of contact moments, including duration.
    - Type of contact (e.g., lecture, lab-work).
    - Individual versus groupwork.
- Other information that is relevant in relation to (time) investment.

4.4 Course requirements

In order to optimize chances for successful completion of the course, it is important to consider course requirements for students. This also helps the teacher (i.e., the curriculum designer) in formulating the exact learning goals for the course. This will further increase the chance of students acquire the desired knowledge, skills and competences in the course.

Things to consider:

- Level of the course.
- In case the course is a joint effort of multiple disciplines (faculties, universities), consider what the course requirements are relating to the different disciplines.

- What type of learning is expected? If you want students to get a general "business level" idea of what can be done with IoT, less prior knowledge and skills are required than when you want them to actually learn the technologies and techniques for building particular IoT-systems.

4.5 Learning goals

Explicitly list the learning goals. Include subgoals where necessary, in order to be very clear about what students are expected to learn in this course. Clear goals and subgoals also help decisions regarding assessment to measure whether the goals are achieved by the end of the course.

Things to consider:

- Consider both course-specific knowledge and skills, and more generic competences.
- Examples of course-specific knowledge and skills:
    - Theoretical knowledge about IoT, including apprehension of the complexity and potential of IoT.
    - Knowledge of different types of sensors and actuators.
    - Basic microcontroller programming.
    - Reading data from sensors.
    - Sending data to a data hub from a micro controller.
    - Analyzing collected data and doing making reasonable business decisions about it.
    - Testing the prototype.
    - Evaluate theoretical and practical implications of IoT systems.
- Examples of generic competences:
    - Collaboration, communication, problem-solving, critical thinking, and creativity.
- Keep in mind the learning environment of the course; it should facilitate achievement of the learning goals.

4.6 Assessment

Describe how students' achievement of the learning goals will be assessed. For each assessment, explicitly refer to the relevant learning goals.

Things to consider:

- Type of assessment, for example individual exercises/assignments, a project result (product), a presentation, a diary, an exam.
- Consider the weight of each assessment on the students' total assessment of the course.
- In case of group work, specify whether the assessment will be at the level of the individual student or of the group as a whole.

4.7 Products of Assessment

List all products of assessment. This way, it is very clear for students they are expected to deliver at the end of the course.

Things to consider:

- Specify what the products (should) consist of.
- Clearly indicate the relation of each product to the assessments described in the previous section.

4.8 Tasks and activities

Describe all tasks and activities of the students.

Things to consider:

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- *Contact moments (e.g., lectures, workshops, lab work).*
- *Individual work (e.g., exercises, workshop preparation).*
- *Group work (e.g., group size, responsibilities – such as keep in contact with SME).*
- *Assessment activities.*

4.9 Teacher support and communication

Offering the right type of teacher support at the right moment in the course is crucial. What exactly is the right support, depends on many things, such as the level of the students, the type of (course) activity, how far along the course is, and the course objectives. It is recommendable that the teacher is available through an online medium.

Things to consider:

- The role of the teacher(s) (e.g., lecturer, coach, facilitator, expert).
- Contact moments (planned and/or upon request).
- Communication tool between teacher and student (e.g., e-mail, Brightspace, Slack).
- Feedback moments (planned and/or upon request)
- Type of feedback.

4.10 Learning management system and other tools.

Specify the LMS and other tools that will be used and describe the purpose. This way students easily know when to use which tool.

Things to consider:

- Which LMS? (e.g., Moodle)
- What will the LMS, and other tools be used for? For example: "In the LMS, the curriculum setup and tasks are included. Students put their products in the LMS for peer feedback and include their own peer feedback as well. In addition, the labs use their own tools that are relevant for their students and tasks. A separate tool – Arena – will be used for international and interdisciplinary collaboration".
- Who will use the LMS? If it's not only for the students, but also for external parties, for example to provide feedback, a platform like GitHub might be more suitable than a regular LMS for collecting and sharing material.
- Which tool will be used for communication?

