The optimization of ASML's Training Center regarding efficiency and effectiveness

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Preface

Dear reader,

This Master thesis is a culmination of the study Integrated Product Design at the Technical University of Delft. Around a year ago when looking for an appropriate and challenging graduation project, in which I would be able to develop my industrial design experiences further, I have been very lucky to get this opportunity with ASML. The assignment I was offered turned out to be a fantastic learning journey, from the start to the end.

Before I begin to present the results of this final project, I would like to take a moment to express my gratitude to all those who have contributed in their way.

First of all, I would like to thank ASML for offering a great environment to learn and develop myself. In particular my mentor, Henri Jaspers, who made me enthusiastic about his future vision from the first minute I met him and the company manager, John Jeuken, for his guidance and support.

Next, a big thank you to all the ASML engineers, who contributed to the final design by sharing their valuable experiences during numerous meetings, interviews, co-creation sessions and usability tests. Without the input of these intended users of the product, the outcomes would not have been so applicable and promising.

I also would like to express my gratitude to Maaike Schuitema, Ileana Ghizdavescu, the entire KXI Studio team and several colleagues in the GTC. The feedback and support provided was very valuable for the design process. It was a pleasure to work with you.

A few words of gratitude also to the supervisory team of the university, Ruud van Heur and Alejandra Ortega Gomez, who have guided me during the entire graduation process.

Furthermore, I want to express my appreciation to the consulted companies – Thermo Fischer, Philips, KLM, Voith, Siemens, Ministry of Defense and Next Learning – for sharing your thoughts and experiences on training. It was great that you wanted to share your specific experiences and practices with me.

Finally, I would like to thank my family and friends who assisted and motivated me in every way possible during the entire graduation period with patience, encouragement and moral support.

I have experienced a highly challenging context at ASML considering organizational complexity, profound systems and well defined procedures and guidelines. Ultimately, a minimum Viable Product has been delivered for which however the best-fit supply and complete system design should still be determined.

And now is the time to present with due pride my project results on micro-managing of training in ASML's Training Center.

Gratefully thanking you,

Eline
Veldhoven, February 2023

Executive summary

The objective of this project is to develop a suitable design proposal for the future context of ASML's Training Center, substantiated by research and stakeholder input. Since training demand will increase also with the introduction of new systems, the company entails the creation of a product that will support this dynamic environment by offering the possibility to create a tailor made training journey, while keeping certain dependencies in mind. A combination of representative techniques, such as Hardware (HW), Virtual Reality (VR), Software (SW) and Theory (TH) will be used to create the most realistic training experience with a strong focus on hands-on capabilities.

A supportive literature and user research has been conducted on training context, aiming at methods and psychology, future trends complemented by in-depth interviews conducted with other technology-focused companies to study their practices. Additionally, the user experience was investigated at the graduation company through a combination of interviews, observations and surveys.

This extensive exploration phase has resulted in a wide diversity of possible future training focus points such as for example (1) improving effectiveness and practice opportunities of hands-on trainings targeting optimal knowledge retention and (2) increasing on-the-job performance support through mentor guidance and manager evaluation. Incorporating the input of the majority of engineers, as part of the User-Centered Design approach, it could be concluded that focusing on a planning tool, while optimizing the amount of effective hands-on modules, was the most promising direction.

Product requirements have been gathered through interactive co-creation and brainstorm sessions with users and business stakeholders. Once the core features were determined, the prototyping phase was launched, consisting of two separate sections. First a UX design was created through wireframing and several conducted rounds of usability testing. Next an effective planning proposal was defined representing a possible training scenario. A balanced merging of these two sections characterizes the High-NA TC planning tool 'MyTraining'.

MyTraining acts as a tool to micro-manage and adapt a training to the needs and preferences of trainees. It supports a flexible environment, where learning by doing is encouraged, and practice opportunities are facilitated. It entails three main functionalities. First, a trainee can book training time slots according to own preferences and availability. The second feature offers the possibility to self-direct the training journey while encountering the planning guidance, followed by the third feature to explore other training programs for personal development awareness. The tool can be perceived as valuable to the users, since it will boost their motivation through a sense of autonomy, mastery and purpose. Furthermore, their confidence level will be increased through practice opportunities and effective modular training slots. Business benefits for the company are improved field self-sufficiency of the trained engineers, which will impact the quality of service to the customers, and decreased training and preparation time which will free up additional capacity for other valuable business-related purposes.

Limitations and recommendations have been formulated for further development and implementation. In the current situation the company does not have enough modules to fulfill the growing need of hands-on practice opportunities. The key recommendation is that the company supply should be aligned with the hands-on training demand to support a practice stimulating environment.

This thesis provides a starting point for the company to explore their way of working in the future Training Center, where learning by doing is crucial to satisfy the engineer's needs and to create optimal field self-sufficiency.

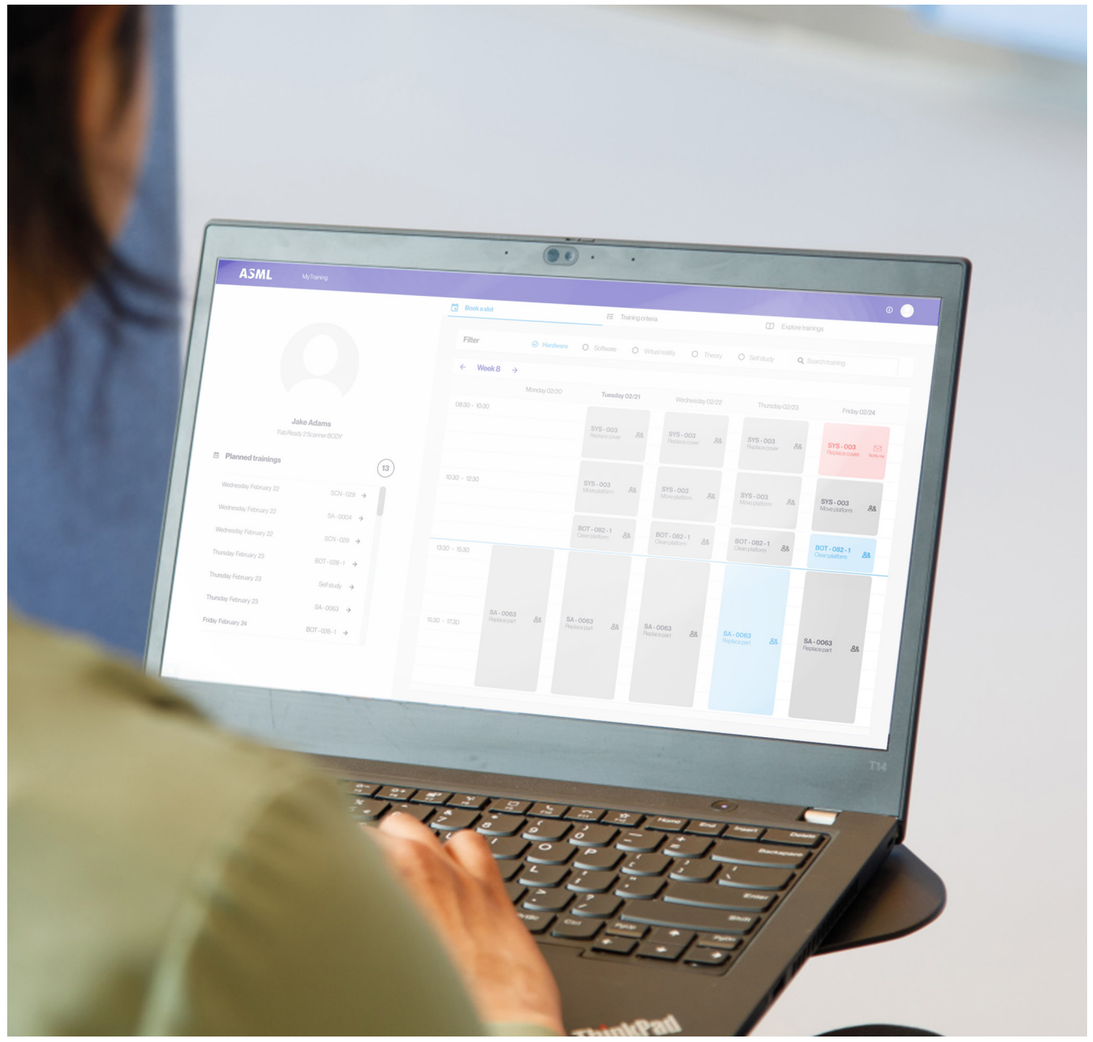

Figure 1: User interacting with the final design proposal in the company context (ASML Picturepark, n.d.)

List of acronyms

Acronym	Meaning	Explanation
BIC	Brainport Industries Campus	This is the location of the ASML's new Training Center in Eindhoven, the context of the design proposal
CARS	Common Access & Recovery State	Represents the most occurring machine states for training purposes
CBL	Case Based Learning	Learning method that makes use of cases representing the real context
CBT	Computer Based Training	E-learning that has to be completed before joining a training, to give background information
CDP	Competence Development Program	Specific personal development that recently was set-up, which engineers can request to gain a certain expertise
CS	Customer Support	One of ASML's departments focused on providing service to the customer
DFI	Design for Interaction	Master type of Industrial Design Engineering faculty at TU Delft
DUV	Deep ultraviolet	Type of light used in ASML machines (NXT) that has a wavelength of 248 and 193 nm and creates larger features on the chips than EUV systems
EUV	Extreme ultraviolet	Type of light used in ASML machines (NXE) that has a wavelength of 13.5 nm and creates smaller features on the chips than DUV systems
GTC	Global Training Center	Overarching department of the new EUV Training Center, also responsible for other training locations
HW	Hardware	One of the training methods in the new EUV Training Center
HW-rigg	Hardware rigg	Specific module, simplified representation of the system, on which the engineers can do hands-on trainings
IPD	Integrated Product Design	Master type of Industrial Design Engineering faculty at TU Delft
IDE	Industrial Design Engineering	Design faculty at the TU Delft focused on product, service and interaction design
KXI Studio	Knowledge eXchange & Innovation Studio	Department in which the graduation project finds place, which includes product and software development
LTA	Long-Term Assignment	Some of the High-NA engineers are in Veldhoven for a Long-Term Assignment to contribute to the design and training developments
MVP	Minimum Viable Product	The final design proposal that contains just the basic functions to show its use and workability with the users
NA	Numerical Aperture	In optics, the numerical aperture (NA) of an optical system is a dimensionless number that characterizes the ability to focus light (Paniagua-Dominguez et al., 2018)
OJT	On-the-Job Training	Sending a trainee immediately to the field to execute tasks, where they learn by doing
R&D	Research & Development	Department focused on innovations in design and products
SA	Service Actions	A service action is a sequence of system machine states in a specific order, often intended to replace a specific component and bring the system back to operational state
SMS	System Machine State	A system Machine State is a defined state of the ASML system. To bring the system from one SMS to the next SMS, a number of actions, described in procedures, must be performed
SMT	Skill Management Tool	A tool through which the engineers can document the SA/CARS they have completed in training and whether they can or cannot execute
SME	Subject Matter Experts	Person who has great knowledge in a certain field
SW	Software	One of the training methods in the new EUV Training Center
TC	Training Center	Location where maintenance trainings are given to engineers
TH	Theory	One of the training methods in the new EUV Training Center
UX	User Experience	Encounters all aspects of the end-user's interaction with a product, service and/or system (Nelson & Nielsen, n.d.)
UCD	User-Centered Design	A problem solving approach that focusses on the user perspective to create products, interfaces, services and systems (Van Boeijen, Daalhuizen, & Zijlstra, 2020)
ViP method	Vision in Product design	Context-driven methodology, focused on visualizing what people value, desire and believe (Hekkert & Van Dijk, 2017)
VR	Virtual Reality	One of the training methods in the new EUV Training Center
WWWWWH	Who, What, Where, When, Why and How	This method serves as a checklist to generate the most important values and questions and to create a better understanding of the problem definition (Van Boeijen, Daalhuizen, & Zijlstra, 2020)

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1. Company and project information

In this chapter the company and project will be introduced. The graduation assignment was created by encountering the company's interests, the training subject context, the student's educational background and personal interests.

Figure 2: Impression of ASML (ASML Picturepark, n.d.)

1.1 ASML: The world's supplier to the industry of semiconductors

This paragraph reflects on the profession of ASML, by explaining the importance of the company, introducing the lithography principle, and giving examples of lithography and metrology systems. Besides that, a summarizing overview of the history of the company is given.

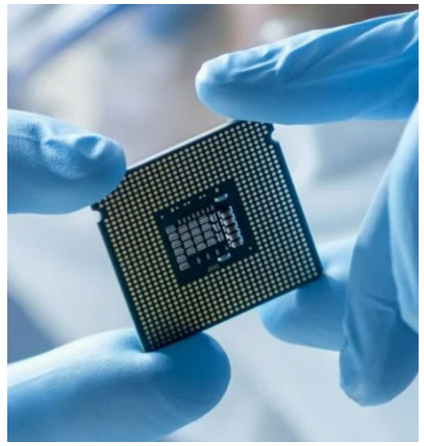


Figure 3: Microchip (ASML, n.d.-h)

General information

A world without chips would be unimaginable today; they are everywhere. An average car consists of 1400 of these semiconductor components that control everything from airbags to the engine. It is expected that in ten years this number will outgrow to 350 billion, which is about 41 chips per person (ASML Academy, n.d.). One of the companies in the semiconductor industry producing the complex systems, that are crucial to the production of microchips, is ASML. The company started in 1984 and after three decades, ASML became a global innovation leader, producing the machines that give the world's leading chipmakers the power to mass produce patterns on silicon. Intel, Samsung Electronics and TSMC are the world's largest semiconductor companies, and ASML's greatest customers (ASML, 2022). By using the most advanced lithography technology, chipmakers are able to create microchips that are more powerful, faster and energy efficient (ASML, n.d.-a) (ASML, n.d.-e).

The company consists of a global team of more than 32.000 people from 122 different nationalities and counting. The headquarter is situated in Veldhoven, the Netherlands. Besides that, the operations are spread across Europe, Asia and the US. These operations

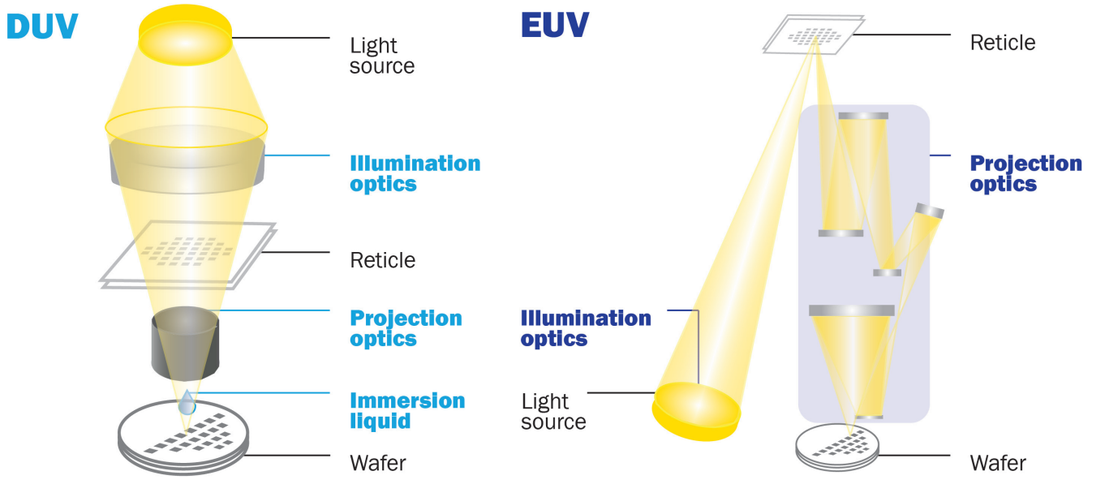


Figure 4: DUV and EUV lithography principles (ASML Academy, n.d.) (Lérondel, Kostcheev, & Plain, 2012)

include several local offices around the world to support the developments at the customer (ASML, n.d.-a) (ASML, n.d.-e).

A lithography or photolithography system is essentially a projection system, see Figure 4. Light is projected via a blueprint of a pattern, a reticle or mask, and printed on a wafer. The wafer, a silicon disk, serves as a substrate for the microchips, which will be printed on top of it. Lithography can be critical because it involves precise light manipulations to expose the desired pattern, while being the only semiconductor production step to process the wafer per small block of semiconducting material (ASML Academy, n.d.) (ASML, n.d.-g) (Techopedia, 2021).

As can be seen in Figure 4, ASML uses two types of lithography systems: Deep Ultraviolet (DUV) and Extreme Ultraviolet (EUV). Their first machines only make use of the DUV principle, in which a combination of lenses as projection optics, the addition of an immersion liquid, and mirrors as illumination optics is used to print a pattern on a wafer. More than two decades after that, a new unique technology was developed, having a 14 times shorter wavelength resulting in higher precision chips: EUV. However, lenses are not suitable for EUV, since these would absorb the light in the machine. A new optical system, while encountering the lithography principles, was developed by using only mirrors, in projection and illumination optics (ASML, n.d.-b) (ASML, n.d.-c) (ASML, n.d.-g).

System types

To improve lithography performance, the company offers several systems, see Figure 5. Using EUV makes scaling more affordable for chipmakers and allows the semiconductor industry to continue its pursuit of Moore's Law. This principle states that because of technical innovation the number of transistors on a microchip doubles every two years, while the cost of these is halved (Tamplin, 2022). EUV systems are used to print the most intricate layers on a chip, with the rest of the layers printed using various DUV systems. Both types of technology will be required in parallel for many years to come and they're continuing to advance both technologies (ASML, n.d.-b) (ASML, n.d.-c).

Besides the lithography systems, machines related to metrology & inspection are offered as well. Delivering speed and accuracy, their metrology and inspection portfolio covers every step of the manufacturing process, from R&D to mass production. The HMI e-beam and YieldStar systems complete the chip manufacturing loop, which can be seen in Figure 5 (ASML, n.d.-d).

Figure 5: Lithography systems and metrology & inspection systems (ASML, n.d.-b) (ASML, n.d.-c) (ASML, n.d.-d)

History of ASML
In the visual below, a brief summary of the history of ASML can be read (ASML, n.d.-i).

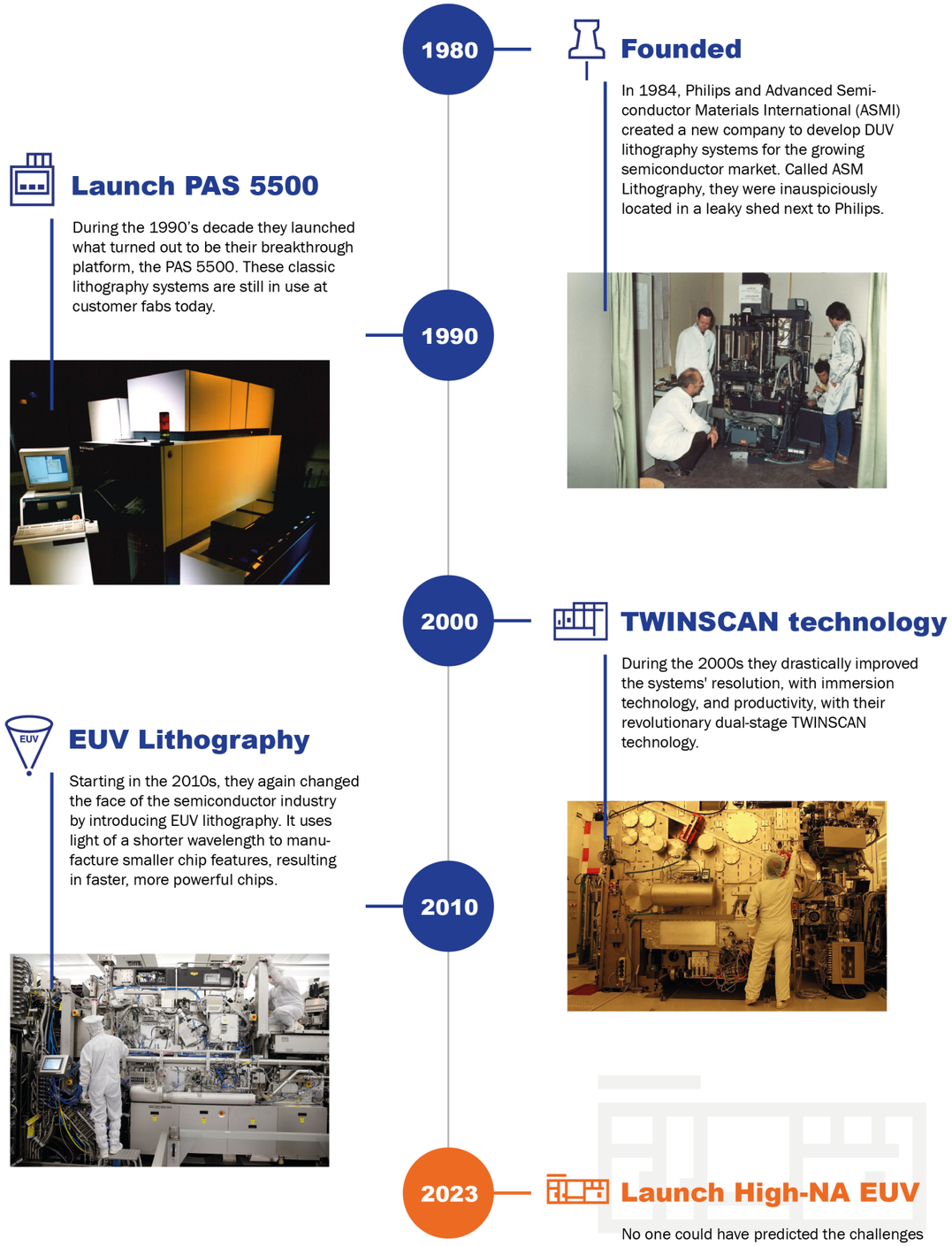


Figure 6: History of ASML (ASML, n.d.-i)

1.2 The High-NA EUV Training Center context

The company contains a wide diversity of departments, such as R&D, Manufacturing, Customer Support, Sourcing and Supply Chain and support functions, that all contribute to building and maintaining the systems. The graduation project finds place in between Knowledge eXchange & Innovation (KXI) Studio, which encounters software and product development, and Global Training Center (GTC). Overarching is the Customer Support department, which evolves around training the engineers that will maintain the systems at customer sites (ASML, n.d.-f).

Launch of High-NA EUV platform
As can be seen in Figure 6, the next step for ASML is launching their newest EUV machine. To enable further innovation in chip manufacturing, ASML is developing the next-generation EUV platform, that increases the numerical aperture (NA) from 0.33 to 0.55 ('High-NA'). This number is associated with the light gathering ability and is related to the angle of the light beam. By increasing a mirror's diameter, a higher NA is reached. This stimulates non-direct rays to enter the lens, resulting in a higher-resolution image, meaning that even more detailed microchips can be manufactured (Rottenfusser, 2013) (ASML, n.d.-c).
The improvement of the several parts and increasing the dimensions of these parts, results in the need of a higher volume machine. This is why the High-NA EUV machine will be greater in size than a NXE machine (Figure 7). The developments of this new platform is ramping up, with first shipments of these advanced lithography systems expected in 2023. These machines will first act as R&D purposes at the customers, but are expected to be fully operational in the customer factories by 2025 (ASML, n.d.-c).

A new and vibrant Training Center
The High-NA EUV system requires a new Training Center (TC), since their current one in Veldhoven will be outgrown when looking at the training demand, but also taking into account the increase in size of the machine, making the current TC not suitable. ASML offers several training locations to engineers in the Customer Support (CS) department, in San Diego (USA), South-Korea and Veldhoven. For this first number of years, the High-NA trainings will only be given in Eindhoven at the Brainport Industries Campus (BIC), which should start to operate in 2023, and will align with the shipment of the first system. In this way, the first engineers able to maintain the system, will be ready at customer's sites. Since the system will not

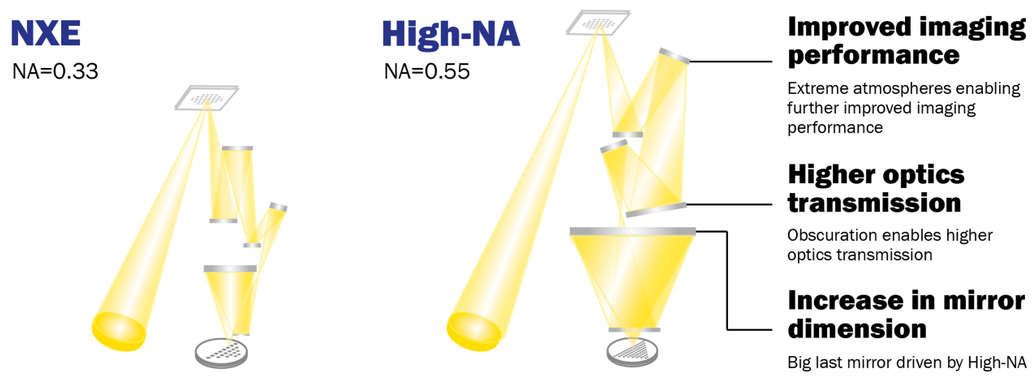


Figure 7: EUV systems and the specific improvements of High-NA compared to NXE (ASML & Zeiss, 2018)

be physically available during training, because this will be too cost-intensive and the first machine will be sent out to the customer, representative simulations and modules have been created. In this environment, a new way of working will be introduced, using Theory (TH)/Hardware (HW)/Software (SW)/Virtual Reality (VR) activities to transfer skills to engineers. A specific curriculum suitable for the High-NA EUV system consists of several steps (Figure 8); Service Actions (SA), which include Common Access & Recovery States (CARS).

Each SA consists of SMS's (System Machine States). A practical example of an SA is for example changing the oil of a car, where an SMS would be all the individual steps, see Figure 8. There are some SMS' that are reoccurring for several SA's, these are called Common Access and Recovery States (CARS). It is seen as crucial to train on these CARS scenarios, since they cover the majority of a training, which is 75%. The total duration to complete the High-NA EUV curriculum, with a total of 350 SA's and 805 unique SMS's, is nine weeks for all competencies.

Demand for training slots is very high, there is an average of 30 High-NA EUV engineers with various roles per Quarter from 2023 onwards. A future vision of ASML's TC is the following according to the company mentor, who is a senior curriculum architect, responsible for the several career paths for CS in ASML's Global Training Center (GTC):

"The future TC will have 'open doors' for the selected engineers who want to develop themselves through a training program. They can book the slots to preference, and can see which trainers are in the training center available that day. Trainers consist of qualified coached by ASML, and fellow engineers who have experience with the selected training. A qualified coach by ASML walks around in the TC to provide feedback or offer help during training. When an engineer needs help, and a coach is not around, a colleague engineer who recently has completed the training can be approached in the TC for questions. The future TC will be a vibrant and inspiring environment, where flexibility and learning by doing, will play a huge role. Besides that, this way of working will also stimulate practice opportunities, which currently is not encountered the way of working."

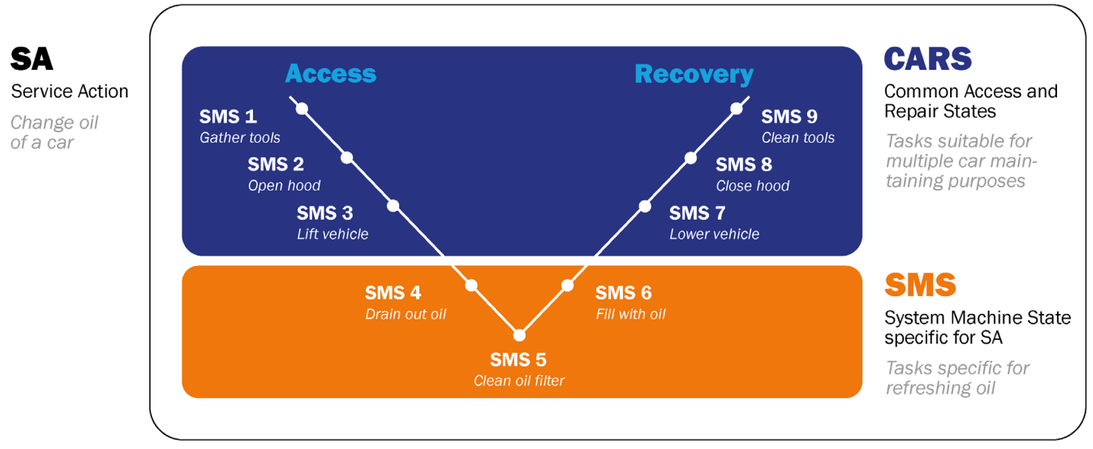


Figure 8: Practical example and comparison of SA's, CARS' and SMS' (O'Reilly Auto Parts, 2018)

Figure 9: Impression of the entrance of the BIC building (SDK Vastgoed, 2022)

Figure 10: Impression of the learning environment of the BIC building (Theeuwen, 2017)

1.3 Project background & definition

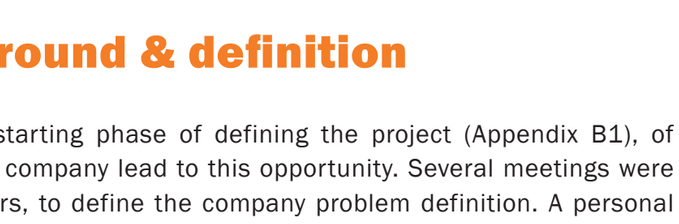
In this chapter, I will clarify the starting phase of defining the project (Appendix B1), of which a previous internship at the company lead to this opportunity. Several meetings were initiated with business stakeholders, to define the company problem definition. A personal twist was given to the project by encountering a critical view on the company's request, while representing personal and educational interest.

