DIGITAL DESIGN PROFESSIONAL

Digital Design Professional - Foundation Level -

Syllabus

Version 1.0.1

June 1st, 2021

Preface

The motivation for creating this syllabus lies in the ideas behind the Digital Design Manifesto that was developed by Bitkom (Germany's digital association) in cooperation with IREB and other organizations. This manifesto postulates the idea that *digital* is an original material that requires a holistic design profession. Such a profession is urgently needed in order to tap into the full potential of digital technology and to improve our ability to design and realize successful digital solutions. No doubt there are already practitioners today who are shaping digitalization in the sense of the manifesto, but there are far too few of them and their methods and techniques are not general knowledge. They have no clear job profile with clear responsibilities and relationships to other professions. Finally, they are not systematically trained in designing with digital materials.

The manifesto refers to an analogy to the professions of architecture and industrial design. Both professions are widely recognized and have clear job descriptions and education programs. This originality and this identity are central factors for the success and benefit of these professions for the economy and society. Just as architecture and industrial design already exist as professions today, Digital Design is needed as an independent and self-confident profession that improves our ability to build successful digital solutions. The authors of the manifesto want to initiate a process of change in order to achieve precisely this goal.

This syllabus is intended as a contribution to this process of change. We intend to help as many people as possible to profit from the ideas of Digital Design. The syllabus assumes that participants have practical experience in some aspects of creating digital solutions. Of course, a syllabus for a three-day course cannot replace university studies; it is therefore not intended for complete beginners but for people who already have some experience in certain aspects of this field, e.g., UI design, software architecture, requirements engineering.

Due to the limited time available in a three-day course, the syllabus focuses on selected methods and techniques. Experts will be aware of other methods and techniques in their particular area. The aim of this syllabus is not to advocate specific methods or techniques, but rather to introduce the profession of Digital Design and to certify that participants have the following competences:

1. A broad overview of the competence spectrum of Digital Design. This knowledge allows participants to assess their own competences in Digital Design and to look for suitable further training opportunities according to their needs in Digital Design.
2. The basics of the practice of Digital Design, from the very beginning of an idea right up to the actual operation and evolution of a digital solution. This end-to-end understanding is an important learning outcome since it enables participants to understand the challenges and necessary competence of each step.
3. Practical competence in the actual integration of Digital Design into the realization of a digital solution. This hands-on understanding is important for tangible results since it enables participants to connect with all the technology people who do the important construction and realization work that brings a digital solution to life.

Finally, participants will have acquired all the knowledge necessary to act as ambassadors for the idea of Digital Design in their own organization and to contribute to the process of change initiated by the Digital Design Manifesto.

Kim Lauenroth, 1st Chair of IREB e.V.

Terms of Use

Acknowledgements

This syllabus was created by David Gilbert, Michael Kemper, Kim Lauenroth, Karsten Lehn, Norbert Seyff, Melanie Stade, and Marcus Trapp.

During this revision, feedback was provided by Bernd Aschauer, Nikola Eger, Thomas Geis, Saskia Hehl, Thomas Immich, Jens Kawelke, Rolf Molich, Knuth Polkehn, Lars Sonnabend, Hans-Jörg Steffe, Stefan Tilkov, Marcus Winteroll, and many others.

Reviews were performed by Michael Burmester, Kurt Schneider, and Martin Glinz.

Approved for release on December 16th, 2020 by the Council of IREB e.V. upon recommendation of Martin Glinz.

We thank everybody for their involvement.

Purpose of the Document

This syllabus defines the Foundation Level of the Digital Design Professional certification established by IREB e.V. The syllabus provides training providers with the basis for creating their course materials. Students can use the syllabus to prepare themselves for the examination. Further details for preparation can be found in the “Education and Training Handbook for the Digital Design Professional”.

Contents of the Syllabus

The Foundation Level addresses the needs of all people involved in the topic of Digital Design. This includes people in roles such as user experience manager, user interface designer, interaction designer, system analyst, requirements engineer, product owner or product manager, developer, project or IT manager, and anyone who wants to shape the digital age.

Level of Detail

The level of detail in this syllabus allows teaching and examination to be consistent internationally. To reach this goal, the syllabus contains the following:

- General educational objectives
- Contents with a description of the educational objectives
- References to further literature (where necessary)

Educational Objectives and Cognitive Levels

All modules and educational objectives in this syllabus are assigned a cognitive level. The following levels are used:

- L1: Know (describe, enumerate, characterize, recognize, name, remember, ...): remember or retrieve previously learned material.
- L2: Understand (explain, interpret, complete, summarize, justify, classify, compare, ...): grasp/construct meaning from given material or situations.
- L3: Apply (specify, write, design, develop, implement, ...): apply knowledge and skills in given situations.

Structure of the Syllabus

The syllabus consists of six main chapters. Each chapter covers one educational unit (EU). The main chapter titles contain the cognitive level of their chapters, which is the highest level of their sub-chapters. The duration indicates the time that a training course should invest for that chapter. Training companies are free to allocate more time but should maintain the proportions between the EUs. Important terms used in a chapter are listed at the beginning of the chapter.

Example:

EU 2	Design Competence (L3)
Duration:	8 hours

This example shows that Chapter 2 contains educational objectives at level L3, and eight hours are intended for teaching the material in this chapter. Each chapter contains sub-chapters. Their titles also contain the cognitive level of their content.

Educational objectives (EO) are enumerated before the actual text. The numbering shows the sub-chapter that they belong to. For example, the educational objective EO 2.1.1.2 is described in sub-chapter 2.1.1. The identifying number of educational objectives can also be found in the side notes of the corresponding sections.

Order of Topics in the Syllabus

The order of chapters in this syllabus constitutes a logical order of topics. However, the topics do not have to be taught in exactly this order. Training providers are free to teach the material in any order (including interleaving of topics from different EUs) that they deem appropriate in the context of their training and that fits their didactic concepts.

The Examination

This syllabus is the basis for the examination for the DDP Foundation Level certificate.

! A question in the examination can cover material from several chapters of the syllabus. All chapters (EU 1 to EU 6) of the syllabus and all terms of the DDP-Glossary can be examined with respect to its cognitive level

The format of the examination is multiple choice. Examinations can be held immediately after a training course but also independently of courses (e.g., in an examination center). A list of certification bodies can be found on the website www.digitaldesign.org.

Version History

Version	Date	Comment
1.0	2021/02/18	First version of the syllabus
1.0.1	2021/06/01	Minor updates: navigable references added, minor linguistic optimizations for comprehensibility, minor changes concerning gender-neutral language, update of definitions for construction and realization.

Table of Contents

EU 1 Introduction (L2) **7**
EU 1.1 The Need for a Digital Design Profession 7
EU 1.2 Understanding Digital as a Material for Building Digital Solutions 9
EU 1.3 An Introduction to the General Building Process for a Digital Solution 12
EU 1.4 Competence Profile of a Digital Design Professional 17
EU 2 Design Competence (L3) **19**
EU 2.1 Integration of Digital Design into the Building Process 20
EU 2.1.1 Fundamentals of Design Processes 20
EU 2.1.2 The Three Essential Steps of the Building Process for a Digital Solution 21
EU 2.1.3 Quality as a Cross-Cutting Concern of the Building Process 24
EU 2.1.4 Additional Skills for Designing a Digital Solution 25
EU 2.2 Conceptual Work in Digital Design 25
EU 2.2.1 Fundamentals of Conceptual Work 26
EU 2.2.2 Pragmatic Document Templates for the Different Abstraction Levels 26
EU 2.2.3 Documentation Techniques for the Solution Level 28
EU 2.2.4 Documenting Design Concepts at the System and Element Level: General Considerations 30
EU 2.2.5 Documentation Techniques for the System and Element Level 32
EU 2.2.6 The Big Picture of Conceptual Work in Digital Design 34
EU 2.3 Application of Prototypes in Digital Design 35
EU 2.3.1 Fundamentals of Prototypes 35
EU 2.3.2 Prototype Categories and Tools 37
EU 2.3.3 The Value of Simple Low-Fidelity Prototypes 39
EU 3 Digital Material (L2) **41**
EU 3.1 Understanding Technology and Its Relation to Quality 41
EU 3.2 Perceivable Technology 42
EU 3.3 Underlying Technology 44
EU 3.4 Technology-Oriented Knowledge Areas 45
EU 3.5 The Digital Design Perspective on Technology 46
EU 4 Cross-Cutting Competences (L2) **47**
EU 4.1 Human Factors 47
EU 4.1.1 Fundamentals of Human Attention 47
EU 4.1.2 Fundamentals of Human Performance 48
EU 4.1.3 Emotions in the User—System Interaction 48
EU 4.1.4 The Role of Prototypes 48
EU 4.2 Business Models for Digital Solutions 49
EU 4.2.1 Fundamentals of Business Models 49
EU 4.2.2 The Difference between Digital Business and e-Business 49
EU 4.3 People Management 50
EU 4.3.1 The Building Process as a Social Process 50
EU 4.3.2 Understanding People through Personality Models 51
EU 4.3.3 Challenges of the Building Process from a Group Dynamic Perspective 52
EU 5 A Building Process for Beginners (L3) **54**
EU 5.1 The Scoping Step 54
EU 5.2 The Conceptual Step 56
EU 5.3 The Development and Operations Step 57
EU 5.4 Lean Startup as an Alternative Approach for Developing a Digital Solution 63
EU 6 Achieving Good Digital Design (L2) **64**
EU 6.1 Contributions of the Digital Design Professional 64
EU 6.2 The Importance of Heuristics and Practical Knowledge 65
EU 6.3 The Importance of Teamwork 65
References **66**

EU 1 Introduction (L2)

Duration: 90 min

Educational objectives:

EO 1.1.1	Describe the technological levels digitization, digitalization, and digital transformation (L1)
EO 1.1.2	Explain the need for a new Digital Design profession (L2)
EO 1.1.3	Explain the scope of Digital Design (L2)
EO 1.2.1	Explain the idea of digital as a material (L2)
EO 1.2.2	Describe the difference between a digital system and a digital solution (L1)
EO 1.2.3	Describe the difference between client, customer, and user (L1)
EO 1.3.1	Describe management as a cross-cutting activity of the building process (L1)
EO 1.3.2	Describe evaluation as a cross-cutting activity of the building process (L1)
EO 1.3.3	Name the three core activity areas of the building process for a digital solution and their work products (L1)
EO 1.3.4	Explain the integration of the activity areas of the building process (L2)
EO 1.3.5	Explain the difference between the building process at the solution, system, and element level (L2)
EO 1.4.1	Describe the skills of a Digital Design Professional at foundation level (L1)
EO 1.4.2	Name the ten principles of good Digital Design (L1)
EO 1.4.3	Explain that the Digital Design Professional is not a new role (L2)

EU 1.1 The Need for a Digital Design Profession

In digital technology[1], three different technological levels can be distinguished: **EO 1.1.1**

- Digitization is the use of digital technology to solve problems with digital data that previously had been solved with non-digital means.
- Digitalization is the use of digital technology to create solutions and business processes that are not feasible with non-digital means.
- Digital transformation occurs when digital solutions impact people and society by changing people's habits and lives with digital means.

When building a system or solution with digital technology, the first challenge is to figure out, with all relevant stakeholders, what to build. Stakeholder is an important umbrella term for all people or organizations involved with the system and is defined as follows: **EO 1.1.2**

> Stakeholder: A person or organization who influences a system's requirements or who is impacted by that system.

Stakeholders can be distinguished by means of roles. One important stakeholder role is the client:

[1]In this syllabus, the term *digital technology* is preferred to *information technology* because digital technologies cover a broader spectrum and are more in line with current language usage regarding *digital*.

Client: A person or organization who orders a system or a solution to be built.

Users and customers as further important stakeholder roles will be defined in EU 1.2. The building team member as a stakeholder role will be defined in EU 2.1.

In projects where there are clients who know what they want to order and stakeholders who know about their needs and the problems that a digital solution shall solve, the challenge of what to build is addressed by a requirements-driven approach.

In product development, however, there are often neither clients who order a solution nor readily available stakeholders who know about their needs and problems. A similar situation occurs when a client demands an innovative solution but nobody has a clear idea about what such a solution should do and what it should look like. Furthermore, the digital solutions to be built are driven by digital technology. This calls for a design-driven approach to building a digital solution: designers explore what could be done, create visions about digital solutions, and finally shape the form, function, and quality of the digital solution. As this kind of creative design is analogous to what industrial designers do when designing physical products, the design of digital solutions is called Digital Design [Bitk2017].

Digital Design [LBGH2018] is a profession that aims to improve our ability to design and build better digital solutions. Digital Design is defined as follows: **EO 1.1.3**

Digital Design: The creative design of digital solutions.

Digital Design understands *digital* as a shapeable material (see EU 1.2). This understanding goes beyond a pure technical understanding of digital technology and aims at a combination of design skills and technical skills similar to an understanding promoted by industrial design and building architecture.

Digital Design means shaping digital solutions by taking a holistic view of the technical possibilities of digital material, of the economic aspects, and of the current or future needs of people.

Digital Design shapes new and optimizes existing digital solutions by:

- Designing the goals, benefits, and means of a digital solution together
- Designing a digital solution on a large and small scale
- Designing perceivable and underlying aspects of a digital solution together
- Designing material and immaterial aspects of a digital solution

Digital Design means taking responsibility for the design of a digital solution and leading the building process for a digital solution from the design perspective. This includes shaping and optimizing the design activities of the building process and intensively cooperating with all other activity areas of the building process.

EU 1.2 Understanding Digital as a Material for Building Digital Solutions

The idea of understanding digital as a noun and as a material is intended to reflect the importance of the digital for our economy and society. **EO 1.2.1**

> Digital (noun): The structure, flow, and transformation of binary data.

This understanding is further intended to make clear that just like other materials, digital can be shaped in order to create digital solutions. This understanding is the basis for a fundamental paradigm shift away from a reactive technical and requirements-oriented development of digital solutions towards a proactive design-oriented development of digital solutions.

A prerequisite for understanding digital material is defining the term system.

> System: In general: A principle for ordering and structuring.
> In engineering: A coherent, delimitable set of elements that —by coordinated action— achieve some purpose.

The following three terms are useful for communicating about systems:

- Form: the elements and the relationships between the elements that make up the system's structure
- Function: capabilities provided by an element, by a combination of elements, or by the system as a whole
- Quality: The degree to which an element, a relationship between elements, or a capability of a system fulfills defined quality characteristics.

Achieving good quality, communicating about quality and evaluating quality require explicitly defined quality characteristics (cf. [ErMa2008]). Quality characteristics can be defined in various ways. In EU 2.1.3, we introduce exemplary approaches for defining quality characteristics.

Digital material is defined as follows:

> Digital material: The technological means that enable the digital, that is, the structure, flow, and transformation of binary data.

Digital material has four essential properties:

1. Digital material has no objective in itself.
2. Digital material has an underlying and a perceivable layer.
3. Digital material has technology neutral aspects.
4. Within limits, digital material can be shaped without programming knowledge.

A flow of data does not exist without a system that processes, transports, and stores the flow of data. Such a system is called a digital system: **EO 1.2.2**

Digital system: A technical system that realizes a digital solution in a given context with digital means, that is, by processing, transporting, and storing binary data.

The user is an important stakeholder role in a digital system and is defined as follows:

User: A person who uses the functionality provided by a system.

In addition to human users, digital systems can be used by animals (e.g., in digital farming). Elements of a system can also be understood as (sub-)systems. This allows the definition of systems that consist of a multi-level hierarchy of systems.

With the concept of a digital system, a digital solution is defined as follows:

Digital solution: A socio-technical system that solves a real-world problem with digital means.

According to the understanding of common systems theory, a socio-technical system is a system that spans software, hardware, people, and organizational aspects. This means that Digital Design is about shaping technical (digital) systems and about shaping socio-technical systems (the digital solution) with digital material.

The customer is an important stakeholder role for the digital solution and is defined as follows:

Customer: A person or organization who receives a system, a product, or a service.

