Coach Manual
Safe-by-Design Serious Game
Guide for teachers to facilitate a serious game workshop

SAFE BY DESIGN
TAKE CARE OF THE FUTURE

Why a serious Safe-by-Design game?

Safe-by-Design is an emerging concept that aims to establish new ways of thinking and acting throughout the chain of scientific and technological innovations. Instead of only focusing on the expected benefits of new technologies, Safe-by-Design encourages researchers and innovators to take potential undesirable effects into account from the earliest phases of research, design or development onwards and to proactively address these. Ultimately, this new way of thinking and acting contributes to developing safer and more responsible scientific and technological developments[1].

This serious game introduces students to a broad scope of safety issues that are relevant for Safe-by-Design. It encourages discussions to highlight the importance of thinking about safety from an early stage onwards.

Overview of serious game workshop

The game is all about developing a solution (innovation/product) to a societal problem. The solution should be safe by its design, ethically acceptable and in line with the needs, demands and wishes of the variety of stakeholders involved in or affected by the solution.

The gaming session starts with a short briefing to introduce the concept of Safe-by-Design, the game mechanics and the societal problem that will be addressed during the game. Students, in teams of 4-6, then have one hour to develop a solution to that societal problem. Their primary task is to talk about what steps need to be taken in each phase of innovation/product development. While working on the development of their solution, teams face various challenges that they have to address and respond to, while improving their prototype under time pressure. After one hour, teams pitch their proposed solution to the other teams. Based on the quality of their design and the amount of "system awareness" and "uncertainty reduction" points (see below), a winner is collectively chosen.

During the subsequent debriefing, the (design) choices, points earned and the chosen winner are used as starting points for a critical group discussion on what it means to design for safety and what is needed to make safer design choices. The goal is for students to leave the session with a broader conception of the potential safety issues around the innovation under discussion and a better understanding of, and curiosity about, the added value of Safe-by-Design.

Please note: throughout the gaming session, no explicit judgement is made as to what 'safe choices' are or what 'Safe-by-Design' is. The aim is to encourage students' critical thinking about what safety/Safe-by-Design is – and what it is not – and how it relates to other aspects of innovation development and implementation in society. It is up to the students to reflect and justify when and why certain Safe-by-Design aspects are considered relevant and need to be included in innovation development. As such, the game can be a basis for additional learning activities that provide more background on the conceptual origins and practical implications of Safe-by-Design.

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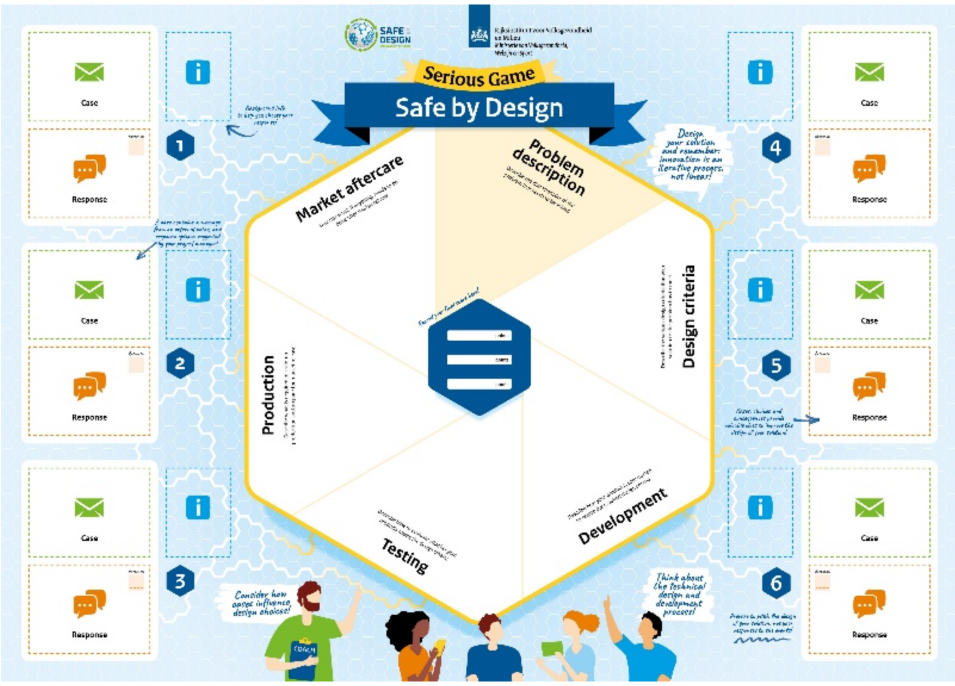
[1] For more information about safe-by-design, see, for example:

van de Poel, I., & Robaey, Z. (2017). Safe-by-Design: from Safety to Responsibility. *NanoEthics*, *11*(3), 297–306

Arentshorst, M.E., Smit, K., Freese, M., Klaassen, P. & van der Vlugt, C. Introducing a new way of safety thinking in higher education: lessons learned from applying the serious Safe-by-Design game. *In development.*

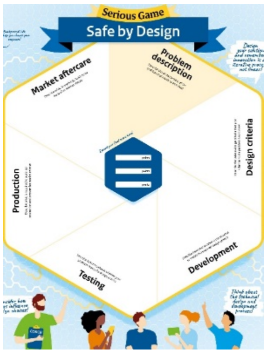
Game contents explained



1 Game board
Size A0

- Stage-gate model in the centre
- 6 intervention boxes at the sides

This game uses a simplified version of the stage-gate model[2] as an analytical tool to identify different Safe-by-Design aspects during an innovation process. The students decide when and based on what information they work on and complete the different stage-gate phases.



The innovation phases are visualised in a hexagon to emphasise that in reality, one has to deal with complexity. In order to end-up with technological applications that are safe by their design and of added value to society, the input of one phase (should) also result in changes and adjustments of other phases in an ongoing process, which has to be understood as an iterative process, not as a linear one.

[2] Cooper, R. G., Edgett, S. J., & Kleinschmidt, E. J. (2002). Optimizing the stage-gate process: what best-practice companies are doing. *Research-Technology Management*, *45*(5), 21–27.

While working on the development of the prototype, teams face challenges – via Case Cards – they have to address and respond to, while improving their solution under time pressure. The cases represent communications from different stakeholders who are involved in or affected by the solution that is being developed, see also Table 2. The game contains six Case Cards in total. A guideline for when to hand out which Case Card is provided in Annexe III.

6 Case Cards

To be placed on the ✉ symbol on the game board

- Description of case on the right
- Response options to address case on the left
- Logo of the sending stakeholder on the top left
- Handed out during the game at specific times (Annexe II)

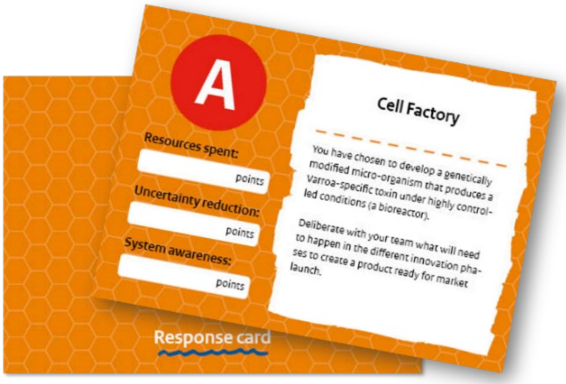
To gain more insight into the options provided to address the case, Information Cards are provided with more information, including implicit references to possible consequences.

23 Information Cards

To be placed on the ℹ symbol on the game board

- Provide more information on response options to Case Card
- Handed out together with corresponding Case Card

After a team decides how to address the case, they receive the corresponding Response Card, describing the consequences of their choice. The cards are a way of providing direct feedback to the students during the gameplay and/or to shift attention back to the design by closing an ongoing discussion.



