

A course on responsible digital developments: a teaching experience report

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Abstract

The paper presents a course that was developed in 2021 and that has been delivered since then on responsible digital developments. The course is built around the notion of responsibility. It aims to help students practice their critical-thinking skills with respect to the implications and consequences of digital developments. It consists of a taught lecture and a tutorial activity, and is driven by real-life examples taken from different sources, including the press, research projects and art work. The course is currently implemented in a format of either three or six hours, and is delivered in three university-level programs in the UK and in France.

Keywords

Digital developments, responsibility, critical-thinking, teaching content.

1 Introduction

In the recent years, a wave of initiatives has been engaged in the various communities of computer science and engineering to revisit different aspects of the traditional model of research. Beyond the widely reported (and necessary) debates on the ethical concerns that are raised by the rapid development of AI (and its moral implications at every level of human organizations), these initiatives range from updated codes of conduct (e.g., ACM Code of Ethics and Professional Conduct [1], IEEE Global Initiative for Ethical Considerations in Artificial Intelligence and Autonomous Systems [2]), discussed topics (e.g., ACM SIGCOMM 2022 Joint Workshops on "Technologies, Applications, and Uses of a Responsible Internet" and "Building Greener Internet" (TAURIN + BGI) [3], social responsibility in game AI [8]), research assessment protocols (e.g., inclusion of required ethical statement for authors and reviewers) or training programs for doctoral students and researchers (e.g., development of ethical reasoning skills for computer scientists [4][5], online MOOCs on Ethics and ICT [6]). These initiatives all participate in evolving, in the various areas of computer science and engineering, what research should today be about, how it is conducted and what role researchers play with respect to the society and the environment.

As a domain of applied research, networking embeds the "societal value found in improving a core civilizational infrastructure" [9]. In particular, it is hard to conceive, in a digital world, computer networks and their evolution as passive agents that do not "exploit and influence social or physical phenomena" and "change the world through their use" [10]. Networked computer systems form today a critical artifact on which human societies build to function. They are the core hardware and software substrate of digital services that are essential to most sectors.

Until now, teaching networking, and more generally digital infrastructures, has mainly been focused on the technicality of systems and their operations. Teaching is typically engineering-focused (how to optimize in order to make system work efficiently), system-based (to build systems to test their feasibility) and physics-inspired (to understand the underlying principles and rules that make networked systems the way they are). The implications of digital infrastructure developments and the penetration of networks in all aspects of our life do however far exceed the sole technical system perimeter and invite us to rethink both the scope and the nature of the knowledge to transfer in a digitized society.

This paper presents a course titled "Responsible Digital Developments" that we developed in 2021 and that has been delivered since then in three (post)graduate programs in one institution in the UK and two institutions in France. The course aims at training students on the notion of responsibility, *i.e.*, *what does it mean for a development to be made in a responsible way?*, by discussing the sense of engagement and responsibilities to which the practitioner of a computer-related area may be confronted. More specifically, a key objective of the course is to interrogate the dominant narratives of technical developments that have been focused to a large extent on performance and cost-effectiveness.

The course finds its origin in a personal initiative that we started to create an informal space for discussion around the socio-technical challenges and ethics of computer science and digitalization [11]. The course is example-based, encourages debates and discussions, and does not provide any definite answers. It is aimed to practice critical-thinking with respect to the implications and consequences of digital developments.

The rest of the paper is organized as follows. Section 2 briefly introduces the origins of the course. Section 3 describes the course objectives in more detail and its current implementation. Section 4 presents the accompanying tutorial activity. Section 5 provides some feedback perspectives.

2 Origins

Computer scientists live, work, and evolve in a set era and a set system. Alike non computer scientists, they benefit from the outcomes of digital developments. As academics under this dual status (*i.e.*, operators and beneficiaries of technological developments), some of us felt the need to have a space to discuss the effects of the use and applications of digital constructs and technologies in the wild. It is however not always straightforward to communicate these interrogations within professional communities that often dismiss such considerations as irrelevant to their purpose. We thus decided to create a reading group that could let participants share and express their opinions on anything related to the digital world [11].