Internship
In February 2022, I joined ASML for a 5-month internship, which was focused on researching and analyzing User Experience (UX) in several departments by creating Customer Journey Maps. I was intrigued by the company because of its complexity and endless possibilities. This had resulted in me wanting to graduate here as well and explore other departments where my Industrial Design Engineering knowledge could be applied, but where I will also be challenged and develop myself as an Integrated Product Engineer. During my internship I have approached several departments about graduation possibilities, and I have chosen the one I found most interesting; creating a planning tool for the High-NA EUV TC to come.

Request and problem definition of company
The request of the company when looking at the graduation assignment, is to create a training planning tool that encounters the SA dependencies and allows the users to plan in trainings to their flexibility. The design proposal should be a Minimum Viable Product (MVP), showing the basic planning functions. To show the functionality, it should not integrate all SA's, to show possible successful implementation.

Company problem definition

"The way of working for an engineer is inefficient and smart planning is missing."



Training planning and arrangements by trainer is time intensive

Missing dependency and **repetitive occurence of SA's** for training types

Figure 11: Problem definition according to company mentor Henri Jaspers (Flaticon, n.d.)

There are two main problems when looking at ASML's current way of training, see Figure 11. Currently the TC is a static environment, lacking in innovation regarding flexibility, personalization and smart planning. In an ideal situation, the engineer can pick when, where and with who they want to do a training part, and create an 'own tailor made journey'.

When looking at flexibility and personalization, all engineers currently follow the same training program. They sign in for a training through ASML's MyLearning platform, on request of the manager at the customer's site, whereafter they're informed on a daily planning by the trainer through email. This is the first problem, because according to the company, this is inefficient when looking at the costs of trainers and other stakeholders managing a training, since the time spent on this, could be of great purpose for helping and educating trainees.

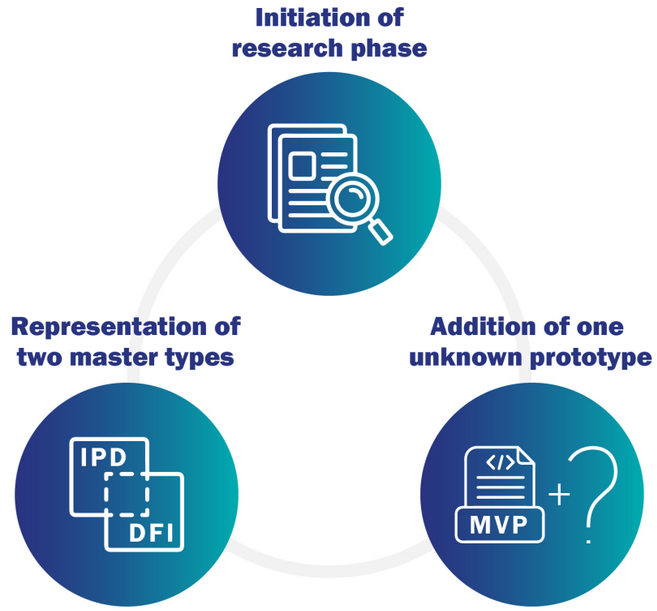


Figure 12: Add-ons of student to project definition of company (Flaticon, n.d.)

According to the company the training planning tool will tackle this problem by handing over the micro-planning responsibility of the trainer, to the trainee.

Considering smart planning, one of the issues is that for the current training module all SMS'/CARS' of a part of the training have to be followed, even though some steps are repeated for each SA. In the changing oil of a car example, see Figure 8, this means that for each training an individual practices to lift or lower the vehicle and to open or close the hood. The company sees it as redundant to repeat these common actions for each training, and finds it important to focus on the typical SMS' of the SA. This means the dependency of these repetitive SMS' is currently missing, and should be created to make the training more efficient, resulting in lower training timeframes and effective training use. Next to that, practicing slots on these common actions should be offered, to make sure the majority of topics are covered.

Student contribution and interest
Besides delivering the main interest of the company; a planning tool representing a tailor made journey with SA dependencies, I have created my own personal twist to the graduation project, see Figure 12. Three aspects will be added to the company assignment, which were defined after having a critical view on the project. The project specifics and content is defined in this way, to make sure the final design proposal has value for the company, while encountering the IPD way of working and student's experience. This personal addition to the project results in having two main phases; a research and prototyping phase. The timeframe and details of each of these phases can be seen in Chapter 1.4.

The first addition would be adding an extensive research phase at the beginning of the graduation project, to make sure a suitable design direction is chosen when looking at the needs of the users and business stakeholders. Several questions

came to my mind when discussing the graduation subject with the company, see Figure 13. These questions were clustered into research topics (Figure 18).

Second, it will not be feasible for the graduate to create a working tool when looking at the complete amount of SA's, the dependencies of those, and the amount of possible training programs. Therefore, I aim to deliver a mock-up of the company's interest; a basic functioning application where a tailor made journey training journey can be specified for one curriculum, while taking into account certain SA dependencies. Besides creating this MVP, I also want to provide the company of useful feedback for further development. Additionally, I want to use the IPD perspective, by having also a focus on the prototyping phase. Here I want to come up with a yet unknown add-on to the prototype, supporting the training planning tool, that will be the outcome of my research proposal of the 4 topics. As an industrial design engineer I will have to research and academically substantiate a design to an extent. By just executing the companies wishes, without encountering the context and needs of all stakeholders, the design will not be valuable, and the likelihood of success will be minimal.

Last, I want this project to be a combination between two IDE's master specializations; Integrated Product Design (IPD), which is my master specialization, and Design for Interaction (DFI). My internship has resulted in an interest in DFI, since I noticed investigating user experience and talking to users to make sure the service fits to their needs, became a passion of mine. I enjoy talking to people, and I'm fascinated by their way of thinking and how this relates to product or service use. This interest and past experience, I wanted to be reflected in this graduation project, resulting in a focus on retrieving user feedback by for example doing research, interviews, having observations, co-designing and other methods. This is in line with the DFI master program, which is focused on the way people and products interact (TU Delft, n.d.-a). Besides that, an User Experience (UX) design approach will be encountered and the UX department will be contacted on their standards, to not reinvent the wheel. Regarding the IPD aspect, I will focus on designing a user-centered product by using methodologies, based on a balance between users and business challenges (TU Delft, n.d.-b).

Figure 13: Possible research topics after having a critical view on company's problem definition (Flaticon, n.d.)

Main challenges

When looking at the complete graduation assignment, I can see multiple challenges for me as an Industrial Designer. After talking to several colleagues and Subject Matter Expert's (SME) on ASML and their way of working, I formulated three main challenges by having a critical view on their comments, see Figure 14. My personal ambitions are formulated to tackle these main challenges, and to make sure their impact is minimized.

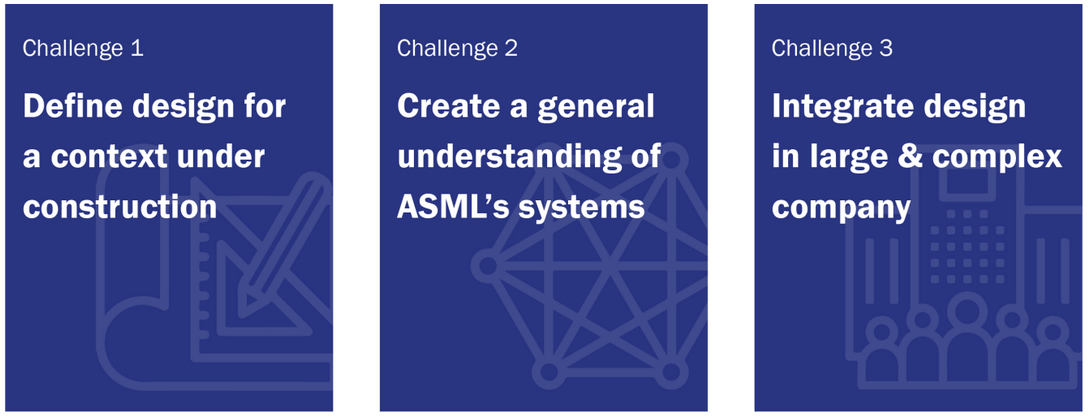


Figure 14: Main project challenges defined by student (Flaticon, n.d.)

Personal ambitions

For this graduation project, the following learning goals were formulated, see Figure 15. The first two learning goals relate to the main project challenges in Figure 14. The third learning goal is related to personal interest, and is seen as great value for the company to substantiate certain design decisions. By focusing on data visualization, the impact of the research on training, can be shown to management, regarding the potential of further implementation of the final design proposal. Since this project's university mentor, is experienced in data visualization, her expertise and feedback is seen as great value for the process.

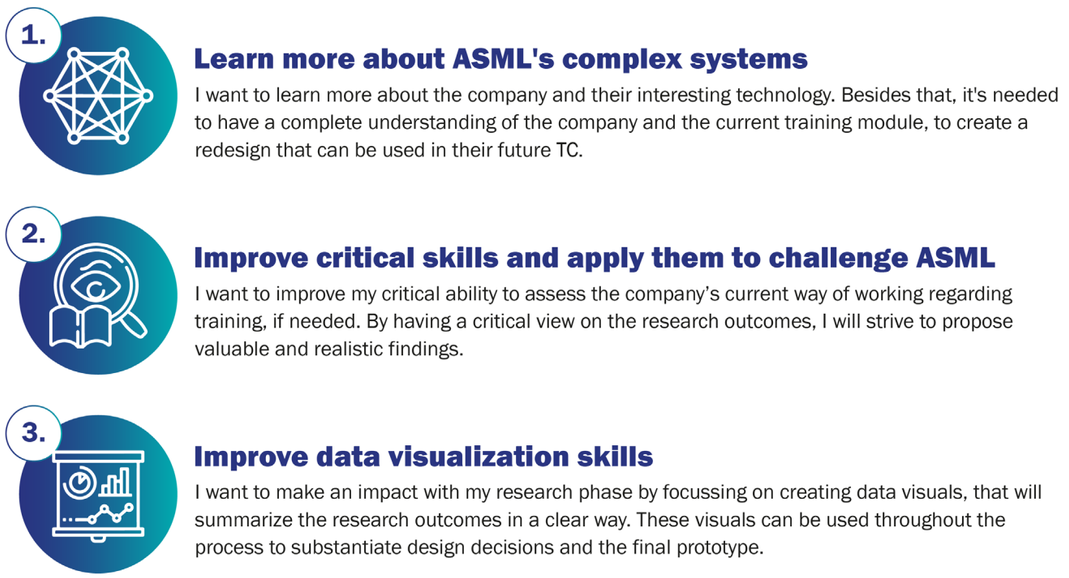


Figure 15: Personal ambitions defined by student (Flaticon, n.d.)

1.4 Double Diamond & project approach

Having defined the project, I opted for the Double Diamond framework and a User-Centered Design approach as guiding foundations. I used the Double Diamond framework as a guide to create an initial Gannt Chart and to track and adjust the project planning when necessary. In this section, the project set-up and the internal stakeholders of this project will be introduced.

Project set-up through the Double Diamond framework

I decided to use the Double Diamond framework in my project because of two main reasons. First, similar graduation projects at IDE have successfully used this framework as a guide to keep track of progress and to substantiate the project structure. Second, as an IDE student I have experience with using this method and I have always been satisfied with the simplicity in use alongside the potential benefits. Last, the company has shown great interest in this method and sees value in its integration with the KXI Studio. In fact, as part of my graduation course, I had the opportunity to present the Double Diamond framework during Dommel Valley, which is a business event about learning and knowledge innovation. In addition, integrating the Double Diamond into a project is beneficial, since it allows tracking project state, prioritizing phases and overcoming possible delays. It indicates where a broad exploratory mindset is necessary and where it is important to refine ideas and come down to a solution. Besides, it serves as a communication tool to the team and other stakeholders (UXplained, 2019).

The Double Diamond, designed by the UK Design Council in 2004, is a visual representation of a design and innovation process. It describes the steps, irrespective of the methods and tools used. It is a universally accepted design thinking concept that guides designers through the design process. It starts with an initial challenge or problem statement (first diamond of Figure 16), moves through the exact definition of the problem in the middle, and ends with the solution (second diamond of Figure 16). The first diamond resembles problem exploration and definition; design the right thing. While the second diamond is about exploring possible solutions and defining a proposal; design the thing right. Each diamond comprises an exploring divergent phase followed by a regaining back focus convergent phase (Design Council, 2022a, 2022b).

After setting up the project by using the Double Diamond Method, I defined the most important stakeholders of the project's context (Figure 17). Additionally, a Gantt Chart planning has been created, of which the initial version and several iterations can be seen in Appendix B2.

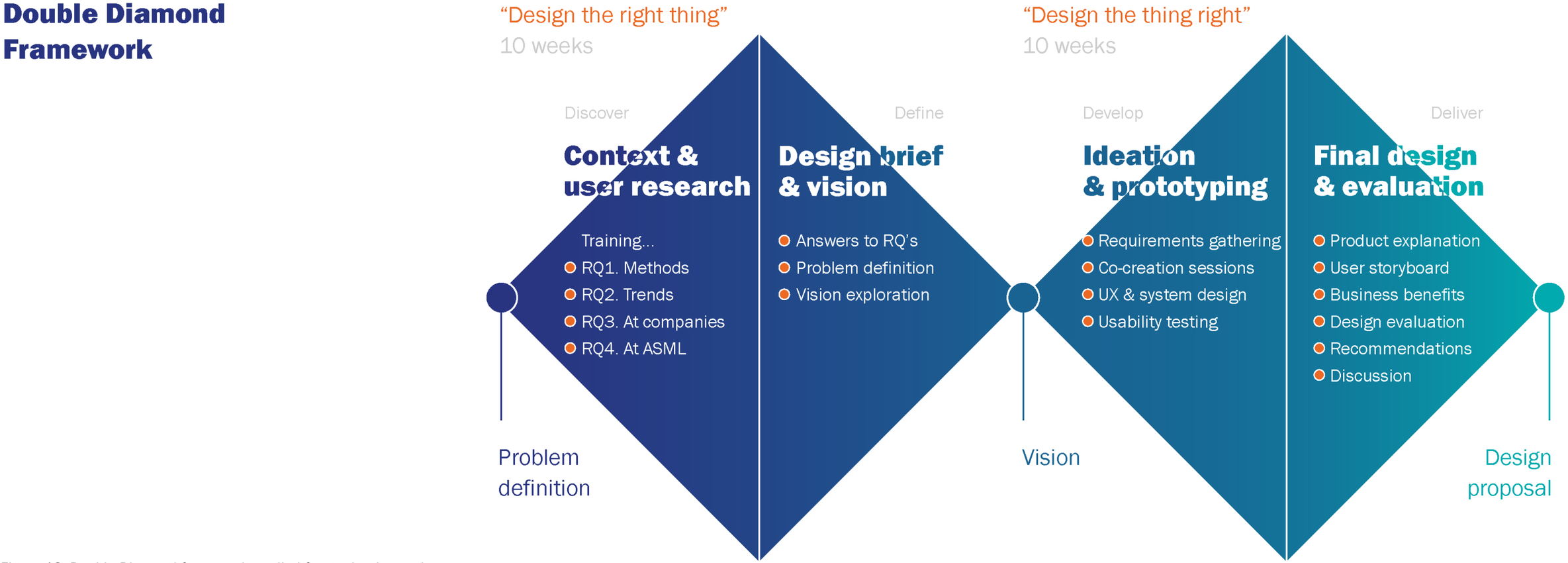


Figure 16: Double Diamond framework applied for graduation project

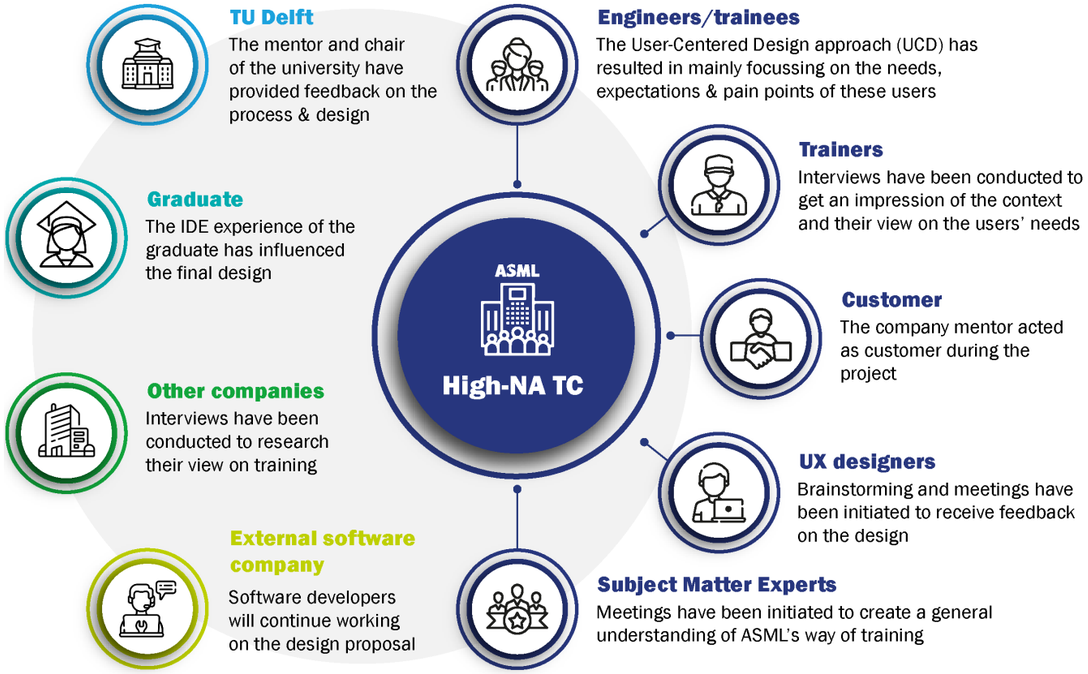


Figure 17: External and internal stakeholders (Flaticon, n.d.)

User-Centered Design approach

During this graduation project, an User-Centered Design (UCD) approach will be taken into account to realize an optimal final design proposal, designed to the needs of the user; High-NA trainees. The focus on UCD positively influences the quality of user experience; by focusing on the needs, design, properties and capabilities of the projected users on a product, interface, service or system. (Van Boeijen, Daalhuizen, & Zijlstra, 2020)

My previous internship at ASML gave insights regarding the human-centered aspect of the company, regarding product design. It indicated that in a majority of the cases, products and services are not designed by using end-user feedback, since it is difficult to assess a product or service because of the strict rules at the customer's site, the customer pressure, and the responsibilities of the engineer. This results in the majority of the products or services being designed by engineers, and being tested by themselves or colleague engineers, which points to a higher chance of invalid feedback given by inaccurate user representation. According to Norman (2013), engineers design products on how they would like a person to use it, instead of taking into account what's intuitive. Testing with users will show insights whether their needs and preferences are represented in the intended product or service.

Because of this observed matter, I will strive for implementing an UCD approach. This project shows opportunities regarding designing for and with the users, since some Customer Support engineers are currently in Veldhoven on Long-Term Assignment (LTA) being involved in the qualification of the first High-NA systems that will go to customers. These engineers are also involved in the validation of the specific High-NA training curriculums.

2. Context & user research

All the above is the problem definition according to the company. When having a look at this, I was wondering if currently a 'tunnel vision' is applied for this. Therefore, I want to challenge ASML's views on training, and even go beyond it with a new future proof design proposal, by using my IPD skills to answer the research questions in table below. For each topic, approximately a two-week timeframe was taken into account.

	Subject	Question	Input type
RQ1	Research **training means** and the psychology behind it	"What is the most effective way of giving a training when looking at proven methods?"	Papers
RQ2	Research **trends and the future of training** of all fields and think out of the box	"What does the future look like of training, while also taking tech (AR/VR/etc.) into account?"	Papers
RQ3	Research training modules and **views on training of other companies**; automotive, aviation, medical etc.	"What do the training modules of other tech-based companies look like, and how do they see the future of training?"	Papers Interviews
RQ4	Research the specifics and **user experience of ASML's training** for NXE, since there is no High-NA training yet	"What are the specifics of ASML's current way of working and what is the user experience of NXE training?"	Survey Interviews Observations

Figure 18: Visualization of research phase

2.1 Training methods and psychology (RQ1)

In this section, I introduce the categorization of training phases (pre-training, training, and post-training) and the relevant variables with their correlations for each phase. In addition, I summarize the literature on training creation and evaluation, and optimal knowledge retention. The created method in Figure 21, serves as input for the company (RQ3) and ASML (RQ4) research.

Categorization of training phases

According to Salas, Tannenbaum, Kraiger, and Smith-Jentsch (2012), training is crucial to the development of an organization: "Continuous learning and skill development is now a way of life in modern organizations. To remain competitive, organizations must ensure their employees continually learn and develop. Training and development activities allow organizations to adapt, compete, excel, innovate, produce, be safe, improve service and reach goals."

During a training period, three crucial phases are identified; pre-training, training, post-training, see Figure 19. The classification of these phases was utilized to create an outline

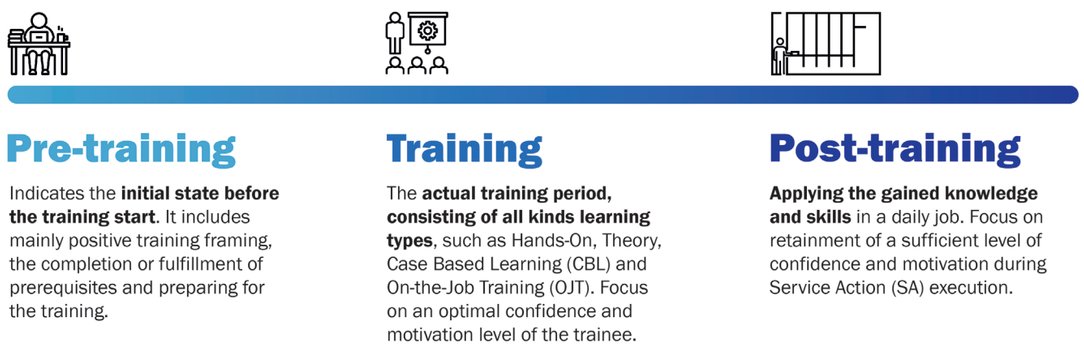


Figure 19: Clarification of the three defined phases in training (Tai, 2006) (Flaticon, n.d.)

of a general understanding in training drivers and their coherence. Figure 21 represents the relationships of several variables in training, where the variety in blue circular shapes represent the phases specific factors and the orange circular shapes are individual related.

Pre-training

This initial phase, see Figure 21, evolves around discovery and evoking training motivation. Several researches show that a complete and positive framing of the training beforehand, by focusing on climate and manager support, results in an increase in self-efficacy, which indicates the confidence of a trainee in the ability to fulfil a certain task successfully (Colquitt et al., 2000) (Tai, 2006). The initial confidence level of an individual, is also dependent on previous experiences and the primary set of skills (Schunk, 1995). Besides self-efficacy, positive training framing also increases the motivation of a trainee (Tai, 2006).

Training

Motivation is necessary for a training to not only be able to commit to a task, but also get all the benefits out of a certain learning opportunity. Being described as the willingness of a person to adopt a certain behavior, motivation has an influence on utility reactions, learning and transfer of motivation (Tai, 2006). However, the confidence level impacts utility reactions and transfer of motivation, having no correlation with learning. In Figure 21 the statements have been visualized.

Utility reactions, according to Ruona et al. (2002), is an individual's understanding of training usefulness to their job tasks. Next to utility reactions, affective reactions indicate the individual's emotional reaction to a certain situation. However, Alliger et al. (1997) emphasizes that utility reactions are more strongly related to learning transfer than affective reactions.

The learning variable influences the post-training competence level and is a performance indicator (Tai, 2006). It is stated that even if a trainee is able to learn a certain kind of training content, considering the academic background, it is likely that the trainee will not succeed in learning without confidence (Colquitt et al., 2000).

According to Tai (2006), transfer motivation implies the commitment to use the gained knowledge in the profession. The study emphasizes that utility reactions and learning are measures to evaluate the effectiveness of a training. Transfer motivation is used as a criterion variable, of which the effectiveness relates to the opportunity for an individual to apply the acquired skills in practice.

Post-training

Once a training has been completed, the individual will apply the gained knowledge in their profession, of which studies show the importance of the preservation or improvement of the confidence level in practice (De Clercq, Haq, & Azeem, 2019). According to Ouweneel et al. (2013), confidence is related to task performance over time, which means that an increase in confidence results in a higher task performance over time. The confidence level of an individual can be influenced by allowing time for repeated practice, to master the learning points (Cole, 2008). When looking closer at confidence, it can be concluded that it consists of four main drivers (see Figure 21), performance outcomes, vicarious experiences, verbal persuasion and physiological feedback (Bandura, Freeman, Lightsey, 1999).

Besides maintaining and stimulating the confidence level of an engineer on the job, motivation should also be preserved (Kirkpatrick & Kirkpatrick, 2021). According to Pink (2009), autonomy, mastery and purpose, are the main factors that play a role in creating a sense of motivation for an individual (see Figure 21). The study mentions that businesses still invest in triggering their employees by using reward systems, even though this doesn't imply a motivational driver. In these cases they work the other way around, resulting in a productivity decrease.

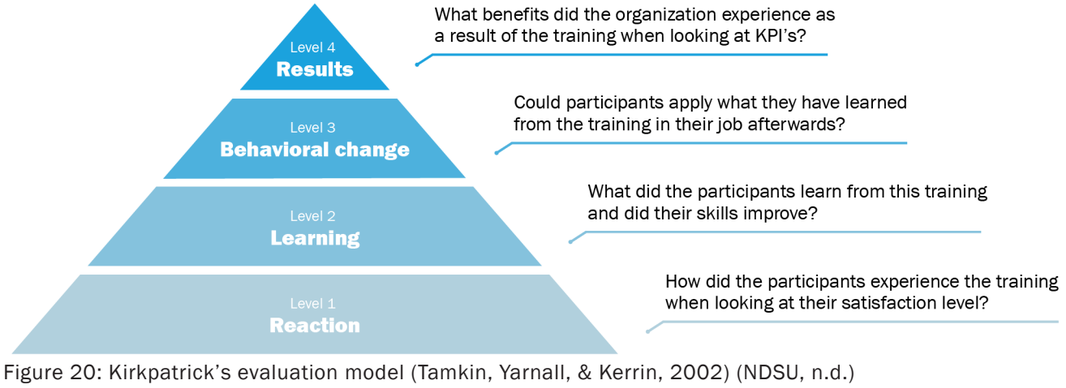


Figure 20: Kirkpatrick's evaluation model (Tamkin, Yarnall, & Kerrin, 2002) (NDSU, n.d.)

Creation and evaluation of training

To make sure an organization if offering effective trainings to their employees, evaluation should find place for the purpose of improvement the content and way of working. A well-known method according to studies, and ASML's training department, is Kirkpatrick's evaluation tool (Tamkin, Yarnall, & Kerrin, 2002). It consists of 4 levels; reaction, learning, behavior and results, see Figure 20. It is widely used in organizations due to its simplicity and effectiveness, besides that it has minimal limitations, but these risks don't outweigh its potential benefits (Bates, 2004). To plan and create a training program, the Kirkpatrick's evaluation tool can be used in reverse. Whereas you would start from Level 1 to evaluate a training program, Level 4 can be used as starting point to first set boundary conditions encountering the results of a training. After the goal and target group has been formulated, program development can be initiated (Kirkpatrick, 2016). In Appendix C, the evaluation model is further elaborated and ASML's eight field model, derived from Kirkpatrick tool, is introduced.

