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A Way To Get Students Consider Ethics And Sustainability In IOT Projects

Jean-Luc SARRADE
HES-SO (HEG), Switzerland, jean-luc.sarrade@hesge.ch

Isabelle LERMIGEAUX-SARRADE
EPFL, Switzerland, isabelle.sarrade@epfl.ch

A WAY TO GET STUDENTS TO CONSIDER ETHICS AND SUSTAINABILITY IN IOT PROJECTS

J-L Sarrade
HES-SO (HEG)
Geneva, Switzerland

I Lermigeaux-Sarrade [1]
EPFL
Lausanne, Switzerland
ORCID: 0000-0001-8828-4084

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ABSTRACT

Sustainability and ethical topics can be embedded and assessed in existing technical courses within an engineering curriculum. This article describes how we integrated a reflection on the importance of ethical and environmental aspects of connected objects through team-based project learning with computer science students in the second semester of their Bachelor degree. Small groups of three were given different projects, in which they had to implement the technical concepts learned in class using both virtual and physical components. The projects followed realistic scenarios chosen at random, each of them using a specific set of sensors and built to question either personal data collection, ethics or sustainability issues. At the end of the project, each group had to demonstrate their connected object proof of

1 Corresponding Author
I Lermigeaux-Sarrade
Isabelle.sarrade@epfl.ch

concept during an oral presentation and to prepare a group written report. The project is one of the continuous assessment elements of this module.

After mapping the different projects and their associated sustainability and ethical topics, we present how the initial assessment grid of the project evolved into a three-fold version. The final grid explicitly invites students to explore sustainability and ethical aspects in their reports, in addition to the technical aspects, and includes a peer review section. Examining to what extent students developed an original reflection on sustainability and ethical aspects of their projects, we finally suggest possible extensions and improvements, and list some context elements that are to facilitate future implementations.

1 INTRODUCTION

1.1 Ethical challenges of Internet of Things in engineering education

The Internet of Things (IoT) is a network of connected things, with applications in all areas of our societies, from personal to professional life. New IDEs (integrated development environment) offer easy access to IoT development for developers, teachers and students. Being key elements of *Industry 4.0* (Roblek et al., 2016), IoT are the result of a collision between different technologies such as wifi, 5G, and powerful microcontrollers integrating security libraries, all in a limited space. Invading our space, continuously exchanging data, the rapid growth of IoT is associated with major data-related ethical issues (Karale, 2021). Data collection related to the use of IoTs raises many questions in relation to the seven principles of ethical decision-making in engineering - honesty, integrity, keeping promises, loyalty, fairness, respect for others, responsible citizenship, striving for excellence and accountability (Josephson,2013).

Mapping ethical practices of European hardware and software developers, the VIRT-EU project found “IoT developers lack practical guidance on the ethical and social issues of data use” (Powel et al., 2017). Guidelines from the EUR-ACE® labelling agency expect students to graduate with an understanding of the societal and ethical impacts of engineering. Mixed-mode approaches, combining traditional taught courses and project-based components (Mills and Treagust, 2003) are recognized as being efficient for teaching technical knowledge and transversal skills together. Byrne introduced macro ethics objectives in a 1st year Bachelor module dedicated to process and chemical engineering, showing that students were able to engage in a macro ethical sustainability informed approach (Byrne, 2012). A recommendation (Isaac et al, 2023) is to implement contextualized teaching and assessment of ethical topics within technical courses in the engineering curriculum, in order to avoid students seeing ethical issues as peripheral.

1.2 Context elements

The IG Bachelor of Geneva School of Management (HEG), from Western Switzerland University of Applied Sciences and Arts (HES-SO) prepares students from various backgrounds for working in software engineering and information systems. Multidisciplinary, the Bachelor study plans also include training in business,

communication and management. Half of students come from pre-university diploma with specialization in economics, the other half from professional diploma.

Having students work on IoT places them at the intersection of various technologies and allows the introduction of multiple interdependent concepts. In 2019, this led the Bachelor teaching team to test two labs using Arduino development WiFi boards within the 14 labs of the WiFi course for second-year Bachelor students.