In parallel to this reflection on the responsibility of our practice as researchers, similar questions starting to emerge regarding our practice as educators. Teaching of networks and digital infrastructures is largely focused on technical systems and does not typically tackle other, equally important dimensions, such as (geo)politics, the society, the environment or the economy.

The opportunity to transpose these reflections into teaching material came in 2020 when we were invited to develop a new teaching module on digitalization in the energy sector. The module is targeted to students enrolled in a Master of Science (MSc) program that specializes in future energy systems at a university in the UK.

The module offered a perfect fit for the creation of a course addressing the notion of responsibility in digital developments. It welcomes every year students from mixed backgrounds, *i.e.*, from engineering, computer science, natural science, business school, which offers an ideal environment to get different perspectives on a complex topic. In addition, the module focuses on digitalization and data for energy, making it a perfect application use case of digital infrastructures as a critical interface between domains with different foundations. In particular, this gives the opportunity to train future practitioners who do not necessarily aim to work in the high-tech not only on the technical side of data and digitalization but also on their sustainability challenges. The postgraduate nature of the program also makes that some students have already had a professional experience, which gave us some (initial) confidence to discuss topics not only from a purely academic perspective.

The "Responsible Digital Developments" course started in 2021 as a one-hour lecture. It has since then been expanding. Its current format can either follow a three- or six-hour model, depending on the type of exercises proposed to the students. It is delivered every year in three different programs that take place in the UK (original setting) and in France (later invitation).

3 Course description

3.1 Main objective and expected outcome

The course revolves around the notion of responsibility. It aims to encourage students to reason about what responsibility means by exploring the narratives of digital developments under the three dimensions of sustainability [12], *i.e.*, environmental, social and economic.

The responsibility component is inspired by the work of Chiodo, Bursill-Hall and Mueller on ethics in mathematics [13]. From their practice in mathematics, Chiodo, Bursill-Hall and Mueller observed that researchers tend to be grouped into different categories with respect to the time they wish to invest in thinking about their responsibilities towards the developments to which they contribute. In particular, they propose a four-level scale [7] to describe these different forms of ethical engagement, *i.e.*, absence of any sense of responsibility (the lowest level - level 0), awareness of ethical challenges (level 1), readiness for actions (level 2) and active advocacy for engagement (highest level - level 3).

The availability of a gradation-based framework based on qualitative rather than quantitative attributes is highly effective for reasoning upon the possible ethical implications and paths a development can take. While initially developed for research in mathematics, the proposed scale-based framework builds upon general observations that can easily be transposed to the digital infrastructure context. In particular, at the end of the course, students are expected to have gained some practice of critical-thinking with respect to digital developments. The course does not provide any definite answers to the questions raised and discussed. It is intended to encourage students to take time to think about the implications of designing, deploying and / or employing digital solutions to address a complex problem that involves multi-faceted challenges.

3.2 Content

The course is driven by example-based situations to engage discussion and debates on the implications and consequences of digital developments. It is divided in four main parts:

- (1) Values and narratives - The first part focuses on the context of digital developments (currently under the framework of the UN for 2030 sustainable development goals). It reviews the pillars of sustainability

and contrasts them against the objective(s) and value of a development. For instance, we use self-driving mobility to illustrate an example where performing a multi-factorial impact assessment is crucial.

- (2) Sustainability challenges (through examples) - The second part of the course focuses on specific sustainability challenges¹ that are illustrated through real-life examples taken from the news, research projects, art work, the professional environment, *etc.* For instance, the value of data is discussed from the point of view of smartphone tracking. Students learn how tracking is implemented, are invited to check the applications that run on their personal device and question the relevance of the data collected from the point of view of the functionality offered by the applications.
- (3) Regulation - The third part of the course focuses on the European regulation as a strategy to mitigate (some of) the impact of digital developments. The course reviews the objectives and main specifics of the current legal frameworks enforced in Europe (*i.e.*, the General Data Protection Regulation, Digital Services Act, Digital Market Act, AI Act) and encourages students to share their opinion on the effectiveness of such mechanisms. It takes advantage of resources produced by the Centre for Internet and Society in France [16] and The Alan Turing Institute in the UK [17] to discuss how the notion of risk is treated at the policy level.
- (4) About us - The last part of the course focuses on impact and solution at our level, whether personal or professional. It does not aim to dictate what to do or not, but instead, encourages student to think about some concrete contradiction in our day-to-day life.