Optimal knowledge retention

The effectiveness of distributed practice is shown by taking into account several studies on Ebbinghaus' forgetting curve (Easley, 1937). One of the main findings of Ebbinghaus' forgetting curve is that optimal knowledge retention can be achieved, when revising the material again at a later moment of time. However, finding the sweet spot of this follow-up study moment, is rather difficult to determine (Kamei, 2021). Several academic researches on Ebbinghaus' theory have tried to determine the time in between those repetition or practice opportunities. According to Resch (2015), see Figure 22, three repetitions after the initial learning moment should find place, the first following up after a day, the second after 1 week and the third

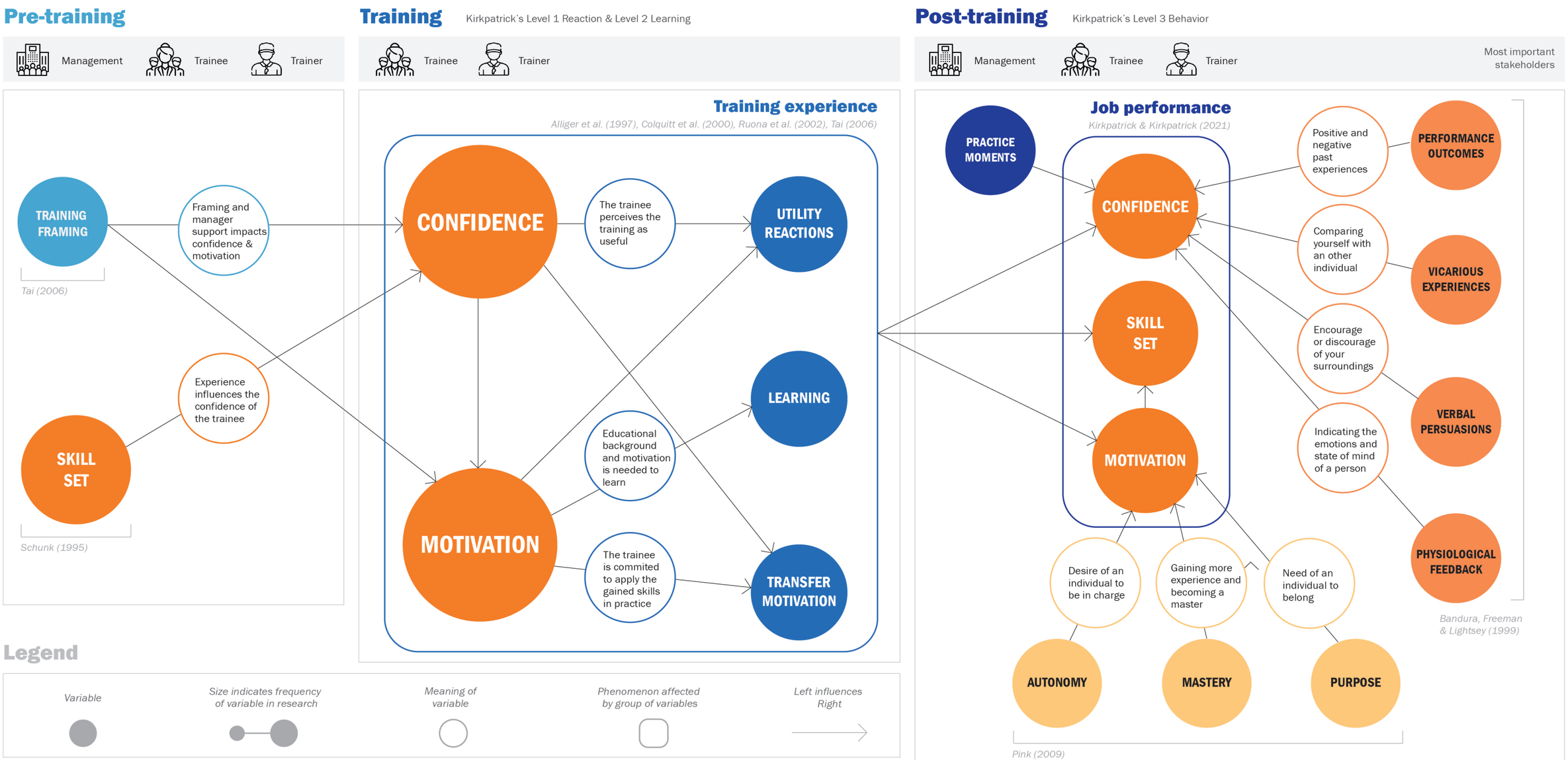


Figure 21: Variables and their relationships deriving from the training research of RQ1 (Flaticon, n.d.)

after one month. Akresh-Gonzales (2018) mentions that this repetitive moment should have a 10 days interval. Last, Chun & Heo (2018) mentions this is a 1-day, 2-day and 3-day interval, see Figure 23. These examples indicate the challenge to determine a sufficient interval between the trends of the forgetting curve. If this will be applied in practice, a suitable interval should be chosen by taking the learning goals and timeframe of a training into account. and timeframe of a training into account.

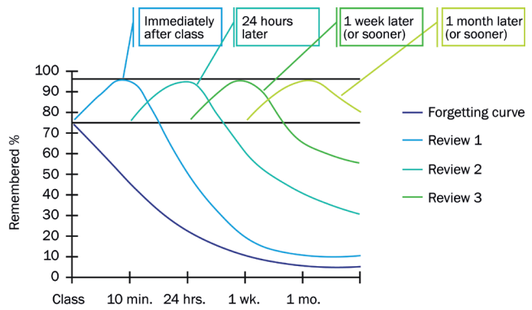


Figure 22: Forgetting curve (1) (Resch, 2015)

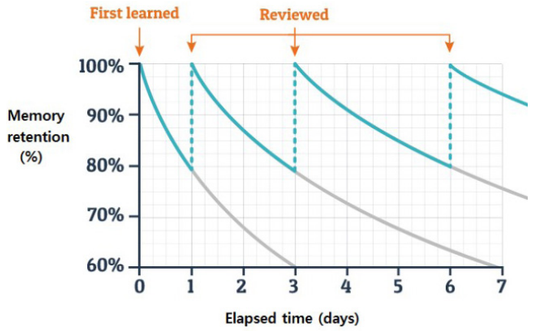


Figure 23: Forgetting curve (2) (Chun & Heo, 2018)

Optimal duration of hands-on training

Similar to the study on determining optimal intervals of the Ebbinghaus' forgetting curve, an optimal duration of a training, was investigated. The outcomes of this observation, are similar to the outcomes of the interval research as well, since this is entirely dependent on the type of training and learning goals. The study of Mahmood et al. (2022) demonstrates that the performance of doctors increases for an ultrasound hands-on training of 90 minutes, rather than a 30-minute or 60-minute timeframe. According to Bergeron (2006), doctors and engineers have similarities in their way of working and professional behavior, resulting in the assumption that this optimal 90-minute hands-on training duration could work for ASML's service engineers as well. Even though Mahmood et al. (2022) demonstrates that a prolonged hands-on time positively influences the performance of the engineer, a wide diversity studies examine an optimal training duration ranging in between 15 and 30 minutes, or above (Morgenroth, 2021).

Conclusion and reflection of RQ1

This study on training methods and psychology created a general understanding and perception on training. The importance is demonstrated of focusing on motivation and confidence during the training and post-training phase. Personal development stimulation can be achieved by taking into account the motivational drivers according to Pink (2009). When looking at confidence, practice moments are crucial to create a sense of mastery and behavior change (Cole, 2008) (Kamei, 2021). Besides that, regular evaluation training would improve current models, as indicators show a trend of high-technology changes for similar companies. In this rapid change context, trainees should be able to adapt to challenges and acquire new skills, through renewed training programs (Tai, 2006). Last, the variables of Figure 21 will be represented throughout the interviews with companies (RQ3) and with trainees at the company (RQ4). It is likely that the created methodology is not optimal and would not entirely fit in the organization. However, investigating the training practices at ASML (RQ4), could possibly give some clarity on whether this visual supports the company's current way of working.

2.2 Future training trends (RQ2)

To make sure the design proposal fits to the current and future training context, I have done a literature research on trends and clustered them on four subjects (Figure 24). Only the trends that reoccur in this report, or are mentioned by stakeholders, will be elaborated in this chapter, additional trends explanation can be seen in Appendix D1. The cluster of company statistics, that is linked to RQ3, I see as most significant and leaning in this research.

Artificial Intelligence

According to Maity (2019), Artificial Intelligence (AI), representing human knowledge, can be used in several situations, such as non-biased recruitment processes, personalized training course recommendations, analysing performance, map trainers to trainees, schedule training programs and more. The main challenge will be to make a system capture certain training feedback, and link trainee information, such as performance (Maity, 2019). Currently, AI is in development for training recommendations at ASML, and also at other companies (RQ3).

Virtual Reality

Several researches have been done on the use of Virtual Reality (VR) in maintenance. According to Schomaker et al. (2019), VR is widely used in training, actual maintenance, on a distance and assembly. For example, VR can be beneficial to asset's downtime, since it shows the location of the malfunction in the system, and narrows it down to a more detailed component level. According to Numfu, Riel, & Noël (2019), VR applications are now widely accepted in training for solving complex tasks. This study shows that simulating fine gestures in a VR environment is challenging.

Augmented Reality

Augmented Reality (AR), can reduce training costs and improve the effectiveness of training by assisting with additional comments to a real life situation. Unlike VR, AR is complementary to the real environment, and is blend of VR and context (Haritos & Macchiarella, 2005) (Schomaker et al., 2019). AR is currently widely used in the medical field for assistance on procedures, but also at ASML for training and maintenance. For the majority of the tech-based companies (RQ3), it is still in development, because it is challenging to keep track of the environment due to the high speed of technological development.

Micro-learning and byte-sized modules

Training programs should be designed in an engaging way for a trainee, making sure their needs are fulfilled. Micro-learnings are small modules, for example an E-learning, that capture the most important take-aways of a certain learning. Besides that micro-learning and byte-sized modules are a great advantage for trainees when looking at accessibility, it is also a beneficial and efficient way of training for the company (Maity, 2019). One of the challenges would be to maintain the materials, and to make sure the learnings are regularly updated.

Learning through real-time feedback

According to Dolan et al. (2013), people learn most and produce best when they're with a group of people experimenting, through On-the-Job Training (OJT) for example, without any guidance of a trainer or supervisor, with access to a knowledge source. Challenges of this real-time feedback through OJT, that these sessions will be disturbing for the environment

and its productivity (Vasanthi & Basariya, 2019). Next to that, a structured competence program should be set-up, to make sure engineers can be qualified through OJT (Steenbakkers, 2021).

Workforce diversity

The workforce nowadays consists of different generations, cultures and genders (Cascio, 2019), resulting in different learning needs. It will be challenging to create the future of training, encountering all these interests, while reflecting the organization's value (Karp & Sammour, 2000). Voith Paper (RQ3) is one of the companies who mentioned this trend as their main future challenge to encounter.

Optimizing learning

A study by Cascio (2019) mentions that optimizing learning through overlearning, is a method to prevent knowledge detention (Figure 22). Having these practice opportunities, makes it possible to train beyond the required. This makes sure the individual can anticipate on stress and can cope with infrequent situations. However, the success depends on the amount of overlearning, the task type, and the retention timeframe.

Personalized learning

The way of training has shifted from providing a great amount of content to as many people as possible, mass upskilling, to personal and individual trainings (Maity, 2019). Trainees have the need for personalized learnings, which is also stated by the majority of the tech-based companies (RQ3). However, personalized learning is easier said than done, as it is complex to create an effective learning system (Bulger, 2016).

Workplace communities

The increase in popularity of social media, also takes over the workplace. Trainees want to share their experiences and show others what they're up to on their professional level (Azourt et al., 2020). However, similar to learning through videos, confidentiality plays an issue here. Besides that, having these company communities has some constraints when looking at security of the individual, possible influence on productivity and filtering data (Akram & Kumar, 2017).

Conclusion and reflection of RQ2

Limitations of this literature study could be that some trends have not been considered, that could be interesting for the graduation company. Besides that, RQ2 has been linked to RQ3, focusing on the interviewed companies. This could have created a tunnel vision, when considering the trends mentioned by the companies, potentially leaving out the discussion of other trends that could be valuable to ASML.

When looking at the company statistics cluster, the majority of the companies mentioned their focus on trends AI, VR, AR, micro-learning and personalized learning. Besides that, Voith Paper is currently developing workplace communities, which is also in development in the training department of ASML.

All companies apply OJT or want to apply this in the future, except for Ministry of Defense. OJT is seen as an effective way of emerging the training and post-training phase, according to company Next Learning (RQ3). However, OJT implementation requires a great shift, having three reasons why it is hard to realize at ASML. First, because all manpower is needed in the field to solve complex issues and this will be at the expense of trainees since their mentor is not always available. Second, customer sites mention that they are no training facilities. Last, machines are too cost-intensive, mistakes can not be made.

Figure 24: Data visualization of company interviews (Blue colors indicate type of training phase, orange color indicates person dependency)

2.3 Training at other technology-based companies (RQ3)

After conducting research on methodologies (RQ1) and trends (RQ2) of training, these insights were used to create interviews with seven technology-based companies on their vision and strategies for the future of training. These serve as a baseline to create a thorough understanding of the modernized way of working in training and the educational technology resources of other companies.

Approach

The goal of this research was to find out whether the vision of the organizations align with the answers to RQ1 and RQ2, and whether there is a relation in way of working between the technology-based companies (Figure 25) and ASML. In order accomplish this goal, seven organizations have been approached, by highlighting the graduation topic, research specifics and the potential benefit of knowledge exchange. On approval of the organizations, the input of all interviews will be provided, having the potential of contributing to their training vision. The contact information of the organizations was obtained through the university, graduation company and personal connections.

Method

The sample of this study consisted of seven company contact persons, of which the gender and age were not considered. As a requirement, the participant needed to have expertise in training or educational sciences in the company's learning department, of which a management or specialist specific role is preferred.

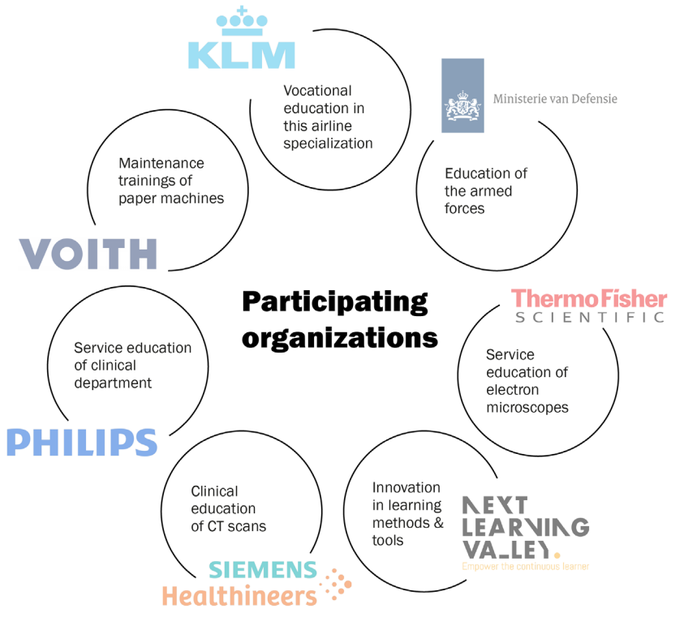


Figure 25: The participating organizations with a description of the effective department (KLM Dutch Royal Airlines, n.d.) (Ministerie van Defensie, n.d.) (Next Learning Valley, 2022) (Philips, n.d.) (Siemens Healthineers, n.d.) (Thermo Fisher Scientific, n.d.) (Voith, n.d.)

The creation of the interview script and the protocol (Appendix E1), has been done by taking into account the interviewing methodology of Van Boeijen, Daalhuizen, & Zijlstra (2020). As an IDE student, I have experience using this typical TU Delft method, resulting in seeing the value of it for this research.

The measures and questions of this interview were constructed by taking into account the created methodology of RQ1 (Figure 21), some technological trends of RQ2 and the example questions of a similar conducted research of Maity (2019). The company representative was asked to share information on the pre-training, training and post-training activities and developments. Next to that, it was asked to reflect on the stimulation of motivation, confidence and performance outcomes in their current way of working. Besides that, their insights on their current educational technology resources and developing resources was requested. Last, their future vision on training, current drawbacks of their training program and shift in behavior of trainees was investigated (Maity, 2019).

For the protocol, a general interview structure was created to improve the quality of the research. A 60-minute interview timeframe was established, since this is the time of an average company meeting, and would require a minimum amount of effort of the organization. Because of the amount of organizations, considering their busy schedules and diversity in locations, an online meeting through Teams was seen as the most suitable method. If the participant gave consent for the purpose of recording the interview, the audio eventually was transcribed to the Excel application. During the interview, annotations were made of impactful or summarizing statements. After the interview had been successfully transcribed, the results of the interview were clustered through an analysis. The quantitative data was changed into quantitative by counting the frequency of specific cluster subjects mentioned, to showcase ratio's in the visual visualization. These clusters will be used throughout the research to compare the interviews of RQ3 and RQ4, and support the design brief creation process.

Results

The qualitative data of the questions (Appendix E2) was transferred into quantitative, and is presented in Figure 26. Besides that, a more extensive visual has been created (Appendix E3), which was shared with all organizations after approval of knowledge exchange.

Considering the future vision on training of the companies, the majority of 57% mentions they expect full use of VR and AR. Also, 43% of the organizations imagine On-the-Job Training (OJT), personal development focus, and the optimization of online training will play a huge role.

For the specifications of the pre-training, all organizations mention this is entirely depended on the training type, and half of the participants mention this is mostly an E-learning environment. For 40% their current pre-training developments are focused on compliancy administration.

When looking at the training phase, 4 out of 7 companies make use of OJT, and video- or micro-learnings. Next to that, 3 out of 7 advocate the use of a combination in hands-on, theory and cases. The majority of 80% mentions the integration of VR and AR in training programs, of which VR is already in use, yet AR is still in development due to high investments.

The main two shifts in the behavior of trainees are face-to-face to online attendance and the generation of target audience. Gen-Z have different training expectations than for example Gen-X or Gen-Y. The main drawbacks of their current training programs, is mainly the training

mindset of the trainees and company.

Regarding measuring performance outcomes, 70% does not make use of this, and focusses on confidence stimulation and group feedback. The majority mentions that they boost motivation and confidence through focusing on personal development stimulation, however this is according to 86% one of the main training developments. They would like to offer AI training recommendations, provide learning communities or change training management. Besides that, 71% mentions they are investing in the use of new educational technologies such as VR, AR, AI and micro-learnings. Last, 41% would like to focus more on training effectiveness by doing training data analyses.

When looking at the input of the post-training phase, half of the organizations express that they offer on-the-job guidance by a mentor. Besides that, they also mention for this phase that motivation and confidence are stimulated by personal development opportunities. However, they also think this is person dependent when looking at demographics or personality. In identifying personal development opportunities, 83% of the organizations mention that the stimulation of this, is currently not in their way of working. However, this is in their scope of developments in the post-training phase. Besides that, all companies want to increase the on-the-job performance support. Last, 33% of the organizations advocate the investment in improving training quality and effectiveness, through training data analyses and evaluation. Currently, training effectiveness is measured by 60%, of which mainly through level 3 of Kirkpatrick's tool (Figure 20).

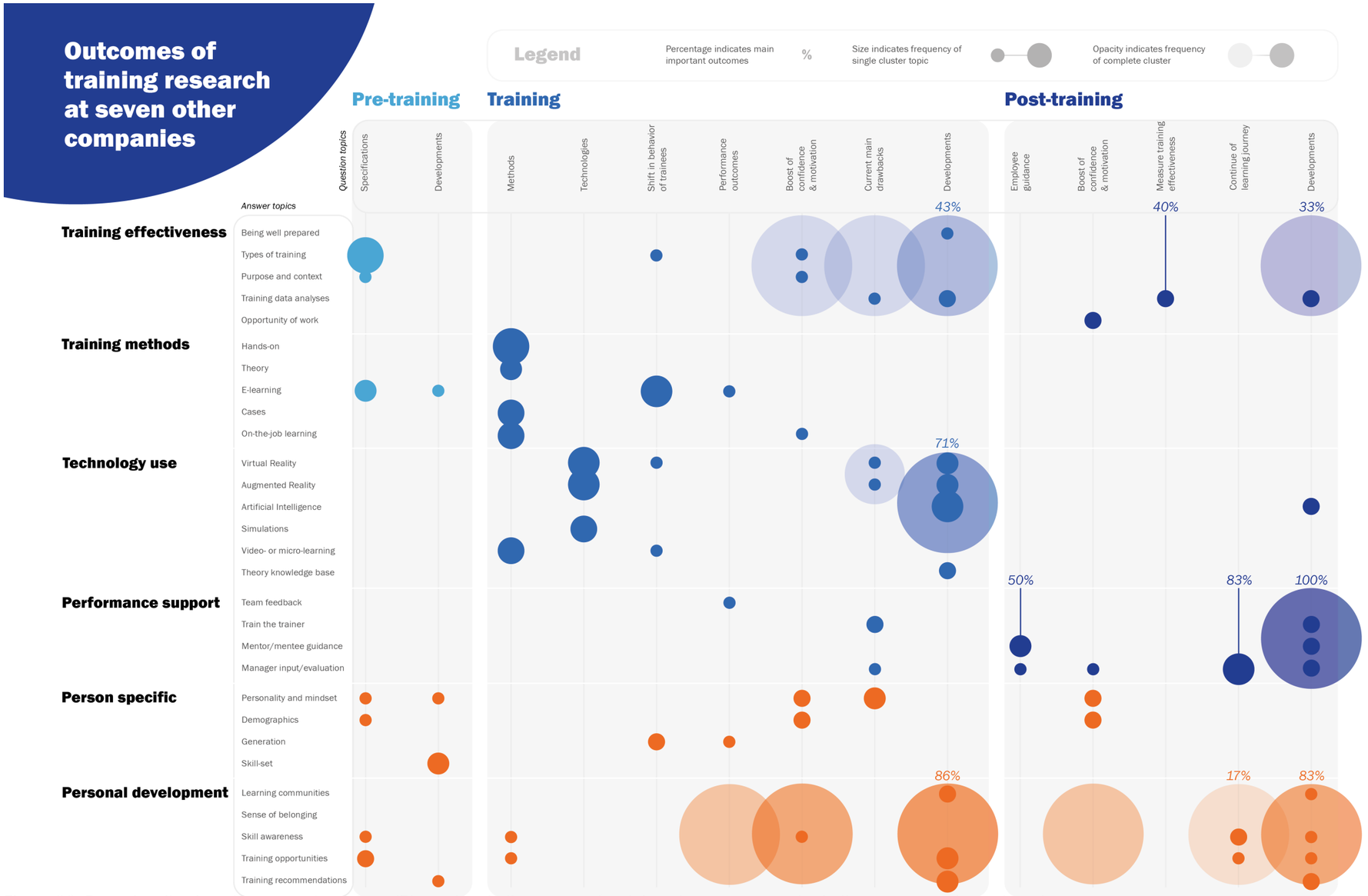


Figure 26: Data visualization of company interviews (Blue colors indicate type of training phase, orange color indicates person dependency)

Conclusion and reflection of RQ3

When looking back at the research, it is perceived that no specific drivers of Figure 21 were mentioned for confidence and motivation stimulation, besides a personal development focus. Practice opportunities for optimal knowledge retention were not discussed with the organizations. There is a possibility that the questions on confidence and motivation were not clear, that I didn't anticipate to ask additional questions, or that this specific information could not be shared. These are potential limitations of the research.

Most organizations assume the future of training will consist of VR/AR/AI educational technologies, personal development focus and on-the-job learning. Resources are investigated to promote more personal development opportunities and ways of personalized learning. Similar to ASML, some of the companies also find on-the-job learning challenging to fully and structurally incorporate. They do want to provide more performance support by having mentor guidance or more manager involvement in the post-training phase.

Voith Paper is a similar company to ASML when looking at hands-on training on cost-intensive machines, which acquires alternative methods of training, such as VR, AR and simulations. Besides that, they also encounter a shifting training target group, resulting in altering their training designs to the preferences of the new generation. Sharing knowledge on training could be potential beneficial when looking at their similarities, to overcome future training challenges.

2.4 Training at ASML (RQ4)

The way of working at the company was investigated through discussions with Subject Matter Experts (SME), interviews on training experience, a survey on training experience, and training observations. The main goal of this research was to create a general understanding of the company's training environment and specifications, but most important, to get a thorough understanding of the needs and possible pain points of the users.

Discussion with Subject Matter Experts

Early in the project, I scheduled several meetings with SME's on their training experiences and expectations. These conversations allowed me to get acquainted with the company and several business stakeholders. The topics discussed during these meetings can be seen in Figure 27. This visual illustrates how SME's mentioned the importance of training methods, hands-on trainings, and personal development opportunities. During these meetings, I noticed that SME's not necessarily encounter trainee motivation. Yet. Motivation is important to acquire skills and it is related to learning (Figure 21). Therefore, it can be concluded that the SME's see the importance of personal development, but supportive resources are limited.

NXE training experience interviews

I conducted several interviews to identify the current needs and training experience of the intended users of the final design proposal, the trainees. Ten engineers were interviewed on their experience with NXE training, to obtain qualitative input. I aimed for the sample size to be diverse in gender and nationalities, to simulate the company environment. NXE trainings have been researched, since the High-NA trainings are not in place yet and these systems cover the generation before High-NA. Besides that, the NXE training should have been recently (< six months) completed, to obtain valid input. Additionally, two trainers and two knowledge managers were interviewed about their view on the NXE training experience.

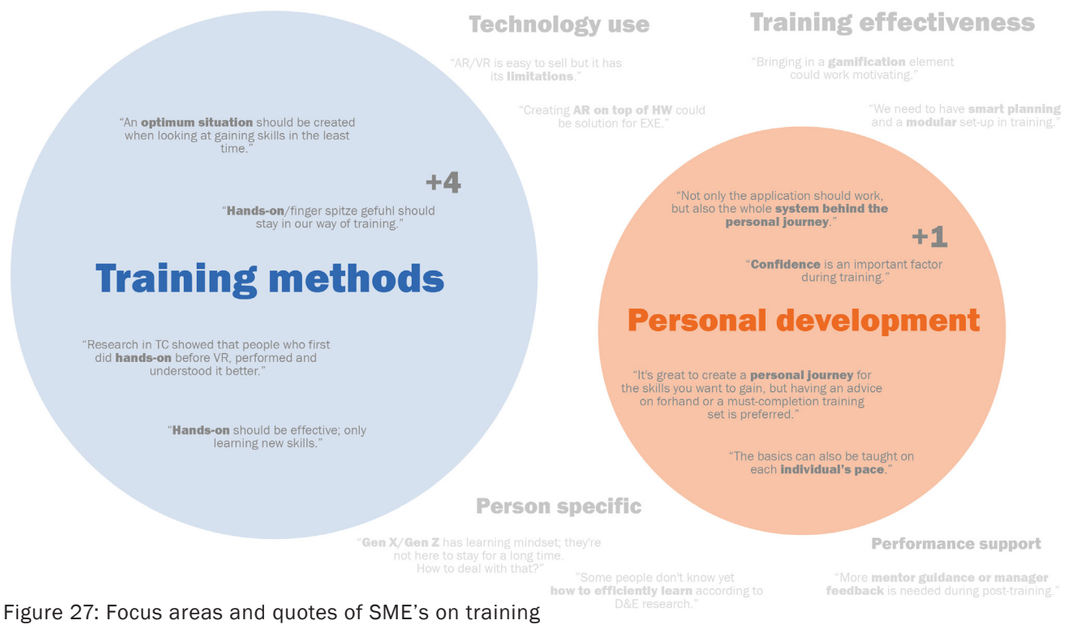


Figure 27: Focus areas and quotes of SME's on training

The creation of the interview script and the protocol (Appendix F1), was done by taking into account the interviewing methodology of Van Boeijen, Daalhuizen, & Zijlstra (2020). Besides that, I used the interview script and protocol of the company interviews (RQ3) as guidelines. In the interview, the input on several variables of the methodology in Figure 21, was asked. Besides their needs and pain points of the pre-training, training and post-training phases. Last, an indication of their confidence and motivation level for these phases was requested.

The qualitative data of the interviews, see Appendix F2, was altered into quantitative by using similar clusters of RQ3, to showcase ratio's in the data visualization. Likewise, this gives the opportunity to compare the interviewing results of the organizations and the graduation company (Appendix X). The data visual in Figure 28 summarizes the most important results out of the interviews. For the pre-training phase, half of the participants mention it is important to be well prepared and to have training context. Besides that, 5 out of 14 participants mention that Computer Based Training (CBT), similar to E-learning, is crucial for the pre-training phase, to create a general understanding of the topic. However, the CBT if often incomplete or superficial when looking at information, resulting in this being a pain point of the pre-training phase.

Some participants mention they consider the training phase as a relaxing time, hence there is no customer pressure. Method wise, 11 out of 14 participants find hands-on trainings crucial and 8 out of 14 find supporting theory classes are needed to create a deeper understanding of the topic. Additionally, the need of purpose and context of training is mentioned during this phase as well, by 5 of 14 participants. Considering the importance of confidence and motivation, mentioned during RQ1, the participants were asked to give an indication of these factors on a scale. The majority of the participants mention that practice is needed to obtain a higher confidence level, and gives an average score of 72% on their confidence level. For the motivation, the average is the same percentage, and 8 out of 14 participants mention this is personality and mindset dependent. A repetitive pain point, when looking back at the pre-training phase, is the lack of purpose and context. An inadequate amount of Case Based Learning (CBL) trainings and hands-on practice opportunities are other pain points of this phase.

The main user need of the post-training phase, according to 5 out of 14 participants, is having a structured mentoring program. Additionally, 4 out of 14 mention they want to develop themselves further through On-the-Job Training (OJT), but opportunity of work is needed for that. Often they can not apply what they have learned in practice, since it is unknown when a certain SA should be executed. When looking at their confidence level, it significantly drops to 56%. One of the participants implies that this is because of opportunity of work: "Confidence drops when you can not apply your skills immediately, caused by operational schedules and amount of systems at the customer." The motivation level increases slightly to 78%, since for some of them it is motivating to eventually work in the real context. However, 8 out of 14 participants would like to have more personal development opportunities when they are in the field, and 6 out of 14 mentions that manager input and evaluations is needed. For the post-training, their main pain points are according to 30% performance support in the field and 60% mentions personal development stimulation is missing. One of the engineers mentions: "My experience is needed in the field, that's why I can not

do any additional training."

NXE training experience survey

A survey was created in Microsoft Forms on NXE training experience to obtain a large amount of quantitative input of engineers, by integrating the variables of Figure 21 into the questions. I found the utilization of an 5-option agree or disagree likert scale most suitable, since using a satisfaction scale might be limited and inaccurate, since participants of different cultures could consider this as too overwhelming and honest.

