

# Design Principles for Tech-Driven Innovation Courses

A Condensed Summary

Kirstin Kohler, [k.kohler@th-mannheim.de](mailto:k.kohler@th-mannheim.de)  
Chutimon Espedal, [c.espedal@th-mannheim.de](mailto:c.espedal@th-mannheim.de)  
Technical University of Applied Sciences Mannheim

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## 1. Summary

The core contribution of this document is the comprehensive set of 22 design principles for course development. The principles serve educators with experience in challenge-based learning practices to create and define courses on tech-driven innovation at their respective universities. The principles guide the course's design with the aim of increasing the student's science-based innovation and entrepreneurial capacity while fostering a collaborative mindset and systems-thinking.

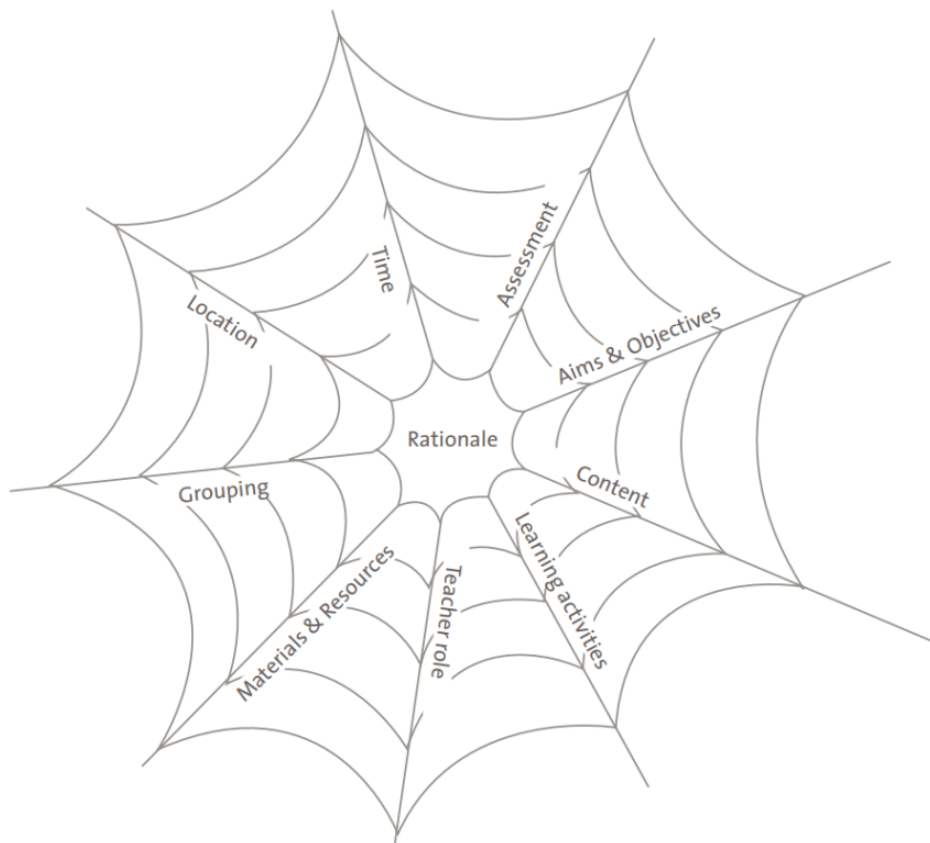
The principles emphasize that courses must be practical and hands-on, follow a tech-driven innovation process that starts with technology exploration, and promote learning goals in three main categories: entrepreneurial skills, technological skills, and the ability to master the innovation process by balancing technological capabilities with societal needs and market potential.

The principles are the essence of the deliverable D2.1: Course Manual for Educators, which is the result of WP2 of the TECH2X project at the end of Phase 1. The full version of D2.1 is available on request.

The principles have been investigated through a rigorous design research process building on the experience of two established tech-driven courses at ESADE and UNIBO. The ESADE course has the name TeSI. At UNIBO the course is labeled TechForward. The knowledge gathered has been codified through methods including document analysis, observations, interviews, and focus groups. Further details about the research process can also be accessed through the public deliverable D2.1 of the TECH2X Project.