The study plans evolved in 2020, with the idea of adapting the contents to the technical evolutions and to offer more opportunities for learning through projects. As the 2019 experimentation was very well received by the students, a new module specifically dedicated to IoT was introduced in 2020 as part of the new 1st year Bachelor study plan.

2 THE EVOLUTION OF THE IOT MODULE

In the Cultural Historical Activity Theory framework, teaching is considered a professional activity (Engestrom, 2000). Teachers continuously improve their professional knowledge (Grangeat and Hudson, 2015), and adapt their practices 1) through short term regulation loops in reaction to the immediate classroom feedback, and also 2) through long regulation loops that result from reflections that the teacher has on the effects of her or his teaching practices (Jameau and Boilevin, 2015).

Since its first implementation in autumn semester 2020, the IoT module has gone through four iterations and evolutions, as shown on the circles of Figure 1. Each evolution results from students' written feedback and/or teacher analysis of final presentations, as summarized under each circle.

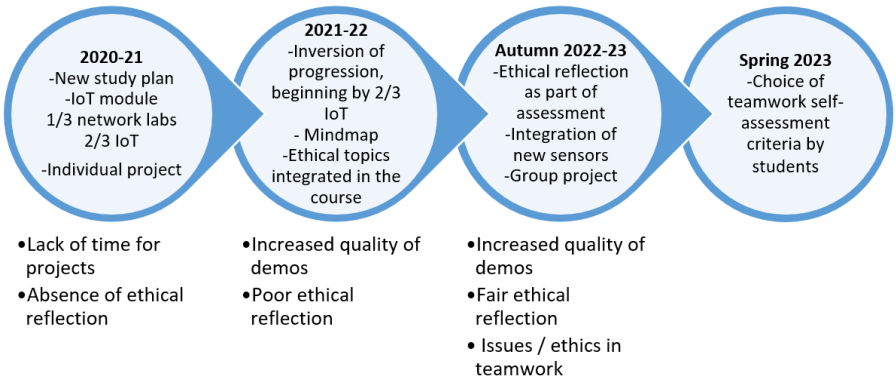

Fig.1. In the circles, short descriptions of four iterations of the IoT module – The lines below summarize the feedback from students, the quality of students' final presentations and of the level of their ethical reflexion

The regulation loops from one iteration to the next are described below, in order to analyse how working on ethical issues enriched the module learning outcomes.

2.1 First iteration in 2020-21

In 2020, the module was a project-based module for the first year Bachelor students. Despite the Covid situation, labs and lectures were given on site. The module took place in the second semester of the Bachelor.

2.1.1 Objectives and activities

The main goal was that students understand the technical big picture of networks and master elements such as programming and cross-compiling software, physical sensor connections, networking, and wireless transmission.

Students were told that the course assessment included a project at the very beginning. The course began with a slide (Figure 1) showing the elements and the interactions that students needed to understand and manage to implement their project at the end of the module.

The progression of the module began with one-third of content on networks, followed by two-thirds of IoT-specific content. Every week, the lecture and lab focused on a specific networking element. In week 9, students received the hardware and their individual project subjects. Students were provided with a rubric assessment grid, covering technical knowledge and presenting skills.

2.1.2 Students' feedback and presentations

At the end of the first iteration, teachers and teaching assistants observed that the students complained about having difficulties managing the project schedule. It was true that the project ended the semester but its overall perception by the students was late, its implementation was delayed and then truncated by the end of semester deadline. In addition, because the students were not used to having the freedom to choose the elements of their project, they encountered difficulties making choices. They tended to be overly ambitious, were slow to get started, and scaled back their projects at the last minute.

Teachers found that the rubric assessment grid was followed step by step by the students that relied on its criteria to build their project. Student feedback showed that they appreciated the fact that the evaluation was strictly in accordance with the rubrics.