23 Response Cards

To be placed on the symbol on the game board

- Response to choice made to address case on the right
- Scores in 3 categories on the left:
  - ***Resources spent*** – refers to the amount of resources spent such as time, money, equipment, etc.
  - ***Uncertainty reduction*** – refers to the effort undertaken to reduce uncertainties.
  - ***System awareness*** – refers to the conscious handling of innovation chain and related stakeholders, their roles and responsibilities.
- Handed out after choice is made how to address case.
- The points and described consequences aim to create insights. These can or should, in turn, be integrated into the further development of the design to optimise it.

On the right you can see an example of the different game cards placed on the gameboard spaces.

Roles in the game

First of all, students take on the role of scientists in this game. Their task is to develop a prototyped solution for the problem that is central to the game. The game leader facilitates the teams in the game. During the game, the students are confronted with different stakeholders (see Table 2). Communications from these stakeholders are provided during the game via the Case, Information and Response Cards that the game leader hands out at specific times during the game (see also the Time Guide in Annexe III).

Table 2. Roles Serious Safe-by-Design game.

Who/element in game	**Role**	**Description**
Students	R&D team	Addressing the problem central to the game
Teacher	Game leader	Facilitating gameplay, handing out interventions and encouraging students to reflect on if and how the interventions influence their design choices
Fictional stakeholders	Representatives of governmental, commercial and/or societal interests	The case cards display logos of different stakeholders that represent various interests. There are different logos to represent governmental interest, commercial interest and societal interest.

Preparation

The gaming session consists of three phases: briefing, gameplay and debriefing. Each phase requires separate preparation, as shown in the table below. This game requires teams of 4-6 students. For larger groups, the briefing can be done plenary, but it is recommended that one teacher (game leader) facilitates the gameplay and debriefing phases for a maximum of 5 teams.

Phase	Preparation
General	• Room with media facilities to present a PowerPoint and separate tables for teams of students to sit at. • Writing materials for each team such as post-it notes, pencils and markers.
Briefing	• PowerPoint presentation that includes an introduction to Safe-by-Design and explains the game (a content guide for the briefing is provided in Annexe II)
Gameplay	• Print and become familiar with the: - Game board (A0) - Cases, Information and Response Cards - Time guide to keep track of teams' progression (Annexe III)
Debriefing	• Guide to assist discussion (Annexe IV)

Game Session (120) minutes

A step-by-step list of actions at each phase of the game is provided below. It is advisable to allow for a 5 to 15-minute break after the game session, prior to the debriefing.

Briefing (15 minutes)

- Present the PowerPoint presentation to the students to introduce them to:
    - the relevance and added value of Safe-by-Design;
    - the simplified stage-gate model as an analytical tool to identify different Safe-by-Design aspects during an innovation process;
    - the aim and rules of the game.
- Answer any questions and address uncertainties.

Game play (60 minutes)

- Start the clock for teams to start deliberating and working on the six elements of the stage-gate model in the centre of the game board.
- Make sure teams focus on writing down the actions they will undertake to develop their solution (on post-it notes or directly on the game board).
- Hand out the Case Cards: the challenges teams need to address. Use the Time Guide in Annexe III as a guideline for when to hand out which case.
- Hand out the corresponding Information Cards and encourage teams to deliberate each response option in relation to their prototype.
- Remind teams that their solution should be safe by its design, ethically acceptable and in line with the needs, demands and wishes of the variety of stakeholder involved in or affected by the solution.
- Make sure that teams write down their chosen response option and arguments resulting in this choice on the game board.
- As soon as a team has chosen how to address the case, give them the corresponding Response Card.
- Ask teams to finish working on the game board after one hour and start the debriefing.