## 2. Building Blocks of Courses

To ensure that the design principles cover all crucial components for course development in a comprehensive way, we derived a list of aspects from the literature as well as from observing and interviewing our project partners. The results of this investigation have been organized by van den Akker's curriculum components [1]. Van den Akker conceptualized the curriculum as a spider web (see Figure 1), where each element is interconnected, forming a strong and cohesive structure. The model emphasizes the need for balance among all components. Over emphasizing one aspect can disrupt the system's harmony, potentially leading to its breakdown. We chose this framework to derive and order our design principles. The single elements - respective to the underlying questions behind each component - of the model is further specified in Table 1. The categories serve as structure for Section 3 that lists the principles.



**Figure 1:** Curricula spider web (Source: van den Akker [1], page 22)

Component	Definition
Rationale	Why are they learning?
Aims & objectives	Which goals are the learning towards?
Content	What are they learning?
Learning activities	How are they learning?
Teacher role	How is the teacher facilitating their learning?
Materials & resources	Which materials, tools or resources are they learning with?
Grouping	With whom are they learning?
Location	Where are they learning?
Time	When are they learning?
Assessment	How to assess their learning?

**Table 1:** Curriculum components (Source: van den Akker [1], page 20)

The “rationale” component has a specific meaning in van den Akker's model, underlined by the location in the middle of the spider web (Figure 1). It determines what knowledge, skills, and values are most important for students to learn. Without a clearly defined rationale, the other components of the curriculum - such as the teaching methods (didactical), the learning activities (pedagogical), and the assessment (evaluative) – lack a cohesive direction.

The principles presented in Section 3 subordinate the overall **rationale** of the courses in the TECH2X project, which is:

Increase the students’ science-based innovation and entrepreneurial capacity while fostering a collaborative mindset and systems-thinking within the HEIs transition to the 4<sup>th</sup> generation university model.

### 3. Principles for Tech-driven Innovation Courses

The following section lists the design principles. Each principle is numbered by an identifier referring to the curriculum components (compare **Table 1**) it is subordinated.

We emphasize the fact that the design principles can't be seen as independent units. The complete collection of design principles forms a coherent, connected set. As van den Akker claims, the components need to be aligned. For the design principles presented here, this means they must be understood as one course framework. Educators won't be able to pick single isolated principles to create the respective course designs but instead must apply all of them as one entity.

Further work in the TECH2X project will provide design principles with more guidance and enrich it with the experience of the partners of Phase 2 of the project.

#### 3.1. Aims and Objectives

##### A01: Course learning goals

The course should foster learning goals in the following categories:

##### (a) Entrepreneurial skills

- Self-directed learning.
- Taking initiative towards actions.
- Working in interdisciplinary teams.
- Communicating concept and critical reflecting concepts.

##### (b) Technological skills

- Understand deep technology to the extent that the gap between scientific discoveries and societal needs can be analyzed.
- Co-create socially relevant innovation applications for emerging technologies through an effective dialogue with researchers.

##### (c) The ability to master a tech-driven innovation process while balancing technological capabilities, with societal needs and market potential

- Formulate and justify design decisions by constructing assumptions and validating hypotheses through evidence-based research process.
- Create viable business models for technology-based solutions, considering commercialization strategies.

## 3.2. Assessment

### AS1: Expected project outcome

Students' main deliverables at the end of the course are:

- A report specifying the (societal) problem as well as the concept of the tech-driven solution that is addressing the problem.
- The final presentation.
- A representation of the solution which demonstrates the main functionalities in a comprehensive way. The representation can have various forms. Examples are a functional prototype, a simulation, or a video.
- Further optional deliverables could be peer reviews and/or posters of the solution and team.

Quality of the outcomes:

- The deliverables should demonstrate depth in the analysis and in the solution (they can have different forms: a functional prototype could be suitable, as well as a video).
- The outcomes should demonstrate the understanding of the process and include a full scan of the opportunities in which the technologies can be utilized.
- The outcomes should focus on what can be achieved, rather than what is to be produced.