Given that topics rapidly evolve, the content of the course is updated every year to reflect new debates and new developments through recent illustrative examples taken from the press, movies, art work, social media, research projects and professional experience feedback.

3.3 Format and current implementation

The format of the course can be adapted to a three-hour session or two three-hour sessions (*i.e.*, a six-hour course) depending on the nature of the accompanying tutorial activity, as described in Section 4. The course is today delivered in three different programs that are presented in Table 1.

The postgraduate MSc program is offered at a university for science, technology, engineering, medicine and business located in London, UK. It involves every year around 50

¹Being able to review the wide spectrum of sustainable challenges would require more than a three-hour lecture.

Program type	Program focus	Location	#students (/year)
MSc	Energy	UK	~50
MEng	Software developments	France	~30
MEng	AI and robotics	France	~10

Table 1: Course settings.

students that come from mixed academic backgrounds and who want to get a specialization in the energy sector. The program is highly selective and gathers both students who have just graduated from an undergraduate program and students with some professional experience. This setting is the original one, in which the course was initially delivered. It has run for six years and is part of a teaching module on digitalization in the energy sector that we created and lead. The course is delivered as a three-hour session with an associated module-long project.

The undergraduate Master of Engineering (MEng) program in software engineering is offered at a global university in Paris, France. It involves around 30 students per year. The program is selective and the course is offered in the last year as part of an elective module² on computer science and society. The course was delivered for the first time in 2025 as a three-hour session and will be given as two three-hour sessions next year.

The undergraduate MEng program in robotics and AI is offered at a top Engineering School (Grande Ecole) in the Paris region, France. It involves around 10 students every year. The program is targeted towards an apprenticeship curriculum (third year) and the course is offered as part of the machine learning module. The course has been delivered for two years as a three-hour session.

4 Tutorial activity

The taught lecture is complemented by a tutorial activity that was introduced as a full component of the course in 2024. The tutorial activity consists in a critical-thinking training exercise applied on a concrete project on which students work as part of their program.

In the case of the MSc program in the UK, the project corresponds to the group projects that are investigated during the two weeks of the module. The topics of the projects are related to the theme of the module, *i.e.*, digital developments in and for the energy sector. Example projects undertaken in the last three years that were more specifically related to digital infrastructures include assessing datacenters footprint, investigating datacenters as an opportunity to mitigate wind curtailment, analyzing the carbon footprint of online services, unveiling urban activities from air monitoring using an Internet of Things platform or documenting the data

²Unite d'enseignement d'ouverture, in French

privacy implication of data-driven management in smart buildings. Students have 14 hours dedicated to the work that includes different tasks depending on the topic, *e.g.*, to critically review a new concept or proposal, to collect and / or get access to a dataset, to (pre-)process data, *etc.* In addition to working as a group, each student has to individually take the tutorial activity and produce an output that counts towards their final mark.

In the case of the two programs in France, the students are asked to select as the scenario to consider for the tutorial activity a project on which they work in one of the modules of their program.

4.1 Exercise description

The objective of the tutorial activity is to guide students on thinking about the implications of their project beyond a technical assessment. To do so, the students are requested to carry out a diagnosis of the multi-dimensional facets of their project. This is done by answering a set of questions using the pre-defined ethics-by-design diagnosis canvas, shown in Figure 1. The canvas is designed to reflect the individual understanding of each student on the challenges and opportunities of the development of their chosen project.