The target audience of this survey, are all engineers who have completed an NXE training program less than 6 months ago, to make sure their input is still valid to experience. The calculation of the required sample size was done to make sure valid conclusions could be drawn of this research (Martínez-Mesa et al., 2014). According to Bullen (2022), a sufficient sample size is 10% of the population. When I considered the target group of 1100 engineers, a total input of 110 would be acceptable. The engineers were asked by email to fill in a survey, while mentioning a significant benefit for them; having impact on their future way of training. Several control variables were asked related to the training phases, such as framing, skill-set, utility reactions, learning, transfer, confidence, motivation, autonomy, mastery, purpose and performance outcomes (Figure 21).

The goal of this survey is to investigate a higher amount of input on the training experience of the engineers. The difference of the survey with the interviews, is that more input can be acquired, however no details are given. Limitations could be that some of the engineers do not understand the questions due to incorrect formulation, resulting in inaccurate answers. When discussing the content of the survey with one of the SME's, it was suggested to not ask certain questions, because the company gives this information on forehand. But did the trainee experience it like that? Or did ASML communicated it in an incorrect way? The survey is the way to find out the gaps between ASML's way of working, and the trainee experience.

The input of the survey shows that the majority of 61% prefers hands-on training and 21% OJT. Next to that, 84.5% still thinks a supportive theory training is needed for a hands-on training. When looking at personal development, 88% of the engineers would like to have more training opportunities besides their daily job, and the great majority of 92% thinks it is important to know the skills of their colleagues. Currently, this is known mouth-to-mouth, and the company only offers Skill Management Tool (SMT), which can be accessed by the individual and management. According to 67.5% of the engineers, management informs them on their performances and skills.

The first main point of improvement according to the majority of 24% , is to increase the amount of effective hands-on trainings. This is supported by 7% of the participants, that would like to have more practice opportunities of these hands-on sessions. This could be a result of the following root cause; 12% want to have a the real context and common cases integration improved. The second main point of improvement is regarding personal development. It is mentioned by 21% of the engineers, that they give

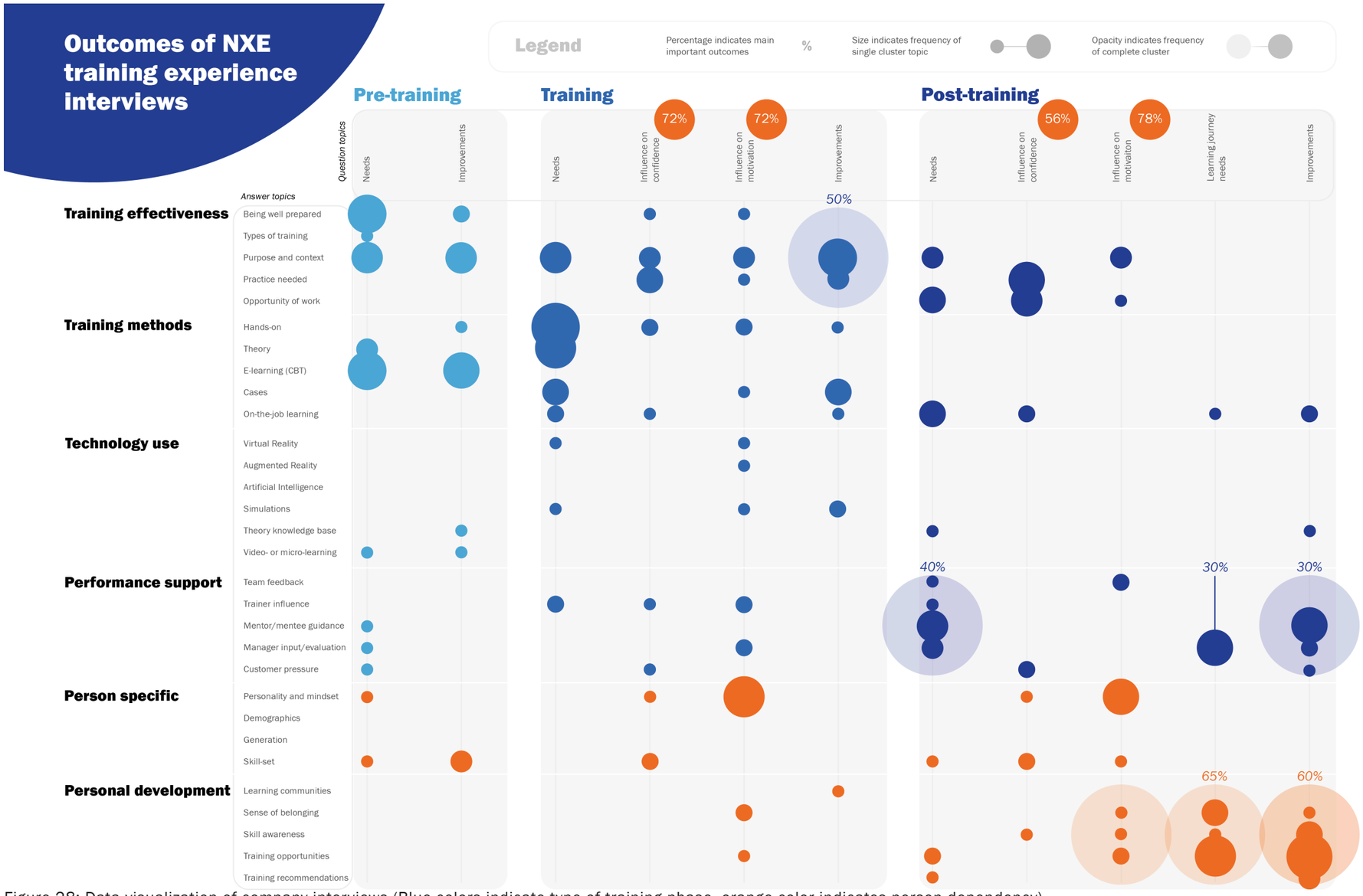


Figure 28: Data visualization of company interviews (Blue colors indicate type of training phase, orange color indicates person dependency)

priority to more training opportunities and recommendations available.

NXE training and High-NA validation observations

To compare input of the interviews and survey with practice, I have done three observations on NXE hands-on and theory trainings in groups of 6 engineers, but also an additional High-NA theory training validation. A method on user observations by Van Boeijen, Daalhuizen, & Zijlstra (2020) was studied to improve the quality. These trainings were also compared amongst each other, to see whether aspects have been changed or improved. An alternative reason to attend High-NA validation training, was to see the context of the design proposal. The notes of these observations can be seen in Appendix F5. For the NXE theory training, the system context was missing and no practical examples were given through CBL, and it mainly focused on procedural learning. Also for the High-NA theory training validation, this was mainly targeted at comparing NXE with High-NA systems, resulting in the purpose and context being left out. It is important to keep in mind that this training served as a validation, which means the final shape of this training is not yet determined. The NXE hands-on training relates to the theory training in a way, by being also focused on procedures. Besides that, the effective hands-on time of an individual is limited, considering that this training mostly consists of groups of 6 engineers.

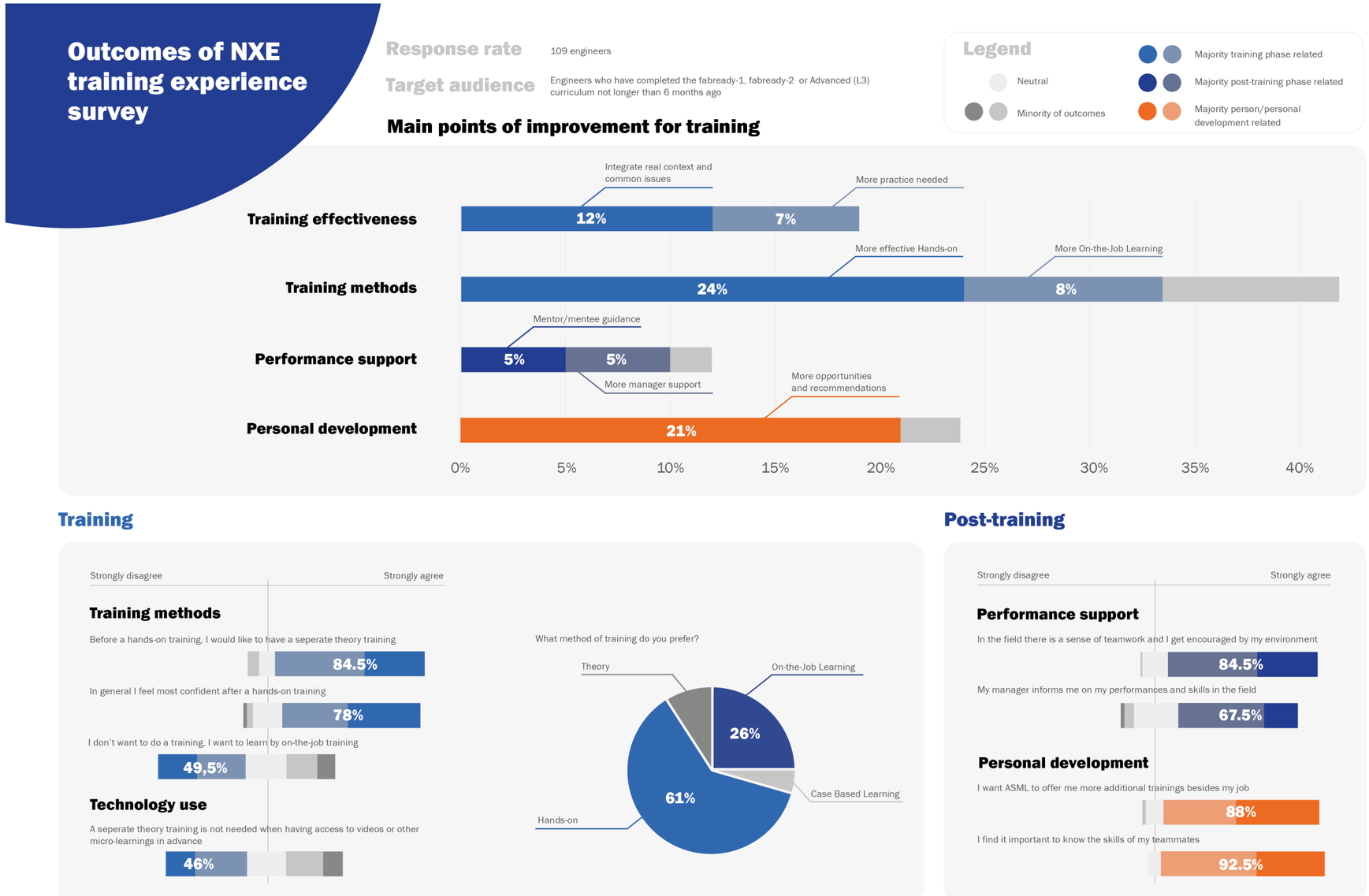


Figure 29: Data visualization of survey on NXE training experience (Blue colors indicate type of training phase, orange color indicates person dependency)

Conclusions and reflection of RQ4

Possible limitations of the research are the following; inaccurate answers of survey could be given because it was misunderstood because I did not formulate it optimally. Besides that, it captured the moment, emotions could have played a role and other types of input could be given at another moment. Last, information could have been left out, because they didn't want to give open input because of the risk of sharing information with management.

When comparing the data visuals of the companies and ASML, see Appendix F3, it can be concluded that there are overlapping interests in developments for training effectiveness, post-training personal development and post-training performance support. There are also some significant differences in way of working. It is important to keep in mind that the graduation company is a niche, when looking at their cost-intensive machines, resulting in alternative learning methods and less OJT.

The SME meetings express the cruciality of hands-on trainings, and the interest of personal development opportunities at ASML. The engineer's interest in these opportunities, results from the interviews as well, indicating that they would like to have additional training opportunities for personal development purposes, besides having more performance support when working in the field through manager evaluation and a suitable mentoring program. Next to that, the survey shows the needs for these personal development opportunities as well, besides the demand of more practice opportunities and effective hands-on trainings. This need is supported by the training observations, which show that the context and purpose of training is often missing.

3. Design brief & vision

After doing an extensive research on training in theory and practice, I have formulated the design brief of this graduation project. In this chapter, the problem definition and supportive design vision will be introduced and explained. The project is scoped by prioritizing a selection of user needs, considering the input of business stakeholders and the supervisory team, and aligning on business goals.

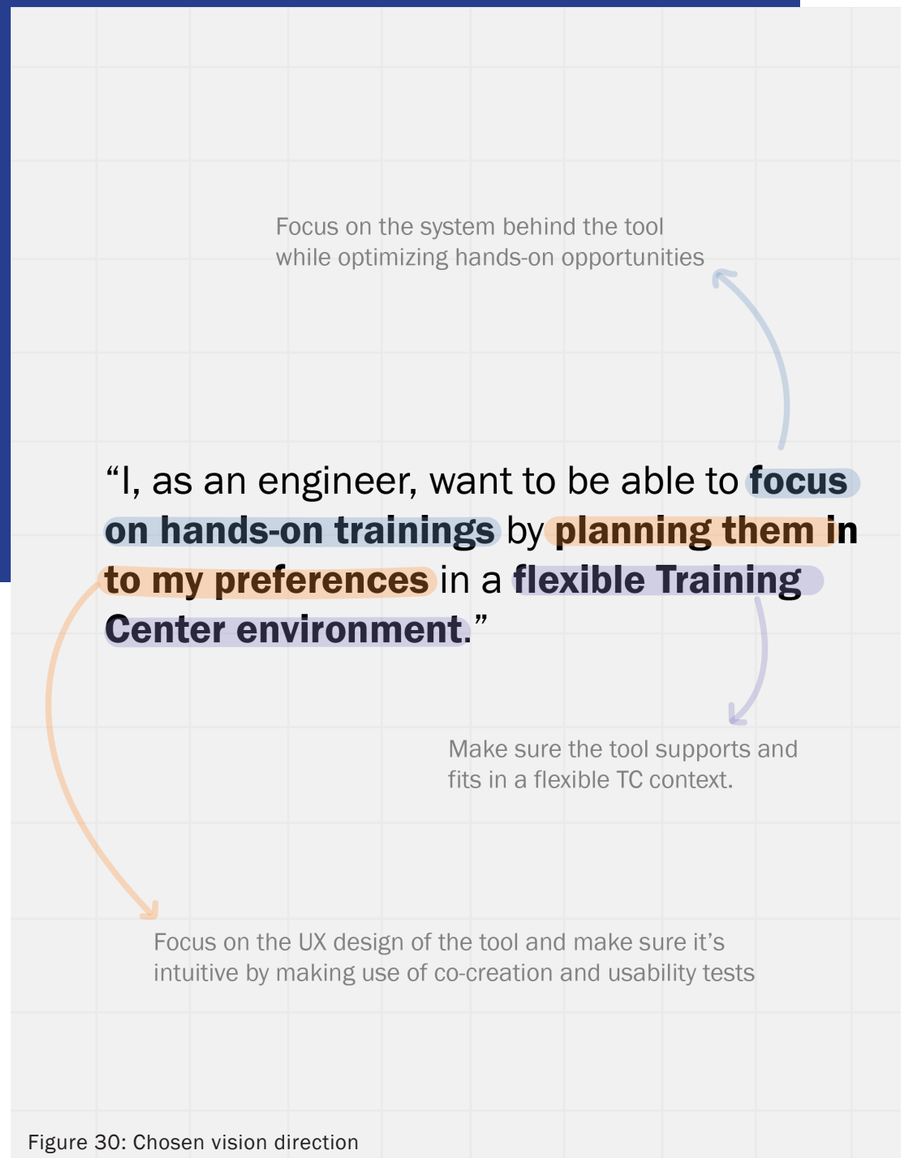


Figure 30: Chosen vision direction

3.2 Problem statement according to graduate

The context & user research resulted in having a wide diversity of possible future training focus points for the company. In this chapter, I will elaborate on the main problems resulting from the research phase. The outcomes and conclusions of Chapter 2, have been summarized and visualized through the clusters, see Figure 31.

Main problems resulting from research phase

When encountering the conclusions RQ3 and RQ4, supported by the findings of RQ1 and RQ2, the three problems are the following. First, the graduation company does not offer a frequent or sufficient amount of personal development opportunities, since engineers have the need for more learnings. This is substantiated by the company SME's (RQ4) and the majority of the organizations (RQ3), since 6 out of 7 companies are not able to provide personal development opportunities to trainees yet. Second, the effectiveness and amount of hands-on trainings to create a sufficient field confidence level, is not optimal. Engineers feel the need to have more practice opportunities for knowledge retention according to the input of the survey and the observations (RQ4). The majority of the SME's also mention that a future hands-on focus is crucial for ASML. Last, performance support after training is not structured and often missing according to user interviews (RQ4), there should be more manager evaluation sessions or mentor guidance. This is also mentioned by the majority of the organizations (RQ3), that are developing suitable mentoring programs or manager sessions.

Reflection on company problem statement

Considering the company problem definition, see Chapter 1.3, encountering training effectiveness and smart planning technology, this is mainly a business approach. The problem definition, that I have formulated after doing an extensive research, is from the user's point of view and taking into account the User-Centered Design (UCD) approach. It can be concluded that both problem definitions, do not relate to each other. However, it could be a challenge to create a final design proposal that can be supportive of both. The defined problems of this project, do support the future vision of the TC; a vibrant environment where the engineer can create an own tailor made journey, while focusing on increasing confidence through practice.

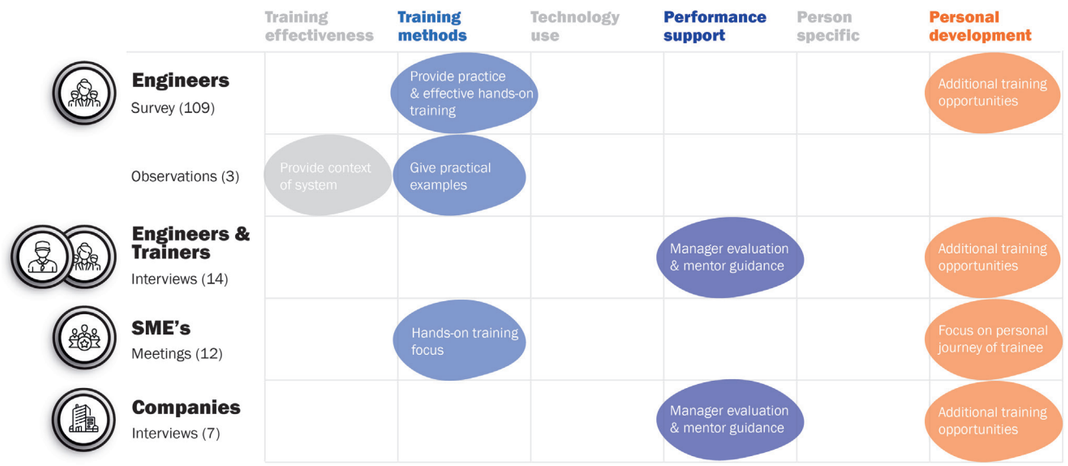


Figure 31: Cluster visualization of main improvement opportunities according to the results of RQ3 and RQ4

3.2 Design Vision

To define the design direction, the ViP method was used to create a vision statement. In this chapter, the ViP method will be introduced, vision possibilities will be proposed and the chosen statement will be clarified. Besides that, the project was further scoped by defining the meaning of effectiveness and determining the vision success.

ViP method and vision exploration

The Vision in Product design (ViP) approach is a context-driven methodology, focused on visualizing what people value, desire and believe. It offers a simple and unique way to come up with a design that adds new value or meaning to people (Hekkert & Van Dijk, 2017). ViP was chosen for three reasons. First, it is suitable for innovation processes in a future context, which is the case for the High-NA TC. Second, it helps to face and translate complex systems into suitable design starting points. Last, as an IDE student, I have experience with using this method, and acknowledged the value of it for this research.

By focusing on the formulated problem definition, a dimensional set-up has been created by encountering the clusters with most potentials, see Figure 31 and Figure 32. The four possible focus areas indicate mentor guidance and manager evaluation of the performance support cluster, and hands-on quality and effectiveness of the trainings methods cluster. Since one of the requirements of the company was to create a training planning tool, to enable the creation of a tailor made journey and a sense of personalization, the cluster related to personal development has been placed central. Indicating that all vision directions will be somehow related to creating a training planning tool for personal development purposes.

Chosen vision statement

A vision had been chosen, even though all directions have potential when looking at the improvement opportunities resulting from the research. Some reasoning on why the vision in Figure 30 was selected:

- First, the fact that a UCD approach is encountered for this project, see Chapter 1.4, results in representing the needs of the majority of the engineers. From the survey, it can be concluded that engineers want to practice on effective hands-on trainings. However, due to the limited time of this project, and the limited knowledge on training content, it was not chosen to encounter quality of hands-on training. Therefore, I have focused on enabling an optimal amount of practice opportunities.
- Second, focusing on the effectiveness of hands-on training by focusing on the structure of the High-NA TC, also contributes to having more timeslots and therefore training opportunities available for the engineer to practice. Hands-on training is the best method according to the engineers, to improve their confidence. Optimizing the amount of timeslots also contributes to the amount of hands-on trainings.
- Last, there are several business strategies covered by this vision focus. ASML strives for field self-sufficiency, by making sure the engineer feels confident to execute SA's in the field, which refers to practice. Besides that, the strive for optimal knowledge retention is one of the global themes, visualized in Figure 22, which is in line with offering practice moments.

Project scoping

When discussing the final vision with the supervisory team and business stakeholders, the main question that came up was: "What does effectiveness mean?" For the project, effectiveness had to be defined, to make sure the project could be scoped for the interest of the student, and expectations could be given to the company.

What I considered as 'effectiveness' for this project, was creating a planning proposal by integrating a High-NA training curriculum into the training planning tool. Variables should be stated for this scenario, such as the amount of trainees and trainers, amount of CARS/SA's/SMS' for that training, the specific training types such as VR/AR/HW/TH, and the capacity of the trainings rooms or modules (HW-riggs). Through the creation of modular slots, encountering the research of RQ1 to calculate the effective time and timeframe in between, recommendations can be done on how to achieve a sufficient amount of practice opportunities. For the next Chapter, requirements have to be set-up, to tackle the unknown variables.

The effectiveness of the final design can not be measured yet, since it is not possible to test this because of TC that is still under development. The design proposal will act as a recommendation on how to operate the environment. In accordance with the company, the success will be determined by the assessment and feedback of business stakeholders, since this is seen as valuable when looking at their experience. Second, the feedback of the engineers on the intuitiveness of the tool, will be leading.

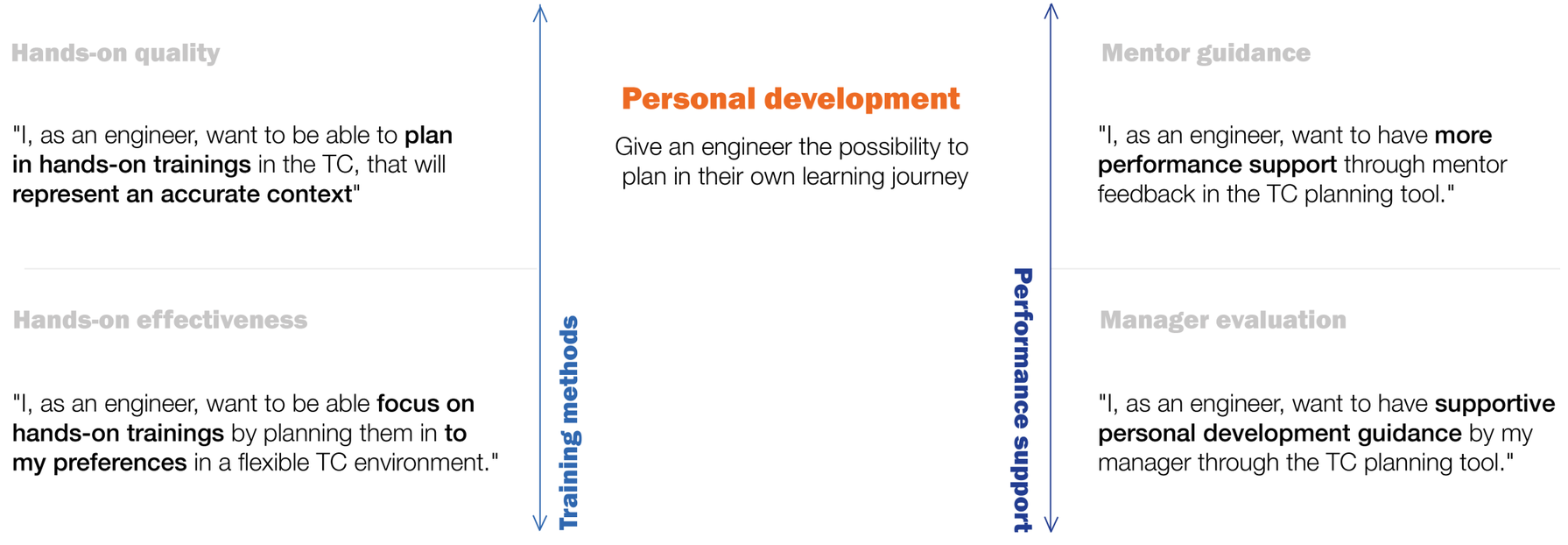


Figure 32: ViP process of creating a suitable vision for the project, see Appendix G for supporting quotes (Hekkert & Van Dijk, 2017)

4. Ideation & prototyping

The midterm presentation marked the end of the research phase, and the start of the ideation and prototyping phase. A new project planning was made (Appendix B2), encountering the focus on the UX design of the training planning tool, and creating an effective scenario. The ideation phase of this project, consisted of exploration of features in the training planning tool, but also gathering requirements through co-designing and brainstorming with users and business stakeholders.

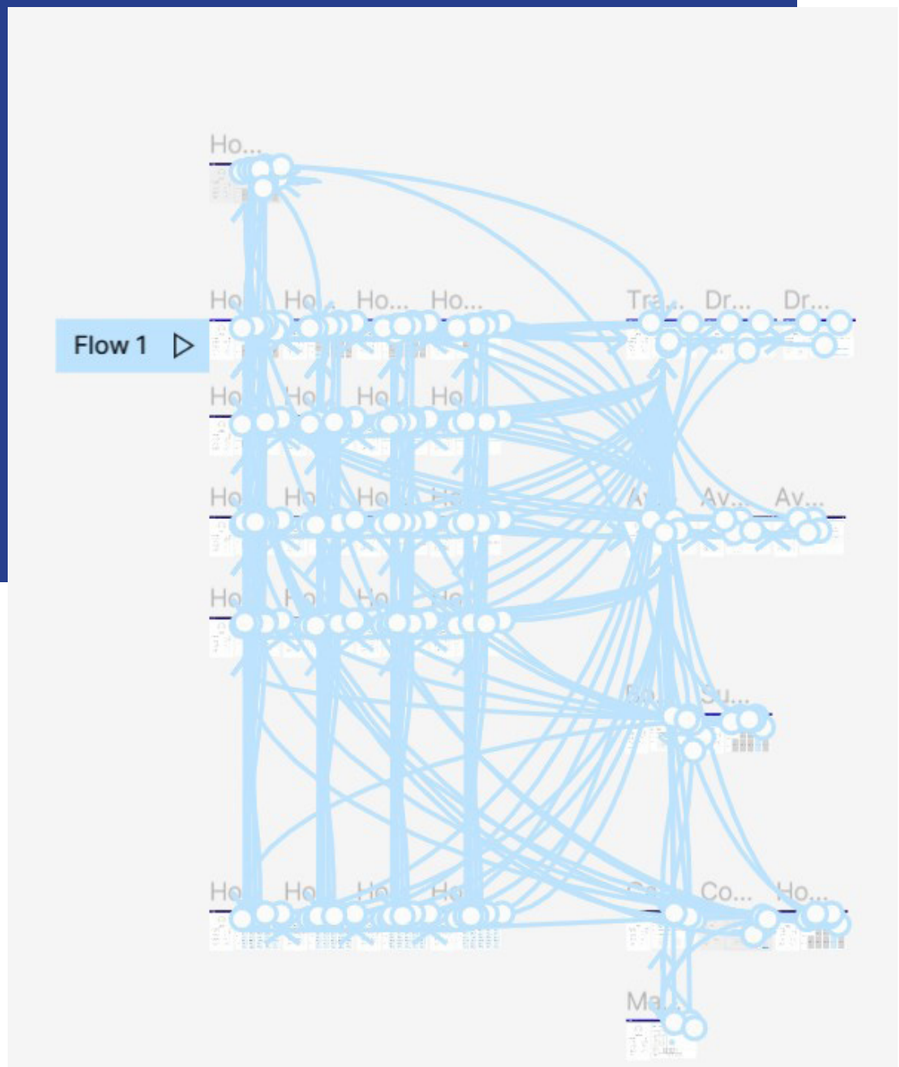


Figure 33: Information structure of interactive UX design prototype (Figma, n.d.)

4.1 Structuring the prototyping phase

Considering the initial requirement (1) by the company, see Appendix A1 for the complete list, a tool should be created that enables the possibility to plan in High-NA trainings in the TC. Because of this, I had chosen to create an interactive User Experience (UX) design of the tool to showcase the Minimum Viable Product (MVP). In this UX design, a training curriculum has been integrated by encountering a scenario given by the company, the effective system.