The term “receiving” includes both buying a solution or obtaining it for free. The definition is very broad to cover various situations and business models. Typical situations are:

- The customer can receive the digital system without any further services. For example, buying an office software.
- The customer can receive a product that is embedded in the digital solution. For example, buying a games console that allows games to be purchased via the internet.
- The customer can receive a service that the digital solution provides. For example, booking a hotel room with the digital solution.

Beyond its intended customers, a digital solution may also have indirect customers. This is the case, for example, a digital solution is employed (by the indirect customer) to improve non-digital services that they provide to their (direct) customers. The indirect customer then benefits as a result of the digital solution.

The two layers of digital material manifest themselves in two layers of a digital solution:

- Perceivable layer: form, function, and quality that can be perceived by stakeholders
- Underlying layer: form, function, and quality that is hidden from the perception by stakeholders and that enables the perceivable layer

In general, context is a network of thoughts and meanings needed to understand phenomena or utterances. In Digital Design, the context is defined as follows:

> Context: The part of the environment of a digital solution or a digital system that is relevant for understanding and realizing a digital solution.

Context includes important stakeholders particularly potential customers and users of the digital solution.

The problem solved and the context are inseparable. This means that a digital solution that works in one context does not necessarily have to work in another context.

An important difference between a digital solution and a digital system is that the digital system represents the technical means to achieve an end in a defined context (the digital solution). From a theoretical perspective, two things are important.

First, the relationship between means and end can be complicated or complex (cf. [Snow2005]): a complicated relationship is characterized by a deterministic cause and effect relationship between means and ends. A complex relationship has a non-deterministic part that makes it difficult or even impossible to analyze it in advance. People who do not have a proper understanding of digital material often consider digital solutions complex. However, with a proper understanding of digital material and with training in Digital Design, it is possible to separate the complicated from complex means—end relationships and to deal adequately with both.

Second, means and ends are independent of each other: an end can be achieved by different means and a means can be used to achieve different ends. This often leads to the impression that the end (the digital solution) should be defined before thinking about the means (the digital system). In practice, means and ends influence each other. It is of course important to start with the end. However, understanding the means to an end improves the understanding of the end as well. This is why design is solution-oriented and emphasizes the importance of prototyping to improve the understanding of means and ends together (cf. [Cros2006]).

The joint consideration of means and ends is particularly important when designing digital solutions. Digital material offers new means, which in turn enable innovative ends to be achieved. Digital Design therefore implies in particular designing the digital solution and the digital system in parallel.

It is important to understand the difference between client, customer, and user to keep a clear focus during the building process. The three stakeholder roles create three idealized external perspectives for the building team: **EO 1.2.3**

- The client orders the building of the digital solution. To understand the client perspective, it is important to understand the objectives of the client for ordering the digital solution.
- The customer wants to receive value by a system, product, or service. To understand the customer perspective, it is important to understand what value should be generated.

- The user uses the digital system within the digital solution and therefore takes part in the value creation. To understand the user perspective, it is important to understand how value is created.

In practice, the three stakeholder roles can be independent people or organizations. However, this is a special situation for building a digital solution. In other situations, stakeholder roles are combined:

- The client is a customer and a user. Example: Ms. Sonnenschein, as the client, orders an in-house enterprise resource planning (ERP) system for her company, and uses the system herself.
- The client is a user but not a customer. Example: Mr. Piepenmeyer orders a customer relationship management (CRM) system for himself and his own organization in order to be able to make targeted offers to his customers.
- The client is not a customer and not a user, the customer is a user. Example: Ms. Schmitt sells garden tools and, in her role as client, she orders an online store to sell her products to her customers, who are supposed to use the digital system within the digital solution.
- The client is a customer but not a user. Example: In his role as client, Mr. Brandt orders a new web presence to present his company to external people (users). Although he is also a customer of the digital solution, he is not one of the users himself..

A clear focus is important in order not to confuse the different perspectives of a particular person on the stakeholder roles. First, in several situations, one person can be the customer and the user at the same time. Such people may have a certain idea about the value (the customer perspective) and about how the value is created (user perspective). To achieve good Digital Design, it is important to be able to separate these perspectives.

Second, the clients often overestimate their knowledge and understanding of the customer and/or the user perspective. This may lead to false assumptions and often to suboptimal or even weak digital solutions. To achieve good Digital Design, it is therefore necessary to carefully evaluate and clarify the input from the clients.

EU 1.3 An Introduction to the General Building Process for a Digital Solution

With an understanding of digital material, we can now look at the building process for a digital solution. In general, a process is defined as follows:

> Process: A set of interrelated activities performed in a given order to process information or materials.

In the context of digital solutions, the word "building" can seem unusual at first glance. We deliberately chose this general term because it fits well with the idea of having digital as a material. For us, building means crafting a digital solution using digital material.

The building process for a digital solution consists of three core activity areas (design, construction, realization) and two cross-cutting activity areas (management and evaluation). We start with the definition of the cross-cutting activity areas.

The activity area 'management' focuses on the governance of the building process and the cooperation between the other activity areas. **EO 1.3.1**

Management: Leading the building process in cooperation with all other activities.

The management of the building process consists of three perspectives:

- Project management perspective: coordination of activities, time, and budget
- People management perspective: managing stakeholder expectations, managing the cognitive process of stakeholders, getting the right people and skills for the activity at hand
- Product management perspective: short-term and long-term strategy for the evolution of the digital solution

The activity area evaluation is intended to focus on the quality of the work products created (the digital solution realized is also considered as a work product). **EO 1.3.2**

Evaluation: A systematic process for determining the value, quality, or appropriateness of something.

In Digital Design, evaluation particularly determines whether a digital solution or a work product used to create a digital solution actually has the qualities and properties that it should have according to the design concepts and the stakeholders' needs. This means that in the building process, evaluation is always related to a work product and therefore related to one of the core activity areas.

The respective perspective on evaluation is therefore described together with the core activities. However, the independent definition of evaluation as a cross-cutting activity is intended to emphasize the importance of evaluation within the building process. To capture and structure the evaluation work, we define a dedicated concept type:

Evaluation concept: A description of the evaluation approach for a work product.

Evaluation concept is again a generic term in order to capture the broad scope of evaluation work during the building process.

Design is a difficult term because it has several meanings (cf [ErMa2008]). **EO 1.3.3**

Design: (1) A plan or drawing produced to show how something will look, function, or be structured before it is made. (2) The activity of creating a design.

The first part of the definition uses the term design as a result. This result is defined as a plan or drawing that is created to show how something will look, function, or be structured before it is made. The second part of the definition refers to the activity of creating this result.

Designing thus means envisioning and properly describing a desired future by means of design concepts. This understanding of design has three aspects:

1. Elaborating and understanding the desired future
2. Defining and shaping a digital solution that will create this future based on a design concept
3. Evaluating the quality of the design concept

The first aspect requires empathy, imagination, and creativity. The second aspect requires skills in digital technology and conceptual work. The third aspect requires skills in various evaluation directions (e.g., technical feasibility, function suitability, usability).

Envisioning a future together with all relevant stakeholders is a challenge and must by no means be underestimated. To describe the desired future, design creates design concepts to describe the digital solution that shall create the desired future. The term design concept is defined as follows:

Design concept: A description of the design of a digital solution, of a digital system, or of an element of a digital solution under the assumption of perfect technology.

Design concept is a generic term for work products that are created during the building process. Further details on conceptual work will be given in EU 2.2.

The assumption of perfect technology compared to real technology [WaMe1986] means defect-free technology as well as infinite computing capacity, infinite storage capacity, and infinite communication capacity. This assumption is important since it simplifies the development of a design concept in several ways (see EU 2.2).

Construction as a second core activity is defined as follows:

Construction: (1) a description of the technical structure of something (2) The act of creating a construction.

Analogous to design, the definition of construction has two main meanings. First, the result (description of the technical structure) as a specification for the actual realization. Second, the activity of construction.

The activity of construction has two aspects. First, the creation of the technical structure of the digital solution, and second, evaluating that the digital solution described by this concept will create the desired future envisioned by the design activity. The technical structure should be understood as a continuation of the design concept, is called the realization concept and is defined as follows:

Realization concept: A description of a digital solution with real technology.

Similar to design concepts, the realization concept is a generic term for work products that are created to enable the realization of the digital solution.

A realization concept must consider real technology and has to deal with all technical details that are necessary to realize the digital solution and its elements[2]. The construction of a digital solution may require the involvement of various disciplines (e.g., software architecture, electrical engineering, mechanical engineering).

Realization as the third core area of activity is defined as follows:

Realization: (1) the actual implementation of something. (2) The act of creating a realization.

The definition of realization also contains the meaning of result and activity. Like construction, realization has two aspects. First, the implementation of the digital solution according to the design concept and the realization concept. Second, the evaluation that the implemented digital solution will create the desired future envisioned by the design activity.

The realization of a digital system is by no means a trivial endeavor. As with construction, the realization of a digital solution may require the involvement of various disciplines.

Realization also has an evaluation aspect. Realization must ensure that the digital solution is implemented according to the design concept and the realization concept to ensure that the digital solution creates the envisioned future. This evaluation is performed in a joint effort together with design and construction.

From a naïve perspective, the core activity areas design, construction, and realization can be considered as subsequent activities. Such a “waterfall approach” has been disregarded as impractical since the very beginning of software development (cf. [Royce1970]). **EO 1.3.4**

A more realistic view of the building process is the understanding of all activity areas as ongoing activities that are performed iteratively and in parallel. Design and construction must work together and complement each other. For each and every form, function, or quality defined by a design activity, a corresponding realization concept is necessary to realize it.

The most important difference between design and construction is the perspective. Design looks at the outside of a digital solution with the aim of understanding and elaborating the desired future. Construction looks at the inside of a digital solution and is concerned with defining the technical realization of the desired future.

In general, the cooperation between design and realization consists of two aspects:

- Clarifying conceptual details for realization
- Evaluating the realized perceivable form, function, and quality

Like the cooperation between design and realization, the cooperation between construction and realization must be distinguished according to the type of element that shall be realized.

[2] This syllabus focuses on design concepts and does not provide further guidance for working on realization concepts.

In general, the cooperation between construction and realization consists of two aspects:

- Clarifying technical details for realization
- Evaluating the realized underlying form, function, and quality

The cooperation between design, construction, and realization focuses on the content details of designing, constructing, and realizing the form, function, and quality of the digital solution.

The building process for a digital solution can be structured according to the following levels: **EO 1.3.5**

- Solution level
- System level
- Element level

This understanding of solutions and systems represents an important terminological difference to other fields. Some disciplines consider the user and existing systems as system context and only the elements as the system. This understanding was suitable for mere digitization projects (transforming existing analog things into the digital world). Digitalization and digital transformation require the broader understanding outlined above, since novelties are created.

The three levels should not be understood as three process steps that follow each other. They are meant to structure the view of a digital solution. The building process for a digital solution always starts with the solution level and with the desired future. With an initial understanding of the desired future, an iterative process starts that takes place at all three abstraction levels in parallel.

The system level is of particular importance for the building process. With a proper understanding of the system level, the following activities can be performed:

- Planning for the necessary people and resources to build a digital solution
- Planning of the long-term evolution of a digital solution
- Planning and management of the subsequent building process for the elements
- Taking core decisions on the technologies that will be used to realize the digital solution
- Ongoing alignment of the individual building processes for the elements with each other and with the system level
- Evaluation and further development of the main objective of the digital solution
- Evaluation and further development of the overall solution idea
- Evaluation and further development of the business model (if applicable)

The design and construction activities at the element level do not necessarily have to wait until there is a proper understanding of the system level. Often, the opposite is the case. Elaborating details of an element creates important insights for the system and the solution level.

The design and construction activities must take place in close cooperation with the realization of the other elements. The design and construction activities at the system level also continue and must align the design and construction details of the system level with the design and construction details of each element as described above. The task of management is to plan, structure, and drive the entire process at the element, system, and solution level.

EU 1.4 Competence Profile of a Digital Design Professional

A Digital Design Professional (DDP) is a person who is considered competent in the field of Digital Design. **EO 1.4.1**

The structure of this syllabus follows the idea of the pi-shaped competence profile [Bitk2017] inspired by the Greek letter **π** as a symbol. The first leg of the pi represents the design competence. At foundation level, the following aspects are important:

- Integration of Digital Design into the building process (EU 2.1)
- Conceptual work in Digital Design (EU 2.2)
- Application of prototypes in Digital Design (EU 2.3)

The second leg represents the understanding of digital material. At foundation level, the following aspects are important:

- Understanding technology (EU 3.1)
- Perceivable technologies (EU 3.2)
- Underlying technologies (EU 3.3)
- Technology-oriented knowledge areas (EU 3.4)

The top of the pi represents cross-cutting competences of Digital Design. At foundation level, the following aspects are important:

- Human factors and experience in Digital Design (EU 4.1)
- Business models for digital solutions (EU 4.2)
- People management (EU 4.3)

To apply this broad competence profile, EU 5 presents a building process that is intended for beginners in Digital Design. This process provides a set of concrete and pragmatic techniques that are suitable for building digital solutions with medium complexity. The competence profile of a DDP is completed by the ten principles of good Digital Design.

EU 6 discusses how the methods and techniques from this syllabus contribute to achieving good Digital Design.

A profession is defined by its methods, techniques, and values. The ten principles of good Digital Design presented in the Digital Design Manifesto [LBGH2018] define principles that guide the values of Digital Design. **EO 1.4.2**

Ten principles of good Digital Design: Good Digital Design…

(1) is useful and usable

(2) is elegant and aesthetic

(3) is evolutionary

(4) is exploratory

(5) focuses on the person as a whole

(6) anticipates the effects of its results

(7) respects data protection and data security

(8) is sustainable and creates sustainability

(9) appreciates analog and digital means equally

(10) uses digital means only where this is necessary.

It is important to recognize the difference between a role and a profession: **EO 1.4.3**

- A role is a position that a person can take in a given situation. A role is defined by its tasks, rights, duties, and responsibilities.
- A profession is an occupation that requires specialized education.

The DDP is not a role, it is a training program for entering the profession of Digital Design. This foundation level syllabus aims to provide a broad overview of Digital Design and at the same time, provide hands-on methods and techniques for practical work.

During the building process for a digital solution, a DDP is able to work in various roles that are related to the activity area design (e.g., product owner, business analyst, requirements engineer).

However, due to the broad scope of Digital Design, certain roles will require additional specialized education to achieve good Digital Design (see EU 6). References to further literature are given as a starting point for this education.