The ethics-by-design diagnosis model is inspired by the work of Maurice Chiodo and Dennis Muller [14] who proposed a framework in the form of a manifesto to identify and address every aspects of ethical questioning when working on and designing a solution to a mathematical problem. Their methodology involves ten main domains that are referred to as pillars, each divided in a series of detailed questions and sub-questions to take into account.

The proposed tutorial activity transposes the manifesto in a format that is manipulable within the time frame of the activity, *i.e.*, less than 3 hours, based on the model of an innovation canvas [15]. In particular, the diagnosis is divided in four main components: Approach, Impact, Opportunity, Capability. The focus is on describing the project objectives, constraints and main hypotheses; identifying the impact of the project developments and results; identifying the benefits and opportunities for the project; and identifying the key capacity for the realization of the project.

Approach: This covers three questions: 1) to summarize the scope of the project, 2) to list its objectives and main constraints, and 3) to identify the main work assumptions. The goal is to verify whether the student has a clear understanding of what the project is about.

Impact: This involves two questions: 1) to identify positive and negative impacts of the project, and 2) to explain why the solution proposed is a good solution. This component focuses on the notion of *goodness*. It encourages students to explain in which way(s) the proposed solution helps

positively address the identified problem and from which perspective(s).

Opportunity: This involves five questions to assess the motives and relevant outcome of the project: 1) to argue why this project is needed, 2) to indicate how the results of the project are communicated, 3) to specify how the work developments are documented, 4) to identify who benefits from the project, and 5) to explain in layman terms the results of the project. The last question is an important one. It makes students step back from the jargon of technical developments and to think about how to present their results in a way that is understandable by most people.

Capability: This part aims to question students on their strengths and limitations when working on the project, *i.e.*, to raise their awareness of the missing skill-set in order to develop the project in a responsible way. It is divided in five questions: 1) to review the background of the people working on the project, 2) to explain what makes these people authorize to use a dataset (if applicable), 3) to identify the limitations and biases of the people working in the project throughout the development process, 4) to summarize the expertise and the know-how of the people who work on the project, and 5) to elaborate on how to respond in case the results of the project are misused.

The canvas format imposes on purpose a space constraint. The objective is not to write an essay. Students are allowed to provide responses as bullet points with the clear instruction that it is not the quantity that makes the quality. They are also reminded that they need to develop their own reflection and that there are no wrong answers as long as the answers are justified.

4.2 Assessment

The tutorial activity is currently only assessed in the case of the MSc program. The marks obtained is individual and counts towards the final grade for the module. The exercise is marked based on two components: presentation that counts for 20% of the mark and quality of the analysis that counts for 80%.

The evaluation does not assess the opinion of the student; what is evaluated is their ability to embed an ethic diagnosis in their project contributions. The quality of the analysis is graded based on a five-level grid, from superficial responses to each question (minimum mark) to constructive arguments for each question and a demonstrated ability of critical thinking with respect to these arguments and proposed solutions (maximum mark).

4.3 Some remarks on the tutorial

The tutorial activity has run for three consecutive years. Most of the students fill their canvas in with care, some

Ethics-by-design diagnosis	
Your name:	OPPORTUNITY O1. Why this project? O2. For who is the project? O3. How are the results of the project communicated? O4. How is the work development documented? O5. How can the results of the project be explained? O6. Can the results be reproduced?
APPROACH A1. What is the project about ? (scope, region, type of data, <i>etc.</i>) A2. What are the project objectives and constraints? A3. What are the main assumptions?	CAPABILITY C1. Who works on the project (team background)? C2. What makes you authorise to use the data? C3. What are your team limitations and biases in the development process? C4. What is the team expertise and know-how to work on the project? C5. How can you respond if your results are misused?
IMPACT I1. What are the positive and negative impacts of the project? Social: Environmental: Economic: I2. Why is the solution proposed a good solution?	Sources [1] M. Chiodo, D. Muller, "Manifesto for the Responsible Development of Mathematical Works -- A Tool for Practitioners and for Management", Technical Report, arXiv, arXiv:2306.09131 [2] Innovation Canvas, Innovate UK, https://www.innovationcanvas.ktn-uk.org/

Figure 1: Ethics-by-design diagnosis canvas.

make insightful observations. Some examples of answers are shown in Table 2. A point 4 and point 6 have in general been observed every year between the average and the min and max marks obtained in the cohort.