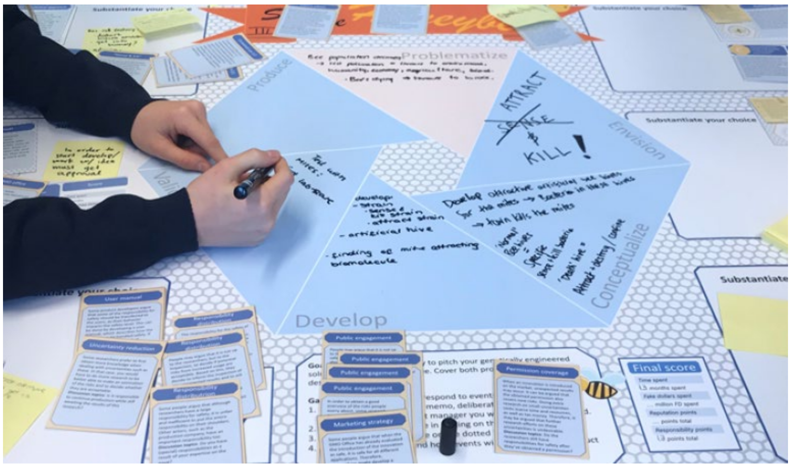


Illustration of gameplay with a previous version of the game materials

Debriefing (30-45 minutes)

- Ask teams to briefly present their prototyped solution to each other based on the six completed stage-gate phases of the game board, including the impacts of the cases addressed on their design.
- Next, ask them to assess other teams' solutions based on the substantiation of (design) choices made and to what extent Safe-by-Design elements are included in the design process.
- Use the students' assessments as a starting point to facilitate a discussion on Safe-by-Design. By delving deeper into the students' choices, specific issues and questions will automatically emerge.

To get the discussion going, an inventory can be made of the final scores of each team and of how the resources spent, uncertainty reduction and system awareness points are distributed among the different teams. Differences in distribution are a good starting point for further discussion. Outliers probably indicate an excessive pursuit of and focus on one element. This will most likely result in a prototype that has less chance to be successfully introduced to the market. Next, you could turn your attention to specific cases and any difference in responses between teams, or to evaluating the actual design choices that the teams made in the design of their solution/product. Throughout the discussion, students should be encouraged to reflect on the implications of the teams' scores, responses and design choices for the safety and feasibility of the eventual solution or product. **The facilitation guide in Annexe IV** describes discussion and related learning points for each of the elements – resources, uncertainty reduction and system awareness – central to the game and the values/general elements that play a role in innovation development.

Tailor this game to fit your learning goals

This game can be seen as a basis and is suitable for adding own examples or focusing on another case. Because the various challenges that are central to this game apply to multiple research and innovation development trajectories, the game can be extended to other domains as well. This is why we encourage personalising this game to fit specific learning goals. See Annexe I for the learning goals defined for this game.

Annexe I – Learning goals

Building on (the revised) Bloom's Taxonomy, the learning goals for this serious game are defined as stated below. The learning goals have been formulated for the game as a whole, different game elements and specific case issues presented during the game. The learning goals associated with the case cards have been generalised and may vary slightly depending on the case theme that is being played. The discussion guide in Annexe IV provides assistance in elaborating on the learning goals related to the different game elements. All of these can be highlighted during the discussion in the debriefing phase of the game as well.

Safe-by-Design Serious Game Learning goals	
Game element	Learning goal
Overall learning goals	
Overall game	To identify, explain and apply Safe-by-Design and its related aspects throughout the innovation process. This includes environmental, societal, ethical, regulatory, commercial and occupational concerns.
Peer discussion	To identify and appreciate the values behind different responses to safety issues and contrasting views on responsibility for those issues.
Design process	To explain and appreciate the responsibility of making technical design choices with a positive impact on broader society.
Game element associated learning goals	
Innovation phases	To identify different phases of innovation and describe how safety plays a role in each of them.
Resource investment points	To explain how safety requires investment in a material and professional sense, and that these investments translate into adherence to regulatory requirements and responsible research and innovation.
Uncertainty reduction points	To explain how reducing uncertainty contributes to a safer innovation process, even if not all acquired insights directly contribute to a safer product.
Systemic awareness points	To explain how thinking and working from a systemic perspective, in which different stakeholders and structures influence each other, can contribute to safer innovations.
Response cards/discussion	To reflect on the distinction between procedurally good action and societally responsible good action.
Case card associated learning goals	
Issue 1: Technical approach	To compare the different safety issues that come with different technical approaches to a solution.
Issue 2: Regulatory requirements	To identify the rules and regulations that apply to one's technical domain.
Issue 3: Public concerns	To compare different approaches in order to address public concerns about the safety impact of an innovation.
Issue 4: Broader impact	To identify the potential safety issues that an innovation may cause on a broader socio-economic scale.
Issue 5: The innovation chain	To compare different notions on responsibility for safety throughout the production chain of an innovation.
Issue 6: Unintended use	To compare different notions on responsibility for safety when an innovation is used in other ways than intended.