During the presentations, teachers also observed that the topics of ethics in the IoT were not at all addressed in the students' projects and that the students' responses to questions about ethics showed very little awareness of potential problems, although some points were brought up in class.

2.2 Second iteration 2021-22

2.2.1 New activity order and concept maps

In 2021, the activity order was modified in order to address the points that are described above, as follows:

- The module started with the IoT part, for students to have more time for the project. Having access to the hardware after week 7, students had the opportunity to elaborate their project for 5 weeks before the final presentation.
- The contents covered by each lecture and labs were highlighted step by step on a concept map, in order to help students gain a global view of the connections between the concepts seen in lectures and labs accompanying the project.
- More emphasis was put on ethics during lectures

- More powerful hardware was also provided, in order to prevent technical issues and provide greater diversity in projects.

During the semester labs, teachers observed that, despite working on separate individual projects, students tend to help each other to solve technical problems. The teachers encouraged them to solve problems by discussing.

2.2.2 Project outcomes

The results of the implemented changes were as follows:

- The quality of students' presentations increased, including original uses of sensors and devices. Some students expanded the scope of their projects, by using additional virtual sensors and networks. However, others had more difficulties and only adapted directly the examples provided in labs.
- Whereas ethical elements were included in lectures, most of the students' answers to the questions about ethical aspects remained poor in the final presentation of their projects. For instance, they did not appreciate the stakes of permanently geolocating people.

2.3 Autumn 2022

2.3.1 From individual to group projects and inducing ethical reflection "by design"

In autumn semester 2022, the project format evolved from individual projects to group projects, with objectives of 1) better preparing students for groupwork in their undergraduate project module, 2) encouraging peer-to-peer support as previously observed, and 3) expanding the scope of projects.

In order to emphasize sustainability and ethics, the project topics were built in order to generate this reflection "by design". To achieve this, all projects involved at least (1) an infrared sensor for detecting human presence (generating sensitive personal data), (2) a messaging broker (for data publication) and (3) a collective messaging broker (for data storage). This specific setting was to induce reflections on personal data storage and publication on distant servers, and also on the nature and choice of data to be shared or not.

Sustainability and ethical reflection rubrics were added to the rubric assessment grid. Students had to implement all available sensors in order to respond to the need of the clients (teachers), even if the clients' wishes raised ethical issues. Then, they had to identify and discuss the ethical and sustainability aspects that are at stake, in a specific part of the written report.

2.3.2 Students' ethical reflection

Table 1 shows the themes and a non-exhaustive list of ethical stakes. The issues that students identified in their written report are in third column.

Table 1. The themes of the projects (left column), associated with a non-exhaustive list of relevant ethical stakes (central column) – Stakes that were identified b students are in the right column.

Theme	Relevant ethical stakes	Stakes identified by students
Surveillance of elderly people using IoT for detecting falls	Personal data (presence sensor) Health data (fall information) Data protection Choosing the person(s) to alert in case of fall detection False positives cases	Data center Safety of people
Cab service management using embedded IoT	Tracking of empty/loaded vehicles Tracking of working hours/ control of breaks Customer follow-up with their location, with whom they are accompanied ...	Employee monitoring Relocation of servers Reduction of power consumption
Personalized weather information service using IoT for home measurements	Personal data related to the person's presence at home Person's opinion of the weather provides data on the person's perception/morale Regularity of use provides behavioral or psychological profile data Potential for resale of free weather information	Sustainability, resource depletion Safety of people Access to private network (Trojan horse)
Air quality data sharing service using IoT for home measurements	Presence of the person Air quality inside/outside the person's home (smoking, ventilation, ... resale of information to insurance companies or contractors related to buildings) A way to know the lifestyle of the person using this type of sensor	Address/presence General pattern of behavior in the neighborhood Safety Sustainability - limiting consumption

In their final written reports, students identified some of the ethical issues related to their projects.