We noticed a general improvement in the quality of the returned diagnosis between the first year when the canvas was introduced as part of the tutorial activity and the last two years. We believe that this the result of us providing better instructions in the last two years. More specifically, in the first year, we had reserved a very short time only (around 5 min) to go through the canvas with the students, leaving them in some autonomy to explore and fill it in. In the last two years, we decided instead to dedicate 15-20 min to present the exercise in detail and better explain its objective and intention, as well discuss what is expected for

each question. While specific examples of answers are not provided on purpose in order not to influence the responses, we explicitly encourage students to directly ask for further clarification during the tutorial.

From next year, we will test a new model for the tutorial. Students are currently requested to fill the canvas in only once, *e.g.*, for the MSc students, this is done after completing their project. As a result, the questions are worked on as an after thought. From next year, a new exercise will be introduced in the MEng settings in France. Students will first be asked to draft the plan of a project idea related to the development of a conversational agent in support of an academic / professional task (the choice will be left to the students). They will then be requested to perform the diagnosis and filling the canvas twice, at the beginning, *i.e.*,

Question	Example answer
Why is the solution proposed a good solution?	Example 1 (2026): <i>Technical "Good": This project is a valuable first step, but not a complete solution. The results are directional and model limitations prevent robust conclusions; Moral "Good": This solution risks locking in a suboptimal fix, diverting pressure away from the real issue: the constrained grid.</i> Example 2 (2025) <i>Considers a wide scope of both economical and environmental impact across the entire company's fleet. Applies proven optimisation techniques that can be reproduced and implemented by the company</i> Example 3 (2024) <i>Adopting a dynamic tariff policy for lower-income areas is a good solution because a) It will diversify Lime's clientele and improve their bike usage rate (currently only 2.6%) b) It aligns with the 15-minute city concept of Paris since it will improve bike accessibility and elevate active mobility trends in the city. c) It encourages social inclusion of all income groups, which is a fundamental principle that fosters a just energy transition.</i>
What are your team limitations and biases in the development process?	Example 1 (2026): <i>Limited computing experience → restricts the complexity of modelling. Team only composed of engineers → technical bias, limits social, economic, and regulatory perspectives. Generative AI tools for code development → may introduce errors + over reliance. Time constraints → restricted the depth of the analysis (e.g. modelling the flexibility potential of DC was not explored)</i> Example 2 (2026): <i>As engineers, we default to technical fixes, but curtailment may be better addressed through policy or behavioural change, such as grid investment incentives or demand-side regulation.</i> Example 3 (2025): <i>- Possible bias towards European data regulations (focus on GDPR). - Limited real-world implementation (theoretical focus rather than deployment). - Technical feasibility vs. real-world adoption gap. (2025)</i>
How can you respond if your results are misused?	Example 1 (2026): <i>Report and appendices are documented so any selective or misleading citation can be checked against the original methodology and caveats. Key limitations are stated explicitly in the report (e.g. price cannibalisation affecting all three countries, not just neighbours; Hungary's model depending on specific import-dependency conditions). The team can publicly clarify or correct misinterpretations, since the work is an academic submission with named authors. The open-data, open-methodology approach means third parties can independently verify or challenge any claim rather than relying solely on the team's framing</i> Example 2 (2025): <i>- Clarify scope: Our work is an academic analysis, not an implementation guide. - Encourage applying our findings ethically and legally. - Acknowledge limitations: Our research is based on theoretical analysis, not direct system deployment. - Engage in discussions: Open to refining ideas through feedback and further research.</i> Example 3 (2024): <i>A suitable non-technical response strategy to wrong results or outcomes is revert to literature for established standards for monitoring and modelling pollutant levels. Thankfully, this is an area with a lot interest and work globally with international organisations such as WHO with published guidelines and studies.</i>

Table 2: Example answers to three illustrative questions in the canvas.

when the type of task is selected, and at the end, *i.e.*, after the full project plan is elaborated. By doing so, we want to see whether, and if so, to which extent, the diagnosis questions have an impact on the development process.