Annexe II – Briefing guide

An example of a briefing previously used to start the game is available with the downloadable content for the Safe-by-Design serious game workshop. Below, please find an overview of the essential points that should be made in all three sections of the briefing. We encourage you to adapt the briefing to the context of your educational setting and program!

Opening	
Title slide	The title slide can be projected at the start of the workshop. Please acknowledge the National Institute for Public Health and the Environment as the source of the game.
Overview of briefing sections	The briefing will discuss the following three points: - The concept of Safe-by-Design - Gameplay mechanics - Case-specific introduction of the narrative
Section 1: *introducing Safe-by-Design*	
Emerging technologies	This slide reminds the students that although emerging technologies such as biotech or nanotech hold huge promise, they come with serious potential hazards. Elaborate on both points with some examples.
Collingridge dilemma	The Collingridge dilemma is a cornerstone idea behind Safe-by-Design. It describes how, throughout an innovation process, there is an inverse correlation between the knowledge of impacts (which goes up), and the flexibility to adapt/influence the trajectory of innovation (which goes down). The point is that when it is easy to adjust a technology, the necessity is often not clear. However, when problems are discovered, and change is necessary, it has often become difficult and expensive.
Complex systems	Resolving the Collingridge dilemma is complicated by the fact that the modern world, and technological innovation, is an increasingly complex process. There are many stakeholders in highly segmented professional domains. This makes it difficult to assign one stakeholder or agent with the responsibility to ensure that innovation leads to safe applications.
Safe-by-Design	Safe-by-Design contributes to addressing these challenges by promoting a work ethic that instils partial responsibility in every stakeholder throughout the innovation chain. That responsibility consists of continuously thinking ahead on what safety issue one's current work may cause for stakeholders and environments down the road, and either addressing those issues through adapted design or communicating/collaborating with stakeholders who are better positioned to address them.
Stages of innovation	It is helpful to reinforce the idea of Safe-by-Design by describing innovation as a process that happens in stages. As early as the first vision of how to address a problem, one can start thinking about the practical issues that will be encountered when implementing such a solution in society. A simplified stage-gate model can be helpful to illustrate this point; it was also the basis for the innovation phases depicted on the gameboard.
Linear vs. iterative process	In addition to the previous notion, it is good to remind students that innovation does not happen in a linear way. Throughout the innovation process, one should continuously look to previous and future innovation stages and see what they can do in their current phase to ensure better outcomes all around. Encourage them to apply this in their gameplay and to approach the design of a solution in an iterative manner.