EU 2 Design Competence (L3)

Duration: 480 min

Educational objectives:

EO 2.1.1.1	Explain the difference between the design of a physical product and the design of a digital solution (L2)
EO 2.1.1.2	Explain important aspects of design processes with the design squiggle (L2)
EO 2.1.1.3	Describe the dual-mode model of design (L1)
EO 2.1.2.1	Describe the three essential steps of the building process for a digital solution, including their work products (L1)
EO 2.1.2.2	Explain the Digital Design responsibilities during the building process (L2)
EO 2.1.2.3	Explain the equal importance of scoping/conceptual and development work for building successful digital solutions (L2)
EO 2.1.3.1	Explain the need for a holistic consideration of quality during the building process (L2)
EO 2.1.3.2	Explain the difference between the quality of a digital solution and the quality of a digital system (L2)
EO 2.1.3.3	Explain the difference between perceivable and underlying quality attributes (L2)
EO 2.1.3.4	Describe a quality model for digital solutions and for digital systems (L1)
EO 2.1.4.1	Know the need for additional skills for designing a digital solution (L1)
EO 2.2.1.1	Name the benefits and limits of concepts as thinking and communication tools in Digital Design (L1)
EO 2.2.2.1	Describe pragmatic document templates in Digital Design (L1)
EO 2.2.2.2	Describe the differences between system and element design concepts (L1)
EO 2.2.3.1	Know the future press release as a technique for describing the vision of a digital solution (L1)
EO 2.2.3.2	Describe a persona template for documenting customer/user groups (L1)
EO 2.2.3.3	Name the structure of a stakeholder list (L1)
EO 2.2.3.4	Name the structure of the value proposition canvas and the business model canvas (L1)
EO 2.2.3.5	Name the structure of a customer journey map (L1)
EO 2.2.4.1	Explain the benefit of different writing styles at the solution and system/element level (L2)
EO 2.2.4.2	Explain the writing style for system and element design concepts (L2)
EO 2.2.5.1	Explain the idea of perfect technology to support the design of a digital solution (L2)
EO 2.2.5.2	Name the sections of a general building block template (L1)
EO 2.2.5.3	Explain templates for building blocks at the system and element level (L2)
EO 2.2.6.1	Apply constructive relationships at the system and element level (L3)
EO 2.2.6.2	Apply constructive relationships between the system and the element level (L3)
EO 2.3.1.1	Name the objectives of prototypes (L1)
EO 2.3.1.2	Explain the notions of prototypes in different disciplines (L2)
EO 2.3.1.3	Characterize disciplines that use prototypes (L1)
EO 2.3.2.1	Explain different prototype categories (L2)
EO 2.3.2.2	Explain the degree of immersion in relation to the fidelity profile of a prototype (L2)
EO 2.3.2.3	Describe tools for creating prototypes (L1)
EO 2.3.3.1	Explain the value of simple low-fidelity prototypes (L2)

EU 2.1 Integration of Digital Design into the Building Process

EU 2.1.1 Fundamentals of Design Processes

The main characteristic of designing a physical product is the separation of design from manufacturing: the creative act of shaping a product's form and function takes place in advance of the physical act of making (realizing) a product, which consists purely of repeated, often automated, replication (cf. [Nobl1996]). **EO 2.1.1.1**

In contrast, the design of a digital solution is an ongoing process during the whole building process (see EU 1.3). Hence, process models for designing physical products do not fit well for Digital Design. Building digital solutions requires process models that provide guidance for integrating design activities into the whole building process.

The design squiggle [Newm2020] shows that a design process is typically a chaotic and iterative activity and shows three different stages: **EO 2.1.1.2**

- Research & synthesis
- Concept/prototype
- Design

The design squiggle highlights the importance of three core aspects of every design process:

- Separation of the understanding of the environment from the creation of solution ideas
- Evaluation of the understanding of the environment and of the solution ideas
- Iteration as an attitude and process approach

A typical beginner's mistake is to assume a linear design process and to understand design only as the third stage of the squiggle. Design is about all three stages and skilled designers are aware of the three stages and of the importance of the first two stages. They have learned to work iteratively and to tolerate the uncertainty of the first two stages.

The dual-mode model of design [Dors1997] describes two modes of working on the design: **EO 2.1.1.3**

- Rational problem solving – the objective mode: in this mode, the designer works in a rational way on the design problem (working in the problem space) through analysis and observation and wants to solve it. The insights from analysis and observation are transformed into a design solution (working in the solution space). The solution itself is again observed, analyzed, and evaluated.
- Reflective practice – the subjective mode: in this mode, the designer works subjectively on the whole design situation, wants to understand it, and aims to define a way to proceed with the design task. The designer works on the design task (the given situation and the time frame) in relation to the desired design solution. The subjective mode is important when the design task is unclear, ill-defined, or if it violates the ethical or moral values of the designer.

EU 2.1.2 The Three Essential Steps of the Building Process for a Digital Solution

The building process for digital solutions can be separated into three steps: **EO 2.1.2.1**

- Scoping step
- Conceptual step
- Development and operations step

The building process is executed by the building team. The building team member is another important stakeholder role:

> Building team member: A person that performs an activity of the building process.

Scoping step

In the scoping step, Digital Design means getting an idea of the overall situation and defining, together with the client, the initial frame for building the digital solution:

- Context: the part of the environment of a digital solution or digital system that is relevant for understanding and realizing a digital solution
- Vision: the overall idea of the desired futures that shall be realized with the digital solution
- Scope: the range of things that can be shaped and designed when building a digital solution
- General terms: available budget, time frame, available resources

This frame is documented in a Digital Design brief (abbreviation: design brief):

> Digital Design brief: The description of the context, vision, scope, and general terms for building a digital solution.

Conceptual step

In the conceptual step, an understanding of the digital solution (including the system and its elements) is elaborated that is sufficient to accept the risk of starting the development step. Elaborating this understanding requires design and construction activities.

During this step, the following design and realization concepts are created.

> Solution design concept: The description of the goals, the business model, and the overall idea of a digital solution.

The solution design concept represents the socio-technical perspective. It focuses on the client's and the customer's perspective. It captures the goals of the client and captures the overall idea for the digital solution in relation to the customer's needs.

To document the evaluation approach for the overall digital solution, we recommend creating a concept for this part of quality assurance:

Solution evaluation concept: The evaluation concept for a digital solution.

Together with the solution design concept, a system design concept is created:

System design concept: The description of the system-relevant objectives and of the overall form, function, and quality of a digital system.

The system design concept represents the technical system perspective (i.e., users in relation to technical elements) and details the digital system inside the digital solution. Keeping the solution design concept and the system design concept consistent with each other is the responsibility of the activity area design. The construction equivalent of the system design concept is the system realization concept:

System realization concept: The description of the technically relevant system objectives and of the overall technical form, function, and quality of a digital system.

In order to capture the approach for evaluating the digital system, we recommend creating a dedicated concept for this part of quality assurance:

System evaluation concept: The evaluation concept for a digital system.

The system evaluation concept combines the design, construction, and realization aspects. Therefore, the system evaluation concept will be elaborated with experts from all activity areas.

Development and operations step

The development and operations step is an iterative design, construction, and realization process for the elements of the digital solution that continues into operation. This step includes the operation of the digital solution, since most digital solutions are also refined and extended during their use. During this step, the elements of the digital solution must be elaborated to a level of detail that is sufficient for realization. These details are typically captured in an element design concept:

Element design concept: The description of the element-relevant objectives and of the form, function, and quality of an element of a digital solution.

The content of an element design concept depends on the type of element (software or device, see EU 2.2). If the element interacts with a user, the user's perspective on the element is important. The concrete procedure for creating these concepts and for realizing the elements depends on the process model selected for building the digital solution. The construction equivalent of the element design concept is the element realization concept:

Element realization concept: The description of the technically relevant element objectives and of the technical form, function, and quality of an element of a digital solution.

In order to capture the evaluation approach, the element evaluation concept is defined as follows:

> Element evaluation concept: The evaluation concept for an element of a digital solution.

Similar to the system evaluation concept, the element evaluation concept is a joint concept of the design, construction, and realization activities.

Keep in mind that the different concept types do not necessarily have to be maintained as independent documents. The distribution of concept types among documents or tools is a question of work organization.

Responsibility during the building process from a Digital Design perspective EO 2.1.2.2

In all three steps, Digital Design means being responsible for the following:

- Coordinating and performing the design activities with the right people and from the right perspective (client, customer, user)
- Elaborating the design concepts with sufficient quality and level of detail
- Gathering feedback from construction and realization experts where necessary
- Maintaining consistency between design concepts and realization concepts
- Communicating the details of the design concepts to the relevant stakeholders under consideration of their perspective (client, customer, user)
- Ensuring that the relevant stakeholders have properly understood the content of the concepts from their perspective (client, customer, user)

Assigning these responsibilities to roles is a management task. The DDP is educated to take these responsibilities in various roles during the building process.

A concept-driven process that focuses on design and construction is cheap and fast. New insights can be included in the concept easily and at little cost. A realization-driven process is, generally speaking, expensive and slow. Realization teams (for example, software development teams, cf. [SeRP2017]) require constant input to remain productive. The incorporation of new insights and correction of significant errors is expensive. EO 2.1.2.3

Parts that have already been built may have to be altered at an additional cost. The difference between concept-driven and realization-driven processes is not an argument for working as long as possible in the concept-driven process to create concepts that are as detailed and as verified as possible.

There are many aspects of a digital solution that can be designed and validated prior to implementation, especially by means of prototypes (see EU 2.3). There are also many aspects of a digital solution that can be validated based on the solution implemented. The real challenge is to decide which category an aspect belongs to and making this decision requires a lot of expertise (cf. [Rein1997]).

EU 2.1.3 Quality as a Cross-Cutting Concern of the Building Process

The quality of a digital solution is determined by various aspects. These include the technology chosen to build the digital system, the process used to develop the digital solution, and the understanding of quality within a given context (e.g., project setting, cultural aspects). Key aspects to consider for a holistic consideration of quality during the building process include: **EO 2.1.3.1**

- Quality as an attitude
- Awareness that process quality influences product quality
- Actively managing quality and understanding different quality aspects
- Considering risk and value
- Differentiating between the quality of the digital solution and the quality of a digital system

The quality of a digital solution has a significant impact on its acceptance and success. **EO 2.1.3.2**

The digital system realizes the digital solution (see EU 1.2). Nevertheless, the digital solution and the digital system are not identical. The digital system is the instantiation of the technical aspects of the digital solution and is only a part of the digital solution. There are qualities of a digital solution that are independent of the qualities of the digital system.

For example, an online hotel booking service for tourists is a digital solution. A smartphone app providing the function for booking a hotel online is the corresponding digital system. The online booking service itself has qualities of its own (e.g., the freedom to book a hotel from all over the world, searching for hotels in various countries). These qualities are independent of the qualities of the digital system. The qualities of the digital system (e.g., ease of use, performance, aesthetics of the app) add to the experience and quality of the digital solution.

The quality of a digital system includes both the perceivable quality (external quality) and the underlying quality (internal quality) of the digital system. While perceivable quality attributes are visible to a user or can be experienced by a user (e.g., usability), the underlying quality attributes include qualities that are hidden to the user (e.g., maintainability) but enable developers to evolve and maintain the system at low costs. **EO 2.1.3.3**

However, the “difference between internal and external characteristics isn’t completely clear-cut because at some level internal characteristics affect external ones” [FrPr2009].

There are several models for defining quality (e.g., McCall [McRW1977], Boehm [BBKL1978], ISO/IEC 9126 [ISO2001], ISO/IEC 25010 [ISO2011]). ISO 25010 is a good starting point for understanding the quality of a digital system. It defines eight main quality characteristics that can be applied to digital systems: **EO 2.1.3.4**

- Functional suitability
- Performance efficiency
- Compatibility
- Usability
- Reliability

- Security
- Maintainability
- Portability

Each of these characteristics includes several sub-characteristics; in total there are 31 sub-characteristics.

User experience (UX) is a key quality for improving the user interaction and the user's perception of the digital solution. Here, the quality model by Hassenzahl et al. [Hass2001] is a good starting point. It distinguishes between pragmatic (e.g., effective and efficient task support) and hedonic qualities (e.g., motivating task support).

Although both qualities focus on users, hedonic qualities go beyond the qualities of digital systems and provide a new perspective on qualities of a digital solution. The perceived hedonic quality focuses on the subjective perception and the sensations caused by the use of the digital solution.

EU 2.1.4 Additional Skills for Designing a Digital Solution

The competences provided in this syllabus define the foundation level, which means that the skills provided are necessary basics but are not sufficient to cover the whole spectrum of skills necessary to design digital solutions. **EO 2.1.4.1**

A DDP therefore has to be aware of the fact that additional skills are necessary. Exemplary skills include:

- Requirements engineering for understanding, validating, and managing requirements of complicated solutions
- Business analysis for understanding and evaluating business-driven solutions
- Industrial design for shaping physical devices as part of digital solutions
- Usability engineering for designing and evaluating the interactive part of digital solutions
- Software testing for the systematic quality assurance of software parts of digital solutions

The spectrum of skills for designing (and for building) a digital solution is very broad. Teamwork is therefore mandatory to design and build good digital solutions (see EU 6).

EU 2.2 Conceptual Work in Digital Design

This EU introduces conceptual work in Digital Design. It illustrates important fundamentals of conceptual work in EU 2.2.1 and introduces a set of pragmatic templates for conceptual work in Digital Design that are suitable for beginners.

The definition and selection of these templates are based on the practical experience of the syllabus authors. In literature, there are many other approaches to conceptual work and experienced people will certainly know and be able to apply other techniques. When defining the templates, the focus was on easy learnability and quick applicability. In this sense, the templates presented in this EU should be understood as pragmatic.

EU 2.2.1 Fundamentals of Conceptual Work

In general, concepts are ideas that occur in thoughts or in communication (written or verbal) and are considered as elements of thoughts (cf. [MaLa2015]). The conceptual work in Digital Design adopts the solution-driven perspective from design (cf. [Cros2006]). Conceptual work means working mentally to create a digital solution, i.e., defining the objectives of the digital solution and the corresponding form, function, and quality of a digital solution. Concepts can occur in a rather linear verbal/written form or in a highly structured technical form. **EO 2.2.1.1**

A design concept is created for several benefits:

- Thinking tool for taming supposedly complex solutions/systems
- Basis for construction and realization
- Communication tool
- External memory for complicated solutions/systems
- Evaluation tool
- Reference point for evaluation

Creating design concepts is inexpensive but has certain limits:

- Concepts are never complete
- Concepts always leave room for interpretation
- Concepts are not the digital solution
- Sophisticated concepts can create false confidence

The benefits and limits of concepts do not determine the intensity and the level of detail appropriate for a particular situation. Using the right intensity and level of detail of conceptual work requires experience.

EU 2.2.2 Pragmatic Document Templates for the Different Abstraction Levels

This EU presents document templates for the Digital Design brief and different abstraction levels of the building process: solution, system, and element. Documentation techniques for elaborating the different concepts will be presented in EU 2.2.3 and EU 2.2.5.

A pragmatic document template for a Digital Design brief consists of the following sections: **EO 2.2.2.1**

1. Context
   - 1.1. Case for Action
   - 1.2. Potential Customers
   - 1.3. Potential Users
   - 1.4. Potential further Stakeholders
   - 1.5. Related Solutions

   1.6. Potential Competitors
2. Vision
3. Scope
   3.1. Solution Space
   3.2. Potential Technologies
   3.3. Constraints
   3.4. No-Gos
4. General terms
   4.1. Schedule
   4.2. Mode of Cooperation
   4.3. Budget
   4.4. Revenue Streams
   4.5. Resources

A pragmatic document template for a solution design concept consists of the following sections:

1. Motivation
2. Context
   2.1. Customer Segments
   2.2. User Groups
   2.3. Further Stakeholders
3. Value Proposition
4. Customer Experience
5. Business Model
6. Constraints

System and element design concepts have the following main sections (see Table 1 for subsections):

1. Introduction
2. Objectives
3. Constraints
4. Form
5. Function
6. Quality Requirements

At the element level, we distinguish between two types of element design concepts:

- The software design concept is an element design concept for an element of a digital solution that is realized with software.
- The device design concept is an element design concept for a hardware device that is part of a digital solution.

Table 1 summarizes pragmatic document templates for system, software, and device design concepts including their differences. **EO 2.2.2.2**

The table can be read as follows:

- the first two columns show the (sub)sections that are relevant for the concepts and the last three columns show the concept types where these (sub)sections apply.
- The markings in the cells have the following meaning:
  - X: the corresponding (sub)section is part of the concept type
  - n/a: the corresponding (sub)section is not applicable for the concept type
  - n/r: the corresponding (sub)section is not recommended for the concept type

Table 1: Pragmatic document templates for system, software, and device design concepts

Section	Subsections	System Design Concept	Software Design Concept	Device Design Concept
Introduction		X	X	X
Objectives		X	X	X
Constraints		X	X	X
Form	Overview of Context	X	X	X
	User	X	n/r	n/r
	User Interfaces	n/a	X	X
	Existing Objects	X	n/a	n/a
	Existing Systems	X	n/a	n/a
	Elements to Realize	X	n/a	n/a
	Software Interfaces	n/a	X	X
	Hardware Interfaces as Parts	n/a	n/a	X
	Hardware Interface in Context	n/a	X	n/a
	Physical Parts	n/a	n/a	X
	Entities	n/a	X	X
Function	Scenarios	X	n/r	n/r
	Use Cases	n/r	X	X
	Functions	n/r	X	X
Quality Requirements		X	X	X

EU 2.2.3 Documentation Techniques for the Solution Level

This EU describes documentation techniques for the solution level: future press release (Digital Design brief), persona templates (solution design concept), stakeholder list (Digital Design brief and solution design concept), and value proposition canvases/business model canvases, and customer journey maps (solution design concept).