Combining the UX design with a training planning scenario

The two separate prototypes; the UX design and the effective system of the tool, have been generated through the design process in Figure 34, and will establish the final design proposal. As inspiration, studies on application design processes have been used to set-up this structure of the prototyping phase. For the ideation, requirements were gathered through brainstorm and co-creation sessions with users and business stakeholders. After that, rough layouts of the screens have been created, wireframes, of which validation found place through usability testing. This feedback will be used to layout the detailed design composites and to add possible functionalities, whereafter a second round of usability tests finds place. At the end, the effective system will be created as part to determine practice opprtunities, taking into account several context variables to propose a specific planning. Especially this last step, will be time intensive, since the High-NA TC is in development (Challenge 2 of Chapter 1.3).

Figma as medium to create the prototype

The medium that was used to build the design, is the web application Figma (Figma, n.d.), because of two main reasons. First, considering the data visualization learning goal, I was eager to consider a new mediums, which I had no experience with yet. As an IDE student, I have used the similar application Axure several times to set-up UX designs, but have never experimented with Figma. Besides that, this application is in the way of working in the UX design department of the company. Using this platform, would also be beneficial for possible future implementation and storage purposes.

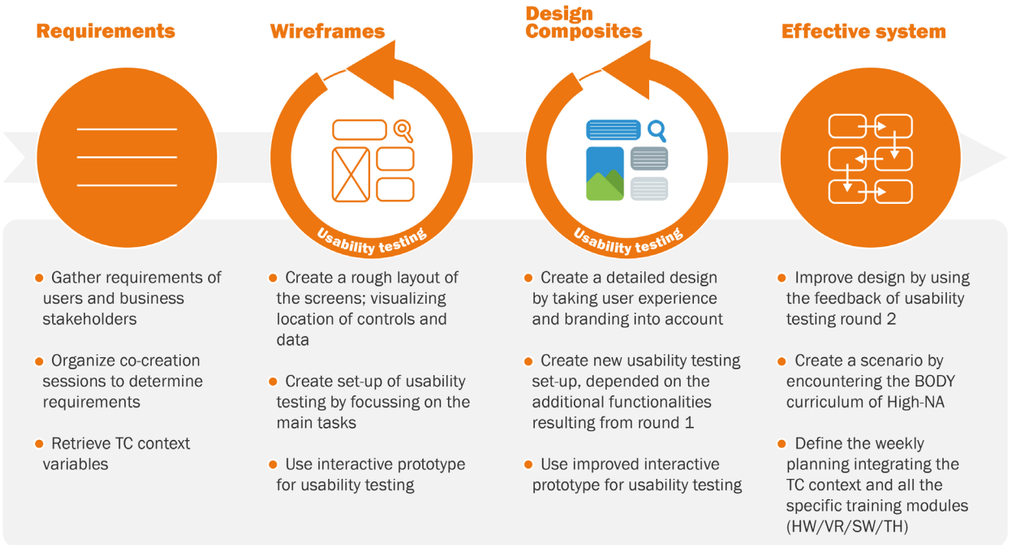


Figure 34: Prototyping phase process and focus points (CodeWithChris, 2018)

4.2 Ideation through brainstorm and co-creation sessions

Requirements were gathered, through several creative sessions with users and business stakeholders. First a user co-creation session was initiated on the tools' core features, followed by a similar brainstorm session with the company mentor. The outcomes were clustered to see overlap in needs and values. Additionally, a brainstorm session was held with three business stakeholders, representing the KXI Studio and GTC department, to scope effectiveness.

Definition of co-creation and its benefits

According to Van Boeijen, Daalhuizen & Zijlstra (2020), co-creation refers to having a collaborative effort on design, together with users, and other stakeholders. There are three main reasons to make use this method during a design process. The first one is that it is seen as valuable to encounter the needs of the user or others affected by the solution. Besides that, the session will give insight in the needs of the users, to create the best possible solution (UCD approach). Last, the stakeholders need to gain support of relevant parties. In this project, the outcomes of this co-creation session, will not only be used to gather a total set of requirements for the product, but also to prioritize the tool's feature considering the project timeframe. Additional requirements resulting from the co-creation session, can be considered as recommendations for future focus points.

Co-creation with users on core features

A co-creation session was initiated to find the requirements of the planning tool, and to make sure it is completely designed to the needs of the user, while also encountering the needs of the business stakeholders. In an ideal situation their requirements will align to a certain extend. Making sure these two are on one line, is seen as a challenge, but also the most favorable outcome when looking at the product value.

The target audience, 5 future High-NA engineers who are currently in the BIC for training validations, were invited for a face-to-face brainstorm session. Several business stakeholders were invited to this session as well, however, in the end only the engineers attended the session. This could've influenced the outcomes, since no validation and discussion with both stakeholders found place. In Appendix H1 the preparation and set-up of the session can be seen, which was done in collaboration with an UX designer at the company. The requirements, core features of the tool, will be selected by considering the top 3 most voted inputs on the ideal way of training and features. Additionally, the engineers were asked to give their preference on possible planning focus points, which I have explored through an ideation session (Appendix H2).

Since there was some unexpected delay in the training class, the brainstorm session was split in two groups. Having these separate sessions could've resulted in non-optimal outcomes, since the discussion session didn't find place with the whole team. Besides that, the second group already could see the input that was given before their session. This could all have influenced the voting and outcomes of the session. However, the outcomes are still seen as valuable regarding requirements establishment, and user testing will indicate the accuracy.
The first topic shows that for the current situation answers were given in three clusters; no slots available, search in MyLearning and not authorized to choose. Regarding no slots available, the majority of the group mentioned that the slots in MyLearning are often limited or fully booked, and the search is time intensive. Last, the engineers are not free to choose their trainings, often their manager or Group Lead (GL) signs them through MyLearning, and autonomy is missing. From above it can be concluded, that the engineers imply on MyLearning when planning in their trainings, which is on macro-level. Contrary to the planning tool, which will cover micro-planning of daily training slots. Because they have no experience yet with the future TC way of working, it makes sense that they keep referring to the as it is situation.

It can be concluded that the brainstorm sessions was successful regarding determining the user requirements and core features, but the usability testing will indicate the sufficiency of this. By encountering the majority of votes, when looking at the ideal way of planning and features, this resulted in seven requirements, see Figure 35 and Appendix A1 for the complete list of requirements. Next to that that, the majority of engineers preferred the categorization in planning on weekly base, see Requirement 15.

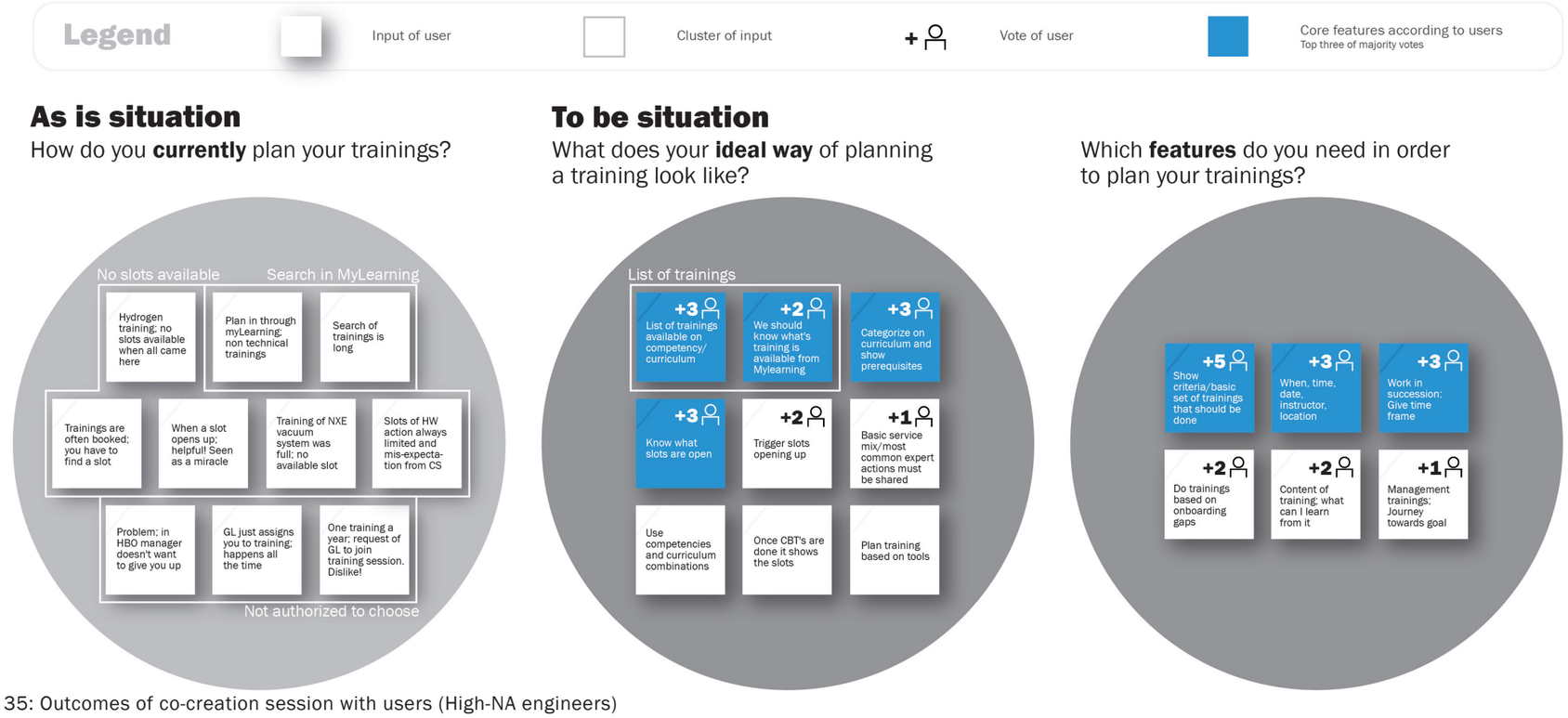


Figure 35: Outcomes of co-creation session with users (High-NA engineers)

Brainstorm with business stakeholder on core features

Besides having a co-creation session on the main requirements with the user, I have had a discussion with the company mentor, on what should be the first focus points regarding the planning tool. This online session was structured by discussing the expectations and problem definition of the company. Besides that, some insights and variables were shared on the TC context, which created a base for the chosen requirements. Generating requirements was done by using the structure of the WWWWWH method of Van Boeijen, Daalhuizen, & Zijlstra (2020). This abbreviation of Who, What, Where, When, Why and How, serves as a checklist to generate the most important values and questions. The requirements resulting from this can be seen in Figure 36 and Appendix A1.

Clustering of user and stakeholder requirements

The outcomes of the co-creation session with the users was utilized to set-up requirements. Besides that, also business stakeholders gave some core features examples that should be integrated in the application, see Figure 36 and Appendix A1. To see similarities between the needs of the users and business stakeholders all these requirements were put together in one visual for clustering purposes, through using the same WWWWWH method of Van Boeijen, Daalhuizen, & Zijlstra (2020). This clustering counted as an alternative mean to align the input of the users and business stakeholders, which was the intention of the co-creation session, of which the business stakeholders were not present.

Clustering all these requirements, resulted in seeing three main points of agreement. The first one is that the users and business stakeholders agree that the tool should give somehow an indication of the mandatory modules, and why a certain module has to be completed when looking at the training program or competences. Besides that, both groups find that the tool should include the location in the TC, where a training method will find place. Last, they think that before joining a training action, the needed materials and prerequisites should be given in advance.

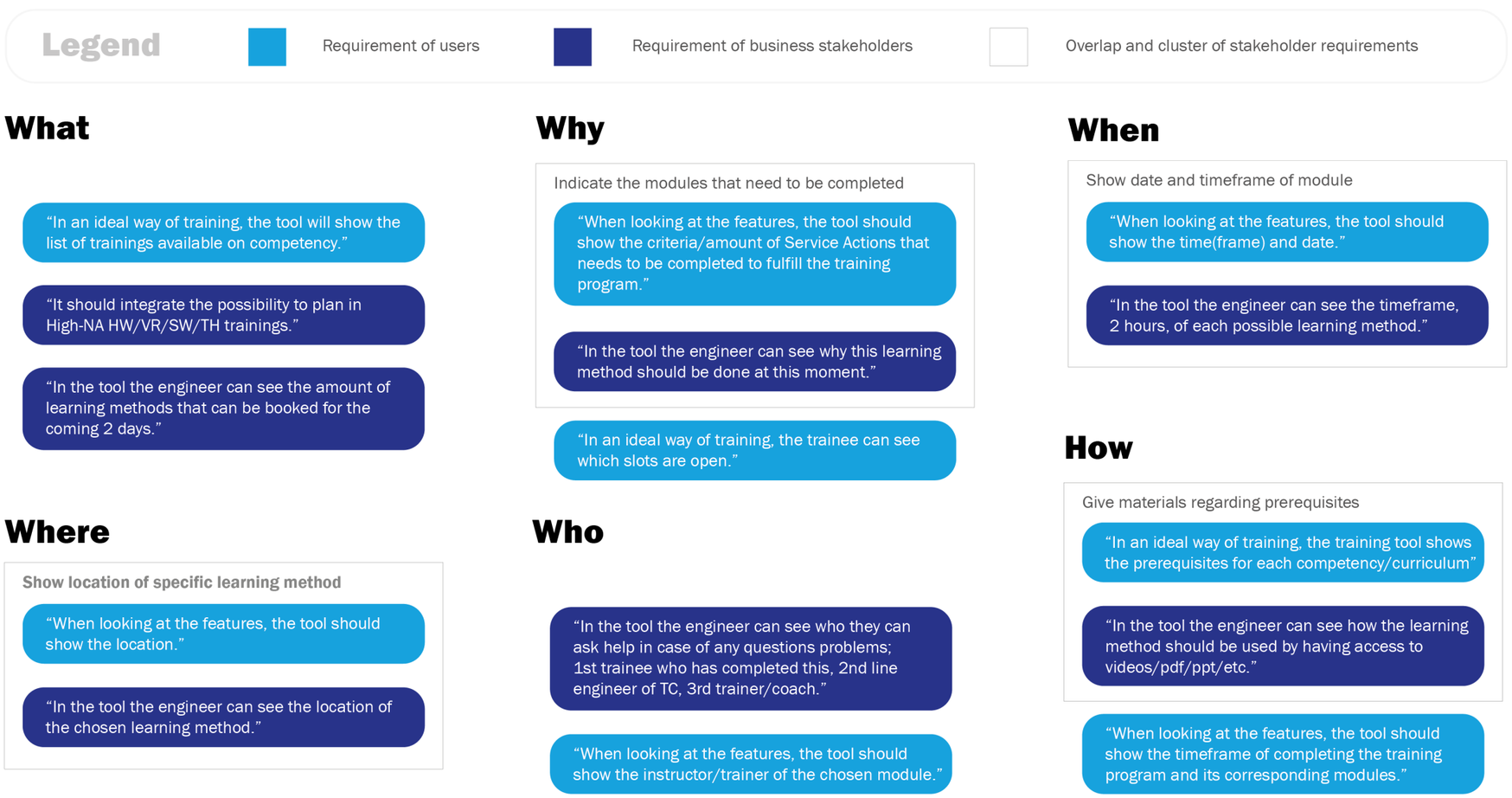


Figure 36: Clusters of user and business stakeholder requirements on the tool's core features

Brainstorm with business stakeholders on system effectiveness scoping

A brainstorm meeting was held with three business stakeholders to determine how to scope effectiveness. The company manager, mentor and High-NA curriculum lead, represented the interest of the KXI Studio and GTC department. During this meeting I gave a short summary of the project, using partly the midterm presentation, and gave a demo of the planning tool until now, which were the design composites in progress. Additionally, we had a lively discussion on how effectiveness could be specified for this project, making sure it has value for the company. See the visual in Appendix H3 for all the comments.

When having a critical look on the outcomes, I noticed that there was no specific direction given, but this could also be the result not leading the brainstorm, since the enthusiasm and the different interests of the stakeholders led the conversation. This meeting acted more as an inspiration to determine the direction. The forgetting curve was often recalled, since this is a leading method when looking at practice opportunities. What if I could imply effectiveness by using Ebbinghaus' forgetting curve and determine the timeframe to obtain optimal knowledge retention and the moments of rest in between? By taking into account the context factors of the TC, a curriculum and the forgetting curve, a scenario can be created to showcase the feasibility.

Additionally, the possible connection to the Skill Management Tool (SMT) was mentioned, which is a platform through which the engineer indicates which SA they have completed after a training, and whether they feel confident to execute. A meeting was initiated with the business owner of SMT, see Appendix L3 for the notes, to share thoughts on how these tools could be intertwined.

4.3 Prototyping wireframes

After gathering the requirements, an initial set of wireframes was created. According to Bruton (2022), creating the outline of your UX design is an essential step of the product design process. It is used to have a clear understanding of page structure, layout and functionalities. The interactive prototype of wireframes will be validated through usability testing.

Methods and main functionalities

The goal of the wireframes creation was to translate the requirements of the users and business stakeholders into an intuitive information structure. It was chosen to create mid-fidelity wireframes to explore design ideas, establish spacings and buttons, and to create a user flow (Bruton, 2022). The frames did not include any images or detailed content, consisted of grey tones and represented the focus on the main functionalities. Based on the requirements of the core features resulting from Chapter 4.2, four main functions in the tool were established (Figure 37):

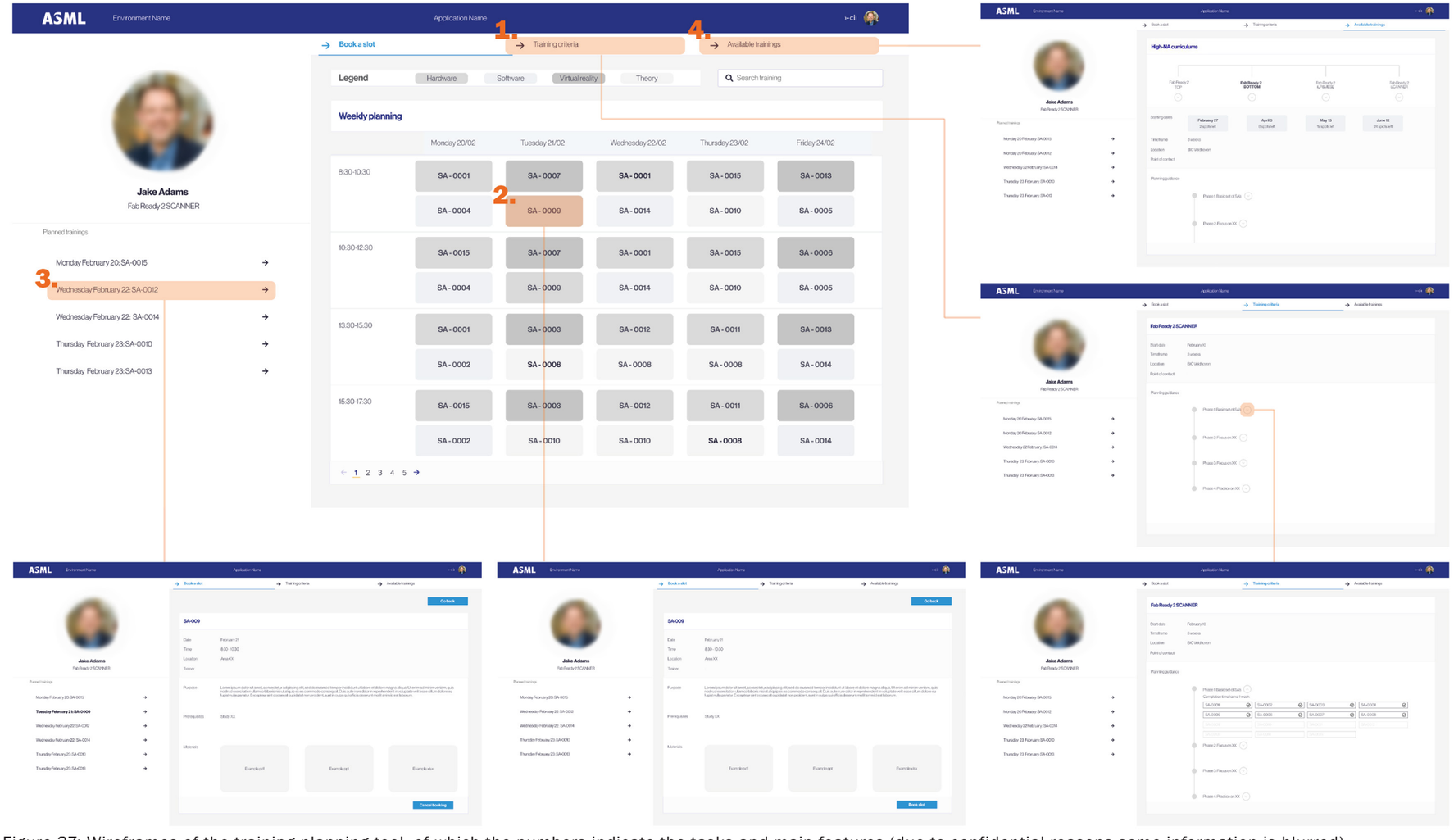


Figure 37: Wireframes of the training planning tool, of which the numbers indicate the tasks and main features (due to confidential reasons some information is blurred)

- Check training criteria (Task 1): This function gives additional information to the user on the training timeframe, and gives a planning guidance on planning the training slots, encountering SA/SMS/CARS dependencies (tackling Requirement 14).
- Book a slot (Task 2): The main feature of the tool is to book a training slot, on the book a slot page. Book a slot by clicking on the training type of preference in the weekly planning. The booking page shows the specific training information, purpose, prerequisites and materials (tackling Requirements 5, 7, 8, 9, 10, 11, 13, 15).
- Cancel a slot (Task 3): An alternative option is to cancel a slot by clicking on the training type in the dashboard. By doing this, the user can also revise the location of the training, and the materials for preparation purposes on forehand (tackling Requirements 8, 10, 11, 13).
- Explore available trainings (Task 4): The engineers have the possibility to browse through other training programs, for exploration purposes. They can access the planning guidance of these curriculums as well, to investigate the typical SA's/SMS'/CARS' (tackling Requirements 13).

For the sake of the simplicity of the wireframes, training slots of 2 hours will be encountered, of which the exact timeframe was determined in Chapter 4.5. Having several constraints and requirements, initial sketches were made of the set-up, before creating the design in Figma (Appendix H4). Since Figma is in the way of working at the company, several standard examples are given in line with the branding style guide. These examples were used as a base to create the wireframes, since it is important for ASML to work in a similar design language for integration according to the company UX designers, see Requirement 21. The dashboard on the left, navigating bar at the top and search bar are examples of what's already included in the company set-ups.

Usability testing of wireframes

After the wireframes were created, they have been presented to the users and business stakeholders to retrieve feedback for design iteration. Considering Requirement 4, one of the goals is to make the design and its operation intuitive for users when looking at the UCD approach. The product usability evaluation method, typical at the IDE faculty at TU Delft (Van Boeijen, Daalhuizen & Zijlstra, 2020), served as inspiration to set-up the testing. Designers could make assumptions on how the intended users will operate and

see the product, however, validations are necessary to have an optimal user representation in the design.

A total of 4 participants contributed to this research, consisting of 3 High-NA engineers and the company mentor. This was an sufficient amount when encountering the product usability evaluation (Van Boeijen, Daalhuizen & Zijlstra, 2020), which states that for a simple and qualitative evaluation, 1 to 4 participants will be sufficient.

The script and the protocol of the usability testing can be seen in Appendix I1. Open research questions were formulated, for each of the four tasks mentioned in Figure 37. Additionally, the NASA Task Load Index (TLX) method, is integrated into the end of the testing (Appendix I2). The multi-dimensional scale from 0 to 20, measures the workload demand, for several variables (Hart, 2006). This methodology was recommended by the university mentor, to add as extra dimension to the research. Besides that, according to Hart (2006), the method is proven to be easy in use and to have considerable value. Last, this quantitative data gives the opportunity to compare the NASA TLX of the wireframes and design composites, to see possible improvements.

Conclusion and reflection of wireframes

The usability testing resulted in a wide diversity of possible improvement points, and also some overlapping recommendations between users and the business stakeholders, see Figure 38 and Appendix I3. The outcomes of the NASA TLX concerning the wireframes, can be seen in Appendix I3, which will be discussed and compared with the outcomes of the design composites in the next Chapter.

All participants mentioned, that they prefer to see the subject in the training slots. Since a great amount of SA's/ CARS'/SMS' are covered in a training program, the codes without the definition are often considered as meaningless (Requirement 17). Next to that, 3 out of 4 participants want to perceive the type of training, aiming at a group, paired or individual context (Requirement 18). This could influence their choice of training, because of their preference and state at that moment.

Moreover, all users indicated the benefit of a link to MyLearning prerequisites on the training slot information page. This comment is not chosen to implement in the design, since the MyLearning tool is on macro-level when looking at training registration. It will give the prerequisites to join the training as a whole, in contrary to the this tool that will show the SA/SMS/CARS dependencies of that training slot, derived from the company problem definition (Requirement 2). An incorrect introduction of the tool by the graduate, could have led to this miscommunication, impacting the feedback. Related to the SA/SMS/CARS dependencies, the business stakeholder declared the value of focusing on the CARS scenarios during phase 1 of the planning guidance, since these cover the majority of a SA (Figure 8). This is followed by phase 2, which will concern the SA's (Requirement 19).

In addition, 3 out of 4 participants mentioned, the use of colors is crucial to indicate completion in the planning guidance (Requirement 20). A limitation of this research, was that the participants commented on colors and icons, that would be covered in the usability testing of the design composites. It could have been possible, that I was not clear during the introduction, about the focus on information structure for this first round of usability testing.

All comments in Figure 38, except for the link to the MyLearning prerequisites, were seen as valuable and have been integrated in the design composites. The impactful changes mentioned above, have been translated into requirements (Appendix A1).

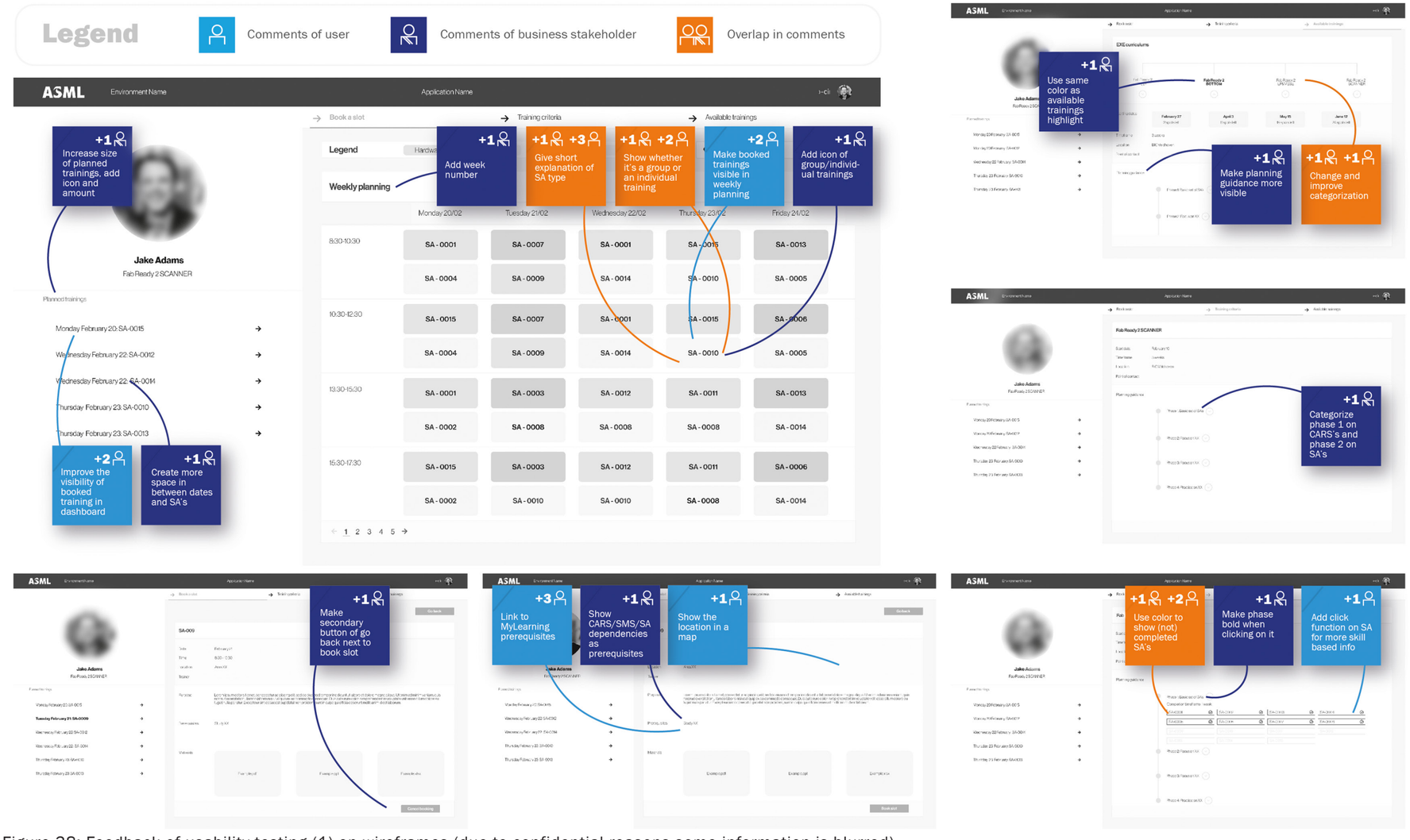


Figure 38: Feedback of usability testing (1) on wireframes (due to confidential reasons some information is blurred)

4.4 Prototyping design composites

In this chapter, the final design composites will be presented, besides the insights of the second round of usability testing. The new requirements resulting from the first usability tests and the other slight changes proposed, were encountered in the redesign. In addition, the design composites were made more detailed by color and icon integration.