4.11 Interdisciplinary collaboration

Given that IoT is such a wide topic, involving multiple disciplines, it makes sense to design an IoT curriculum together with several faculties or universities. One of them could, for example, have more knowledge on embedded programming and could teach those aspects on IoT. Then another faculty/university could teach about IoT platforms and enterprise IoT architectures. A third faculty/university could teach about the business cases around IoT. This way, students of three disciplines can follow the course and collaborate.

Alternatively, one could develop an IoT course within one faculty of a university and realize interdisciplinary collaboration in another way. For example, professors from another faculty or university could share their expertise and give feedback on products of students.

Things to consider:

- Which disciplines are involved?
- Which parties are involved?
- What kind of collaboration will take place?
- Do all parties have a common understanding of what the shared goals are and why each of them is part of this collaboration?
- Is every partner aware of their responsibilities relating to the course?

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- In case the course is a joint effort of multiple disciplines (faculties, universities), be aware of the challenges in aligning concrete things such as learning goals, starting levels, and schedules.
- Specify the tools and or platforms that will be used for interdisciplinary communication and collaboration.

4.12 International collaboration

The different disciplines involved in the course are not necessarily all from the same country. Given that practically everything can be done online and remote, it might be interesting to involve external parties from abroad to collaborate with. This way, you do not have to limit your resources to those available in your own country. International collaboration can also take place by involving a foreign company as a client.
Things to consider:

- Is it necessary that international partners are involved? International collaboration could be very valuable, but it can also make things complicated. Challenges could arise with respect to differences in cultures, languages, time zones, and to remote communication.
- Specify which (international) parties are involved.
- Specify what kind of collaboration will take place.
- Specify the tools and or platforms that will be used for international communication and collaboration. For example: "The Arena is an online environment, which is connected to the LMS. The Arena is used for the student assignments coming from SMEs, for testing prototypes with clients, for including the final products to be used by SMEs, and for the assessment and evaluation by the SME of the prototypes and end-products".

4.13 Schedule

Provide a structured overview with a timeline of the course, including contact moments with peers, teachers, SME's and other (international) parties, and assessments.
Things to consider:

- Elements of the schedule: contact moments, activities (lecture, lab work), duration of activities, assessment moments, time for individual work.
- In case the course is a joint effort of multiple disciplines (faculties, universities), be aware of the challenges in scheduling the course for all different students.

5 Curriculum examples from IoT Rapid Proto Labs

5.1 Developing connected products and services for the Internet of Things

While the population of wheelchair users is growing worldwide, it becomes urgent to design supportive technologies for wheelchair users. We aim to develop products for improvement of wheelchair users' well-being. This design is a data product that collects data from sensors, processes this data and actuate user interactions embedded on the wheelchair. A prototype demonstrates its technical feasibility and minimal user testing highlight its usability. While collecting data to learn from the usage of our products, personal data collection and processing must be handled with responsibility.

The course was designed around an open-source, domain-specific design platform: the internet-connected wheelchair. The design platform was composed of standard hardware components only (Arduino, Raspberry Pi, Wi-Fi, Bluetooth, sensors, actuators) and communicated with the Data-Centric Design Hub via standards such as HTTP and MQTT. It

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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 course was composed of three phases:

1. Discovering: Students received a bare wheelchair to be transformed into a design platform following a step-by-step guideline. They learned about sensors, actuators and communication elements.
2. Experiencing: Students used the wheelchair to collect and analyze data, and tried pre-set algorithms to control actuators.
3. Designing: Students designed and prototyped a product or service by extending or leveraging the design platform.

Level and investment

This was a first-year master level course. From February 25th 2019 to April 15th 2019 (8 week period) students worked one day every week (Monday). The course is **3 ECTS** (56 hours of work: 7x4 hours lecture; 7x4 hours self-study/assignments).

Learning goals

The learning goals focused on the development of development and data skills and the integration of data into the design process.