The future press release [Ross2019] is a technique for documenting a strong vision. It takes the reader into the future and describes the central success that the planned digital solution will have achieved. **EO 2.2.3.1**

In the design process, personas are a valuable tool for developing an understanding of the goals of a customer or user, and a crucial instrument for generating ideas and evaluating design concepts (cf. [Coop2004]). We define a persona as follows: **EO 2.2.3.2**

Persona*:* A fictitious character representing a group of people with similar needs, values, and habits who are expected to use a system or benefit from it in a similar way.

A good persona helps to reveal the behavior and motivation of a customer or user. At the solution level in particular, personas help to identify which customers or users are the most important ones to address in the design process.

A persona should consist of a picture, basic background information, and information about goals and behavior. In addition, the pains with the current situation or solution can also be specified.

High-quality personas are created by means of user research. For initial personas (referred to as ad hoc personas, cf. [CECN2014]), an initial understanding/idea of potential user types is sufficient.

A stakeholder list is a structured table for documenting stakeholders. It consists of the following columns [CPRE2020]: **EO 2.2.3.3**

- Name of the stakeholder
- Function (role) of the stakeholder
- Personal and contact data, including availability
- Area of responsibility and extent of expertise

In addition, documenting non-public information about stakeholders can be useful: temperament, level of understanding, and commitment (see EU 4.3), as well as goals and interests in relation to the digital solution.

The value proposition canvas is a template for describing customer profiles in relation to the values offered [OPBS2014]. The persona templates (see above) are used to describe each customer/user type in general, whereas the value proposition canvas focuses on the particular value of the digital solution for the customer/user. **EO 2.2.3.4**

A value proposition canvas consists of a customer profile and a value map. The customer/user profile describes:

- Customer jobs
- Gains
- Pains

The value map describes:

- Products and services
- Gain creators
- Pain relievers

A business model canvas [OsPi2010] is a template that describes a business model in a compact form. It consists of the following elements:

- Key activities
- Key resources
- Partner network
- Value propositions
- Customer segments
- Channels
- Customer relationships
- Cost structure
- Revenue streams

A customer journey map is a tool from service design [PoLR2013] and can be used for working on the form, function, and quality of digital solutions and thereby on the customer experience. A customer journey map covers the following aspects: **EO 2.2.3.5**

- The motive behind the customer starting the journey.
- A timeline documenting the journey of the customer. The journey begins when the customer first learns about the solution and ends when the customer finally stops using the solution.
- Touchpoints between the customer and the solution as elements of the timeline. Touchpoints include digital interaction situations with the elements of the solution, but also further analog situations (e.g., contact with customer support). Each touchpoint should be detailed with the needs, emotions, experiences, and actions of the customer.

A simple documentation approach for customer journey maps is a canvas with the motive and a table for the timeline. Each column represents one touchpoint with a detailed visual and/or textual description as one row. Further rows are used to describe the additional aspects.

We recommend creating customer journey maps for all customer personas defined in the solution design concept.

EU 2.2.4 Documenting Design Concepts at the System and Element Level: General Considerations

The Digital Design brief and the solution design concept rely on a continuous text documentation and a canvas-oriented documentation approach. To create design concepts at the system and element level, a different and more structured approach is useful to achieve the necessary level of technical detail to build a digital system and its elements, and to manage the building process. **EO 2.2.4.1**

The structure of a system (or element) design concept is defined at two levels:

- The headline level defines the document structure of a concept and gives clear guidance and access to the content of each section of the concept.
- The building block level is used to describe a particular aspect of the system (or the element) that must be realized.

A design concept building block (in short, building block) is a standardized description element type with defined relationships to other building blocks. A basic set of building block templates will be introduced in EU 2.2.5.

This separation between headlines and building blocks is especially useful for:

- Learning to write system and element design concepts at the necessary level of detail
- Quality assurance for the system and element design concepts created
- Distribution of work in teams
- Defining precise relationships between building blocks

In explanatory texts, repetition of facts is often understood as a didactic means to promote the learning of certain information or to avoid looking up important information in other parts of a text. However, repetition is not desirable in concepts. **EO 2.2.4.2**

Redundancies increase risks to the quality of concepts and the process of creating them, because redundant information is a source of misunderstandings and inconsistencies and reduces the ability to modify and extend concepts. Furthermore, redundant documentation alone increases the effort required for creation and maintenance, since the information must be described more than once. This increase is also noticeable when copying and pasting since text fragments generally cannot be copied one-to-one from one section of the document to another.

Cross-references are the stylistic tool of choice for avoiding redundancies in concepts. If an item of information (e.g., a set of rules, a data set, or a function) is needed more than once in the concept, then this item of information should be described as a separate information module and referenced with a cross-reference at the appropriate places.

Besides understanding the particular building blocks and templates of a concept, it is important to understand the relationships between these types of building blocks and templates. Understanding the relationships is important for creating a complete and consistent concept:

- Completeness means that the concept is complete in itself, i.e., any information referenced in a concept is actually present and described in the referenced part of the concept.
- Consistency means that a particular item of information in a concept is used in the same way as in all other concepts and that the items of information at different places in the concept do not conflict with each other.

Constructive relationships describe the relationships between the form, function, and quality that make up the digital system. Further details on constructive relationships will be explained in EU 2.2.6. Instructive relationships provide explanatory information that motivate the form and function of a digital system or an element in relation to the solution design concept or other sources.

Important instructive relationships are:

- Source relationship: description of the source of a certain building block
- Constraint relationship: description of a constraint that has led to a particular building block
- Goal relationship: description of the purpose in terms of the motivation for a particular building block

EU 2.2.5 Documentation Techniques for the System and Element Level

The assumption of perfect technology compared to real technology [WaMe1986] supports the design of a digital system. In particular, it means defect-free technology as well as infinite computing capacity, storage capacity, and infinite communication capacity. This assumption simplifies working on design concepts because the limits of technology do not need to be taken into account in the design concept. However, the assumption of a perfect technology does not extend to users or existing systems. **EO 2.2.5.1**

The assumption of perfect technology is also not free from considerations of the limits of technology. It is merely a simplification for design concepts. In the further course of the building process, the assumptions made by perfect technology have to be removed step by step. This is done through intensive cooperation with the activity area construction (see EU 1.3).

Using templates is a proven technique for providing a reference structure to represent constituents of concepts or specifications (cf. [CPRE2020]). Mandatory elements of a basic template are: **EO 2.2.5.2**

- Identification number with title
- Relationships to other elements
- Description of the particular element

Optional sections of a basic template are:

- Source (see above, useful for referencing additional information)
- Status (e.g., to describe if an element is, for example, agreed, under implementation, or done)
- Change log (e.g., to document the evolution of an element)

The purpose of a digital system (or an element of the digital system) can be described by a set of goals (e.g., business goals or user goals). A goal template is used as a textual description of a particular goal for the digital system or an element. It is useful to distinguish between the following two types of goals: **EO 2.2.5.3**

- Hard goals can be described in a way that their fulfillment can be measured objectively.
- Soft goals can only be described in a way that their fulfillment is measured subjectively.

If possible, soft goals should be concretized by detailed hard goals or other criteria that allow for the evaluation of the goal fulfillment.

The constraints of a digital system (or an element of a digital system) can be described by a constraint template. Each template represents a particular constraint that has to be fulfilled. If possible, the part of the system (or element) that must fulfill the constraint should be referenced. If possible, the constraint should be described in a measurable way to support evaluation.

The following templates are useful for elaborating the different building blocks of system and element design concepts:

Form at system level:

- Object template: short and abstract description of an existing object as perceivable form
- Existing system: short and abstract description of an existing system as underlying or perceivable form)
- User template: short and abstract description of a user type as perceivable form
- Device template: short and abstract description of a device to be built as perceivable form
- Software element template: short and abstract description of a software element to be built as underlying or perceivable form

Function at system level:

- Scenario template: description of a scenario that illustrates the usage of the system as underlying or perceivable function)

Form at element level:

- Entity template: informal or tabular description of a particular entity as underlying form
- Hardware interface template (applicable for devices only): description of an underlying or perceivable hardware interface of a device or an object
- Physical part template (applicable for devices only): description of a physical part (e.g., housing) that makes up the underlying or perceivable form of a device
- Software interface template: description of a software interface of an element, an object, or a related software as underlying form
- User interface template: description, including a visual representation, of a user interface as perceivable form

Function at element level:

- Function template: informal or algorithmic description of the transformation of data performed by an element as underlying function
- Use case template: semi-structured description of the interaction that the element offers as perceivable function

Quality at system and element level:

- Quality requirement template: description of a qualitative characteristic of the digital system (form or function) as perceivable or underlying quality

EU 2.2.6 The Big Picture of Conceptual Work in Digital Design

Constructive relationships describe the relationships between form, function, and quality that make up the digital system (see EU 2.2.4). Remember, goal and constraint relationships are instructive relationships (see EU 2.2.4).

For beginners in Digital Design, we suggest considering the templates as building blocks in a literal sense. Similarly to real bricks, only certain types fit together. The constructive relationships define which building blocks fit.

The constructive relationships at the element level can be characterized as follows: **EO 2.2.6.1**

- Every element of the digital system needs interfaces to interact with its environment.
- Interfaces create data flows.
- Visual user interfaces are special case of interfaces and also create a data flow.
- Entities and functions are the backbone of each element of a digital system.
- Software interfaces are the counterpart of user interfaces for the underlying form.
- Quality requirements define qualitative details of the form and function.
- Use cases put the other building blocks into a frame.

The constructive relationships at the system level can be characterized as follows:

- The elements of the system (user, existing objects, existing devices, software elements, and digital devices) interact with each other in terms of data flow.
- Scenarios frame the interaction between the elements by means of exemplary interaction flows (the complete behavior is described at the element level).
- Quality requirements describe qualitative characteristics of elements or their interaction.

The constructive relationships between the system level and the element level can be characterized as follows: **EO 2.2.6.2**

- Every relationship between two system elements from the system level must be captured by interfaces at the element level.
- All relationships at the element level must be reflected at the system level.
- The function described by the scenarios at the system level must be reflected by the use cases/functions at the element level.
- The function described at the element level (use cases and functions) must not contradict the function (scenarios) at the system level.
- Quality requirements defined at the system level must be also fulfilled at the element level.
- Quality requirements defined at the element level must not contradict the quality requirements defined at the system level.

In addition, goals and constraints defined at system/element level must not contradict each other.

Although the solution design concept is documented with different documentation techniques (see EU 2.2.3), there are important relationships between the solution and system/element level as well:

- The value proposition defined for the customer must be fulfilled by the system and the use cases of the elements.
- Customer groups and user groups must be consistent (keep in mind that customers and users are not always identical).
- The constraints for the solution must be consistent with the constraints of the system and the elements.

EU 2.3 Application of Prototypes in Digital Design

EU 2.3.1 Fundamentals of Prototypes

The use of prototypes is a key technique in design. They help to achieve several (partly overlapping) objectives (cf. [McEl2017]): **EO 2.3.1.1**

- Explore the problem and the customer or user needs and requirements.
- Communicate solution ideas and concepts.
- Test and improve concepts and solution ideas.
- Advocate a solution or a solution idea.
- Increase the probability that a solution idea can become a real innovation.

In all of these cases, the creation of prototypes supports the iteration of problems, requirements, concepts, solution ideas, or solutions. The DDP learns from building a prototype and can use it for gathering feedback from stakeholders and for a subsequent improvement based on this feedback. Such iteration cycles are essential parts of all building processes (see EU 2.1).

The creation of a prototype takes a certain effort. However, this effort is well spent if the feedback gathered helps to base decisions on more information and enable better decisions. By exploring solution ideas in many fundamentally different directions using prototypes, many of these ideas will fail but will also generate new ideas for better solutions. Using this power of iterative prototyping can boost finding innovative and excellent concepts and solutions and significantly increases the probability that a solution idea becomes innovative.

Building a digital solution may cover a wide range of disciplines and professions (see EU 1.3). To ensure unambiguous communication between experts from these areas, it is important for the DDP to understand that there is no unique and generally accepted definition of what a prototype is. **EO 2.3.1.2**

Experts and stakeholders might have a different understanding when talking about prototypes because they have a different background from the discipline they are working in.

Experts from different disciplines also use the term “model,” encompassing a simplified representation of an entity with the goal of studying this entity. Sometimes, experts use the term “model” for different notions or to refer to a prototype.

To reduce communication problems with the other disciplines involved in building a digital solution, the following definition provides a broad understanding of the term “prototype” for use in the context of Digital Design and building digital solutions.

Prototype: A preliminary, partial instance of a design solution.

Prototypes can be used as

1) A manifestation of an idea for a future digital solution in a format that communicates the idea to others or can be tested with customers or users
2) A model for later stages or for the final, complete version of a digital solution
3) A means of obtaining early feedback from stakeholders on a concept by providing a working model of the expected digital solution before actually building it

based on [McEl2017] and [IEEE2017]

The use of a prototype or prototypes is also referred to as “prototyping”. As stated in [Dick2019], the term “prototype” (the object) is sometimes used when “prototyping” (to prototype, or the process of working on and using a prototype) is meant.

In the above definition, an “idea” might be an idea of a customer or user need, a technical problem, or a business model for a product or service. The use of prototypes in the definition above links the significance of a prototype to an objective the prototype is built for.

Prototypes play an important role in various disciplines. The following list gives examples from the digital industry and other disciplines outside the digital domain: **EO 2.3.1.3**

- Building architects, for example, work with floor plans, airflow models for ventilation, heating, and cooling, daylight simulations for optimizing the incidence of light through windows, material studies, aesthetic models, and building simulations, where users virtually can walk through the planned building (see [McEl2017]).
- Industrial designers use sketches (e.g., created by real or digital pencils), foam models, or models from additive manufacturing (e.g., 3D printing). They conduct material studies, use aesthetic models, make scaled mock-ups, and create final forms as prototypes before communicating the design result to manufacturing (see [McEl2017]).
- Industrial designers usually create form, function, and technical designs in parallel with technical designers who create the electronic design for an electric device. Prototypes consisting of selected and assembled electronic components are useful for studying the implications for and optimizing the industrial design (see [McEl2017]).
- Filmmakers use storyboards and previews to visualize the flow of a movie before filming it.
- Interaction designers, who develop user interfaces of software applications, use prototypes such as sketches, user flows, wireframes, coded prototypes, and visual designs to iteratively improve a solution (see [McEl2017]).
- Software architects and software developers use coded pieces of software as functional prototypes (see EU 2.3.2) to explore the feasibility, verify requirements, or study certain software quality aspects of alternative software solutions.

The examples above show that creating and using prototypes is a common and successful technique in various disciplines. The examples are meant as inspiration and motivation for the DDP to create and use diverse types and categories of prototypes—which do not necessarily have to be a prototype in a digital format—to build digital solutions.

EU 2.3.2 Prototype Categories and Tools

There are several approaches for categorizing prototypes. Studying such classifications helps the DDP to understand the broad scope of prototypes and helps with the selection of an appropriate prototype in a given situation and at a specific process phase. **EO 2.3.2.1**

Level of interaction

A categorization according to the level of interaction distinguishes between horizontal and vertical prototypes:

- Horizontal prototypes consist of a comprehensive user interface with little or no functionality.
- Vertical prototypes exhibit a subset of the target functionality in depth but do not cover many functions or the complete user interface.