Section 2: Gameplay	
Main task	The main task for students is to design a solution/product in response to the problem that is central to the game, by describing what needs to happen at each innovation stage to develop this solution/product that is feasible and safe. • Remind students that in a fictional exercise, technical detail is not the main focus. They should focus on what technical features their solution should possess (design criteria), and how they will develop it to a market-ready product (development process). • The outcome of this task will be pitched to other students at the end of the gameplay.
Case cards	The students' secondary task is to respond to the case cards as they are handed to them. The case cards, information cards and response cards are intended to broaden their scope of relevant context to consider during development. So, encourage students to think about how the problems, views and consequences should affect their design in the main task.
Mechanics	Students can write relevant details about their technical design or development process directly on the game board or – if you want to re-use the game board – on post-it notes. The game facilitator (you) delivers the case cards and information cards are delivered throughout the game session (see Annexe III), 1 case + 3-4 info cards at a time. Once the team has made a decision, they indicate this to the game facilitator who will then bring the corresponding response card.
Section 3: problem	
Problem description	Case-specific: description of the issue for which the students will be developing a solution/product.
Problem characteristics	Case-specific: additional information that specifies details of the problem. This may help students to better understand the problem that they need to solve and discuss an approach for their solution/product.
Game start	This slide indicates the start of gameplay. It may be helpful to display a running countdown timer on this slide.
Closing	
Closing slide	The closing slide can be projected at the end of the workshop. Please acknowledge the Dutch Ministry of Infrastructure and Water Management as the funder for the development of the game.

Annexe III – Time guide

The table below helps game facilitators keep track of the cards handed out to different teams by noting this down in the respective columns/cells. It gives a rough indication of when specific interventions should be given to the students, both in terms of time and in relation to the progress that students are making with their primary task of designing a solution/product.

Safe-by-Design Serious Game Game facilitator guide											
Briefing	T = -15	The briefing is conducted as a 15-minute plenary presentation that explains the background of the game, the game mechanics & setting, and the problem-to-be-solved.									
Gameplay		**Team**									
		1		2		3		4		5	
	Time	Case	Resp	Case	Resp	Case	Resp	Case	Resp	Case	Resp
Case 1	T = 0										
Case 2	T = 5										
		Before handing out the next Case Card, teams should ideally have some ideas written down in the 'design criteria' phase of the stage-gate model.									
Case 3	T = 20										
		Before handing out the next Case Card, teams should ideally have some ideas written down in the 'testing' phase of the stage-gate model.									
Case 4	T = 35										
		Before handing out the next Case Card, teams should ideally have some ideas written down in the 'production' phase of the stage-gate model									
Case 5	T = 45										
Case 6	T = 55										
Debriefing	T = 60	End the game and give the groups 10-15 minutes to prepare their pitch and select their presenter (and have a quick toilet break).									
	T=70	Have the groups pitch their presentations, 1-3 minutes per group depending on the # of groups.									
	T=80	Have the groups hand out points to the team they think was best. The highest total number of points wins.									
	T=85	Facilitate a discussion on why they made their assessments the way they did.									
	T=90	Ask about specific scores, who got the highest/lowest for each score type and why they think they got this score and what it means for their decision making and end-result.									
	T=105	The session ends.									

Annexe IV – Guide to assist discussion

For general guidelines to facilitate a discussion, see the following reference documents:

- Teaching Tolerance. *Civil Discourse in the Classroom. Chapter 3: Take It Over. Moderating a Discussion.* https://www.tolerance.org/magazine/publications/civil-discourse-in-the-classroom/chapter-3-talk-it-over/moderating-a
- Center for Research on Learning & Teaching, University of Michigan. *Guidelines for Discussing Difficult or High-Stakes Topics*. http://crlt.umich.edu/publinks/generalguidelines
- Center for Research on Learning & Teaching, University of Michigan. *Guidelines for Classroom Interactions.* http://crlt.umich.edu/examples-discussion-guidelines