### AS2: Student assessment method

Students' grading is based on:

- Deliverables.
- The learning journey (how students navigated through the innovation process).

Group performance has the highest percentage in the total assessment.

### 3.3. Content

#### CO1: Amount of theory input

The courses should be very practical orientated / hands-on. Theoretical input is only provided in short 20-30 minute sessions.

#### CO2: Integration of societal impact learning

The integration of societal impact can have various facets. It could be implicit (e.g. by expecting the elaboration of the societal impact of the provided solution as one “quality dimension” of the project outcome) or explicit (e.g. by providing learning activities that foster the consideration of the societal impact):

- **Implicit:** Given through the context of the course, students are required to identify / choose a problem with (societal) impact to be addressed by the given deep-tech. The (societal) impact of the presented solution needs to be explored and presented at the end of the project as justification for the value of the solution (compare “expected project outcomes”).
- **Explicit:** Learning activity during the “opportunity identification” phase of the innovation process can give the students guidance on how to identify the problem.

Examples of such learning activities are input and exercises on system thinking. Learning activities like “Back of the Envelope Calculation”, conducted during the i2Planet week, give the students guidance on how to estimate and communicate the societal impact.

#### CO3: Integration of technology understanding

Students’ exposure to technology has three important facets:

##### 1. Timing of tech introduction

- The program starts with technology (and therefore, differs from other well-known user-centered processes, which are conducted in courses like ME310) [2]
- Introducing and exploring the technology is done in an early phase of the course.

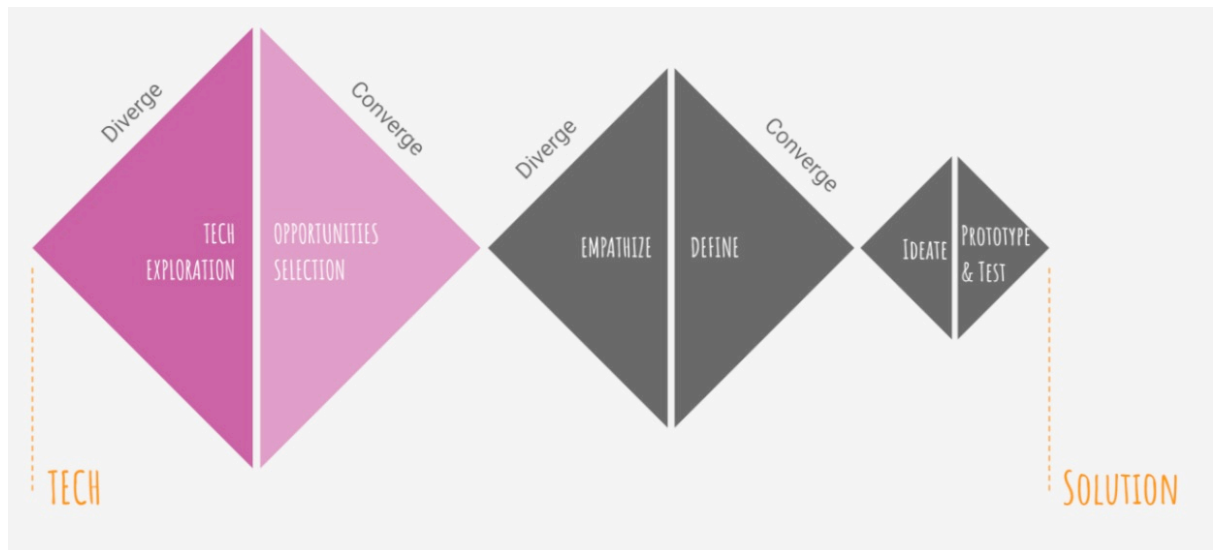
##### 2. Assignment of technology to teams within the course:

- The course offers a set of technologies provided by the tech partners.