Goal of prototyping

Floyd [Floy1984] categorizes prototyping for exploration, experimentation, and evolution depending on the goal of prototyping within the given project situation.

- Exploratory prototypes are useful for collecting ideas, for requirements elicitation, and for requirements validation. The focus lies on the exploration of different alternative concepts and solutions.
- Experimental prototypes support the evaluation of the feasibility or usefulness of a certain solution before considerable effort is put into the realization of the digital solution.
- Evolutionary prototypes aim at continuous development and further development of prototypes together with the target system. At some point at the end of the realization process, the prototype is, or the prototypes are, integrated into the final digital solution.

Level of fidelity

The level of fidelity of a prototype describes, on a continuous scale from low to high, how close the prototype is to the final digital solution. This applies to the (visual) representation as well as to the behavior of the prototype.

- Low-fidelity prototypes are far away from the final digital solution. Usually, this category is in another medium, has a small number of functions, and normally has no design visuals. One example is a paper prototype.
- High-fidelity prototypes are at the other end of the fidelity scale and close to the final digital solution. Usually, this category is in the final medium of the digital solution, has visual designs, and includes real content. One example is a build of a physical object, e.g., a headphones housing, as a sample before mass production starts.

This categorization provides a coarse categorization of the overall fidelity level of prototypes.

Dimensions of a prototype

The following five different dimensions of a prototype provide a sophisticated and practically applicable prototype categorization:

- Sensory refinement
- Breadth of functionality
- Depth of functionality
- Richness of interactivity
- Richness of data model

A prototype might have different levels of fidelity (on a scale from low to high) for each of these dimensions. If the fidelity level differs between these dimensions, such a prototype is called a "mixed-fidelity prototype." This model is an extension of the approach introduced by McCurdy et al. [MCPK2006].

Technical systems for creating a virtual reality (VR) provide a certain degree of immersion, which is the technical precondition for enabling the psychological state of presence for the user. Presence is the feeling of the user of "being there" in the virtual environment while forgetting the fact of physically still being in a different (the real) environment. EO 2.3.2.2

According to Jerald [Jera2016] (cited after [SlWi1997]) "Immersion is the objective degree to which a VR system and application projects stimuli onto the sensory receptors of users in a way that is extensive, matching, surrounding, vivid, interactive, and plot conforming.".

These six elements mentioned in the definition of immersion can be applied to prototyping and related to the five dimensions of a prototype (see above). This mapping can be used to identify important dimensions of a prototype in order to create the desired level of immersion according to the objective of the prototype.

The selection of the most appropriate category and tool for the creation of a prototype in a given project situation requires a certain level of experience. A beginner in this field should start with simple technologies, such as sketches, paper prototypes, or storyboards (see EU 2.3.3). Technologies that are more complex should be used only after careful consideration. The following overview shows the broad scope of prototype creation tools. EO 2.3.2.3

Software design and development tools and technologies for prototype creation

Standard software development environments can be used to create prototypes. The following simplifications help to create a cost-effective software prototype:

- Using simple web technologies, such as HTML5, CSS, and JavaScript instead of the target technologies
- Using tools to build graphical user interfaces (UI builder) by drag and drop, instead of a customized UI implementation
- Coded parts of the software application with simplifications, such as a simpler programming language, omitting error-handling routines, or omitting special cases of the program control flow

When developing a software prototype, the final shape and capabilities of the device running the software (e.g., screen size, computation capacity) should be considered in order to create a realistic prototype.

Industrial design tools for prototype creation

Industrial designers have a long tradition in prototyping and use prototyping tools to design the interaction of the user with a physical product and to study the feasibility of such a product. The following three types are distinguished (cf. [IDSA2020]):

- Drawing tools for sketches and illustrations
- Rendering software for three-dimensional renderings
- Additive manufacturing for tangible mock-ups

As explained above, industrial designers sometimes use the word “model” to refer to a prototype, whereas software engineering has a different understanding of the term model (cf. [IEEE2017]). A definition of the term “prototype” within the context of Digital Design is provided above.

Interaction design tools for prototype creation

Interaction design is the discipline that deals with the creation of user interfaces (cf. [Coop2004]). The following interaction design tools are useful for building user interface prototypes:

- Drawing tools for sketching, storyboarding, and wireframing
- Paper and pencil for paper prototyping
- Rendering software for high-quality rendering

Sketching, wireframing, or high-quality rendering of user interface screens can be used for integration into a clickable prototype (click prototype, click dummy).

Other tools

Furthermore, prototyping tools and technologies from production engineering and electrical engineering may also be used—for example, creating a device prototype by means of additive manufacturing (e.g., 3D printing).

EU 2.3.3 The Value of Simple Low-Fidelity Prototypes

Paper prototypes and cardboard prototypes are easy to build and practical for creating low-fidelity prototypes. A paper prototype usually consists of (1) hand-sketched images of the target display screens of the digital solution, and (2) a description of the sequence of these screens when the user interacts with the digital solution (interaction flow). This description can be a storyboard or some other form of specification of the logical flow of the screens, e. g., what happens when the user touches a button or when a particular event happens. When the screens are drawn on small pieces of paper or on sticky notes, they fit into a model of the target device (hardware display). Several of these drawn screens can be used to present the screen flow. A large piece of paper or cardboard can serve as such a model. **EO 2.3.3.1**

Paper prototyping is a simple and flexible method that uses paper prototypes in iterative loops to gather valuable feedback quickly from users and other stakeholders. Interaction designers apply it frequently to improve user interface design. In many cases, they prefer this kind of prototype over click dummies because of its flexibility (cf. [Snyd2003]).

EU 3 Digital Material (L2)

Duration: 90 min

Educational objectives:

EO 3.1.1	Explain the idea of perceivable and underlying technology (L2)
EO 3.1.2	Explain the importance of technological understanding for Digital Design (L2)
EO 3.1.3	Describe how technology choices can have an impact on quality attributes (L1)
EO 3.2.1	Name the different types of end user devices (L1)
EO 3.2.2	Describe different types of interaction technologies (L1)
EO 3.2.3	Describe different software user interface technologies (L1)
EO 3.3.1	Describe the importance of programming technology for Digital Design (L1)
EO 3.3.2	Describe the importance of hardware and software technology for operating software for Digital Design (L1)
EO 3.3.3	Describe the importance of communication technology for Digital Design (L1)
EO 3.4.1	Describe software architecture, complexity theory, and human-computer interaction as important knowledge areas (L1)
EO 3.5.1	Describe the Digital Design perspective on technology (L1)

EU 3.1 Understanding Technology and Its Relation to Quality

The technological possibilities for realizing a digital solution in the area of hardware and software have grown enormously in recent years and will continue to grow in the future (see [Kell2016]). **EO 3.1.1**

Digital Design means understanding digital technology as shapeable material for building a digital solution (see EU 1.2). To structure the access to and communicate the knowledge about technology, Digital Design uses the form, function, and quality model of digital material. A fundamental aspect of this model is the differentiation between the (1) perceivable layer, which can be perceived by the stakeholders, and the (2) underlying layer, which is hidden from perception by the stakeholder but enables the perceivable layer. In the following, this aspect of the model is sketched for the form and function along with examples. The quality aspect of this model is addressed below.

- Perceivable hardware
  - Form: end user device, e.g., a PC or Smartphone, glass, metal, plastic, wood
  - Function: movement, adjustment, opening
- Perceivable software
  - Form: user interface elements, e.g., buttons, sliders, panes
  - Function: interaction flow
- Underlying hardware
  - Form: microprocessor system, communication system
  - Function: hardware encryption, electrical circuit
- Underlying software
  - Form: operating system, cloud system
  - Function: algorithm

A profound understanding of technology and technological development offers the following important benefits for the DDP: **EO 3.1.2**

- Avoidance of unrealizable solutions
- Inspiration for novel solutions
- Substantial communication with software experts
- Substantial communication with experts for physical products
- Substantial communication with vendors or partners

As digital technologies are subject to constant development, the DDP must continuously monitor current technological developments and learn about recent technologies to keep up to date.

It is important to recognize the difference between technological knowledge and the ability to design and develop using this technology. Only the knowledge about the possibilities and limits of the available technology enables the best possible digital solution to be built. The DDP does not necessarily have to be an expert in all technological fields. For example, the DDP must understand all possibilities and limits of user interactions using the current technologies. However, experts in interaction design deal with this kind of design even more extensively in order to create an interactive system (see also EU 2.1.4).

The choice of certain technologies has an impact on the quality of a digital system and hence the overall digital solution. Technology choices can manifest themselves in different quality characteristics affecting perceivable and underlying qualities. **EO 3.1.3**

The selection of adequate technologies, therefore, has to be in line with and depends on the defined quality criteria for a digital system and for the overall digital solution. If technologies are chosen without knowing or considering predefined quality criteria, this can lead to digital systems and solutions that do not meet the expected perceivable quality criteria of their users and hence these solutions might not be accepted by the users. Furthermore, inadequate technology choices can also influence underlying quality criteria and prevent or at least make it cumbersome for developers to maintain the system. All these considerations are applicable to hardware and software and for the form and function of perceivable and underlying technologies.

EU 3.2 Perceivable Technology

Perceivable technologies are used to realize the parts of a digital solution a user can perceive.

Standardized end user devices, such as notebooks, tablet computers, or smartphones are often used to realize digital solutions. These devices can be classified as perceivable technology. On the other hand, such devices provide technical capabilities that can be assigned as underlying technology (e.g., Wi-Fi). However, Digital Design has no direct influence on the internal structure of this kind of devices and therefore, the perceivable form is the most appropriate category in this context. If standardized end user devices are used as part of a digital solution, the assumed technical capabilities must be clearly defined in order to define and provide the necessary resources for the digital solution. **EO 3.2.1**

The following distinction provides coarse classes of end user devices:

- Stationary devices at fixed locations, such as personal computers, smart speakers, or smart scales
- Portable devices usable at different locations—this class ranges from multi-purpose devices, such as notebooks, tablet computers, or smartphones to (the growing number of) single-purpose devices, like card readers, fingerprint or retina scanners, consumer goods ordering devices, or customer satisfaction stations
- Wearable devices worn on the body or even implanted into the body—examples are activity trackers, blood glucose meters, and smart watches

Modern interaction technology consists of a combination of complex hardware and software systems, which belong to the perceivable form and function. From the perspective of the DDP, the interactive aspects of this user experience are most relevant. Therefore, the DDP mainly focuses on the perceivable functions. **EO 3.2.2**

We distinguish between three user interface paradigms:

- Command line interface (CLI)
- Graphical user interface (GUI)
- Natural user interface (NUI)

In addition to these user interface paradigms, we can distinguish between different interface types. Many of these types map to the aforementioned user interface paradigms. The interface types that have a certain significance today are listed below (see [ShPR2019]):

- Audio interface
- Voice interface
- Touch interface
- Gesture-based interface
- Haptic interface
- Tangible interface
- Brain—computer interface
- Mixed reality (MR)
- Virtual reality (VR)
- Augmented reality (AR)
- Ambient interface

The selection of an interface type or a combination of interface types for a custom-made end user device is an important decision for the design of a digital solution and can only be revised at high cost in the further course of the building process. If different interaction forms and interface types are considered, the suitability of these alternatives for a digital solution should be investigated by the use of prototypes in order to reduce the risk of a wrong decision at an early stage.

(Visual) user interface (UI) technology falls into the category of software for the perceivable form and function. It determines, e.g., both the visual structure (form) of the user interface and the dynamic behavior of the user interface (function). For example: **EO 3.2.3**

- Windowing, scrolling, zooming
- Speech synthesis
- Speech and gesture recognition
- Software-enabled metaphors, such as pick, drag, and drop
- Software-enabled virtual devices, such as virtual keyboards, virtual sliders, or virtual analog instruments

User interface technology for other sensory modalities also falls into this category. Currently, technologies for audio and haptic input and output are important as well as technologies for visual interfaces.

A wide range of software development environments are available that enable the creation of applications with such interfaces. To run applications on the device categories named above, there are operating systems, such as Android, iOS, or Windows. Such a framework that is composed mainly of a device and an operating system is called a computing platform or platform.

Modern development environments for application development for mass market devices are very well documented to reduce the barrier to starting development for a certain platform and for migrating existing applications to other platforms. For the most frequently used platforms—Android, iOS, and Windows—we can basically distinguish between four types of applications: (1) native, (2) web, (3) hybrid, and (4) cross-platform applications.

Replacing user interface technology in an existing digital solution can be expensive since the technology is typically integrated very deeply into a digital solution. Therefore, the user interface technology should be selected with care and the DDP should be involved in the selection process in order to obtain the best possible technology for the design of the solution.

EU 3.3 Underlying Technology

Underlying technology is used to build those parts that enable the perceivable form, function, and quality of a digital solution. At foundation level, a DDP should be aware of programming technology, technology for operating software, and supporting hardware.

Programming technology is used to implement the perceivable form and function of a digital solution (see EU 3.2). However, programming technology also determines a significant part of the underlying form, function, and quality of a digital solution. **EO 3.3.1**

In addition to writing new software, there is a large volume of software already available that addresses a special purpose. At foundation level, a DDP should be aware of the following types of special-purpose software:

- Data storage technologies are designed to manage and persistently store large sets of data or information (cf. [Wiki2020] for a list of databases).
- Software frameworks provide standardized generic functionality that can be used to implement software.

Via the World Wide Web, API technology offers functionality that can be integrated into your own solution via a technical interface.

Computing and communication technology provide the infrastructure for building a digital solution. **EO 3.3.2**

Computing technology consists of *computer hardware*, with processors, memory, and storage as the typical building blocks, and *operating systems*. Computer hardware is mostly built in large volumes as a standardized commodity. Specialized hardware, e.g., for data encryption, is built when certain quality requirements (in particular, speed and security) cannot be achieved with standard hardware. Operating systems are required to manage the computer hardware, provide basic software services such as organizing hardware storage with a file system, and also to provide an environment for running application software.

Hardware and its operating systems can be provided as a:

- Part of a standardized device (e.g., a smartphone)
- Part of a custom-made device (e.g., a do-it-yourself smart home controller)
- Local server (e.g., a desktop computer)
- Remote server (e.g., in a data center)
- Service on-demand over the Internet (cloud computing)

Communication technology consists of communication hardware, such as cables, antennas, radios, receivers, etc., which is operated by a stack of protocol layers that are realized with computer hardware, and communication software. Together, they provide communication services at various levels, for example: **EO 3.3.3**

- Basic services, such as Ethernet, Wi-Fi, Bluetooth, and mobile, cellular telephony including 5G, radio-frequency identification (RFID), near-field communication (NFC), and infrared (e.g., for facial recognition)
- Network services, such as the Internet or the network that connects phones when a number is dialed
- Application services, such as WWW or email

A DDP needs to know the basics of the form, function, and quality of underlying computing and communication technology, for example:

- Form: which technologies are available on which devices?
- Function: which services can be provided by these technologies?
- Quality: what is the quality of these services in terms of speed, storage capacity, communication bandwidth, availability, reliability, etc.?

EU 3.4 Technology-Oriented Knowledge Areas

The following knowledge areas are important for a DDP at foundation level:

Software architecture deals with the definition of the fundamental organization (i.e., underlying form and function) of a software system and is an important aspect of the construction and realization of a digital solution. There are basic architectural styles that can be used to build systems (e.g., layered architecture, event-driven architecture, microservices). Selecting a proper software architecture is significantly important for achieving perceivable and underlying quality. Once a decision on a suitable software architecture has been made and the system implemented, it is costly to make changes to the underlying architecture. Defining an underlying architecture allows for a detailed analysis of the software system's behavior before the system is built and an understanding of whether the future software system will fulfill the desired perceivable and underlying qualities. This understanding is especially important for fostering efficient collaboration between design and construction during the building process. **EO 3.4.1**

Computational complexity theory deals with the question of the quantity of computational resources required to solve a given problem [Wegn2005]. Designing a digital solution includes being aware of its complexity. A DDP can seek advice from experts if a digital solution deals with complex algorithmic problems, but ideally, the DDP will already have a basic overview of relevant topics regarding complexity theory.