They showed awareness of direct and indirect physical safety issues:

> *"a malfunctioning panic button can have serious consequences."*
>
> *"to know if a person is present or absent from his home, or to know in which room of the dwelling he is currently, if he is sleeping… etc. A way to determine which homes would be an ideal target for a burglary for example."*

They also perceived the risks linked to the storage of personal data and the related environmental issues of using cloud storage:

> *"storing sensitive information about employee movements or customer itineraries on servers located outside our territories could be problematic"*
>
> *"(risk of) making an attack via the connected object in the house"*
>
> *"sustainability: would it be reasonable to relocate our servers beyond our borders?"*

Two of them made a stand and disagreed with systematic monitoring of people:

> *"Monitoring the activity of individuals in their homes and accumulating data thanks to sensors, in order to ultimately transmit them / make them available to companies or states would lead to the disappearance of the last bits of intimacy that human beings still enjoy."*
>
> *"Employee monitoring is the first ethical issue that comes to mind (...) do not store this data beyond one working day (…) nevertheless the problem of real-time monitoring persists"*

Another tended to leave it to the legislator to decide:

> *"(ask) whether public health (the health of the elderly) is an important enough value to preserve to accept the risks raised above. This is a task for legislators (and an ethics commission, for example)."*

2.4 Spring 2023 - Introducing ethics in group work

In spring semester 2023, after experiencing a first round of group grading, and noting that ethics in group work should be explicitly addressed, teachers proposed to the students to add related criteria in the group evaluation. The objective was on the one hand to value the capacity to work in group, and on the other hand to modulate the mark between the members of the group in the cases where it proves to be necessary (for example in case of "freeloaders"), the teachers' perception being modulated by the self-evaluation provided by each student.

Seeking for rubrics for constructing a groupwork assessment grid, previous work of Roach et al. (Roach et al., 2017), offered interesting perspectives: aiming to scaffold teamwork skills, these authors analyzed rubrics written by students for the evaluation of group work, according to affective domains, and extracted 51 items that they grouped into 5 themes (*valuing, responding, organisation, internalization*, *receiving*).

Of the 51 items extracted by Roach et al, we rewrite 20. Teachers choose 2 rubrics to be mandatorily assessed, and students were asked to select 4 additional rubrics for peer group work assessment. To guide them in choosing rubrics, three levels of self-assessment were described. Table 2 shows examples of rubrics.

Table 2. For each theme, an example of rubric, associated to its three groupwork assessment levels – Inside brackets, the number of groups that chose the given rubric.

Themes	Rubrics	Insufficient	Sufficient	Very good
Valuing	Contributes to ideas (7)	Doesn't come up with technical ideas	Contributes some technical ideas	Provide many good ideas
Responding	Responds to communications (7)	Doesn't answer emails, doesn't express himself / herself	Is able to communicate with others	Is able to give effective feedbacks to others ideas or comments
Organisation	Completing assigned tasks (6)	Delays and / or submits incomplete tasks	Completes tasks more or less on time without impacting others	Always respects deadlines and submits complete tasks
Internalisation	Group motivation (6)	Stays strictly in his own bubble	Motivates others by sharing knowledge	Encourages, explains and supports others in acquiring skills
Receiving	Accepting of ideas (7)	Does not accept other people's ideas	Considers the ideas of others	Values the ideas of others and incorporates it

2.4.1 Students' choices

There were 19 groups of 3 students and 4 groups of 2 in the spring semester cohort, 23 groups in total. From the 23 groups, 5 groups were made by associating randomly the students that did not attend lectures. These 5 groups did not make rubric choices.

Below are the choices of the 18 remaining groups.

- Theme choices: *Valuing* is the most chosen theme, with 37.5% of selected rubrics. Then came themes *Responding*, *Receiving*, *Organisation* and *Internalisation* (19%, 18%, 15%, 10% respectively of the selected rubrics.
- Rubric choices: The most selected rubrics were the examples given in table 2. The rubrics "Contributes to ideas (*Valuing*)", "Responds to communications (*Responding*)" and "Accepting of ideas (*Receiving*)" were selected by 7 groups out of 18 (38%). The rubrics "Completing assigned tasks (*Organisation*) "and "Group motivation (*Internalisation*)" were selected by 6 groups out of 18 (33%).