After completing the course, the students should be able to lead and conduct the development process of data-driven IoT-enabled services or products, more specifically:

a. Acquire the necessary knowledge and thinking of collaborating with developers and engineers throughout the design process.
b. Integrate data science and software engineering methods in the design process to develop innovative IoT products and services.
c. Identify and select appropriate development tools and use them effectively throughout the development process.
d. Use data science methods to generate insights and knowledge from IoT data and make it intelligible for stakeholders
e. Balance the interests of users, business and societal challenges regarding to ethical data issues such as data privacy, data confidentiality, data quality, data ownership, etc.

Assessment

Student performance was assessed with six group assignments (50% of final grade) and an individual exam (50% of final grade). Each assignment was due before the next session start on Mondays at 8:45.

Products of assessment

The products of assessments within the assignments included a poster, a video, and a working prototype.

1. **Poster** (involved assessment of **all** learning goals)
   - Brief design concept
   - Technical architecture with sensors, actuators, network technologies
   - Algorithms
   - Main data insights (data visualisation)
   - Data Responsibility

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2. **Video** (involved assessment of learning goals **b**, **c** , and **d**)
    - Working prototype in action
    - Glimpse of user tests
3. **Working prototype**
    - Implemented wheelchair with sensing, processing and actuation capabilities (involves assessment of learning goals **b**, **c** , and **d**)

Tasks and activities

Throughout the course, students prototyped, evaluated and iterated on the design of products in the context of wheelchair users.

Interactive lectures and workshops were delivered by the instructors every Monday morning (8:45-12:30; see Table 2.1). All students were required to attend these sessions.

Table 5.1. Lecture/workshop schedule

Week	Date	Theme
3.3	25 February, 2019, 8:45 – 12:30	Introduction – wheelchair design platform
3.4	4 March, 2019, 8:45 – 12:30	Sensors and data
3.5	11 March, 2019, 8:45 – 12:30	Machine Learning
3.6	18 March, 2019, 8:45 – 12:30	Actuators and closing the loop
3.7	25 March, 2019, 8:45 – 12:30	Product analytics
3.8	1 April, 2019, 8:45 – 12:30	Responsible Design
3.9	8 April, 2019, 8:45 – 12:30	Poster & Video Exhibition
3.10	15 April, 2019, 8:45 – 12:30	Exam

Students could work on assignments on Monday afternoons (see Assignment schedule in Table 5.2). Every Monday afternoon was reserved for teamwork. Students were not obligated to work on this course in these hours, but as this course required a lot of teamwork, this was facilitated by making room for it in your weekly schedule. Course instructors were available (most of the time) for help and discussions.

Table 5.2 Assignment schedule

Week	Due Date	Assignment	Deliverable
3.3	25 February, 2019, 8:45	Assignment 0: Downloads and setting up	Optional, to speed up the starting process
3.4	4 March, 2019, 8:45	Assignment 1: Sensor exploration	Selection and understanding of sensors
3.5	11 March, 2019, 8:45	Assignment 2: Initial data collection	Data visualisation
3.6	18 March, 2019, 8:45	Assignment 3: Actuator exploration	3-minute pitch
3.7	25 March, 2019, 8:45	Assignment 4: User tests	User test video
3.8	1 April, 2019, 8:45	Assignment 5: Metrics to evaluate the prototype	
3.9	8 April, 2019, 8:45	Assignment 6: Reflection on responsibility	Poster and prototype

5.2 Multidisciplinary software project

This course entails development of software solutions in the Softala framework. The software projects in this course are commissioned by a customer company or organization. Students

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implement and demonstrate ready-to-use solutions to the customer. Students learn the needs of the customer, specify and plan the solution and agree with the customer upon the used technologies, which are the best-suited ones for this problem. More information on the course can be found here: http://www.haaga-helia.fi/en/opinto-opas/opintojaksokuvaukset/PRO4TF024.

In Pilot 1 round students were working on this "Cafeteria queue monitoring" system. In the project the students built a system for monitoring the queue length in a busy cafeteria. They built a service for displaying the queue length. Their service calculated and showed estimated queuing times for any given point in time. They tried to find correlations between the cafeteria menu and the queue length to make better estimates.