Algorithms are an integral part of digital systems. They are abstract descriptions for solving well-defined functional problems. All algorithms have inherent time and space boundaries that need to be considered when deciding which algorithm to use to solve a specific problem. The "big O notation" is commonly used to classify algorithmic complexities and it describes the execution time needed or the space used by an algorithm. Understanding these worst-case scenarios regarding an algorithm's time and space complexity supports developers in selecting algorithms that are in line with the stakeholder needs and that satisfy requested perceivable quality attributes such as performance.

Human-computer interaction (HCI) is a knowledge area that is "concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them" [[Hewe1992] Hewett, T. T., Baecker, R., Card, S., Carey, T., Gasen, J., Mantei, M., Perlman, G.: ACM SIGCHI Curricula for Human-Computer Interaction. Technical Report. Association for Computing Machinery, 1992.]. This means that HCI is about connecting humans and machines by considering human needs and providing adequate interaction technologies. HCI includes research on how to improve existing user interfaces and how to provide innovative new ones (e.g., augmented reality). Overall, human-computer interfaces have undergone significant changes in the last two decades. From the perspective of Digital Design, HCI and the user interface belong to the perceivable form and function of a digital solution that deals with the immediate interaction between the digital solution and its users. For the DDP, it is important to have an overview of existing interface types and to understand the specific characteristics of these interfaces from the user perspective in order to select the most suitable interface for a digital solution.

EU 3.5 The Digital Design Perspective on Technology

To conclude this EU, we will go back to the Digital Design perspective. From this perspective, the following factors are important when selecting technology: **EO 3.5.1**

1. Compatibility with the intended context
2. Legal constraints
3. Capability to implement the intended functions
4. Inspiration for additional functions
5. Reuse vs. implementation risk
6. Availability of skilled personnel
7. License costs

Factors 1–5 address the technical feasibility of a digital solution. From the Digital Design perspective, they are important for selecting the best-fitting technology for the intended functions and they can also be a source of innovation. Factors 6–7 address the business model and the overall building process for a digital solution. The costs for manual implementation, for skilled (or unskilled) personnel, and for licensing the technology must be considered in the business model and the plan. Finally, the list of factors shows that technical decisions are closely intertwined with design decisions related to a digital solution.

EU 4 Cross-Cutting Competences (L2)

Duration: 210 min

Educational objectives:

EO 4.1.1.1	Name characteristics of human attention (L1)
EO 4.1.2.1	Name characteristics of the selection and execution of actions (L1)
EO 4.1.3.1	Describe the role of emotions in the interaction between user and digital solution (L1)
EO 4.1.4.1	Explain the benefits of prototypes for understanding and avoiding human factor and user experience issues in a digital solution (L2)
EO 4.2.1.1	Explain the importance of business models for Digital Design (L2)
EO 4.2.1.2	Name the five business model patterns (L1)
EO 4.2.2.1	Explain the difference between digital business and e-business (L2)
EO 4.3.1.1	Describe the importance of the people dimension in the building process for a digital solution (L1)
EO 4.3.1.2	Explain the building process for a digital solution as a social process (L2)
EO 4.3.2.1	Name the four temperaments from the Keirsey Temperament Sorter (L1)
EO 4.3.2.2	Explain communication types with the Keirsey Temperament Sorter (L2)
EO 4.3.2.3	Name limits of personality models (L1)
EO 4.3.3.1	Name main challenges of the building process steps for a digital solution from a temperament perspective (L1)

EU 4.1 Human Factors

EU 4.1.1 Fundamentals of Human Attention

Three overlapping aspects are relevant that characterize human attention: attention as a filter, limitations of attention, and attention control. **EO 4.1.1.1**

The presence of a stimulus provided by a digital solution does not necessarily mean that the users actually sense and really perceive this stimulus. One reason is that the human senses are limited. Another reason is that only a small amount of sensed information is actually perceived. Attention as a “filter” [WHBP2016] steers how many and which stimuli reach the human perception.

To see, humans have to move their eyes and focus, whereby several factors influence where the eyes finally look (e.g., salience). One negative consequence of this visual selective attention can be “change blindness” [WHBP2016]. To hear, humans divide their attention and receive stimuli from different auditory streams by means of an unconscious fast switching between these streams. Based on a pre-processing by the brain, the brain steers which sound stream the human finally perceives and which auditory stimulus is not “heard.”

Attention is controlled from the top down or from the bottom up [WHBP2016]. In the case of top-down control, the current active goals and tasks of the humans steer their attention, while bottom-up control refers to physical characteristics of a stimulus that steer the attention.

EU 4.1.2 Fundamentals of Human Performance

EO 4.1.2.1

Given that humans have perceived information, they decide on an action and execute this action. In doing so, humans can be very fast and accurate, but they can also make errors. Nevertheless, humans can detect and correct their errors.

A digital solution should prevent the users from making errors. However, "it's impossible to build a system that is impervious to human error" [Wein2011]. Thus, a digital solution should also support the users in detecting and correcting their errors—for example, with system feedback and error messages.

In order to support error prevention and error correction, the DDP should be aware of error types. Errors can be divided into [WHBP2016]:

- Mistakes
- Slips
- Lapses

EU 4.1.3 Emotions in the User—System Interaction

EO 4.1.3.1

Humans do not just sense and perceive stimuli and then decide on (simple) actions, like detecting and clicking buttons provided by a digital solution. A digital solution can unleash subjective reactions in the users, which in turn, can affect if and how the users will interact with the digital solution, now or in the future.

One model that describes this relationship is the "Component model of User Experience (CUE)" [ThMa2007] [Ming2020]. When a user interacts with a digital solution, the user's emotional response to the digital solution is shaped by the perception of instrumental (e.g., effectiveness) and non-instrumental (e.g., visual aesthetics) qualities of the system. Emotions mediate between both types of perceptions. Finally, the user's emotional response and the perception of the two system characteristic types influence the consequences of usage, such as overall judgment and intention to use.

EU 4.1.4 The Role of Prototypes

EO 4.1.4.1

To avoid a realized digital solution having flaws related to human factors or generating negative reactions, prototypes should be built early. They help to iteratively understand and influence the behavior and the experience of the user in an intended way. Moreover, an evaluation of the prototype can help to identify if and why issues related to human factors occur in the prototype. Evaluations are divided into expert-based and user-based approaches. Any prototype category can be tested, but the prototype category—among many other aspects—might affect the extent to which issues in the prototyped solution that are related to human factors can be identified at all. To achieve good Digital Design, it is important to foster and plan prototyping as well as iterative prototype testing. The decision about when to conduct the testing activities should be taken wisely, for example, as far as a sufficient maturity of the solution is achieved or before moving from one step to the next step in the building process.

EU 4.2 Business Models for Digital Solutions

EU 4.2.1 Fundamentals of Business Models

A business model describes how an organization plans to create value [OPBS2014]: **EO 4.2.1.1**

> Business model: The rationale of how an organization creates, delivers, and captures value in economic, social, cultural, or other contexts.

Whenever a digital solution plays a major role in the value chain of an organization, there are important relationships to consider between Digital Design and an organization's business model, including its value proposition to internal or external customers:

- The value proposition of the business model (see EU 2.2) must be realized by the digital system.
- The capabilities and limits of digital material define the capabilities and limits for delivering value.
- The customers of the business are often users or stakeholders of the digital system.
- Costs for building and operating a digital system are often a significant part of the cost structure of a business.
- Creating the revenue stream is often part of the digital system (e.g., collecting data on payment, interaction with a payment provider).

Building a digital solution is therefore not only about the form, function, and quality of the digital system that realizes the digital solution (see EU 1), it is also about defining a business model together with the digital system (see EU 2.1).

[OPBS2014] defines the following business model patterns: **EO 4.2.1.2**

- Unbundling business model
- The long tail business model
- Multi-sided platform business model
- Free as a business model
- Open business model

EU 4.2.2 The Difference between Digital Business and e-Business

A digital business aims to harness digital solutions to enable new business models that give an organization a competitive advantage. In contrast, e-business primarily aims to digitize (see EU 1.1) an existing business model, typically with the goals of saving costs or attracting more customers, but without fundamentally changing the business model. **EO 4.2.2.1**

In turn, digital business is an enabler for digital transformation, i.e., when digital solutions change the behavior and lives of people and impact society. Social media, such as Instagram, or entertainment streaming services, such as Netflix, are examples of where digital solutions drive the digital transformation. The three-horizon model [BCW1999] is a tool for thinking systematically about the scope and future possibilities, of the digital business, about the insight maturity of a digital solution, and for defining the level of business transformation, in three time steps.

EU 4.3 People Management

People management is an important cross-cutting competence for a DDP. It is not sufficient to manage people's skills, experiences, and availability. For the building process of a digital solution, personality indicators, an effective team diversity, and team fit must also be taken into account. There are several challenges for the building process that can be addressed by taking people management seriously.

EU 4.3.1 The Building Process as a Social Process

This section introduces the people dimension of the building process for digital solutions. People play a central role in different aspects of building digital solutions: **EO 4.3.1.1**

- People can be the future users or customers of the digital solution
- People can be clients that order the building of a digital solution
- People can be stakeholders who pose requirements to the digital solution
- People also can execute the building process in different roles

The human dimension—i.e., people as users, customers, clients, and stakeholders—is at the core of Digital Design and has been addressed explicitly in this syllabus. The techniques presented in EU 2 are intended to support people in taking the user's, customers, and client's perspective into account during the building process, especially from the Digital Design perspective.

However, there is an additional dimension to people in the building process. Similar to EU 4.1 on human factors, which aims to create awareness for the human dimension of digital solutions, this section aims to create awareness for the people who perform the building process.

The building process should not be considered a mechanical process. Instead, it should be considered as a social process that takes place between the people who participate in the building process (cf., e.g., [VPGV2008]). This includes the people who actually build the digital solution and the people who provide input to the building process (i.e., future users and other stakeholders). **EO 4.3.1.2**

The social process perspective takes into account the individual people, their relationships, their understanding of the digital solution, and the communication between the people involved. The following perspectives are useful for understanding the building process as a social process:

- People and organizations prefer different ways of communication.
- People and organizations have different starting points (e.g., education, personal experience, origin) for working on a subject matter.
- People and organizations prefer different ways of working to accomplish a task depending on their personality.

- The different steps of the building process provide different challenges for the people and the organization in terms of leadership.
- The working environment (e.g., time or expectations) has a decisive influence on people's actions and behavior.

The broad scope of these perspectives underlines the importance of understanding the building process as a social process. Dealing with all these perspectives goes far beyond the foundation level. In the following, the Keirsey Temperament Sorter is presented as a tool to get an introduction to working with the people dimension.

EU 4.3.2 Understanding People through Personality Models

EO 4.3.2.1

Temperament and its psychometrics are a configuration of observable personality traits, such as traits of communication, patterns of action, and sets of characteristic attitudes, values, and talents. The Keirsey Temperament Sorter [Keir1998], which is based on the Myer-Briggs Type Indicator (MBTI), is a starting point for understanding people. The Keirsey Temperament Sorter also encompasses emotional needs, the way what behaviors can be observed in collaboration, the kinds of contributions that individuals make in the workplace, and the roles they play in society. Each temperament has its own unique qualities and shortcomings, strengths, and challenges. The following table shows the four basic temperaments defined by Keirsey:

Table 2: The Keirsey Temperament Sorter

Temperament	Description	MBTI
Artisan	Artisans are *concrete* and *adaptable*. Seeking stimulation and virtuosity, they are concerned with making an impact. Their greatest strength is tactics. They are excellent at troubleshooting, agility, and manipulating tools, instruments, and equipment. The “Go West” pioneers from America are an archetype for this temperament.	sensitive perceiving (SP)
Guardian	Guardians are *concrete* and *organized* (scheduled). Seeking security and belonging, they are concerned with responsibility and duty. Their greatest strength is logistics. They are excellent at organizing, facilitating, checking, and supporting. The “citizen” of emerging cities is an archetype for this temperament.	sensitive, judging (SJ)
Idealist	Idealists are *abstract* and *compassionate*. Seeking meaning and significance, they are concerned with personal growth and finding their own unique identity. Their greatest strength is diplomacy. They are excellent at clarifying, individualizing, unifying, and inspiring. The “Blue Helmets” of the United Nations are an archetype of this temperament.	intuitive, feeling (NF)
Rational	Rationals are *abstract* and *objective*. Seeking mastery and self-control, they are concerned with their own knowledge and competence. Their greatest strength is strategy. They are excellent in any kind of logical investigation such as engineering, conceptualizing, theorizing, and coordinating. The “Star Trek” characters are an archetype for this temperament.	intuitive, thinking (NT)

With respect to communication, two general communication types can be derived from Keirsey: **EO 4.3.2.2**

- Some people talk primarily about the external, concrete world of everyday reality: facts and figures, work and play, home and family, news, sports, and weather—all the who, what, when, where, and how-much things of life.
  Important for the building process: they look more at details and rely on knowledge from the past.
- Other people talk primarily about the internal, abstract world of ideas: theories and conjectures, dreams and philosophies, beliefs, and fantasies—all the why, if, and what-might-be issues of life.
  Important for the building process: they have a better chance of seeing the big picture and find it easier to look into the future.

You should be aware that models such as the Keirsey Temperament Sorter should not be confused with precise measurement instruments that allow people to be categorized in a precise manner. **EO 4.3.2.3**

Personality models are a starting point and a good tool for improving the ability to understand people and their behavior. However, they should never be used as the only source for understanding the behavior of people.

EU 4.3.3 Challenges of the Building Process from a Group Dynamic Perspective

The steps of the building process for a digital solution (see EU 2.1) pose different challenges for the people involved. The different temperaments (see above) are differently suited to the different steps. In order to unleash the full collective intelligence of the team during the building process, the organization must perceive people management in the building process as a success factor. **EO 4.3.3.1**

Incorrect personnel dispositions in the team lead to an inadequate vision of the future, premature selection of ineffective implementation variants, wasted time in finding solutions, and individual stress. Personality patterns support the people manager in setting up the building team and identifying risks of passive, hidden resistance or in discovering hidden economic potential at an early stage.

We distinguish and elaborate these aspects in terms of people management in the building process:

- Managing understanding, perception and learning potential
- Thinking into the future
- Managing working style and role assignment
- Managing leadership during the building process
- Considering the working environment and subject matter understanding

Table 3 serves as an initial guide to knowing the main challenges of each step and to classifying the suitability of the temperaments for each step at a foundation level. Being aware of these challenges and their relation to temperaments supports the DDP in better understanding the behavior of the people involved.