- Students might get the opportunity to wish for a specific technology after being exposed/introduced to all technologies, or they get assigned to one technology by the teaching team.
  - Each team handles one technology, which differs between teams, so that everyone gains deeper knowledge of one specific technology.
  - By exchanging between the other teams during the course, the overall exposure to technology is therefore broader.
- 3. Entry to technology**
- The students should get a lightweight, simplified and accessible entry to the technology. Example: Tech-Cards provide one suitable format to introduce a technology. They give a short characterization of the deep-tech's capabilities and properties, without frightening non-technical-background students.
- 4. Direct contact with tech owners and CERN experience**
- Direct contact with the tech owners fosters the engagement with technology
  - The CERN stay, provided as part of i2Planet, provides additional deeper insights and understanding of technology.

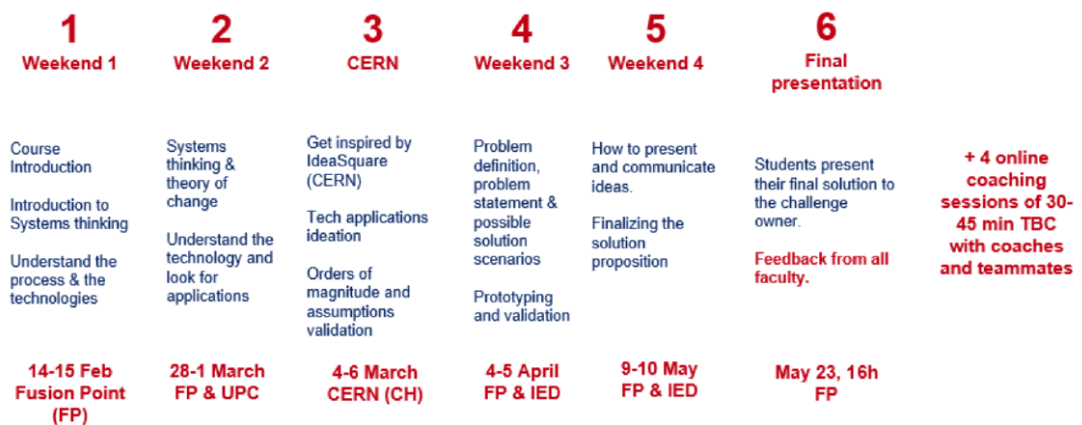
#### CO4: Innovation process

- During the course the students are navigated through a tech-driven innovation process which includes the following phases:
  - Tech exploration
  - Identification of societal impact
  - User need exploration
  - Concept creation
- Students should be engaged in dedicated learning activities that give them methodological support in the respective phases as they move along the process (compare design principle “learning activities”).
- The overall structure of the course should give boundaries within this process by expecting certain intermediate outcomes or reaching certain phases at a given schedule in the course (e.g. by providing milestones).
- **Figure 2** illustrates the innovation process conducted in TechForward, for example (see also [3] for more information).
- **Figure 3** illustrates the phases through referring to the expected intermediate work artefacts and activities as conducted in TeSI as an example.
- The conducted innovation process does not define/require a certain amount or type of iterations/prototypes. Students decide self-directed and guided by coaches how to iterate and navigate between different phases/activities depending on the project development/context.



**Figure 2:** Tech-Push innovation process according to [3].

## TeSi 2024 Innovation Journey



**Figure 3:** Innovation process guided through as conducted in TeSi as example.

### 3.4. Grouping

#### GR1: Group forming

The student teams should have a size of between 4-6 people. The process of building the team should be thorough, with the aim of creating teams with a high diversity (balancing disciplines, personalities, gender, knowledge in processes and technology etc.).

#### GR2: Eligible students

Students should be enrolled in a Master's program: all disciplines are welcome.

#### GR3: Prerequisite

Students should be proficient in English and willing/motivated to get in touch with technology.