Level and (time) investment

This was a Bachelor-3-level course. From January 16th 2019 to May 15th 2019 (18 week period) students worked two days every week (Wednesday and Friday). The course was **15 ECTS** (420 hours of work).

Learning goals

During this course, student should learn to:

a. Use most of the software engineering skills needed in solving the real customer problem.
b. Understand and document customer's needs and to propose appropriate software solutions.
c. Independently acquire technology knowledge and skills.
d. Take personal responsibility over a certain part of the commonly created solution.
e. Share acquired knowledge to other members of the team or course.
f. Implement a valid and ready-to-use solution to the customer's problem as a software team.

Assessment

Assessment were based on student's skills and efforts as indicated in the course contents. The emphasis of the grade were the following:

- **Researching new technology and tutoring others 15%.**
  Student take responsibility of studying one or more technologies needed in the project and teaching it/them to the others e.g. in a workshop (see 0 Tasks and activities).
    - This concerns learning goals **c** and **e**.
- **Project management and project final essay 35 %.**
  Student has many role- or competence-based tasks and responsibilities in the project. Students devise and maintain appropriate project management and progress monitoring documentation and take care of project traceability both from internal and external controls' points-of-view. Student reflects on his as well as the team's actions in the final essay.
    - This concerns learning goals **c**, **d**, **e** and **f**.
- **Appropriate documentation of the results and the technical solution that fulfills customer's needs 50 %.**
  Often most of the costs of an information system come from maintenance and changes. Also, the future developers of the system are different from the original developers. Thus, we put a big emphasis on the quality of the documentation, source etc. code, and automated testing and continuous integration of the professional development pipeline. Quality of the documentation does not mean lengthy or all-covering documentation, but that needed and most valuable information is available and only that. Also, high-quality code is often self-explanatory.

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- This concerns learning goals **a**, **b**, **c**, **e** and **f**.

Products of assessment
Results and tasks that were evaluated per project team:

- **Software requirements:** defined, audited, and accepted by the customer.
- **Technical requirements:** defined, well-argued, and accepted by the customer.
- **Source etc. code:** in common version control system.
- **Testing**: testing planned, plan accepted by the customer, corresponding tests run, and test report published.
- **Project and work management**: appropriate project management (external control) and agreed practice (internal control) documentation, following the agreed timelines, and sound communication.

The first four points from this list are about the development of the IoT-solution (third part of the assessment described in paragraph Assessment). The last point is about the project management while working on this IoT-solution (second part of the assessment described in paragraph).

Examples of results and tasks that were evaluated per individual student:

- **Research and tutoring**.
  The technology that was the responsibility of the student has been taken into use in the team appropriately. Technology was taught to others based on their need (see Tasks and activities). Student has been able to reflect his/her own responsibility area.
- **Integrity and trustworthiness**.
  Taking responsibility for oneself and of the team.
- **Development tasks**.
  The student's completion of the responsibilities in planned timeframe (implementation days, sprint, …) and the quality awareness and assurance (e.g. definition of done).
- **Project final essay.**
  Grade-wise criteria were discussed in the beginning of the course.

Tasks and activities
Students organized their work according to the principles of agile software development as prescribed in the Agile Manifesto (www.agilemanifesto.org).
The most important principles emphasized during the course were:

- Student team collaboration.
- Project team communication.
- Iterative design principles.

The main student team consisted of 4 last semester bachelor level ICT students at Haaga-Helia. They had studied mainly web- and mobile-programming. The team was mentored by a teacher and an outside company representative (from Houston Inc). Haaga-Helia was leading this project. Haaga-Helia's students were responsible for implementing the project. Houston Inc. provided the necessary IoT-infrastructure (sensors and an IoT platform) and project coaching.

The activities in this project were threefold:

1. **Active participation in the project** with mandatory presence in the project work lab room.
2. **Participating large software project in student's employer's organization** (s.c. Educationalisation)
3. **Recognizing and validating prior learning** (RPL)
   Students devised a teaching plan and teaching material about a technology or method that was topical. Students gave an expert lecture about a large software project that

he/she has actively participated, describing its development method, practices, principles and technical solutions. The lecture and its material were assessed.