Table 3: Challenges of the building process from a temperament perspective

<table>
<tr><th>Step</th><th>Main challenge</th><th colspan="2">Suitability of the temperament</th></tr>
<tr><td rowspan="2">Scoping step</td><td rowspan="2">Vague future understanding, need for orientation, finding a vision, deciding a direction</td><td>Rational problem solving
● Guardians or artisans describe the concrete problem.</td><td>Reflective perspective
● With their imaginative power, rationals design attractive future scenarios.
● With the client, rationals discover the narrative for “case for action” translated and communicated by idealists.</td></tr>
<tr><td colspan="2">Provide input for defining the Digital Design brief:
● Idealists collect stories and perceive cultural forces..
● Rationals and idealists filter relevant topics and design an acceptable vision, a design framework, and identify future stakeholders. They orientate the team to get an understanding of the scope.
● Guardians or artisans describe their understanding of stakeholders, context, and current culture as an indicator of the change readiness of the people involved.</td></tr>
<tr><td>Conceptual step</td><td>Explore solution ideas, frame the context, clarify the vision, build a community</td><td colspan="2">● Rationals (outside of the industry) offer new ideas and challenge them together with laterally thinking rational process experts, who are willing to break current rules. Together, they clarify the potential, the feasibility and the requirements.
● Idealists define stories, collect demands, engineer requirements, find fans in the community, ensure understanding, evaluate commitment, and facilitate the team process.</td></tr>
<tr><td>Development & operations step</td><td>Elaborate the details, build, and improve</td><td colspan="2">● Idealists and artisans define stories, collect feedback, engineer requirements, and ensure understanding.
● Guardians manage the building process.
● Idealists facilitate the team process.
● Guardians and artisans implement the solution.
● Rationals verify the quality of the overall architecture and recommend actions for its evolution.
● Idealists scale the community, check the acceptance by the decision makers, and recommend measures for continuation.</td></tr>
</table>

EU 5 A Building Process for Beginners (L3)

Duration: 210 min

Educational objectives:

EO 5.1.1	Justify design thinking as an approach for scoping a Digital (L2)
EO 5.1.2	Justify an analysis-oriented approach for scoping a tame problem (L2)
EO 5.1.3	Name guidelines for defining the general terms for building a digital solution (L1)
EO 5.2.1	Justify human-centered design as a process model for the conceptual step (L2)
EO 5.2.2	Describe the four phases of the conceptual step (L1)
EO 5.3.1	Name the phases, levels, work products, and events of the process for the development and operations step (L1)
EO 5.3.2	Apply five pragmatic work item templates in combination with design concepts (L3)
EO 5.3.3	Explain the backlog preparation by means of element design canvases and a story map (L2)
EO 5.3.4	Describe the difference between the realization of the first release and the further evolution of a digital solution (L1)
EO 5.4.1	Describe “Lean Startup” as an alternative approach for the development of a digital solution (L1)

This EU provides guidelines for the three steps of the building process for a digital solution (see EU 2.1.2). It originates from the experience of the authors of this syllabus. Beginners should be aware that there are many other approaches for building a digital solution. Studying other approaches is important and studying other approaches with practical experience is even better. The intention of this guideline is to provide a starting point for beginners to gain their own experience and to develop their own building processes. Experienced readers will be familiar with other approaches and will be able to define a completely different process or will even apply the techniques presented in other steps or situations.

The guidelines presented in this syllabus assume that the reader is the person responsible for the digital solution and the management of the building process. In analogy to product owners in product management and agile development, we call this person the *product owner*. The product owner is authorized by the client to decide all matters related to a digital solution in consultation with the building team, the client, and other stakeholders.

The guidelines presented further assume that the product owner works with a building team that has all the necessary skills to build the digital solution. A member of this team is called a building team member. The team members can of course change within the three steps depending on the skills needed.

Since these guidelines cover the whole building process, they go beyond the scope of Digital Design. However, this broader perspective is necessary to understand the integration of Digital Design into the building process.

EU 5.1 The Scoping Step

The goal of the scoping step is to define the context, the vision, the scope, and the general terms of the digital solution (see EU 2.1) together with the client. From a foundation level perspective, two situations for the scoping step should be distinguished [RiWe1973]:

- Wicked problem: a problem that is difficult or impossible to solve because of incomplete, contradictory, and changing requirements
- Tame problem: a problem that is well defined with clear and stable requirements

The task of the scoping step for a *wicked problem* is to improve the understanding of the problem and explore potential solution directions to better understand the problem. **EO 5.1.1**

Design thinking [Brow2009] is a popular approach for such situations. It provides an iterative process with clear rules and emphasizes the importance of evaluating ideas with early prototypes. The rules of design thinking further recommend that an interdisciplinary team performs the design thinking process. If necessary, the building team should therefore be extended with further experts. The result of a design thinking process is a set of solution ideas validated by means of early prototypes, as well as a building team with a detailed understanding of the problem and possible solution ideas.

At the end of the design thinking process, a lot of material has been created. It is the task of the product owner to evaluate this material. If the results are not convincing, a further design thinking process should be planned.

The Digital Design brief template serves as guidance for documenting the results (see EU 2.2.2). The design thinking process may produce different possible directions for creating a solution. All directions should be documented in the Digital Design brief.

The task of the scoping step for a *tame, well-understood problem* is to analyze the problem, to challenge the problem understanding of all relevant stakeholders, and to define a clear vision for the digital solution among all relevant stakeholders. A series of observations and interviews and a compact scoping workshop format is recommended for this situation. **EO 5.1.2**

The results of this series of observations and interviews can be documented in the Digital Design brief. If there is no clear picture of the problem, the recommendation is to shift to the approach for wicked problems (see above).

If the results show a clear picture of the problem, a scoping workshop is recommended to discuss the results of the interviews and to create a final version of the Digital Design brief. If it is not possible to create a final version, a second round of interviews and a second workshop should be scheduled to clarify the open issues. If the second round does not produce a clear result either, the procedure should be changed to the approach for wicked problems.

The general terms in the Digital Design brief separate schedule, budget, and available resources (see EU 2.2.2). The following guidelines support the definition of the general terms: **EO 5.1.3**

- Schedule: During the scoping step, it is usually unrealistic to be able to define precise schedules. However, without an initial schedule, it is difficult to keep track of the progress. Make use of iterative and time-boxed schedules to obtain regular feedback.
- Mode of cooperation: Schedule regular coordination meetings between the building team and the client and other relevant stakeholders. Adjust the interval of these meetings to the urgency of the issues. If there are many urgent issues, use short intervals to make decisions quickly. Define rights and obligations of the building team and the relevant stakeholders. Define an escalation instance for the event of a crisis.

- Budget: Budgeting is as difficult as defining the schedule. However, without a budget, it is difficult to keep track of the progress compared to the costs. Always plan initial budgets for the conceptual as well as for the development and operations step with your client. Even if this step is difficult for your client, these budgets are an important reference point for the building process to recognize that the budget is not sufficient.
- Potential revenue streams: Similar to the budget and schedule, it is difficult to define potential revenue streams during this step of the building process. Choose one of the digital business models from EU 4.2 and make rough assumptions of the revenue. If it is not possible to define at least a rough idea of the revenue stream, the chance of defining a strong business model is rather low.
- Available resources: Available resources cover personnel and technical resources that are necessary for conceptual work or the development and operations. An explicit definition of these resources is necessary to have them available when they are needed. Consider resources for the conceptual step as well as resources for development and operations.

EU 5.2 The Conceptual Step

The goal of the conceptual step is to gain a sufficient understanding of the intended digital solution to take the risk of starting development. Two results are created for this goal: the initial solution design concept and the initial system design concept. These concepts are called initial because they are further refined and revised during the development and operations step (see EU 5.3).

A general process model for the conceptual work step is the human-centered design process [ISO2019]. It consists of four iterative activities of equal importance: understand, specify, design, and evaluate. **EO 5.2.1**

Performing these activities iteratively and with equal intensity allows for the elaboration of solution and system design concepts with a level of detail and confidence that allows for an informed decision for or against the start of the development.

The following phases are recommended as a work structure for the conceptual step: **EO 5.2.2**

- Phase 1: Explore the digital solution space from the customer perspective
    - Create personas together with value proposition maps
    - Create customer journey maps for each persona
    - Explore current and potential future experiences in relation to the persona’s needs
    - Define solution ideas
- Phase 2: Elaborate and evaluate solution candidates from a business perspective
    - Create business model canvases to evaluate solution ideas
    - For each promising solution idea, elaborate an initial solution design concept and system design concept

- Phase 3: Approach a promising solution candidate from a feasibility perspective
    - Iterative evaluation and elaboration of solution design and system design concepts until a stable solution and system design emerges
      Otherwise consider going back to the scoping step
- Phase 4: Final evaluation of the solution candidate with the client

It is also possible to elaborate element design concepts in the conceptual step. However, for beginners, we recommend focusing on the solution and system level since keeping an appropriate level of detail in an element design concept during the conceptual step is a challenging task for beginners.

If there is a need for guidance in terms of realization concepts for software, [Arc42] is recommended as a source for templates. For devices, expertise from product design/industrial design should be taken into account.

If the results from the final evaluation (phase 4) are positive, the development and operations step can start. Otherwise, further iterations are recommended.

EU 5.3 The Development and Operations Step

The goal of the development and operations step is to bring the digital solution to life and to maintain it during its operation.

For reasons of simplicity, it is assumed that the elements of the digital solution can be developed by a single building team. The development of digital solutions with several building teams requires more complicated management techniques. Such techniques go beyond the scope of this foundation level. It is further assumed that the development team has the necessary technical skills to realize the digital solution.

The process presented in this section was inspired by Kanban and Scrum and uses elements from both sources, which we believe are particularly suitable for getting started in developing digital solutions. The process is therefore neither Kanban nor Scrum in its purest form.

Kanban is a lean approach for managing software development processes [Ande2010]. Scrum is a framework for developing and sustaining complex products [ScSu2020]. Both are valuable and widely adopted, they have large communities that can provide beginners with various resources for development processes. A practical aspect of using Kanban and Scrum as a foundation is that they are well supported by several software tools.

The process for the development and operations step consists of four phases: **EO 5.3.1**

- Phase 1 – Backlog preparation: in this phase, the product owner and the building team create an initial backlog that is sufficient for starting the development of the initial release.
- Phase 2 – Development of the initial release: in this phase, the building team and the product owner work on the initial release.
- Phase 3 – Further evolution during operation: in this phase, the initial release of the digital solution is in operation, the building team maintains it and works on the evolution by further releases.
- Phase 4 – Retirement: in this phase, the solution is withdrawn from use.

The process defined in this EU works at the three levels defined in EU 1.3:

- The solution level process focuses on the client and aims to achieve the goals of the client through the digital solution. This process is about communication and coordination between the client and the product owner.
- The system level process focuses on the customer perspective and aims to realize value for the customer through the system. This process is about communication and coordination between the client and the product owner from the customer perspective.
- The element level process focuses on the user perspective and aims to realize value for the user. This process is about communication and coordination between the building team and the product owner.

At the *solution level*, the work is managed with the following work products:

- Solution work item: a work item that provides a resource or any other means necessary for the development or the operation of the digital solution
- Solution backlog: a list of work items ordered by the product owner that have to be processed to realize the digital solution
- Solution board: a Kanban board for managing the work items at the solution level
- Release plan: plan for releases; a release is a particular instance of the digital solution that is ready for operation; a release can be defined by a collection of epics (see below)

At the *system level*, the work is managed with the following work products:

- Epic: a work item that describes a characteristic of a digital system that provides value for stakeholders.
- Story map: a two-dimensional arrangement of user stories. The horizontal dimension describes the narrative flow of the system, while the vertical dimension provides details for each part of the narrative flow.
- Epic board: a Kanban board for managing the long-term development of the digital system from the customer perspective by means of epics.

At the *element level*, the work is managed with the following work products:

- System work items: description of work to realize elements of the system; the following work item types are distinguished:
    - User story: a description of a need from a user’s perspective together with the expected benefit when this need is satisfied; a user story constitutes a work item in which the user’s need is realized
    - Concept work item: work item for the elaboration of conceptual details as a prerequisite for realizing a user story
    - Technical work item: work item for the elaboration/realization of a technical prerequisite for realizing a user story
    - Prototype work item: work item for the creation of a prototype of an aspect of the digital solution

    - Evaluation work item: work item for the evaluation of a prototype or an already realized aspect of the digital solution
    - Defect: work item for a defect in the solution that needs to be analyzed and fixed
- System backlog: a list of work items ordered by the product owner and building team that have to be processed during the realization of the elements of the digital system
- System board: a Kanban board for managing the work items of the building team and the product owner

The concepts of “Definition of Ready” and “Definition of Done” help to manage work items at the solution, system, and element level:

- Definition of Ready: a set of general criteria that must be met to consider a work item ready for processing or implementation
- Definition of Done: a set of general criteria that must be met to consider a work item done

The process defined in this EU requires the following activities:

- Daily: a short and time-boxed meeting on a daily basis to inspect the progress since the last daily and to plan the work until the next daily
- Release planning: a time-boxed meeting on a regular basis in which the client, the product owner, and the team work on maintaining the backlogs and work items at the solution and system level
- Iteration planning: a time-boxed meeting on a regular basis in which the product owner and team work on maintaining the backlog and the work items at the element level
- Iteration: a time-boxed unit of work in which the building team works on a selected set of work items and completes them
- Retrospective: a regular meeting for self-improvement to inspect and adapt the process
- Solution review: a presentation and review of the results of an iteration for the client and other relevant stakeholders

The work items are created for the backlogs and to manage the work at the three levels of the building process. We recommend a work item template that consists of the following sections: **EO 5.3.2**

- Identifier and title for easy identification of the work item
- Information for managing the work item in the process (management information):
    - Assignee: person that is working on the work item
    - Creator: person that created the work item
    - Release: the release to which the work item belongs
    - Estimated effort: amount of effort that has been estimated
    - Effort spent: effort already spent
    - Remaining effort: estimate of remaining effort

- Information for describing the work (work information):
    - Task description: details of the task (see below)
    - Prerequisites: other work items that are required to be done before work can start
    - Acceptance criteria: individual criteria that must be met to consider the particular work item completed
    - Relevant elements: elements of the digital solution that are related to the work item
    - Epic reference: reference to the epic to which the work item belongs

The work item is temporary; therefore, the work item should contain only information that is of particular importance for the work at hand.

Table 4: Guidelines for creating task description and acceptance criteria in relation to design concepts

Type	Task description guideline	Acceptance criteria guidelines
Epic	• Customer profile that benefits from the epic • Goal at system level that is achieved by the epic • Scenario that describes the achievement of the epic	• Quality requirements/ constraints at system level • Criteria related to the referred goal • Scenario aspects expected to work
User story	• User type that benefits from the story • Goal at element level that is achieved by the user story • Use case/function that describes the achievement of the goal	• Quality requirements/constraints at element level • Parts of the use cases/functions that are expected to work
Concept work item	• Building blocks to be elaborated/revised/extended • Reference to further information sources	• Reviews from team members • Reviews from stakeholders
Prototype work item	• Definition of the prototype category to be created • Building blocks to be realized in the prototype	• Quality requirements that the prototype has to fulfill • Reviews from team members • Review from stakeholders
Evaluation work item	• Evaluation objective: description of the objective that shall be achieved with the evaluation • Evaluation subject: building blocks from design concept and/or realized part of the digital solution • Reference to the evaluation concept that describes the evaluation procedure in detail	• Expected outcome quality of the evaluation task

All design information on the digital solution that has to remain should be documented in design concepts. References between work items and design concepts are used to achieve this separation and to provide a compact description of the work item. We recommend a similar approach for other realization concepts and evaluation concepts.

Table 4 provides guidelines for creating task descriptions and acceptance criteria of work items in relation to design concepts.

It is important to recognize that user stories refer to use cases and functions from the element design concept (see EU 2.2.5) to define the concrete function that has to be realized and the quality requirements as acceptance criteria that have to be fulfilled by the implemented user story.

All other building blocks from the element design concepts that are relevant for realizing a particular user story are accessible by means of constructive traceability relationships (see EU 2.2.6).

Before the actual development can start, initial backlogs are required. For beginners, the following procedure is advisable: **EO 5.3.3**

1. Elaborate element design canvases (see below) for each element defined by the system design concept.
2. Elaborate a story map; prioritize and group the user stories into epics that define a distinguishable and realizable customer value. Define an initial release with the most relevant epics.
3. Elaborate all concept and technical work items necessary to achieve the "Definition of Ready" for all user stories of the 2–3 most relevant epics.

As a rule of thumb, the work items for the three most important epics should be elaborated. This should create a backlog with a sufficient amount of work for a typical building team size (6–7 people).

The elaboration of further epics can take place in parallel with the other development work.

The element design canvas is a temporary work product and consists of the following aspects:

- Main objectives that the element has to achieve
- Function: core use cases and functions
- Form: parts (if applicable), hardware and software interfaces, user interfaces, and entities
- Quality: initial list of quality requirements and constraints.

The main goal of the element design canvas is to name the aspects and to develop an initial understanding of their relationships within the team. Further details (for example, attributes of entities, detailed shape of a user interface) are defined as results of the iterations.