### 3.5. Learning Activities

#### LA1: Pedagogy methods

The courses are interdisciplinary courses following a problem-based pedagogy. The main learning happens through solving a real-life innovation challenge as a team. The conducted process is experimental (iterative, prototyping based). Students work in collaboration with scientists/tech partners. The learning activities are guided by the innovation process. However, the students are responsible for navigating through the innovation process by themselves, with the guidance of coaches in a self-responsible way. Students learn to navigate and jump between exploring the feasibility, exploring the problem-solution fit.

#### LA2: i2Planet – Intensive Learning Activity at CERN

##### **Students' perspective:**

The i2Planet learning activity in combination with the CERN visit has the following impact:

- It encourages out-of-the-box thinking.
- It supports ideation beyond normal project constraints (diverging /craziness).
- It improves team dynamics.

##### **Teaching team perspective:**

The i2Planet learning activities are mainly in the hands of the CERN team. Significant preparation work has been conducted before the visit to adapt and connect the i2Planet to the technologies/challenges of the programs and teams. The adaptation happens through the selection of the appropriate i2Planet module, the crafting of the narrative and the lectures/expertise provided by the CERN team during the stay. It requires significant effort to align between the respective teaching team from the lighthouse courses and the CERN team.

The curriculum should contain an intensive week (practical week) in which participants work, for approximately up to 40 hours equivalent to a full working week, on developing cognitive qualities supporting their tech understanding, as well as group work and working in innovation at large. Such qualities include: openness to alternative futures, managing uncertainty and complexity, and self-organized transdisciplinary teamwork.

The fostering of such skills during a practical week should take place outside the university, such that the students' passive role as a receiver of knowledge, as well as the pressure of performance and receiving grades is less apparent. Instead, an external location shifts the focus to actively seeking out information. Research institutions or co-working spaces are well suited for this purpose as they - in addition to taking away the "educational pressure" of a university setting - typically provide an environment that supports collaboration.

The content/narrative of that intensive week should be created collaboratively between the hosting institution and the course's professors.

### LA3: Innovation process activities

Learning activities should provide methodological support in the respective phases of the innovation process:

Examples of such learning activities are:

- Opportunity identification can be instructed with the "Technology Transfer Toolbox – a step-by-step guide" from TU Delft (Sem Carree and Darp Hartmann) or with the methods of "divergence map and tech functional scenarios" provided by Balboni et al. [4]
- Ideation and Prototyping during the phase of concept realization with methods from Design Thinking toolkits like the Ideo Design Kit [5].

### 3.6. Teachers' Role

#### TR1: Teachers' role

The teaching team is covered by people contributing to the following three roles:

- The main contact for the students is a teaching assistant, who is responsible for the course organization and serves as a main contact.
- In addition, several professors are associated with the program (this is helpful to align the course with different departments from an administrative, legal point of view, but also to cover the various disciplines in these interdisciplinary student teams).
- The teams are accompanied by coaches, who talk to the students on a regular basis and consult with them depending on their project status. Professors and teaching assistants could also act as coaches.
- Additionally, the personnel at IdeaSquare completes the learning experience of the students through their input and expertise during the i2Planet learning unit.

If possible, the teaching team should also be interdisciplinary composed to support interdisciplinary teamwork.

In addition, the courses leverage the knowledge from the university network in a flexible manner to support the students with their projects on specific topics. The teaching team provides contacts with specialists within the university for specific (vertical) problems that can occur in the various projects. Especially in the context of deep-tech projects this is particularly valuable, as a specialist of various disciplines can be accessed easily.

### 3.7. Location

#### L01: Location

The courses can be organized in a **hybrid setting**. A meaningful distribution between activities in-person/online is the following:

**Online sessions:** They are easier to organize timewise, due to the interdisciplinary / distributed student team members (having different schedules in their faculties or joining from different universities) and distributed teaching team members/coaches (coming from different organizations/universities). The following activities are well suited to be conducted online:

- Coaching
- Teamwork (self-organized by students)
- Meeting with tech partners / exposure to deep technology (if they are located in a different country). If they are conducted online, a sequence of meetings should be curated by the teaching team to intensify the contact of the students with the technology experts.