Table 5.3 Project schedule

16th of January: The project will start. Student team at Haaga-Helia is formed.
16th of Feb: First iteration of the project is completed and demoed internally at Haaga-Helia
16th of March: Second iteration of the project is completed and demoed internally at Haaga-Helia.
1th of April: The students at Haaga-Helia, Delft and Timisoara have a meeting to discuss the review tasks in the project.
15th of April: The students at Delfth and Timisoara deliver their review reports to the students at Haaga-Helia.
6th of May: Third iteration of the project is completed and demoed to a representative of the cafeteria company.
16th of May: Third Final version of the project is completed and demoed. The project ends.

5.3 Internet of Things: A business perspective

General introduction to the course

This course is for you if you have an interest in the business potential and opportunities that arise from new waves of technologies expanding the boundaries of traditional business landscapes especially with the Internet of Things (IoT) having connected devices or the Industrial Internet of Things (IIoT) enabling smart manufacturing. Join this virtual course and explore how connectivity is re-defining the nature of our ways of everyday living, in homes and at workplaces.

This course offers a comprehensive view into the business implications of Internet of Things (IoT) and Industrial Internet of Things (IIoT). The main goal of the course is to enable students learn and identify the role of new technologies in modern day business world with special focus on commercial, operational, managerial, and strategic perspectives. This course is divided into five modules.

Module 1: Introduction to the Internet of Things

This module starts with setting the stage by providing the background of the main concepts necessary to grasp the broader business implications of IoT and IIoT. This module helps students get familiarized with definitions and descriptions of various basic concepts. This module also offers theoretical foundations to students in order to view the bigger picture of related topic areas in business and management contexts.

Module 2: Business Transformation towards IoT/IIoT (Operational Perspective)

The available networks and smart devices connect our world creating number of opportunities in our lives and business. There is a warranted need to look beyond IoT & IIoT as a mere IT-based technological topic. The possibilities arising from these topics drive business transformation and strategy. In this module, we look into the new role of managers in business process transformation focusing on concepts like IoT ecosystem, IoT business models, digital twin, business automation improving workplace practices and efficient business processes. Using industrial case examples and statistics, students develop an understanding of factors that influence successful integration of the IoT and IIoT in a business landscape.

Module 3: Customer Experience and Value Creation (Managerial perspective)

This module highlights how new technologies like IoT/IIoT enhancing digital capability of businesses to respond to customer needs, improving customer experience. Students review and compare few case examples of how value creation is achieved through IoT/IIoT in today's business landscape. Having an understanding of these concepts, student identify possible ways to maximize value creation in connected business environment.

Module 4: Capturing Growth through IoT & Industrial IoT (Strategic perspective)

In this modules, students take a deep dive into the topic; learning the concept of the IoT ecosystem. Students thinking is developed around aligning business models and strategy with available new technologies. By reviewing case examples, students explore business growth and scalability through such integration possibly creating strategic advantage over competitors.

Module 5: Future towards sustainable smart businesses (Leadership perspective)

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This module encapsulates potential business opportunities and corresponding challenges while implementing IoT/IIoT technologies and implementation strategies. Using industrial case examples and statistics, students understand the potential role of new technologies and trends that need to be prioritized by leaders in conducting businesses in future. In addition to that students learn about next generation emerging technologies, discovering in given case examples, how IoT/IIoT is driving a change in the way we work, live, and interact towards a sustainable business and social environment.

Level and (time) investment

- 5 ECTS course.
- 3rd semester onwards for bachelor level students. (can also be offered to masters level students).
- Course level: free-choice (could be part of a specific path).
  Course type: non-compulsory.
- Self-paced implementation helps students to complete this course virtually with convenience within 8 - 12 weeks.
- Course does not require contact teaching.

Course requirements

Prerequisite: some prior knowledge of business and management fields. (course does not require specific IT/software related knowledge).