During the work on the element design canvases, additional realization concepts can be created, to address realization topics. It is assumed that these concepts are created in close cooperation between the building team and the product owner.

Once the element design canvases have been created, the work on step 2) can start. User stories can be derived from the goals, use cases, and functions that are described in the element design canvas, by means of a story map [Patt2014].

The main structure of a story map is a two-dimensional arrangement of user stories:

- The horizontal dimension focuses on the backbone, meaning the narrative flow of the solution (overall process provided or the customer journey).
- The vertical dimension provides details for each part of the narrative flow as well as a separation of items according to the priority of the user stories from a function perspective.

As soon as the story map is ready, the user stories defined can be grouped into epics. It is important to recognize that the definition and prioritization of epics is typically a strategic decision of the product owner. We recommend defining epics from the perspective of customer value. This means that the realization of an epic creates an observable value for the customer.

In contrast to the element design canvases, the story map is permanent, i.e., it is used and maintained to communicate with the client.

With the initial prioritized backlogs, the first iteration can start to initialize the series of iterations for developing the particular elements and with this the first release of the digital solution. The building team works on the work items according to the priority from the backlog (see above). Iteration planning and release planning are scheduled on a regular basis to maintain the backlogs and the story map. **EO 5.3.4**

When the iteration period is over, the solution review is used to present the implemented parts to important stakeholders in order to obtain their feedback. Retrospectives should be scheduled regularly to inspect and adapt the process. The story map (see above) and the epic board are used to maintain the roadmap for the development of the whole digital solution and to align the priorities in the backlogs from a solution perspective.

As soon as the first elements are implemented, an evaluation can be considered to get feedback from users/customers and to test for usability issues (see EU 4.2).

As soon as an accepted first release of the solution has been created through this process (all epics defined for the release have been implemented and evaluated successfully), the solution is put into operation. The concrete procedure depends on the type of solution and must be defined with the relevant stakeholders.

As soon as the digital solution is in operation, the working mode changes since the activities of fixing defects, incorporating feedback from stakeholders, and the further evolution of the digital solution must be prioritized against each other.

For beginners, the recommendation is to capture defects of the digital solution in operation as work items in the backlog and to relate them to the epic that fits the bug. Additional feedback from stakeholders can be handled as follows: if the feedback can be related to an existing epic and if the feedback is very concrete and easy to implement, it can be captured as a new user story. Otherwise, it should be treated as a new epic.

EU 5.4 Lean Startup as an Alternative Approach for Developing a Digital Solution

A core characteristic of the process presented is that the digital solution will go operational as soon as a first complete version has been realized. We believe that at foundation level, a DDP should be aware of the fact that this is not the only approach for building a digital solution. In the following, we will briefly introduce lean startup as an approach that follows a different philosophy.

Lean startup [Ries2011] is a methodological framework that aims to shorten product development cycles by adopting a combination of business hypothesis-driven experimentation, iterative product releases, and validated learning. **EO 5.4.1**

The central hypothesis is that startup companies should invest their time into iteratively building a product to meet the needs of early customers. They can thereby reduce the market risks and sidestep the need for large amounts of initial project funding and expensive product launches and failures.

Lean startup is particularly useful if the chances of success of a digital solution cannot be reasonably estimated by other methods. In this case, the development is approached very quickly in order to bring an operational digital solution as a minimum viable product (MVP) to the market with minimal resources. Feedback from real users can then be used to estimate whether the solution can be successful and how it can be developed further.

EU 6 Achieving Good Digital Design (L2)

Duration: 45 min

Educational objectives:

EO 6.1.1	Explain how a Digital Design Professional can contribute to achieving good Digital Design (L2)
EO 6.2.1	Describe the importance of heuristics and practical knowledge for achieving good Digital Design (L1)
EO 6.3.1	Describe the importance of additional experts and teamwork for achieving good Digital Design (L1)

EU 6.1 Contributions of the Digital Design Professional

EO 6.1.1

Achieving good Digital Design should be part of the attitude of every DDP. Knowing and understanding the ten principles is the foundation for achieving good Digital Design (see EU 1.4). The ideas presented in this syllabus make an important contribution to the achievement of good Digital Design:

- During the building process (EU 2.1 and EU 5), the DDP uses the ten principles to guide all decisions related to the digital solution.
- With conceptual work (EU 2.2), the intended positive benefits, usefulness, usability, elegance, and aesthetics should be made explicit, as well as the directions for evolution and exploration. Data protection and security is not only a technological issue, it must also be explicitly addressed in design concepts.
- The creation of prototypes (EU 2.3) is an important technique for evaluating the defined solution against the ten principles. For example, usefulness and usability can be evaluated with user interface prototypes. Furthermore, prototypes allow exploration of (fundamentally different) alternative concept directions and solutions.
- Digital technology (EU 3) has an impact on several principles. For example, evolutionary and exploratory development depends on the flexibility of technology and requires a fast and flexible construction and realization process.
- Understanding the impact of human factors (EU 4.1) is important for useful and usable digital solutions, but also for understanding the impact of the digital solution on people.
- The business model (EU 4.2) is the foundation for creating an economically successful digital solution and for obtaining the necessary financial resources for the further development of a digital solution. However, the business model can also be the cause of negative developments. For example, platform business models can lead to precarious employment or have a negative impact on the market.
- People management (EU 4.3) is important for involving all relevant stakeholders and for getting commitment to develop the envisioned digital solution according to the ten principles.

EU 6.2 The Importance of Heuristics and Practical Knowledge

In addition to the content of this syllabus, there are many other resources that can inspire the development of good Digital Design. One important source is experience, and a good shortcut to experience is to learn from the experience of other people. Literature offers a rich collection of these experiences in the form of heuristics, practice reports, and other books: **EO 6.2.1**

- [Dors2003] gives a broad introduction to design as a profession.
- Critical text on the development of digital technology and its impact on society (e.g., [Lani2011]) raises awareness of the possible effects of a solution.
- [Wein2011] is a collection of 100 heuristics from human factors for designers.
- A collection of heuristics that improve the usability of software can be found in [Niel1994].

EU 6.3 The Importance of Teamwork

Good Digital Design is an issue for the whole building process and requires close cooperation with management, construction, and realization. DDPs should therefore continuously assess their own competencies (and the competencies of their teams) against the ten principles and involve additional experts where necessary. **EO 6.3.1**

This syllabus further shows that Digital Design is a profession that requires a diverse range of skills. We believe it is possible to understand the importance of and the relationship between all these skills. We further believe that it is possible to become a master in some of these skills. Becoming a master of the whole spectrum of skills is possible, but only for people with exceptional talents.

For average people, such as we authors are, the following thought remains as a conclusion to this syllabus:

Good Digital Design can be achieved only
through transdisciplinary teamwork
with a team
that can cover the diversity of Digital Design skills.

References

[Ande2010] Anderson, D. J.: Kanban: Successful Evolutionary Change for Your Technology Business. Blue Hole Press, 2010.

[Arc42] arc42: better software architectures. https://arc42.org, last accessed November 21, 2020.

[BCW1999] Baghai, M., Coley, S., White, D.: The Alchemy of Growth: Kickstarting and Sustaining Growth in Your Company. Orion Business Books, 1999.

[BBKL1978] Boehm, B. W., Brown, J. R., Kaspar, H., Lipow, M., McLeod, G. Merritt, M.: Characteristics of Software Quality. North Holland, 1978.

[Bitk2017] Bitkom e. V.: Rollenideal Digital Design - Erfolgreiche Digitalisierung und Digitale Transformation erfordern ein Umdenken in der Softwareentwicklung, 2017.

[Brow2009] Brown, T.: Change by Design. Harper Business, 2009.

[CECN2014] Cooper, A., Reimann, R., Cronin, D., Noessel, C.: About Face: The Essentials of Interaction Design. 4th Edition, John Wiley & Sons, Inc, Hoboken, 2014.

[Coop2004] Cooper, A.: The Inmates Are Running the Asylum: Why High-tech Products Drive Us Crazy and How to Restore the Sanity. Que, Indianapolis, 2004.

[CPRE2020] IREB Certified Professional for Requirements Engineering - Foundation Level Syllabus, Version 3.0.1, October 7, 2020.

[Cros2006] Cross, N.: Designerly Ways of Knowing. Birkhäuser, 2006.

[Dick2019] Dickel, S.: Prototyping Society. Transcript Verlag, 2019

[Dors1997] Dorst, K.: Describing Design - A Comparison of Paradigms. Delft University Press, Delft, The Netherlands, 1997.

[Dors2003] Dorst, K.: Understanding Design - 150 Reflections on Being a Designer. BIS, 2003.

[ErMa2008] Erlhoff, M., Marshall, T. (eds.): Design Dictionary: Perspectives on Design Terminology. Birkhäuser, 2008.

[Floy1984] Floyd, C.: A Systematic Look at Prototyping. In: Budde R., Kuhlenkamp K., Mathiassen L., Züllighoven H. (eds). Approaches to Prototyping. Springer, 1984.

[FrPr2009] Freemann, S., Pryce, N.: Growing Object-Oriented Software, Guided by Tests. Addison-Wesley, 2009.

[Hass2001] Hassenzahl, M., Beu, A., Burmester, M.: Engineering Joy. In: IEEE Software Vol. 1, 2001.

[Hewe1992] Hewett, T. T., Baecker, R., Card, S., Carey, T., Gasen, J., Mantei, M., Perlman, G.: ACM SIGCHI Curricula for Human-Computer Interaction. Technical Report. Association for Computing Machinery, 1992.

[IDSA2020] Industrial Designers Society of America, “How they do it”, http://www.idsa.org/education/how-they-do-it. Last accessed February 15, 2020.

[IEEE2017] ISO/IEC/IEEE 24765: Systems and Software Engineering — Vocabulary. Second Edition. ISO/IEC/IEEE 24765:2017). New York: The Institute of Electrical and Electronics Engineering, 2017.

[ISO2001] ISO/IEC 9126-1: Software Engineering—Product Quality—Part 1: Quality Model. ISO, 2001.

[ISO2011] ISO/IEC 25010: Software Product Quality – System and software quality models. https://iso25000.com/index.php/en/iso-25000-standards/iso-25010, 2011, last visited June 2020.

[ISO2019] ISO 9241-210:2019: Ergonomics of human-system interaction — Part 210: Human-centred design for interactive systems. ISO, 2019.

[Jera2016] Jerald, J.: The VR Book: Human-Centered Design for Virtual Reality (ACM Books). Morgan & Claypool Publishers, 2016.

[Keir1998] Keirsey, D.: Please Understand Me II: Temperament, Character, Intelligence. Prometheus Nemesis Book, 1998.

[Kell2016] Kelly, K.: The Inevitable: Understanding the 12 Technological Forces That Will Shape Our Future. Viking, 2016.

[Lani2011] Lanier, J.: You Are Not a Gadget: A Manifesto. Penguin, 2011.

[LBGH2018] Lauenroth, K., Bramsiepe, H., Gilbert, D., Hartwig, R., Lehn, K., Schubert, U., Trapp, M.: The Digital Design Manifesto, https://www.digital-design-manifest.de/wp-content/uploads/2021/03/Bitkom_LF_Digital_Design_Manifest_EN.pdf, last accessed 2021/05/02.

[MaLa2015] Margolis, E., Laurence, S. (eds.): The Conceptual Mind: New Directions in the Study of Concepts. MITpress, 2015.

[McEl2017] McElroy, K.: Prototyping for Designers. O'Reilly, 2017.

[McRW1977] McCall, J. A., Richards, P. A., Walters, G. F.: Factors in Software Quality. Rome Air Development Center, 1977.

[MCPK2006] McCurdy, M., Connors, C., Pyrzak, G., Kanefsky, B., Alonso V.: Breaking the Fidelity Barrier: an examination of our current characterization of prototypes and an example of a mixed-fidelity success. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '06). ACM, 2006.

[Ming2020] Minge, M.: meCUE 2.0. http://mecue.de/english/index.html. Last accessed May 25, 2021.

[Newm2020] Newman, D.: The Process of Design Squiggle. https://thedesignsquiggle.com/. Last accessed January 12, 2020.

[Niel1994] Nielsen, D.: 10 Usability Heuristics for User Interface Design: https://www.nngroup.com/articles/ten-usability-heuristics/. Last accessed May 25, 2021.

[Nobl1996] Noblet, J. de: Industrial Design: Reflection of a Century. Flammarion, 1996.

[OPBS2014] Osterwalder, A., Pigneur, Y., Bernarda, G., Smith, A.: Value Proposition Design: How to Create Products and Services Customers Want. Wiley, 2014.

[OsPi2010] Osterwalder, A., Pigneur, Y.: Business Model Generation. Wiley, 2010.

[Patt2014] Patton, J.: User Story Mapping: Discover the Whole Story, Build the Right Product. O'Reilly, 2014.

[PoLR2013] Polaine, A., Løvlie, L., Reason, B.: Service Design: From Insight to Implementation. Rosenfeld Media, 2013.

[Rein1997] Reinertsen, D.: Managing the Design Factory. Simon and Schuster, 1997.

[Ries2011] Ries, E.: The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses. Crown Books, 2011.

[RiWe1973] Rittel, H. W. J., Webber, M. M.: Dilemmas in a General Theory of Planning. In: Policy Sciences, Vol. 4, No. 2, 1973.

[Ross2019] Rossmann, J.: Think Like Amazon: 50 ½ Ideas to Become a Digital Leader. McGraw-Hill, 2019.

[Royce1970] Royce, W.: Managing the Development of Large Software Systems: Concepts and Techniques. In: Proceedings of IEEE WESCOM. IEEE Computer Society Press, 1970.

[ScSu2020] Schwaber, K., Sutherland, J.: The Scrum Guide: The Definitive Guide to Scrum: The Rules of the Game. November 2020, https://scrumguides.org/docs/scrumguide/v2020/2020-Scrum-Guide-US.pdf last accessed May 25, 2021.

[SeRP2017] Sedano, T., Ralph, P., Péraire, C.: Software Development Waste. In Proceedings of IEEE/ACM 39th International Conference on Software Engineering (ICSE), IEEE Computer Society Press, 2017.

[ShPR2019] Sharp, H., Preece, J., Rogers, Y.: Interaction Design: Beyond Human-Computer Interaction. John Wiley & Sons, 2019.

[SlWi1997] Slater, M., Wilbur, S.: A Framework for Immersive Virtual Environments (FIVE): Speculation on the Role of Presence in Virtual Environments. Presence: Teleoperators and Virtual Environments, Vol. 6, No. 6, 1997.

[Snow2005] Snowden, D.: Multi-Ontology Sense Making: A New Simplicity in Decision Making. Informatics in Primary Health Care, Vol. 13, No. 5, 2005.

[Snyd2003] Snyder, C.: Paper Prototyping: The Fast and Easy Way to Design and Refine User Interfaces. Morgan Kaufmann, 2003.

[ThMa2007] Thüring, M., Mahlke, S.: Usability, Aesthetics and Emotions in Human–Technology Interaction. International Journal of Psychology, Vol. 42, No. 4, 2007.

[VPGV2008] Van de Ven, A., Polley, D., Garud, R., Venkataraman, S.: The Innovation Journey. Oxford University Press, 2008.

[WaMe1986] Ward, P., Mellor, S.: Structured Development for Real-Time Systems. Pearson, 1986.

[Wegn2005] Wegner, I.: Complexity Theory. Exploring the Limits of Efficient Algorithms. Springer, 2005.

[Wein2011] Weinschenk, S. M.: 100 Things Every Designer Needs to Know about People. New Riders, 2011.

[WHBP2016] Wickens, C. D., Hollands, J. G., Banbury, S., Parasuraman, R.: Engineering Psychology and Human Performance. Taylor and Francis, 2016.

[Wiki2020] Wikipedia: Outline of databases. https://en.wikipedia.org/wiki/Outline_of_databases. Last accessed February 2, 2020.