5 Discussion and future perspectives

The course has run for six years. This has enabled us to test different things. In particular, several adjustments have been made over the years to both the content and the format in order to adapt both to the evolution of topics and challenges, as well as to the evolution of students themselves. It is noticeable that students are today more familiarized with the use of data and digital infrastructures (*e.g.*, APIs, cloud service instances) in their daily routine than they were a few years ago. The widespread development of generative Artificial Intelligence (AI) technologies has also had an incidence on how students engage, at the academic level, on the issues discussed through the course.

In addition to noting these evolutions, we have had to consider other key challenges when designing the course.

Sense of legitimacy In 2024, we organized an online event to discuss initiatives that work on developing tools to embed ethical, social and environmental considerations in research practices. The event gathered participants from four initiatives who brainstormed on the reasons, goals and challenges of starting these initiatives and developing relevant tools. A challenge that was raised during the event relates to the sense of legitimacy, *i.e.*, to not feel legitimate to talk about this type of issues. During the event, some participants mentioned that as not specialists of these questions, they sometimes felt that they were not entitled to talk about them. Others argued however that even if we are not specialists, we generally possess more knowledge than the students do, which makes our intervention still valuable. This sense of not necessarily being legitimate has strongly impacted the way the course has been developing. In particular, it has

significantly encouraged us to get back to study in order to consolidate our own knowledge on key concepts underlying the course, especially in ethics, sustainability and systemic assessment. We believe that this personal commitment has also been a useful for us to rethink our own practice in research.

Course title Finding a relevant title for the course has not been an easy task. Different keywords have been considered to describe what the course is about, including ethics, responsibility, accountability or sustainability, each word not only involving different aspects but also conveying different values. By essence, this type of courses cannot avoid polarized views, an aspect that Chiodo, Bursill-Hall and Mueller had also reported [13]. Delivering a course on what responsible digital developments entail needs to factor in that students have different cultural and socio-economic backgrounds, and that values are relative to one's background. The opportunity to offer this course in three different settings with different types of audiences has enabled us to gain a rich experience. The UK setting is in general more international than the French settings but also represents an environment where students tend to come from well-off backgrounds. The two French settings also differ in the type of students that they involve. The French Engineering School system (Grande Ecole) tends to favor the enrollment of students coming from privileged socio-economic groups, while universities tend to offer more equality of opportunities. Discussing the multi-dimensional challenges of digital developments with students enrolled in different types of engineering programs has had a significant impact on our own perspectives.

Environmental footprint A key aspect of responsible developments concerns the environmental footprint of digital systems. While the course discusses environmental challenges, it does so to a limited extend only. We believe than being able to go with the students into the details of these grand challenges would require to significantly expend the scope of the course and make it a full module. A full module (e.g., 20 hours) would make it possible to cover in-depth all aspects of sustainability, including the economic models, and to introduce theoretical components. This would however require a complete change in its overall organization. In particular, this would require to involve other lecturers with expertise in each of the different topics, which makes it a very different scale. We leave for the future the opportunity to turn the proposed course into a full module.

Our experience teaching responsible digital developments has been encouraging and we believe that there are opportunities for the course to continue to be delivered and to evolve in the years to come. Our rational when working with students in the course is not in terms of short timescales. To

us, the horizon of transformation for making dominant narratives evolve is in the longer term. We thus feel rewarded when students come at the end of the class to continue the discussion with us. It gives us some confidence that not everyone sees the discussion as a tick box exercise with which to comply. We hope that by sharing this experience, we can help other researchers and teachers to create their own version of a course discussing the challenges of responsible digital developments.

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