Learning goals

After completing the course, student shall be able to:

- understand the concept and scope of the Internet of Things (IoT) and Industrial Internet of Things (IIoT) in the current business and industrial landscape.
- identify and analyse the application of IoT and IIoT in various business settings.
- students develop an understanding of factors that influence successful integration of the IoT and IIoT in a business landscape.
- assess the suitability and benefits of certain IoT enablers in various business models to achieve competitive advantage.
- apply the key concepts of IoT and IIoT in possible business transformation thinking and reasoning.
- understand the potential role of new technologies in conducting businesses in future.

Assessment

Assessment is based on individual student performance in demonstrating the learning throughout the course. This course is divided into five modules.

Module 1: Introduction to the Internet of Things – 15 pts

- Quiz = 5 pts
- Descriptive task = 10 pts

Module 2: Business Transformation towards IoT/IIoT – 25 pts

- Quiz = 15 pts
- Descriptive task = 10 pts

Module 3: Customer Experience and Value Creation – 25 pts

- Quiz = 5 pts
- Descriptive task = 20 pts

Module 4: Capturing Growth through IoT & Industrial IoT – 25 pts

- Quiz = 10 pts

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- Descriptive task = 15 pts

Module 5: Future towards sustainable smart businesses – 10 pts

- Descriptive task = 10 pts

Competence Assessment

Grade 1: The student is able to define the key concepts and topics of the IoT & IIoT. S/he recognizes the scope and purpose of these concepts in current business. S/he can describe business and management from the viewpoint of new technological thinking.

Grade 3: In addition to the competences in grade 1, the student can apply the key concepts in her/his thinking and reasoning. S/he can evaluate the application of these models in the industrial sectors. S/he is able to acknowledge the potential benefits and value in strategy work.

Grade 5: In addition to the competences in grades 1 & 3, the student can analyze the purpose of an organization to adapt to the IoT/IIoT business models in creating value. S/he develops business and management from the viewpoints of digital thinking. S/he is able to think critically and solve problems in a changing operational environment.

Grading scale – Total 100 points: student must attempt all the quizzes, descriptive tasks, and essay within five modules to pass the course.

Fails:	0-39 points
Grade 1:	40-59 points
Grade 2:	60-69 points
Grade 3:	70-79 points
Grade 4:	80-89 points
Grade 5:	90-100 points

Products of Assessment

Product of assessment are:

1. student's understanding of theoretical concepts – this is assessed based on the completed descriptive tasks.
2. student's ability to identify core/fundamental elements – this is assessed based on performance in the quizzes.
3. student's competence to analyze certain business scenarios – this is assessed based on completed descriptive tasks.

Tasks and activities

Modules include reading text material, case studies, industry reports, and watching videos. Each module has short tasks, quizzes and assignments to ensure student learning.

Teacher support and communication

1. Role of responsible teacher: is to administrate the course as well as evaluate the assignments, give feedback on the completed tasks, answer any questions from students and finally upload the course grades in Peppi system.
2. Contact moments: This course is created to be offered virtually. Students complete the modules in their own pace and speed. There are no online weekly zoom sessions. Two Planned consultation sessions can be incorporated in the implementation plan.
3. Communication tool: Moodle environment, emails or if required on zoom.
4. Feedback: shall be given to individual students on completed tasks.

Learning management system and other tools.

Course content and related material shall be shared in Moodle environment. (The use of an LMS is not that relevant.)

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International collaboration

This course can be offered to students from a partner institutes. HH teacher can coordinate with teacher from a partner institute.

Interdisciplinary collaboration

The course can be offered to interdisciplinary student body e.g. business, IT etc. The collaboration takes place mostly e.g. via Zoom, if required.

Schedule

This course is divided into five modules. Self-paced implementation helps students to complete this course virtually with convenience within 8 - 12 weeks.
Module 1: Introduction to the Internet of Things (duration 1-2 weeks)
Module 2: Business Transformation towards IoT/IIoT (duration 2-3 weeks)
Module 3: Customer Experience and Value Creation (duration 2-3 weeks)
Module 4: Capturing Growth through IoT & Industrial IoT (duration 2-3 weeks)
Module 5: Future towards sustainable smart businesses (duration 1-2 weeks)
(Peer interaction depends on the implementation plan).