Discussion and related learning points for elements central in the game

Discussion point	**Learning points/goals**
Uncertainty reduction	The uncertainty reduction points earned in the game reflect the efforts undertaken to reduce uncertainties related to the development of the solution/product and its potential future consequences. • *Different types of uncertainty* can be identified in each phase of innovation development. For example, uncertainties related to the technology itself (is it safe to use?), methods and materials used to develop a technology (are they safe, sustainable and responsible for developers and users?) and uncertainties related to the implementation and embedding in practice (are there potential unforeseen side effects for humanity and/or the environment?). Although not all identified uncertainties will result (in the short-term) in a safer product, this contributes to establishing a product that is safe by its design, ethically acceptable and (as a minimum) compliant with the needs, demands and wishes of the variety of stakeholders involved in or affected by the solution. • *Identification uncertainties.* By taking uncertainties about new materials, products, processes or technologies into account integrally in research and innovation trajectories – and from the very first phases onwards – undesirable side effects can be proactively addressed during the design or development phase. This prevents adjustments in the design and/or production at a later stage, which are usually very expensive and time-consuming at that time or may cause the innovation to fail (i.e., Collingridge Dilemma of Control). This is why Safe-by-Design requires a mindset that goes beyond 'what needs to be done'. **Learning point**: reducing uncertainties during innovation development contributes to safer innovations that most likely result in a product that has a higher chance of being used in practice, because many unforeseen and potential (negative) side effects are addressed in an early phase of development. Remember that the key to Safe-by-Design is to take uncertainties into account integrally in the innovation development trajectory. A focus on identifying uncertainties does not imply that innovation development should be delayed or stopped: it is about addressing the uncertainties during the design and development phases.

System awareness	The system awareness points earned in the game reflect the extent to which different stakeholders involved and affected by the prototype – with their various roles, responsibilities, potential conflicts, et cetera – are taken into account and involved in the development of the prototype. • *Dynamic process of innovation development*. Technologies and their embedding in society (socio-institutional embedding) co-evolve. This means that several aspects of a technology become articulated over time due to interactions between different processes. In other words, science and technology are influenced by, and co-evolve with, societal demands and events. As a result, innovation development is a dynamic process that involves a wide range of stakeholders. • *System perspective.* Large societal systems, for example, the health system, function thanks to different groups of stakeholders (e.g., technology developers and health professionals) who share certain characteristics such as aims, strategies and perceptions and act as a unity in order to fulfil their functions in the system. Alignment of activities between different stakeholder groups results in, for example, the development of new therapeutic options. However, stakeholders have unequal resources and opportunities to realise their aims. This results in conflict and power struggles in certain situations. In addition, the main structure of a large system is resistant to change, causing difficulties for innovations that are not aligned with existing structures. • *Involving citizens.* Concerns of citizens/publics are often framed as scientific ignorance and emotional reactions. The assumption here is that knowledge generates public acceptance of science and technology, and hence facilitates the embedding of innovations. As a consequence, many educational programmes and communication strategies to augment the knowledge of the 'general public' have been developed in recent years. However, these strategies have not reduced societal concerns nor increased public acceptance of science and technology. Other factors such as values, trust and the framing of technologies appear to be more influential in determining acceptance of science and technology. **Main learning point.** Taking into account the different stakeholders and their structures, various roles, responsibilities, potential conflicts, et cetera during innovation development contributes to realising a product that is (minimally) compliant with the needs, demands and wishes of the variety of stakeholders involved in or affected by the solution. This also involves taking relevant structures regarding the implementation of the innovation in society into account, including functional application in practice.
Resources spent, efficient development and (change of successful) market approval	Points allocated in the category resources refer to the resources spent such as time, money and equipment. Here, the relation between resources spent, the efficiency of the development trajectory and the related (chance of successful) market approval have a central place. • Striving too much for efficiency most likely resulted in a prototyped solution that does not comply with the needs and wishes of societal stakeholders (see also uncertainty reduction and system awareness points) and consequently in a prototype that has a lower chance of being successfully introduced to the market. This is because the solution does not comply with the needs, demand and desires of those who are envisioned to use the solution in

practice or those who are affected by the solution in practice. The solution, for example, does not solve a problem at all in their view or the solution does not (sufficiently) solve the problem or is not considered advancement. Related to this are potential barriers and challenges that were not included in the design related to the use of the solution in practice, its (experienced) negative side effects, et cetera.

- Striving too much for safety and certainty, on the other hand, may have resulted in a prototype that failed due to lack of financial means and investors or is still in the early phases of development and has in the meantime been outdated by other solutions.

Main learning point: the resources spent during innovation development – including those to reduce uncertainty and connect to all the system elements involved – have an effect on the progression of the prototype development, which in turn has consequences for the chances of successful market approval.