The following activities are well suited to be conducted **in-person**:

- Kick-off / final presentation
- Team building activities
- Meeting with tech partners / exposure to deep technology (if they are close by or an intensive workshop can be organized)
- Lectures and certain group activities (especially first application of methods introduced during the lectures and deep dives)

If joint time in person is hard to organize, special **intensive weekends** or **intensive days** for specific project work on dedicated topics, team building, new method or technology exposure are recommended.

The i2Planet provides an additional opportunity to intensify work in presence at a location outside the university.

### 3.8. Timing

#### TI1: Effort/timespan

Courses should span at least one semester (3.5 months). Given the learning goals and transformative character of the courses the expected workload of the students should be covered by 12-15 ECTS. It must be ensured that the students get these credits included in their study records.

#### TI2: Contact hours

Contact hours are defined by:

- Lecture units
- Coaching sessions
- i2Planet week
- Kick-off / final presentation
- Meeting with tech partners / exposure to technology

A time span between 60 and 120 hours without the additional coaching time per team.

#### TI3: Timeline

The course calendar is roughly mapped to phases of the innovation process in a way that certain weeks have dedicated themes, project goals or hard milestones. Methods that support the various phases of the innovation process navigate the students through their journey and are applied after being introduced in a lecture.

#### TI4: Preparation effort

The preparation of the course requires significant effort from the teaching team to identify research partners, set their expectations correctly and prepare the collaboration between researchers and students. This might require the setting up of additional courses/trainings for researchers to prepare them for the collaboration.

### 3.9. Materials and Resources

#### MR1: Learning resources & materials

Miro templates are provided to the students to support their activities. The use of Miro for their project documentation is mandatory. They also share their results / progress with the coaches via Miro. The digital, collaborative documentation facilitates the creation of a report at the end of the course (compare “learning outcome”). It also facilitates the exchange within the (distributed) student team and in the communication with the coaches during online meetings.

The slides from lectures are provided to the students. Additionally, they might get hints to literature or other sources on project demand by the coaches. There is no book or script as foundation of the courses.

### 3.10. Miscellaneous

This category summarizes findings that could not be sorted according to one of the previous curriculum elements. However, we noted them as important in the context of the tech-driven innovation courses and therefore list them in an extra section.

#### 01: Financial contribution

The trips should be covered by the universities. It should not require financial contribution from the students or technology partners. Students may get a grant payment from the university, which allows them to self-organize and cover the travel expenses. For trips, it is recommended to have everyone hosted in the same accommodation for the reason of team building.

#### 02: Course administration & policies

Students might come together in the course from different universities.

Universities offering this course should establish mechanisms to formally recognize students' participation and learning outcomes. This could include elective credits, internship recognition, or documentation in a diploma supplement. Each institution must adapt the approach to its own curriculum structure.

Policies:

- During the courses the supervisors are not very strict with the deadlines of intermediate work artefacts.
- Final deliverables and presentations are fixed and non-negotiable.
- If students can't participate due to illness, they must inform their teaching team and team-mates.

## Glossary

Deep Tech	
4th generation university model	The 4th generation university model is an integrated approach that combines learning, research, and innovation to actively co-create with industry, government, and society to solve real-world problems and foster regional development.
Curriculum	According to Taba's definition a "plan for learning". The curriculum activities mentioned in the report focus on the meso and micro level according to van den Akkers' taxonomy. The micro levels describe course activities.
DBR	Design Based Research
Deep Tech	Technologies based on substantial scientific discoveries and engineering innovations
EDR	Educational Design (Based) Research
I2Planet	Special learning format conducted at CERN IdeaSquare as part of the Tech-driven innovation courses
Lighthouse courses	TeSI and TechForward are the Lighthouse courses. Their curricula are investigated through the conducted Educational Design Research with the intention that other universities (in particular TH-MA and METU) can set up similar courses.
TechForward	Tech-driven innovation Course at UNIBO
TeSI	Technology for Social Innovation course led by Esade as part of the Fusion Point partnership between Esade, UPC (engineering school) and IED (design school)
TRL	Technology Readiness Level gives a metric for evaluating the maturity of a technology

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