Disclaimer & Credits

1. This course uses several resources in form of books, journal articles, conference proceedings, videos, white papers, industry case examples, industry reports, industry statistics, survey results, web pages, blogs, etc. to elaborate the business implications of new technologies including the Internet of Things (IoT) and Industrial Internet of Things (IIoT) for student learning and knowledge creation in academics.
2. The course developer (teacher responsible) does not own the rights of these resources. Each resource has been referenced according to the best of knowledge. The citations have been made explicit with each resource used.
3. Image credits have been cited/referenced, where applicable. (for example: main course image credit - https://www.iotworldtoday.com/galleries/top-iot-trends-to-watch-in-2020-gallery/
4. In case of any query, please contact teacher responsible via Email: **syed.mubaraz@haaga-helia.fi**

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5.4 IoT project

General introduction to the course

This is a project-based course, where students apply their IoT programming skills and build a solution for a real client problem. The client commission can come from an international partner. The student group can collaborate with students from other disciplines in the project. This collaboration could be with e.g. business, design or electrical engineering students who would have their own responsibilities in the project.

Level and (time) investment

3rd year bachelor level, 10 ECTS course. One semester, or 16 weeks.
3 hours contact teaching and 13 hours of independent or group work per week.

Course requirements

The student has completed several programming courses (possibly some IoT programming courses) and some basic level project work courses or can demonstrate medium/advanced level skills and knowledge in programming and project working.

Learning goals

Upon successful completion of the course, the student is able to solve customer problems through his/her software development skills. The student understands and is able to define customer needs and requirements, and s/he is able to utilize proper software solutions. The student is able to develop independently his/her competence in learning and discussing new technologies. The student is able to assess and select the proper technologies and approaches to solving the problem. The student is capable of taking responsibility for implementing designated tasks. The student is able to share the developed competence with other team members. As a member of a team, the student is responsible for implementing production-level software solutions for customer needs and requirements.

Assessment

Assessment is based on the project results (20%), observing the project work (10%) and assessing an individual analysis essay written by the students after the project (70%). The students are assessed in their ability to apply technologies when solving a real client problem and in applying project working methodologies when organizing the project work.

Products of Assessment

Working project results (software) and individual final analysis essay written by each student.

Tasks and activities

The students

1. Study customer needs.
2. Define and plan the solution.
3. Organize their group work.
4. Determine the technologies that are appropriate in solving to the problem.
5. Develop the working software solution at a near production level one iteration at a time.
6. Demonstrate their work to the client and ask for feedback iteratively during the project.
7. Evaluate the results and plan the future improvements.

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Teacher support and communication

The teacher is a coach and a technology and project work expert that guides and supervises the work. The teacher meets the students group roughly once a week to give feedback on the progress and help in possible problems. The communication can happen face-to-face or e.g. over Teams. Usually there is at least a weekly status check meeting, but the students can also request help more frequently. The teacher gives comments on the technology and project working choices the students have made and helps with solving difficult programming problems where possible.

Learning management system and other tools.

The use of an LMS is not that relevant. Some material can be shared in Moodle.

International collaboration

The client commission can come from an international partner. The student group can collaborate with students from other countries in the project. The collaboration takes place mostly e.g. via Microsoft Teams.

Interdisciplinary collaboration

The student group can collaborate with students from other disciplines in the project. This collaboration could be with e.g. business, design or electrical engineering students who would have their own responsibilities in the project. The collaboration takes place mostly e.g. via Microsoft Teams.

Schedule

During the 16 week semester there are:

1. Weekly meetings with student group and the teacher
2. Two weekly working slots for the student group to work individually
3. Monthly demonstration and planning sessions with the student group and the client
4. Possibly monthly meetings with students from other disciplines working in the same project.

5.5 Haaga-Helia IoT solution developer learning path

Description of learning path

This learning path will give the student a general capability to implement IoT-projects involving databases, server-side components and sensors ("things").