Methods and additional features

As it was mentioned by the user that they prefer to see progress in completion of trainings through colors, a research was done on color meaning in ASML tools, see Figure 39. By doing this, I wanted to create a sense of familiarity and intuitiveness for the engineers when using the tool. Since blue indicates ready, this color was linked to the completion of a training type. The green had been referred to the 'in planning' stage of a training, meaning that it was scheduled. Last, the yellow color indicated that a training had not been planned yet, and therefore has not been completed. Intentionally, I had not chosen to integrate the red color, since this could be experienced as alarming and intimidating, and there are no issues when a SA/SMS/CARS has not been planned yet. The user testing will give insights on how to engineer's interpret the meaning.
To make an accessible design for all users, color blindness is taken into account. Especially when considering a majority of male engineers, of which 1 out of 12 is color-blind according to a study of Rogers (2020). Using suitable color palettes is crucial to make sure these engineers can easily access the tool. According to Cravit (2023), there is a diversity in suitable color schemes, of which grey tones is one amongst them. Therefore, it was chosen to use several opacities in grey tones (Requirement 22), to make sure a color-blind engineer can see the difference between training slots and to maintain simplicity in the design. Suitable color combinations were taken into account throughout the design process. However, no validation testing was done with these users.

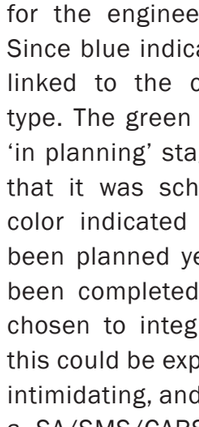


Figure 39: Meaning of colors in existing applications of the company related to profile updates

Several prototype demonstrations were given to other business stakeholders. They commented on the capacity of slots, since there could be a chance considering the amount of trainees and the supply, that full bookings will occur. This was also mentioned by one of the engineers during the first round of usability testing. These insights were used to establish Requirement 23, indicating that the engineer can be notified when there is a cancellation of a full booking.

Usability testing of design composites

The same set-up of the wireframes usability testing, had been used for the design composites, see Appendix I4. However, in the protocol can be seen that one additional task had been added, which refers to the new notification function. Next to that, encountering the limitations

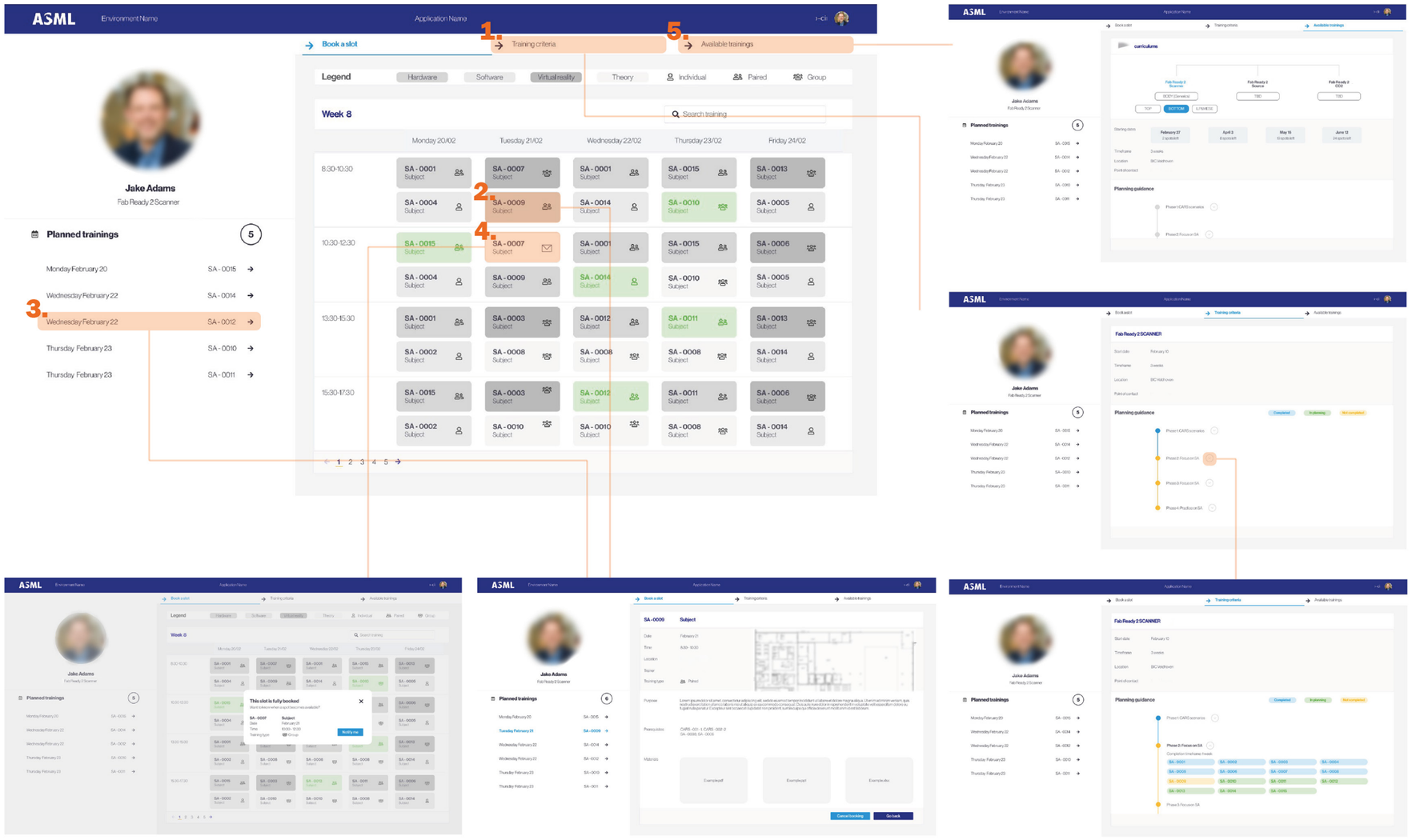


Figure 40: Design composites of the training planning tool, of which the numbers indicate the tasks and main features (due to confidential reasons some information is blurred)

of the first round, this resulted in an increase in attentiveness regarding complete introduction. During the first round, the insufficient information, resulted in inaccurate feedback. This was prevented in the second round, by making sure the design context is explained thoroughly.
A total of 7 participants contributed to this research, consisting of 4 High-NA engineers and 3 business stakeholders. According to the product usability evaluation (Van Boeijen, Daalhuizen & Zijlstra, 2020), 1 to 4 participants will be sufficient, meaning this can be considered a large amount. However, too many participants could overcomplex the results according to Martínez-Mesa et al. (2014). The outcomes will indicate whether the information is scattered, which could impact the conclusions.

Conclusion and reflection of design composites

The second round of usability gave insights on possible points of improvement and overlapping interests between users and business stakeholders, see Figure 41 and Appendix I5. Therefore, scattered feedback due to a high number of participants, was not applicable for this research. When comparing the outcomes of the NASA TLX of both tests (Appendix I3 & I5), a significant difference can be seen regarding the increase of performance. The mean of the performance variable went from 10 to almost 20. Next to that, the effort it took to execute the tasks, also decreased from 7 to 4. However, it can be concluded that the temporal demand, indicating how hurried the participant considered the task, and the frustration increased slightly. The non-consistent participant attendance due to availability, implying that different users attended round 1 and 2, can be considered as a limitation but also an advantage, since they're not familiar yet with the tool.

First, the majority of participants mentioned they experience the intended meaning of the green and blue color in the planning guidance the other way around. Since this was also mentioned by a company UX designer, it will be encountered for the redesign. Besides that, 3 out of 7 participants would like to personalize the notification time of a fully booked slot. They mentioned timeframes ranging from 1 day to 1 month, which should be encountered when creating the planning tool's data set-up, as it will be out of scope. Therefore, this point of improvement will act as a recommendation. Third, 2 out of 7 participants find a link to the CARS prerequisites in the booking page useful, since they want to be informed on the subject. To avoid over complexing the tool, I have chosen to implement the subject to these CARS scenarios for the final design proposal first, before adding new features to the tool. Next, 3 out of 4 users mention they want to click on SA's/CARS'/SMS' in the planning guidance, to retrieve more information. Because of the same reason mentioned above, the corresponding subject will be integrated into the planning guidance, to maintain a simple design. The design validation could possibly give insights on whether these were effective solutions. Additionally, 2 out of 4 users mention they find a zoom-in function of the map useful to determine the location. Last, 2 out of 4 users share their enthusiasm on the possibility to explore other trainings, because of an increased involvement in the training registration process.

In Figure 41 it can be seen that several other comments were given by stakeholders, which were translated into the final design, without becoming requirements. The fact that the participant attendance was not consistent, could also have influenced the outcomes of the feedback. Nevertheless, are the comments seen as valuable and leading for making certain decisions for iteration.

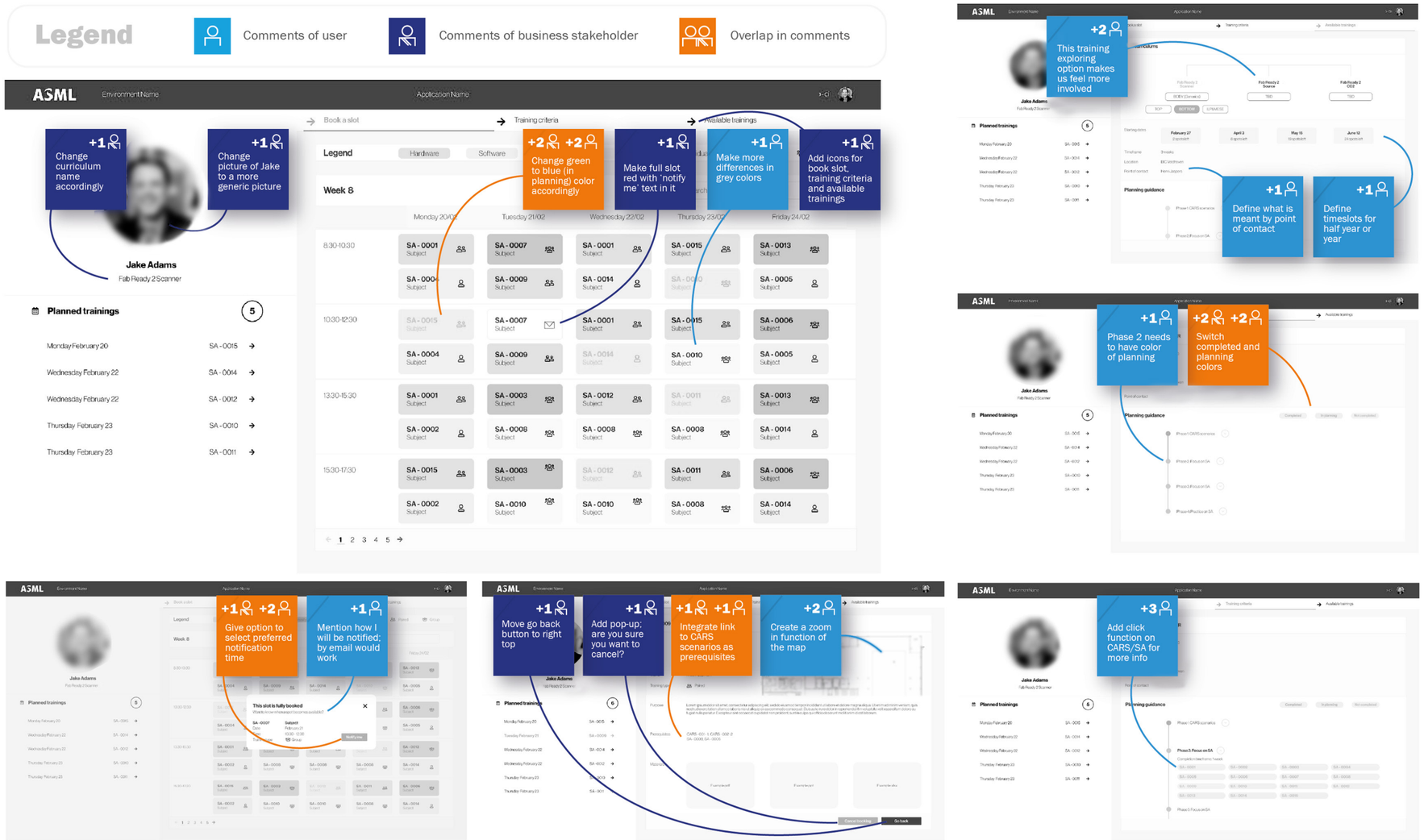


Figure 41: Feedback of usability testing (2) on wireframes (due to confidential reasons some information is blurred)

4.5 Prototyping system by curriculum integration

After the UX design had nearly been finished, a proposal on a possible planning was created. The specifics of one of the training curriculums was analysed, for tool integration. Requirements and TC context variables were gathered trough meetings with business stakeholders.

Requirements gathering of training types and the High-NA TC context

Setting up the requirements was seen as challenging, since several variables are not known yet of the TC. This resulted in taking initiative to approach several business stakeholders of the GTC to determine the unknown variables. In Appendix A2, all the system and context related requirements can be seen, which are elaborated below. Together with the company mentor, a scenario was determined. A planning proposal has been created, by encountering a first target audience of 30 engineers, 5 trainers, one curriculum, and one Hardware module (HW-rigg) for the hands-on trainings of that curriculum.

Based on a confidential Excel file with detailed curriculum training information, consisting of specific SA/SMS/CARS subjects and timeframe estimations of the represented training types HW/VR/SW/TH, modular slots were made by rounding up or down the estimations. Besides that, the capacity of the HW/VR/SW/TH training types was calculated by considering the number of rooms or modules and the occupation, see Figure 42.

Timeframe of training slots

Based on the estimated times in the confidential Excel file with detailed training information, several training timeframes were taken into account. When looking at the optimal duration of hands-on trainings in Chapter 2.1, a study by Mahmood et al. (2022) demonstrated that 90-minute hands-on training resulted in the highest performance, compared to 30- and 60-minutes. However, booking separate one and a half hour slots for several hands-on training of 5 or more hours, might overcomplex the tool. Therefore, it will be recommended to have breaks in the hands-on sessions after 90-minutes, to have optimal performance of the engineer.

Figure 42: Planning prototype of the BODY curriculum, encountering generic subjects for the SA'/SMS'/CARS' (based on Requirements 24 to 29 in Appendix A2)

Conclusion and reflection of practice opportunities

A proposal on a schedule of the BODY curriculum had been created by encountering the training content and the requirements mentioned above. Since there is 1 HW-rigg available in the TC for this curriculum, this resulted in a 4-week timeframe of for alle engineers to complete the required HW slots. Because SW slots have to be planned after HW trainings, this type also extends to 4 weeks, see Figure 42. Since the BODY curriculum also requires a 4-week timeframe, according to the company, this means no additional hands-on practice opportunities can be provided with 1 HW-rigg, indicating that supply is not equal to demand of more practice opportunities. One additional HW-rigg should be implemented in the TC for the BODY curriculum, to provide 3 practice moments for 30% of HW trainings. Taking into account that 30% of the HW trainings can be completed in approximately 1 week (Figure 42), multiplied by 3 practice opportunities, is equal to a full 4-week occupation of 1 HW-rigg. See Chapter 6.2 for further elaboration.

5. Final design & evaluation

The final design marks the ending stage of the graduation project, and contains the most important outcomes of all Chapters. First, the meaning and functionalities will be elaborated, followed by a user storyboard to showcase the intended product interaction. Additionally, the business benefits are demonstrated, before evaluating the design.

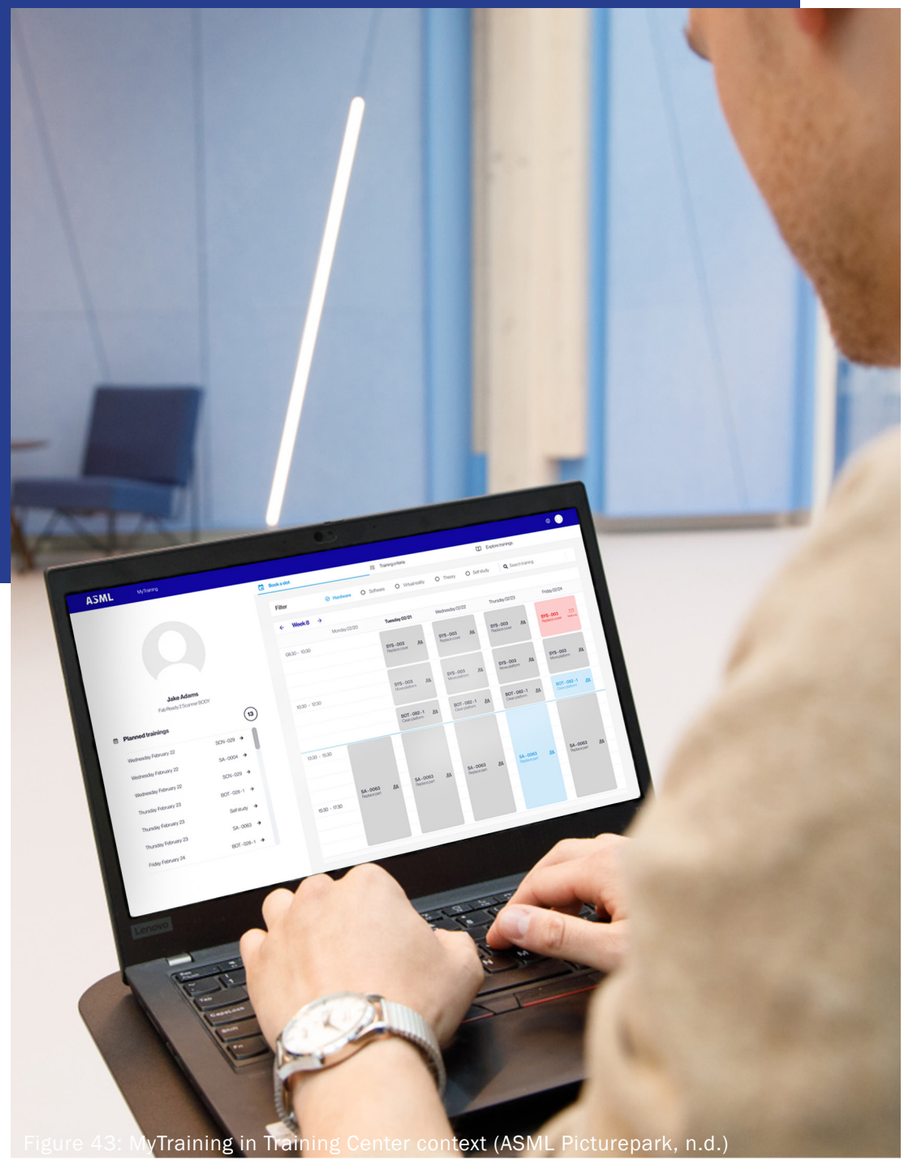


Figure 43: MyTraining in Training Center context (ASML Picturepark, n.d.)

5.1 Design meaning and functionalities

The UX design, that was iterated through two rounds of usability testing, and the training planning proposal had been emerged to establish the final design. The TC training planning tool is called ‘My Training’, resulting from the majority of stakeholder votes (See Appendix I6), and supports the micro-management of the tailor made training journey of the engineer.

Core features
MyTraining contains three main features, that support the High-NA TC environment. It offers the possibility to book preferred trainings in a weekly schedule, focusing on Hardware, Virtual Reality, Software and Theory methodologies. Besides that, a planning guidance can be accessed, acting as a guideline to go back to when the user will plan in their training. This will lead the engineers through their tailor made journey, to prevent that they will feel lost in this sense of autonomy, Requirement 14. Last, it enables the trainee to investigate other curriculums as well, through the explore training function. In this way, they are stimulated to focus on personal development, by exploring and defining the continuation of their learning journey.

Represented motivational drivers
The motivation theory of Pink (2009), see Chapter 2.1, has been incorporated into the tool and its meaning. The final design offers engineers a sense of autonomy, by self-directing their training planning to their preferences and needs, while encountering the required timeframe. They feel in control when using the tool. Second, it enables the mastery motivational driver, considering the tool supports a flexible environment where practice opportunities are incorporated. Improving their skills through practice, results in greater confidence and knowledge retention. Last, it gives purpose to the engineer by making them feel more involved in the process. Engineers would like to be in involved in the training process while being in charge of their path, which is a result of the fact that a GL or manager mostly assigns them for a training. This is a reoccurring need, mentioned in the interviews, co-creation session and prototype usability testing. In the next pages, quotes of users from the usability tests that support these statements, can be perceived. Due to confidentiality reasons, some information in the figures of the final design has been left out or blurred.

Logo
A suitable logo of MyTraining was explored by encountering existing company logos, see Appendix J. It was mentioned by 3 out of 3 users, that the logo in Figure 43, is most suitable and complimenting to the tool, see Appendix K.

myTraining

Figure 44: Logo of the High-NA TC training planning tool

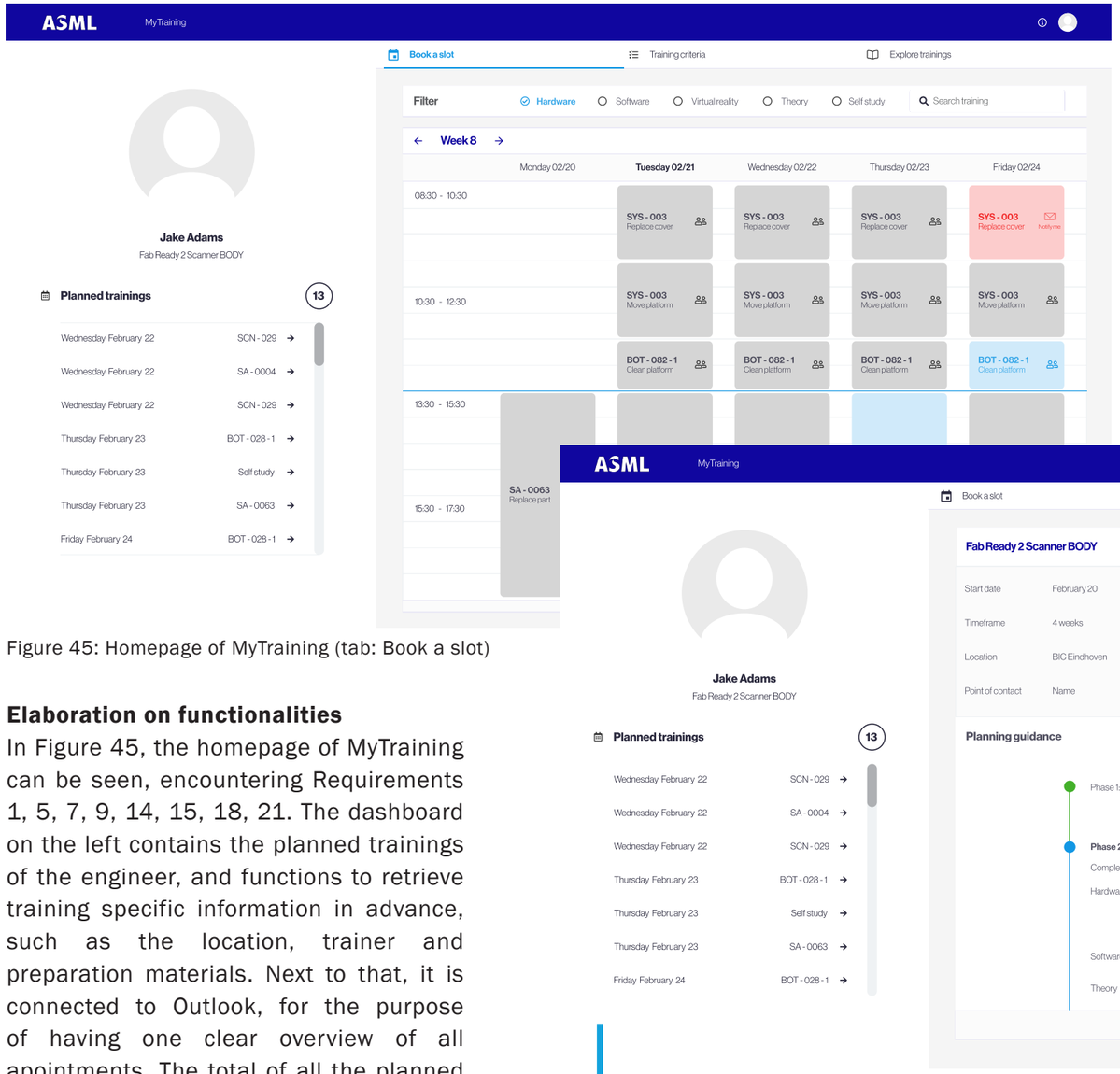


Figure 45: Homepage of MyTraining (tab: Book a slot)

Elaboration on functionalities

In Figure 45, the homepage of MyTraining can be seen, encountering Requirements 1, 5, 7, 9, 14, 15, 18, 21. The dashboard on the left contains the planned trainings of the engineer, and functions to retrieve training specific information in advance, such as the location, trainer and preparation materials. Next to that, it is connected to Outlook, for the purpose of having one clear overview of all apointments. The total of all the planned trainings is provided on top, and will light up once a training slot has been added, or cancelled.

Several colors were integrated into the weekly planning frame, representing the state of training slots. The grey tones represent the training types (HW/VR/SW/TH), that are available to schedule. To promote practice opportunities, no indication through color will be given of completion. Blue indicates that the training is in planning, see Figure 45. In addition, the red color indicates a fully booked

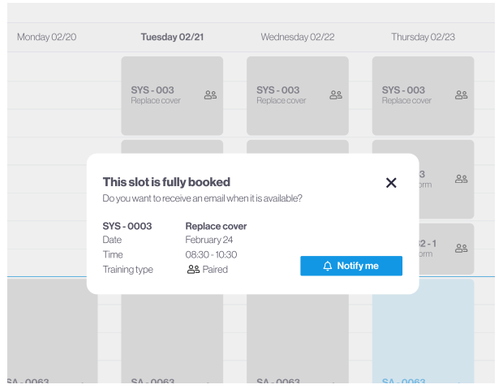


Figure 48: Notification of full booking

training slot, considering the meaning of colors in Figure 39. When clicking on a fully booked slot, the notification box in Figure 48 appears, containing specific training information and a notification button that is linked to Outlook (Requirement 23). Utilizing grey, blue and red color combinations, is in line with suitable color schemes for color-blind users, considering accessibility for all users, Requirement 22.

In Figure 46, the specific curriculum information and its planning guidance can be seen. The meaning of those colors, resulted from the input of the majority of participants of the usability testing, see Requirement 20. Since CARS scenarios cover the majority of all SA's, and SMS'

> "This is perfect! Normally our manager will assign us, but now we can explore it by ourselves."
>
> - User quote

Figure 46: Planning guidance of curriculum (tab: Training criteria)

> "It is really intuitive, some ASML tools are overcomplex these days. This one is straightforward and simple in use."
>
> - User quote

Figure 47: Investigate other High-NA curriculums (tab: Explore trainings)

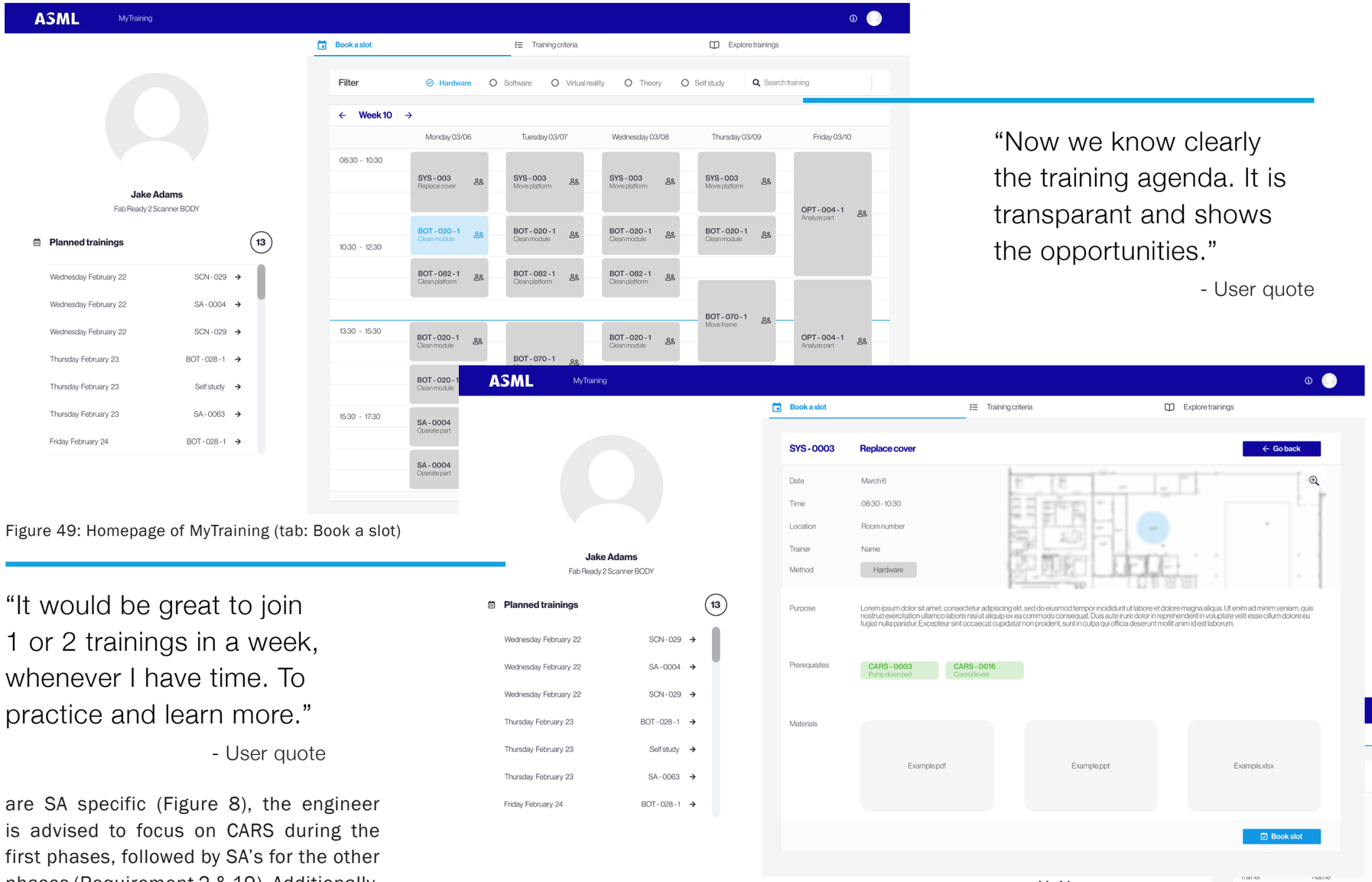


Figure 49: Homepage of MyTraining (tab: Book a slot)

"Now we know clearly the training agenda. It is transparant and shows the opportunities."