3 DISCUSSION

3.1 About the current assessment grid

From 2020 to 2023, the assessment grid evolved. It always included 3 parts. In 2020, because of Covid, students were allowed to video record their demonstrations. Fig. 4 shows the evolution of the IoT module assessment grid.

The ethical reflection on IoT was an implicit objective of the module in 2020. After the first iteration, it became obvious to teachers that developing students' awareness of ethical issues related to IoT was an important goal. However, in 2021 the focus for assessment stayed on technical knowledge and scientific writing.

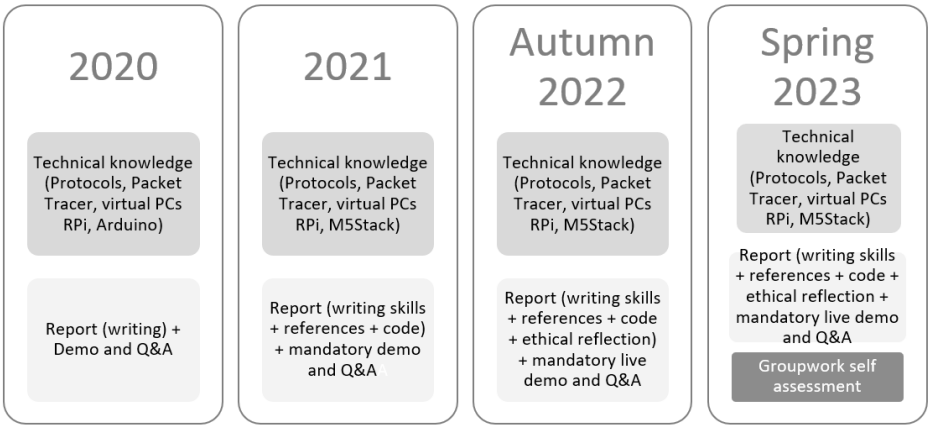

Fig. 4. Evolution of the IoT module assessment grid

Additional rubrics were added to the grid, in order to encourage students to be more rigorous in citing references and/or code they used for the project. In

2022, ethical reflection was integrated into the evaluation grid, with four level indicators (see Figure 5).

The current assessment grid is the result of the evolution of the module, reflecting the alignment of objectives, activities and assessment modalities (Biggs, 1996). It became a more accurate and useful tool for both teachers and students, at the cost of a more complex appearance.

Level	1	2	3	4
Reflection on ethics ans sustainability (in the written report)	Few elements provided, or general consideration not related to the project	Some elements are identified, the links with the project remain unclear	Correct reflection based on some elements related to the project	Complete and in-depth reflection directly related to the project

Fig. 5. Four level indicators of the ethical reflection rubric

3.2 About the sustainability of the module

Warren and Robinson (2018) suggested to consider courses through the lens of the *product life-cycle.* From this point of view, after 4 iterations, the IoT module may have reach its *maturity* level. Continuing to give the course, in its current format, should be the next step in its *life-cycle*.

At this stage, we feel it is important to raise the question of the sustainability of the module itself. In HEG, study plans are finalized by the teaching team and validated at the beginning of each academic year. The issue of faculty motivation for sustainability was identified by Thurer et al. (2018) as a key issue for integrating sustainability into engineering education, and programme directors expressed the need of faculty training to support them in integrating sustainability in their programmes (Leifler and Dahlin, 2020).

Since ethics was not embedded in the first iteration of the IOT module in 2020, potential changes in the composition of the teaching team entails a risk of losing the ethical component in the learning process for this module, insofar as the new team may not have the same sensitivity and motivation for ethics.

A module entitled “Ethics” does exist in HEG second year Bachelor study plans. However, we think important to contextualize the teaching of macro ethics, as suggested by Isaac et.al, and to give opportunity to first year students to rapidly develop an ethical reflection (Isaac et al, 2023). This leads us to recommend the setting of an educational policy that ensures keeping integration of ethics and sustainability within the IOT module.

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