Structure of the learning path (35 ECTS):

- Introduction to networks 5 ECTS
- Python programming 5 ECTS
- Databases 5 ECTS
- IoT experimental project 5 ECTS
- Linux servers 5 ECTS
- IoT project 10 ECTS

IoT solution developer learning path gives student the basic understanding needed to be involved in projects around the Internet of Things (IoT). Student will learn the basics of networking, python programming especially for sensors, servers and databases. With this knowledge student can build own small scale IoT-solutions involving sensors and easily programmable micro computers like ESP32 or Rasperry Pi. After building own small project, student has the capability to be involved in a real IoT customer project, where he or she can

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further enhance his/her own knowledge around e.g. cloud based IoT hubs or even Machine Learning and large scale data processing and visualization.
This learning path gives student a good capability to work e.g. as a system designer or programmer in real world IoT-projects.

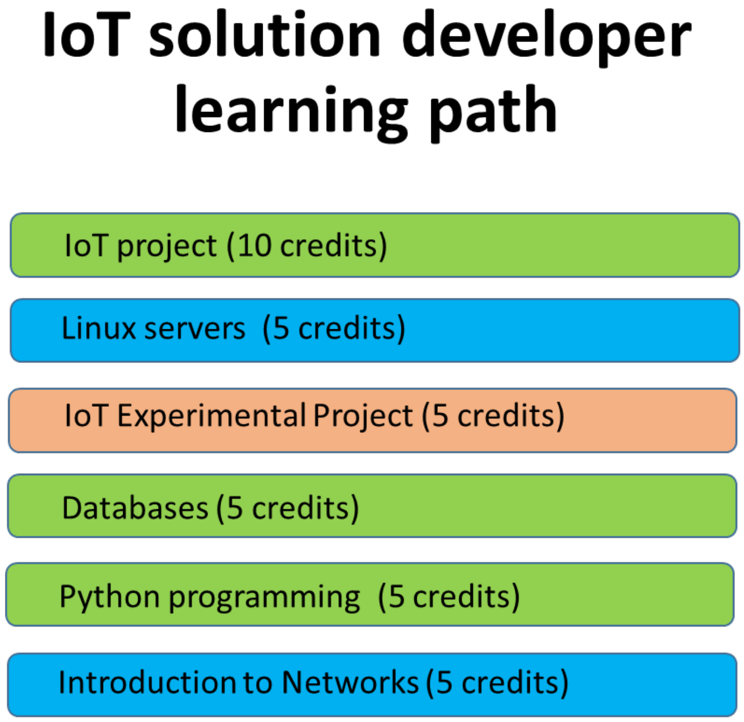

Figure 5.1 IoT solution developer learning path.

Competences developed in the courses of the learning path:

Name of the course	**Competences developed**
Introduction to Networks	Data networking basics, Ethernet local area networks, IP networks (IPv4 and IPv6), IP subnetworks, TCP and UDP
Python programming	Basic Python syntax, solving problems with Python, MicroPython and running python on micro computers, reading sensor data with python
Databases	Relational databases, SQL-syntax, transactions, creating a MariaDB database, querying databases with SQL
IoT Experimental Project	Designing and implementing Internet of Things systems, Programming micro computers, problem solving, critical thinking, creativity
Linux Servers	Linux server administration, Linux command line, Linux server maintenance and development

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IoT project	Applying programming skills to real world problem solving, Project work with Scrum methodology, Describing customer needs as user stories, iterative software development, assessing technologies, learning new technologies independently, teaching new concepts to team members, presenting skills, using cloud systems, collaboration, communication, planning, problem-solving, critical thinking, autonomy

Collaboration with external stakeholders

If the student is interested in developing their skills more in more advanced IoT-concepts such as embedded programming, low energy solutions etc., they can include these studies into the learning path by taking IoT-courses from other universities.

The IoT project course involves a customer project from an external company. In this project course the students can also collaborate with students from other disciplines to develop an optimally designed and implemented solution to the client problem.

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