- User quote

"It would be great to join 1 or 2 trainings in a week, whenever I have time. To practice and learn more."

- User quote

are SA specific (Figure 8), the engineer is advised to focus on CARS during the first phases, followed by SA's for the other phases (Requirement 2 & 19). Additionally, the subjects of each SA/SMS/CARS ID has been integrated, since this was also one of the points of improvements according to the users, to make sure the navigation through the tool is optimal (Requirement 17).

The booking page contains a wide diversity of information, considering Requirements 8, 10, 11 and 13. It includes the purpose of the specific SA/SMS/CARS ID, highlighting the reason why this training should be completed. Next to that, the exact location can be augmented

Figure 50: Booking page of a SMS (tab: Book a slot)

by clicking on the zoom-in icon. Last, a link to the SharePoint environment is provided for specific training materials, such as procedures, presentations and more. The possibility to cancel a scheduled training, can be accessed by clicking on a planned SA/SMS/CARS in the dashboard. However, the training timeframe of a training is fixed, meaning that a high frequency of cancellations is not seen as beneficial for the progress. The system behind

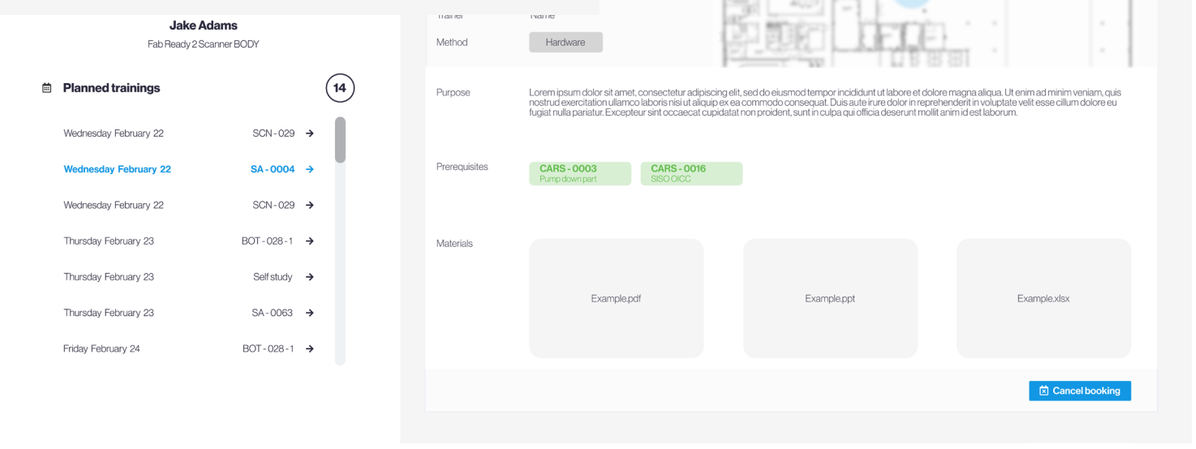


Figure 51: Cancel booking page of a SA (tab: Book a slot)

cancellations, amongst the acceptable amount and timeframe, should be further investigated.

When looking at the planning content, it can be concluded that all Requirements in Appendix A2 have been encountered to set-up this initial schedule. Considering the initial amount of 5 trainers for scenario, it is recommended that 1 trainer assists each HW/VR/SW/TH training type. Except for the HW trainings, because of the effective hands-on trainings need, 2 trainers will be available to assist.

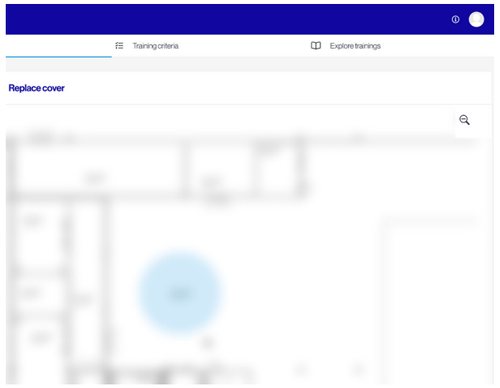


Figure 52: Zoom-in of exact location

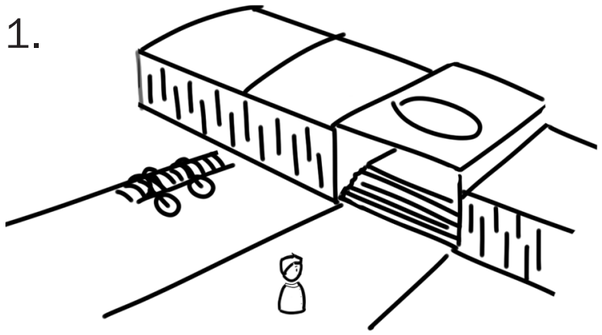
5.2 User storyboard

To communicate the design and its context with stakeholders, a user storyboard has been created through drawings. It demonstrates the interaction of the product, by showing how the tool is used in a given scenario (Van Boeijen, Daalhuizen & Zijlstra, 2020. In Figure 53, readers can experience the intended activities, and how MyTraining supports that.

Persona

A simple persona of the user was created, based on the participants of RQ4. He is a 1st-line engineer from the US, that registered for the new High-NA training in accordance with his manager. For quite some time he has been looking forward to learning more on this new system. There were several arrangements that had to be done before going to the Netherlands, such as booking accommodation, flights and more. He started the training one week ago, and uses MyTraining as planning guidance to schedule trainings.

1.



"Hi, I'm Jake! It is 9 a.m. and I have just arrived at the BIC to join several High-NA trainings."

2.

"To start, I check my schedule in the preparation room, for which I have booked a seat"

3.

"Let me see the overview of today's planning in Outlook. That's a tight schedule!"

4.

"The first training starts in 1 hour, I will study the materials beforehand through MyTraining."

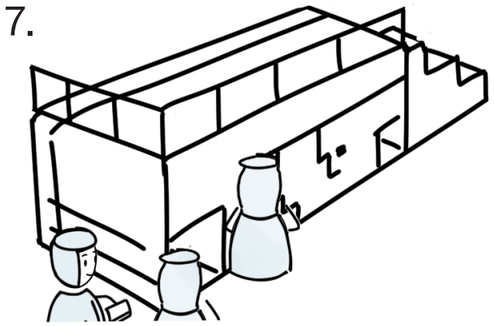
5.

"After the preparation, I join the Theory class on a CARS scenario together with colleagues."

6.

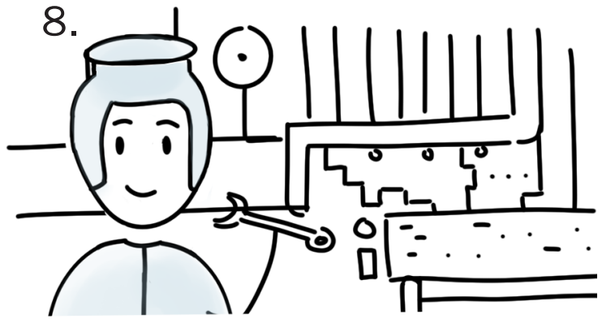
"After that, I have planned the complementary Hardware training. Let's go!"

7.



"Together with 2 other engineers, we discuss how to tackle this CARS scenario."

8.



"Since we're with a small group, there is plenty of time to practice on the Hardware."

9.

"I have booked a seat in the preparation room for the end of the day to check my training progress."

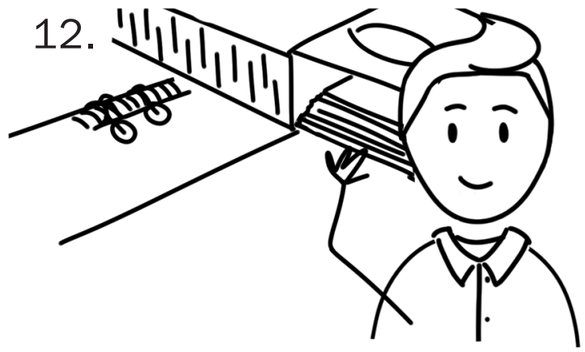
10.

"I see I still have to finish two SA's to fulfill phase two."

11.

"I will book the slots by encountering my schedule and my preferences."

12.



"That wraps up my day! See you tomorrow BIC, for again another training day."

Figure 53: User storyboard of MyTraining

5.3 Business benefits

In addition to the value of MyTraining for the users of the tool, complimentary business benefits have been determined in close consultation with stakeholders, such as trainers, SME's and the company mentor. The training planning tool for the High-NA TC context, offers following 4 main advantages, stimulating further development and implementation.

• First, the integration of modular slots and minimizing hands-on activities will result in an increase of training effectiveness. The current effective hands-on time is estimated maximum 20% considering the limited hands-on time of an individual in a group of 6 or more engineers. A rough and indicative calculation performed has demonstrated a possible further increase to a level of approximately 80%, implying an increase of the effectiveness by a factor of 2. For calculation details see Appendix L1.
• Next, the tool provides a solid support to high-quality engineers. More autonomy regarding training planning will increase the motivation of an individual (Pink, 2009). Next to that, MyTraining facilitates practice opportunities, aiming at higher confidence levels and solving power of the engineer. Optimizing this field self-sufficiency, is one of the company's key service strategies in delivering more value to customers.
• Furthermore, trainers currently spend approximately one hour per training on preparations, which includes sending updates, reservation of the meeting location and studying training material (Appendix L2). Assuming a yearly quantity of 50 NXE training sessions would save a trainer 50 hours on training management, which is a considerable amount of time freeing up, that can be used for other valuable business related purposes.
• Finally, several documentation related benefits of this tool will apply when considering the fact that completion of training sessions will be captured in the system. Storing of this specific data will provide spin-off opportunities related to other training applications, such as the Skill Management Tool (SMT) and to registering training progress and capabilities (Appendix L3). Currently each trainee is allowed 15-minute documentation time in SMT after each training day to enroll the finished training types. This documentation time can be avoided if MyTraining will be implemented and used.

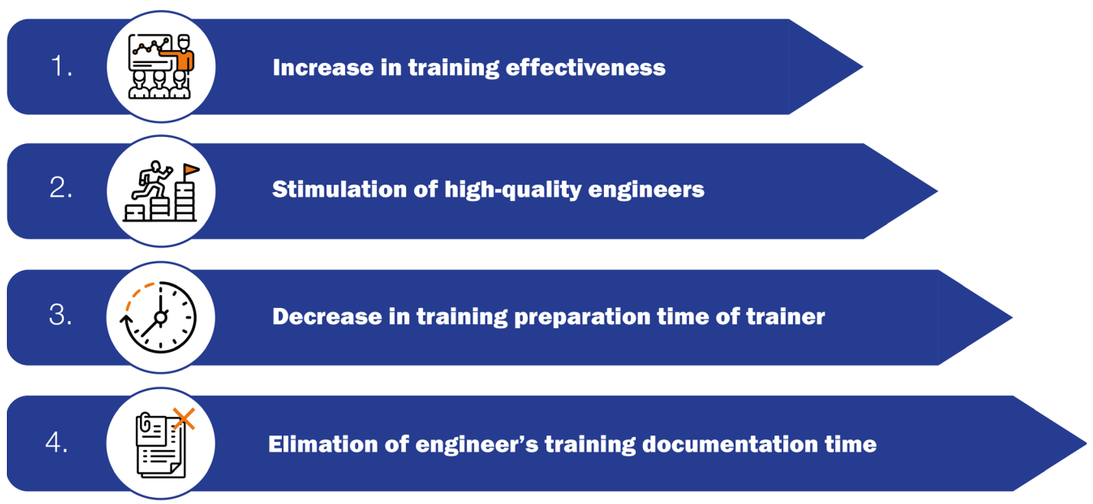


Figure 54: Business benefits of MyTraining (Flaticon, n.d.)

5.4 Design evaluation

This Chapter evaluates the final design, by encountering the comments and feedback of the users, business stakeholders and an external software company. The desirability, feasibility and viability of the design is emphasized, while also remaining critical and indicating the points of improvement. Several constraints should be considered, if the company has the intention to implement the training planning tool.

Validation with users

For the final design evaluation test with the users, the same protocol has been used of the usability testing (see Appendix I4), which was established by using the typical IDE methodology of Van Boeijen, Daalhuizen & Zijlstra (2020). Open research questions were interrogated during a 30-minute online meeting, aiming at the execution of the five tasks mentioned in the protocol. This final design evaluation with the users, is seen as crucial to understand their interpretation of the design, and how its value can be improved. This was done by inviting users to the evaluation that already tested or experienced the design during a previous session, to make sure they have sufficient knowledge of the context and product. A total of 3 participants contributed to this research, consisting of High-NA engineers. This was a sufficient amount when encountering the product usability evaluation (Van Boeijen, Daalhuizen & Zijlstra, 2020), which states that for a simple and qualitative evaluation, 1 to 4 participants will be sufficient.

It can be concluded that the majority of the engineers are enthusiastic on the tool, especially when they compared it on own initiative to MyLearning, it significantly increased in usability considering the layout and the interaction. All participants find it simple and intuitive to navigate around, because of the accessible design, intended use in color, the provided subjects of the SA/SMS/CARS types and the appealing graphics. A single engineer mentions that using the tool has a low stress factor, considering the straightforward features. Additionally, 1 participant advocates the transparency of the curriculums towards the trainees, and finds the possibility to explore other programs enjoyable. This comment originates from the customer pressure they experience, meaning they currently have minimal input on their trainings, since often their manager assigns them in to a suitable training that fits to the needs of the company at that moment

However, some users mention limitations, implying on the system and content of the tool. First they would prefer to have a clickable function on the training modules in the planning guidance, to access additional information on the SA/SMS/CARS type. Next to that, it was mentioned that they find the notification option useful, but question what would be the impact on training progress if there will be a consistent amount of fully booked slots. This should be further determined.

> "What to do if a training slot is fully booked, when assuming the completion timeframe is fixed?"
>
> - User quote

It can be concluded that the design is desirable according to the users, when looking at the benefits it will bring, aiming at practice opportunities, the transparency in

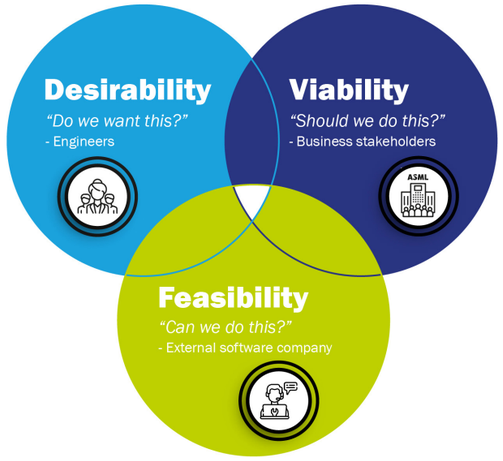


Figure 55: Desirability, feasibility and viability

other training programs and the possibility to self-direct their training journey to their likings. However, they encounter some limitations in the design feasibility. This will be elaborated in the next paragraphs.

Validation with business stakeholders

The viability of MyTraining was evaluated with business stakeholders, amongst SME's, trainers, curriculum architects, and the company mentor. Considering Challenge 3 of Figure 14, company alignment is crucial to spread the word on the creation and potential benefits of this tool. A 30-minute online or face-to-face meeting was initiated, to discuss the concept and business benefits, and to give a demonstration of the tool. A complementary PowerPoint presentation was used for this purpose.

Regarding the created planning system, several business stakeholders of the EUV TC department mention that it shows feasible for the scenario. The department lead mentions it is an effective way of training, and assumes one trainer per room would be sufficient to provide the needed support. However, what will be the system behind the support? Can you just approach them or will it be integrated into the system? These questions by one of the TC

> "A correct balance should be found between supply & demand for implementation."
>
> - Business stakeholder quote

leads should be further investigated, and relates to the yet unfulfilled Requirement 12. An additional stakeholder mentions that supply needs to be matched with the demand, and an ideal balance should be found. However, this is still unknown and difficult to determine in the relatively unknown TC context.

According to the company mentor, it can not be demonstrated yet if the EUV curriculum complexity could be integrated into the tool. In addition, the design's scalability has to be further researched, next to the integration of OJT and additional training methods, which are for now out of scope. The tool will be difficult to implement, since change in ways of working and training management would be necessary. However, the implementation should still be considered, when encountering that the TC will be booming in a few years because of the increase in training demand. This tool will help to structure the future TC, through efficient planning and training slot modularity.

The TC planning department finds the initial research multi-leveled, and therefore supportive of the design. Besides that, the multiple verification rounds with the end-user, add great value to the result. The created scenario of one of the curriculums shows the feasibility of the design in this particular context. The variables, modular slots and calculations seem to add up. However, pilot testing should show whether this is feasible also in a greater context with more than 30 engineers, which will be the TC of the future.

From the evaluation with the business stakeholders, it can be concluded that the product is viable and that it would benefit them in multiple ways. However, it seems feasible, but there are several challenges when looking at if it is possible to integrate the complexity and make it scalability and also integrated OJT. To investigate the feasibility, the external software company of the graduation department, has been interrogated on the possible challenges when developing MyTraining.

Validation with external company

To determine the feasibility of the design, a meeting was organized with several business stakeholders and an external software developing company. A similar PowerPoint presentation was given including the goals of the project, as well as the functionalities of the tool. Additionally, an extensive demo was provided, to give an impression of the needed data structure.

> "It seems feasible, however, there are questions in terms of business logic and retrieving data."
>
> - External stakeholder quote

MyTraining seems feasible to establish, especially when looking at the simplicity of the layout and design. The software developers referred to the dependence of data from other systems, as main obstacle. It will be challenging to make sure the correct information is given and is represented in all company specific tools. Next to that, there are still several questions in terms of business logic, and how everything will be established in the context and in the data base, by giving a correct representation of the availability

Conclusion and reflection of evaluation

It can be concluded that the concept has a sense of desirability, viability of feasibility. The engineers find it intuitive and easy to work with, while it offer opportunities to plan in practice moments. Next to that, it seems viable to the company, and they can see the benefits that MyTraining brings to the organization. However, the information structure and the optimal TC supply should still be established. The external software highlights the challenge of gathering the data and making sure the data represents the real-time situation.

Furthermore, the usability testing protocol of the previous set-up, has not been changed. It should have been focused on the product meaning and the benefits in general for the engineers. Eventually, it was mainly targeted at the features, which should not have been the entire focus of the final evaluation test. However, I still managed to get detailed and valuable input by interrogating the engineers.

Third, the created planning system for in the tool, hasn't been tested separately. The use and structure has been demonstrated, but no feedback was given on the distribution of slots. However, since this is a specific and detailed matter, it makes sense that it is difficult to understand for the users and some business stakeholders, when seeing it for the first time. Therefore, there were not questioned on the value of the training planning tool, except for a single business stakeholders.

When revising the defined scope and the determination of product success in Chapter 3.2, it can be concluded that the final design proposal succeeds the assessment, while offering several points of improvement. However, measuring the success and effectiveness of the design is critical. A combination of pilot testing and evaluation of implementation through level 4 of Kirkpatrick's tool (Figure 20), should indicate whether the design is valuable to the company.

6. Discussion & limitations

In this Chapter, the outcomes of the graduation project will be discussed, and opportunities of implementation will be elaborated. This was done by comparing the research results with the final design, to find out whether these are related. Additionally, several limitations are acknowledged to demonstrate the credibility.

Figure 56: Impression of discussion (ASML Picturepark, n.d.)

6.1 Discussion

The discussion consists of a repetitive analysis of the research phase, while linking the main outcomes to the meaning and features of the final design proposal. Additionally, the impact of MyTraining on the company's way of working is explained.

It can be concluded that the title of this Master's thesis, including efficiency and effectiveness, is reflected in MyTraining to a certain extent. Considering effectiveness, it provides modular hands-on training slots, having a minimal capacity compared to their current way of working, resulting in an increase in effective hands-on time. Considering efficiency, this tool benefits the trainee and the planning management, by making use of an automated system to provide modular slots, tackling the company problem statement. Related to second part of this statement, it takes into account dependencies when looking at CARS scenarios, making sure these are first introduced to and completed by the trainee.

For RQ1 the effectiveness of distributed practice is demonstrated, influencing the individual's confidence level and optimal knowledge retention (Tai 2006) (Easley, 2017). MyTraining supports an environment where practice opportunities of hands-on trainings are stimulated. Additionally, motivation is needed for an individual's capability to learn and gain skills (Tai, 2006). According to Pink (2009), autonomy, mastery and purpose are the main motivational drivers, which are represented in the design. An engineer is able to self-direct their training journey, gain more experience by having moments of practice, and to feel involved because of the transparency in training opportunities and the ability to be in charge of their training path.

When looking at the represented trends (RQ2) in MyTraining, it includes optimized learning, by stimulating overlearning and repetition (Cascio, 2019). In addition, the training planning tool could be steering towards workplace communities, by focusing on trainee relationships (Azourt et al., 2020). A sense of personalized learning is covered, considering the fact that the engineers are able to plan in their trainings to preferences (Maity, 2019). Being able to plan these learnings according to the user's needs, influenced by generation or demographics, tackles the challenge of workforce diversity (Cascio, 2019).

The outcomes of the interviews with the organizations (RQ3) demonstrate an increased focus on training quality and effectiveness developments for 43% of the companies. The use of modular slots in MyTraining and decreasing the capacity of hands-on slots, aims at improving training effectiveness as well. Next to that, all companies tend to focus on providing personal development opportunities. Which is in line with the purpose of MyTraining, since it will promote personal development through the creation of a tailor made training journey, while having opportunities regarding composing a training to the individual's needs.

Furthermore, the majority of the engineers mentions during the user research at ASML (R4), that the amount of effective hands-on trainings should increase. Besides that, they have the need for more learnings when looking at practice and personal development opportunities. Their decrease in confidence level when going to the field, is a result of having a minimal hands-on time considering the training group size, and procedural focused

sessions with superficial reasoning and representation of the context. MyTraining anticipates on this matter, by supporting an environment where practice opportunities are encouraged, and by providing hands-on slots with a minimized occupation for improved effective individual training time.

The needs and preferences of the engineers have been reflected in the tool by encountering the User-Centered Design (UCD) approach (Van Boeijen, Daalhuizen, & Zijlstra, 2020) for interviews, usability testing and co-creation sessions. The UCD approach has been applied since the graduate's internship experience resulted in insights on the involvement of the user in design processes, which could be improved. Next to that, the company advocates the increase of user representation in their products and services for the future. Creating the planning tool by encountering this human-centered mindset, has resulted in an interface in which the user's needs and preferences are reflected. Engineers mentioned the increase in usability when comparing MyTraining to the current macro-planning tool MyLearning, therefore, it can be said the UCD approach did have a positive impact on the intuitiveness of the tool. This indicates that focusing on a UCD approach has significant benefits for ASML when looking at the succession timeframe when using a product or service, but also the general employee satisfaction. However, testing the tool will indicate whether it is complimentary and still straightforward in use for the engineers in the TC context. Additionally, when implementing the tool there is a possibility that the design of the tool will change when business stakeholders will prioritize certain requirements, which could be at expense of the user representation.

During this project, other company typical tools were explored to define possible connections. MyTraining relates to MyLearning when considering the fact that they align on planning a training, whereas MyLearning is focused on assigning to trainings and planning on a macro-level. However, MyTraining is focused on creating a day-to-day planning, and therefore relates to micro-management of the training. A link of MyTraining should therefore be integrated into MyLearning, when the engineer has been assigned to the complete curriculum. Next to that, the Service Action (SA) completion data should be linked to Skill Management Tool (SMT), to improve the documentation of completed training. However, the link to the Competence Development Program (CDP), which is a personal development program that the engineer can request to gain a requested expertise, is not established and should be further investigated to enable further company alignment.

To fit the tool in ASML's company structure, the way of working in the training planning management should change, since an automated system will be introduced that will run by the engineer's input, instead of a pre-defined complete training planning by the TC department. Next to that, alignment with other departments and tools has to be explored, making sure data exchange is achievable and in place. Additionally, the complete High-NA curriculum content needs to be captured and modularized in the tool, since currently only the BODY curriculum has been considered. As well as how to achieve the hands-on practice opportunities, by making sure the supply of modules, rooms and trainers in the TC is in line with the training demand of engineers. The forgetting curve by Ebbinghaus (Chun & Heo, 2018) can be used as a guideline to determine the time in between trainings, when three practice opportunities are allowed for each engineer. However, pilot testing should indicate the preferred timeframe.

6.2 Limitations and recommendations

A critical look will be given on the design process of the project, by taking possible constraints and improvement opportunities into account. Additionally, recommendations are given for the development and implementation of MyTraining in the TC context.

Limitations

This thesis includes limitations regarding the sample size of the project's target audience, which are approximately 8 High-NA engineers. A total of 6 engineers were taken into the process of designing the tool through co-designing, usability testing etc. Even though this number represents almost the complete target group, the number is not that large to draw definite conclusions of their beliefs and reasoning. If there would be a greater target audience, a higher amount of input would result in more valuable outcomes. However, a sample size of 8 participants is also considered as meaningful when taking into account the number of qualitative evaluation sessions done for the task-driven user testing.

Furthermore, the consistency in the same participants, could have resulted in monotonous feedback, but also in profound feedback because they became familiar with the tool. Besides that, the preference of some engineers for a training planning tool, could also have resulted in not entirely objective feedback. This could also be considered for the input of the company mentor, considering his initiation of the graduation assignment.

Third, some of the engineers were having reserved attitudes when interrogating them on their training experiences. It could be possible that incorrect or superficial information is given during the user interviews, considering their assumption that their manager or Group Lead (GL) could be informed on their input.

Next to that, several requirements resulted from the co-creation session with users. However, only a selection of 6 core features were considered (Figure 35), when encountering the project timeframe, resulting in the likelihood of leaving out other complementary core features. Since the integrated features were seen as most valuable by the engineers, it can be assumed that supplementary input is seen as less significant to implement in this first design proposal. Additionally, it was aimed that both users and business stakeholders would attend this session, to obtain alignment in their needs when looking at the tool's core features. In the end, the business stakeholders were not present, due to other high-priority meetings. The impact of this was minimized by having separate co-creation sessions, and seeing where their values overlapped by clustering the outcomes.

Lastly, no specific usability testing was carried out effectively for the curriculum specific planning, that was integrated into the tool. This was demonstrated during the final evaluation usability testing with users, and the demonstration to the business stakeholders. The method and requirements on creating the planning was shared, however, it was not tested if this was done correctly. Nevertheless, most business stakeholders and especially users have no experience with the content and exact classification of the curriculum, except for the specific curriculum architects. In addition to that, only one curriculum is represented in the planning proposal, which will not be sufficient to determine the complete supply when looking at the training demand.

Recommendations

For development and implementation, the final design should be further defined through company alignment, an implementation plan, software programming and the complete training program integration. For the scenario of one curriculum, a single HW-rigg is taken into account, which entails the supply of the context. The created planning demonstrates, that the curriculum specific HW-rigg is utilized for the complete 4-weeks, to complete the required training elements, implying that no hands-on practice opportunities can be offered to the engineers. Therefore, it is recommended to reconsider the supply, since implementing one more HW-rigg, would already result in having three practice opportunities for 30% of the Hardware trainings.

Next to that, I want to emphasize that the curriculum can be optimized to 3 weeks, if additional HW-riggs would be provided in the TC, encountering the unoccupied schedules of the other training types, such as Virtual Reality, Software and Theory. Also, the amount of cranes in the TC should be increased, to prevent inefficient waiting lines, when upscaling the capacity.

Pilot testing should be executed during the implementation and development process. This will serve as validation of the complete tool and the TC context. I would advocate taking into account the optimal hands-on training performance timeframe of 90-minutes (Mahmood et al. 2022), by including a reasonable amount of breaks, see Chapter 2.1. Besides that, the support system should be further investigated, aiming at determining the exact amount of trainers per training type. Requirement 12, on the automation of referring a trainee to a fellow who recently completed a training slot, has not been considered for this design and is recommended to examine further.

The value and benefits of MyTraining in the TC context can be perceived, through evaluating level 4 (results) of Kirkpatrick's evaluation model (Figure 20), to see the effect of this tool on certain KPI's.

A connection to OneNote could be established for communication purposes between the trainee and trainer, and to fulfill the engineer's need of an increase in performance support. Currently, OneNote is already used by engineers as a separate tool to write down comments on trainings. This additional dimension to the tool's functionalities, could be beneficial when considering the documentation of learnings.

Encountering the amount of features and functionalities in MyTraining, it is recommended to apply the five moments of need methodology, for optimal use and information structure of the tool (Appendix L4). Several specific functions should be considered, amongst an acceptable cancellation timeframe, notification time of an available training, the sequence in interaction, and possible exceptions.

Virtual Reality (VR) can be beneficial as additional learning method for optimal knowledge retention. According to a study on the effects of VR on learning and retention by Smith et al. (2016), it will be valuable to integrate this technology into the way of working, as complementary and supportive to Hardware hands-on trainings. Therefore, investigating this alternative method to stimulate remote practice, is recommended to the company.

As can be perceived, there are several points of improvement for further research and testing, when considering the MyTraining concept. However, this thesis provides a starting point for the company to explore their way of working, while encountering the rise in training demand for the future TC, where learning by doing is crucial to satisfy the engineer's needs and to create optimal field self-sufficiency.

References

Akram, W., & Kumar, R. (2017). A study on positive and negative effects of social media on society. International Journal of Computer Sciences and Engineering, 5(10), 351-354.

Akresh-Gonzales, J. (2018). Spaced repitition: the most effective way to learn. NEJM Knowledge+. NEJM Knowledge+. https://knowledgeplus. nejm. org/blog/spaced-repetition-the-most-effective-way-to-learn/. Accessed, 20.

Alliger, G.M., Tannenbaum, S.I., Bennett, W., Traver, H. and Shotland, A. (1997), "A meta-analysis of the relations among training criteria", Personnel Psychology, Vol. 50, pp. 341-58.

ASML. (n.d.-a). ASML at a glance. https://www.asml.com/en/company/about-asml/asml-at-a-glance

ASML. (n.d.-b). ASML's DUV lithography systems. https://www.asml.com/en/products/duv-lithography-systems

ASML. (n.d.-c). ASML EUV lithography systems. https://www.asml.com/en/products/euv-lithography-systems

ASML. (n.d.-d). ASML's metrology & inspection systems. https://www.asml.com/en/products/metrology-and-inspection-systems

ASML. (n.d.-e). ASML vision & mission. https://www.asml.com/en/company/about-asml/vision-and-mission

ASML. (n.d.-f). Company organization - Supplying the semiconductor industry. https://www.asml.com/en/company/about-asml/organization

ASML. (n.d.-g). Lithography principles. https://www.asml.com/en/technology/lithography-principles

ASML. (n.d.-h). Learn all about microchips. https://www.asml.com/en/technology/all-about-microchips

ASML. (n.d.-i). Our history – Supplying the semiconductor industry. https://www.asml.com/en/company/about-asml/history

ASML. (2022, March 14). So you want to work in the semiconductor industry? https://www.asml.com/en/news/stories/2021/work-semiconductor-industry

ASML Academy. (n.d.) Lithography at the heart of the semiconductor industry: Introduction

to Lithography [Powerpoint slides]. ASML CS Global Training Center.

ASML Picturepark. (n.d.). https://asml.picturepark.com/contentmediaLibrary?search=laptop

ASML, & Zeiss. (2018). High-NA EUV Lithography: Exposure tool progress [Powerpoint slides]. SPIE Conference on Photomask Technology and EUV Lithography, Monterey CA, USA.

Bandura, A., Freeman, W. H., & Lightsey, R. (1999). Self-efficacy: The exercise of control.

Bates, R. (2004). A critical analysis of evaluation practice: the Kirkpatrick model and the principle of beneficence. Evaluation and program planning, 27(3), 341-347.

Bergeron, H. E. (2006). Some thoughts on why doctors are considered professionals and engineers are not. Journal of Professional Issues in Engineering Education and Practice, 132(2), 151-152.

Bruton, L. (2022, September 8). What is wireframing? A complete guide. UX Design Institute. https://www.uxdesigninstitute.com/blog/what-is-wireframing/

Bullen, P. B. (2022, September 28). How to choose a sample size (for the statistically challenged). Tools4dev. https://tools4dev.org/resources/how-to-choose-a-sample-size/

Bulger, M. (2016). Personalized learning: The conversations we're not having. Data and Society, 22(1), 1-29.

Cascio, W. F. (2019). Training trends: Macro, micro, and policy issues. Human Resource Management Review, 29(2), 284-297.

Chun, B. A., & Heo, H. J. (2018). The effect of flipped learning on academic performance as an innovative method for overcoming ebbinghaus' forgetting curve. In Proceedings of the 6th International Conference on Information and Education Technology (pp. 56-60).

Clark, C. S., Dobbins, G. H., & Ladd, R. T. (1993). Exploratory field study of training motivation: Influence of involvement, credibility, and transfer climate. Group & Organization Management, 18, 292-307.

CodeWithChris. (2018, September 18). The App Design Process. YouTube. https://www.youtube.com/watch?v=cU6T_0j2Pp4

Cole, N. (2008). How long should a training program be? A field study of "rules-of-thumb". Journal of Workplace Learning.

Colquitt, J. A., LePine, J. A., & Noe, R. A. (2000). Toward an integrative theory of training motivation: a meta-analytic path analysis of 20 years of research. Journal of applied psychology, 85(5), 678.

Cravit, R. (2023, January 23). How to Use Color Blind Friendly Palettes to Make Your Charts Accessible. Venngage. https://venngage.com/blog/color-blind-friendly-palette/

De Clercq, D., Haq, I. U., & Azeem, M. U. (2018). Workplace ostracism and job performance: roles of self-efficacy and job level. Personnel Review.Design Council. (2022a, June 8) Framework for Innovation:

Design Council's evolved Double Diamond. Design Council. https://www.designcouncil.org.uk/our-work/skills-learning/tools-frameworks/framework-for-innovation-design-councils-evolved-double-diamond/

Design Council. (2022b, June 6). The Double Diamond: A universally accepted depiction of the design process. Design Council. https://www.designcouncil.org.uk/our-work/news-opinion/double-diamond-universally-accepted-depiction-design-process/

Dolan, P., Leat, D., Mazzoli Smith, L., Mitra, S., & Todd, L. (2013). Self-organised learning environments (SOLEs) in an English school: an example of transformative pedagogy?. Online educational research journal., 3(11), 1-19.

Easley, H. (1937). The curve of forgetting and the distribution of practice. Journal of Educational Psychology, 28(6), 474–478. https://doi.org/10.1037/h0057409

Figma. (n.d.). The collaborative interface design tool. https://www.figma.com

Flaticon. (n.d.). Free Icons and Stickers - Millions of images to download. https://www.flaticon.com/

Haritos, T., & Macchiarella, N. D. (2005). A mobile application of augmented reality for aerospace maintenance training. In 24th digital avionics systems conference (Vol. 1, pp. 5-B). IEEE.

Hart, S. G. (2006, October). NASA-task load index (NASA-TLX); 20 years later. In Proceedings of the human factors and ergonomics society annual meeting (Vol. 50, No. 9, pp. 904-908). Sage CA: Los Angeles, CA: Sage publications.

Hekkert, P.P.M., & van Dijk, M.B. (2017). Vision in design - A guidebook for innovators. BIS Publishers.

Kaestner, L. (2022). Artificial intelligence: Training the trainer. British Journal of Haematology, 198(5), 805-806.

Kamei, R. K. (2021). Strategic Learning: A Holistic Approach to Studying.

Karp, H. B., & Sammour, H. Y. (2000). Workforce diversity: Choices in diversity training programs & dealing with resistance to diversity. College Student Journal, 34(3), 451-451.

Kessels, J.W.M., Smit, C.A., & Keursten, P. (1996). The eight field instrument: analysis framework for training effects. Kessels & Smit, the Learning Company.

Kirkpatrick, W. K. (2016). Kirkpatrick's four levels of training evaluation. Association for Talent Development.

Kirkpatrick, J.D., & Kirkpatrick, W.K. (2021). An Introduction to The New World Kirkpatrick Model. Kirkpatrick Partners.

KLM Royal Dutch Airlines. (n.d.). KLM Royal Dutch Airlines - Boek vluchten online - KLM Nederland. https://www.klm.nl/

Lérondel, G., Kostcheev, S., & Plain, J. (2012). Nanofabrication for plasmonics. In Plasmonics (pp. 269-316). Springer, Berlin, Heidelberg.

Mahmood, O., Jørgensen, R., Nielsen, K., Konge, L., & Russell, L. (2022). Hands-On Time in Simulation-Based Ultrasound Training–A Dose-Related Response Study. Ultrasound International Open, 8(01), E2-E6.

Maity, S. (2019). Identifying opportunities for artificial intelligence in the evolution of training and development practices. Journal of Management Development.

Martínez-Mesa, J., González-Chica, D. A., Bastos, J. L., Bonamigo, R. R., & Duquia, R. P. (2014). Sample size: how many participants do I need in my research?. Anais brasileiros de dermatologia, 89, 609-615.

Mathieu, J. E., Martineau, J. W., & Tannenbaum, S. I. (1993). Individual and situational influences on the development of self-efficacy: Implications for training effectiveness. Personnel Psychology, 46, 125—147

Ministerie van Defensie. (2023, February 1). Ministry of Defence - Defensie.nl. https://english.defensie.nl/

Morgenroth, J. (2021, May 12). 5 Things To Consider To Find The Optimal Length Of A Training Course. eLearning Industry. https://elearningindustry.com/length-of-a-training-course-5-things-consider

NDSU. (n.d.). Kirkparick's Four Levels of Training Evaluation in Detail — Evaluation. https://www.ag.ndsu.edu/evaluation/documents/kirkpatricks-four-levels-of-training-evaluation-in-detail-1/view

Next Learning Valley. (2022, October 26). Home - Next Learning Valley. https://nextlearningvalley.com/

Norman, D., & Nielsen, J. (n.d.). The Definition of User Experience (UX). Nielsen Norman Group. https://www.nngroup.com/articles/definition-user-experience/

Norman, D. A. (2013). The design of everyday things. MIT Press.

Numfu, M., Riel, A., & Noël, F. (2019). Virtual reality based digital chain for maintenance training. Procedia CIRP, 84, 1069-1074.

O'Reilly Auto Parts. (2018, February 26). How To: Change Motor Oil In Your Car. YouTube. https://www.youtube.com/watch?v=F37Gbxb1hNE

Ouweneel, E., Schaufeli, W. B., & Le Blanc, P. M. (2013). Believe, and you will achieve: Changes over time in self-efficacy, engagement, and performance. Applied Psychology: Health and Well-Being, 5(2), 225-247.

Paniagua-Dominguez, R., Yu, Y.F., Khaidarov, E., Choi, S., Leong, V., Bakker, R.M., Liang, X., Fu, Y.H., Valuckas, V., Krivitsky, L.A. and Kuznetsov, A.I. (2018). A metalens with a near-unity numerical aperture. Nano letters, 18(3), 2124-2132.

Philips. (n.d.). Nederland | Philips. https://www.philips.nl/

Pink, D. (2009). The puzzle of motivation. TEDGlobal 2009.

Rao, Y., Xu, B. L., Jing, T., Zhang, F., & Zhao, X. Y. (2017). The current status and future perspectives of virtual maintenance. Procedia Computer Science, 107, 58-63.

Resch, J. (2015). Part I-A case study in post-secondary mathematics: the importance of mental health awareness. arXiv preprint arXiv:1511.06699.

Rogers, C. (2020, October 9). Colour blindness in engineering. Engineering & Technology Jobs. https://engineering-jobs.theiet.org/article/colour-blindness-in-engineering

Rottenfusser, R. (2013). Proper alignment of the microscope. In Methods in Cell Biology (Vol. 114, pp. 43-67). Academic Press.

Ruona, W.E.A., Leimbach, M., Holton III, E.F., & Bates, R. (2002). The relationship between learner utility reactions and predicted learning transfer among trainees. International journal of training and development, 6(4), 218-228.

Salas, E., Tannenbaum, S.I., Kraiger, K., & Smith-Jentsch, K.A. (2012). The science of training and development in organizations: What matters in practice. Psychological Science in the Public Interest, 13(2), 74-101.

Seidenberg, S. (2009). Copyright in the age of YouTube. ABAJ, 95, 46.

Schomaker, L., Albano, M., Jantunen, E., & Ferreira, L. L. (2019). The future of maintenance. The MANTIS Book, Cyber Physical System Based Proactive Collaborative Maintenance, River Publishers, 555-567.

Schunk, D. H. (1995). Self-efficacy and education and instruction. Self-efficacy, adaptation, and adjustment, 281-303.

SDK Vastgoed. (2022, December 20). Brainport Industries Campus – Locatie 1. https://

www.sdkvastgoed.nl/projecten/brainport-industries-campus-locatie-1/

Siemens Healthineers. (n.d.). https://www.siemens-healthineers.com/

Smith, S. J., Farra, S., Ulrich, D. L., Hodgson, E., Nicely, S., & Matcham, W. (2016). Learning and retention using virtual reality in a decontamination simulation. Nursing education perspectives, 37(4), 210-214.

Steenbakkers, L. M. P. (2021). Proving competence whilst improving competence: How Field Service Engineers can be qualified within Structured On the Job Training (Master's thesis, University of Twente).

Tai, W. T. (2006). Effects of training framing, general self-efficacy and training motivation on trainees' training effectiveness. Personnel review.

Tamkin, P., Yarnall, J., & Kerrin, M. (2002). Kirkpatrick and Beyond: A review of models of training evaluation. Brighton, England: Institute for Employment Studies.

Tamplin, T. B. (2022, December 14). What is Moore's Law? Finance Strategists. https://learn.financestrategists.com/finance-terms/moores-law/

Techopedia. (2021, May 28). Wafer. Techopedia.com. https://www.techopedia.com/definition/2326/wafer-electronics

Theeuwen, M. (2017, December 11). Eerste "fabriekje" van de toekomst in Eindhoven loopt vol met high tech-makers. ed.nl. https://www.ed.nl/eindhoven/eerste-fabriekje-van-de-toekomst-in-eindhoven-loopt-vol-met-high-tech-makers~ab1dfd79/

Thermo Fisher Scientific. (n.d.). https://www.thermofisher.com/nl/en/home.html

TU Delft. (n.d.-a). MSc Design for Interaction. https://www.tudelft.nl/onderwijs/opleidingen/masters/dfi/msc-design-for-interaction/

TU Delft. (n.d.-b). MSc Integrated Product Design. https://www.tudelft.nl/io/studeren/masteropleidingen/msc-integrated-product-design

UXPlained. (2019, March 28). What is the DOUBLE DIAMOND? [Video]. YouTube. https://www.youtube.com/watch?v=JGETnwgkV5U

Van Boeijen, A.G.C., Daalhuizen, J.J, & Zijlstra, J.J.M. (2020). Delft Design Guide: Perspectives-Models-Approaches-Methods. Amsterdam: BISPublishers.

Vasanthi, S., & Basariya, S. R. (2019). On the job training implementation and its benefits. International Journal of Research and Analytical Reviews (IJRAR), 6(1), 210-15.

Voith. (n.d.). https://voith.com/corp-en/index.html

Appendices

Appendix A1: List of requirements (1)

Number	WWWWWH clustering (if applied)	Requirement	Initiative of			
			Company	User	TU Delft	Graduate
1.		The MVP should integrate the possibility to plan in High-NA Theory & Hands-on trainings	The initial graduation assignment		The initial graduation assignment	The initial graduation assignment
2		The planning tool should show the SA/SMS/CARS dependencies	The initial graduation assignment and company problem definition			
3		The add-on resulting from the research should link to the planning tool				Graduate: One complete design proposal
4		The tool is intuitive in use according to users by testing the interactive prototype				Value for users and encountering an UCD approach
5	What	In the tool the engineer can see the amount of learning methods that can be booked for at least the coming at least 2 days	According to business stakeholders			
6	What	In an ideal way of training, the tool will show the list of trainings available on competency		According to the users during co-creation session		

7	Why	In an ideal way of training, the trainee can see which slots are open		According to the users during co-creation session		
8	Why	In the tool the engineer can see why this learning method should be done at this moment by showing the criteria and must-completion modules of the training program	According to business stakeholders	According to the users during co-creation session		
9	When	In the tool the engineer can see the time, timeframe, and date of each possible learning method	According to business stakeholders	According to the users during co-creation session		
10	Where	In the tool the engineer can see the location of the chosen learning method	According to business stakeholders	According to the users during co-creation session		
11	Who	When looking at the features, the tool should show the trainer/instructor of the chosen module		According to the users during co-creation session		
12	Who	In the tool the engineer can see who they can ask help in case of any questions problems; 1st trainee who has completed this, 2nd line engineer of TC, 3rd trainer/coach.	According to business stakeholders			
13	How	In an ideal way of training, the training tool shows the prerequisites for each competency/curriculum and gives access to preparation materials such as videos/pdf/ppt/etc.	According to business stakeholders	According to the users during co-creation session		
14	How	When looking at the features, the tool should be guiding by giving the timeframe of completing the training program and its corresponding modules		According to the users during co-creation session		
15	How	When considering the layout of the planning tool, it should focus on weekly schedules with the possibility to book training slots		According to the users during co-creation session		
16		For the first prototype of the tool, it will be accessed only by computer	According to business stakeholders			Accessibility for all users
17		The subjects of the specific SA/SMS/CARS should be given in the training slots	According to company mentor after usability testing (1)	According to the users after usability testing (1)		
18		The type of training when looking at individual, paired and group context should be provided	According to company mentor after usability testing (1)	According to the users after usability testing (1)		
19		Emphasize the focus on CARS scenarios for phase 1 of the planning guidance, which is followed by a focus on SA's in phase 2	According to company mentor after usability testing (1)			
20		Use suitable colors in the planning guidance to show completion of SA/SMS/CARS	According to company mentor after usability testing (1)	According to the users after usability testing (1)		
21		The tool is in the ASML branding style and meets the guidelines	According to UX designers of company			
22		The HW/VR/SW/TH training slots are represented in grey tones for accessibility of color blind users				Accessibility for all users
23		The training planning tool shows the fully booked slots, and a notification can be requested when there is a cancellation	Result from alignment meetings with business stakeholders	According to a user during usability testing (1)		

Appendix A2: List of context & system requirements (2)

Number	Requirement	Initiative of			
		Company	User	TU Delft	Graduate
24	A scenario of 30 engineers, 5 trainers and one HW-rigg will be taken into account to create an initial planning	Context variables stated by company			
25	A planning will be created for the BODY curriculum				Determined by student when considering project timeframe
26	For a TH training there can be max 10 persons, for a HW around 4, for VR around 3, and for SW around 10	Context variables stated by company			
27	Prioritize CARS scenarios first in the schedule, and after that the SA'/SMS', of which the sequence doesn't matter (Related to requirement 19)	Context variables stated by company			
28	The TC consists of 3 HW-riggs, 5 VR rooms, 1 SW room, 3 TH rooms and 1 preparation room	Context variables stated by company			
29	Since an ideal timeframe of hands-on trainings is 90-minutes, breaks should be taken every 90-minutes, if a HW training requires longer than that				UCD approach and study by Mahmood et al. (2022)

Appendix B1: Project brief of kick-off meeting

TU Delft

Personal Project Brief - IDE Master Graduation

Optimize Efficiency & Effectiveness of Training in ASML's TC — project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 12 - 09 - 2022 — 10 - 02 - 2023 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

ASML is starting up a new training-center (TC) for its newest system platform. A new way of working will be introduced, using Theory/Hardware/Software/Virtual Reality activities to transfer skills to engineers. A specific curriculum (CS-Maintenance Fab-Ready Delta) consists of several stepts; Service Actions (SA). Each SA consists of SMS's (System Machine States). An practical example of an SA is for example changing a car's tire, where an SMS would be all the individual steps. Such as lift the vehicle of the ground, remove the lug nutts, take the tire off etc. The total duration to complete the curriculum, with a total of 350 SA's and 805 unique SMS's, is nine weeks (all competencies). Demand for training slots is very high, there is an average of sixty engineers with various roles per Quarter from 2023 onwards.

A future vision of ASML's TC is the following: The future training center will have 'open doors' for the selected engineers who want to develop themselves and follow certain trainings. They can book the slots they want, and can see which trainers are in the training center available that day. Trainers consist of qualified coached by ASML, and fellow engineers who have experience with the selected training. A qualified coach by ASML doesn't stick to one training for an hour, but walks around in the training center to help multiple engineers in slots. When an engineer needs help, and a coach is not around, he/she can also select an engineer who is located in the training center at that moment, who has done the same training previously. The future TC will be a vibrant and inspiring environment, where flexibility and learning by doing, will play a huge role.

When looking at the context and future vision formulated by the company from a critical point of view as an Industrial Designer, four main research topics were formulated:
- The assignment is about creating a redesign of the current training module, which means I should investigate the TC s current way of working.
- I want to compare training modules of other technology-based companies to ASML s, to see where they are doing good and where they can improve.
- ASML mentions their future vision of a training center, but I want to go beyond that and look at predictions of future training trends.
- Last, I want to find out how to give the most effective training, and compare this to their current one.

Stakeholders in this project will be the following;
- Training Center (BIC); This will be the context of the design.
- Engineers (1st line/2nd line/Install/GSC with NXE-FR/DUV/New Hire experiences); They will use the design that I will create. Interviews will be done to find out their needs, expectations and current pain points.
- Qualified trainers; they will use the design that I will create. Interviews will be done to find out their needs, , expectations and current pain points.
- Customer/mentor Henri Jaspers; He will assess the design and findings during the graduation process
- TU Delft (mentor/chair); They will assess the design and findings during the graduation process.
- Software team; They will continue on working on the design proposal, and possibly help me inbetween.

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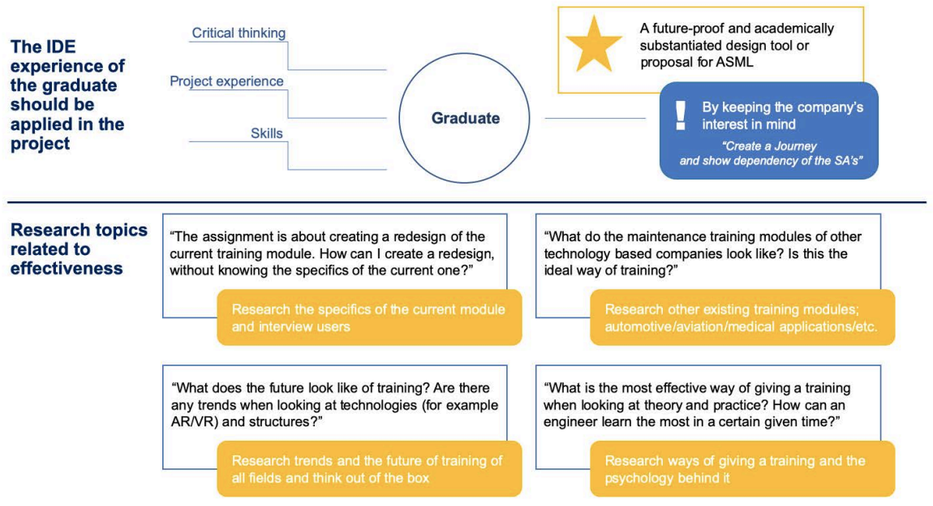


image / figure 1: Input and output of graduate; research topics

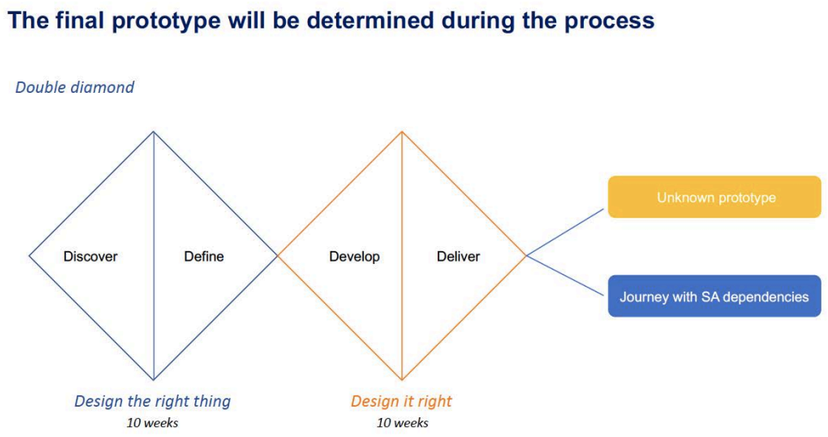


image / figure 2: Double diamond as driver for the graduation project

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

ASML's current way of training doesn't correspond to the innovative company they are. The TC is a static environment, where a certain amount of flexibility, personalisation and smart planning is missing. When looking at flexibility and personalisation, all engineers currently follow the same training program. This should be changed into a situation, where the engineer can pick when, where and with who they want to do a certain part of their training, and create his or her 'own tailor made journey' . When looking at smart planning, one of the issues is that for the current training module all SMS's of a part of the training have to be followed, even though some steps are repeated for each SA. This means the dependency of these SMS's is currently missing, and should be created to make the training more efficient.

All the above is the problem definition according to the company. When having a look at this, I was wondering if currently a 'tunnel vision' is applied for this. Therefore, I want to extend the research to come up with the best solution for this problem definition, and even go beyond it with a new future proof design proposal, by using my IPD skills to answer the following subquestions:

1. What is the most effective way of giving a training when looking at theory and practice?
2. "What does the future look like of training, while also taking technologies (AR/VR/etc.) into account?
3. What do the maintenance training modules of other technology-based companies look like, and is their current module the ideal way of training?
4. What are the specifics of current way of working in the TC and their current training module?

This results in the following general problem statement: "How to Optimize Efficiency and Effectiveness of Training for different engineers in the TC?".

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

The coming 20 weeks I will research what is the most efficient way of giving trainings, besides the needs and pain points of the engineers and trainers in the TC. Based on this initial research, I will come up with a design proposal, which I will be turned into a MVP by creating a yet unknown and research depended prototype, besides the design proposal for the tailor made journey and SA dependencies.

For the graduation assignment, I aim to deliver a mock-up of the company's interest; a tailor made journey with SA dependencies. It should be a MVP, with basic functions. Besides that, I want to use the IPD perspective, by having also a focus on the prototyping phase. Here I want to come up with a yet uknown prototype, that will be the outcome of my research proposal of the 4 topics, besides the prototype of the main interest of the company;

1. Research ways of giving a training and the psychology behind it
2. Research trends and the future of training of all fields and think out of the box
3. Research other existing training modules; automotive/aviation/medical applications/etc.
4. Research the specifics of the current module and interview users

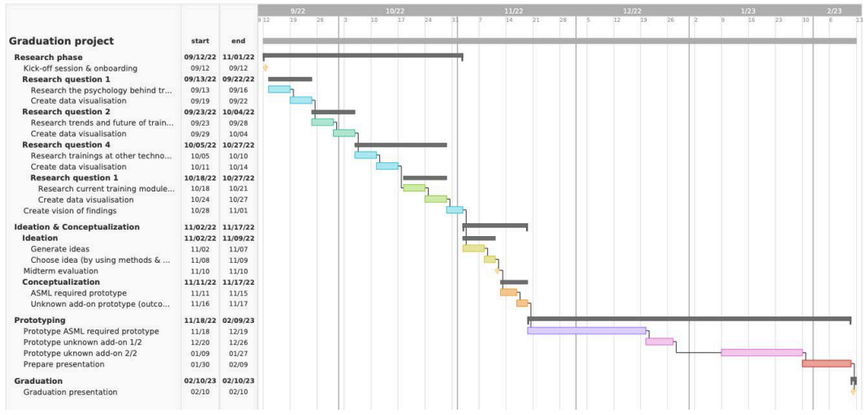
During researching these topics, I will focus on the factor effectiveness. Data visualisations will be created, using variables related to this, to make an impact of the research and to substantiate a vision. When looking at training and education, a lot of variables are available to measure effectiveness. Examples of variables are time to complete a training, time to complete a SA after a training, the amount of SA's completed in a x amount of time (Productivity), Confidence and Transfer. However, it's likely that during the research other impactful variables will be found.

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 12 - 9 - 2022

10 - 2 - 2023 end date



Graduation project	start	end
Research phase	09/12/22	11/01/22
Kick-off session & onboarding	09/12	09/12
Research question 1	09/13/22	09/22/22
Research the psychology behind tr...	09/13	09/16
Create data visualisation	09/19	09/22
Research question 2	09/23/22	10/04/22
Research trends and future of train...	09/23	09/28
Create data visualisation	09/29	10/04
Research question 4	10/05/22	10/27/22
Research trainings at other techno...	10/05	10/10
Create data visualisation	10/11	10/14
Research question 1	10/18/22	10/27/22
Research current training module...	10/18	10/21
Create data visualisation	10/24	10/27
Create vision of findings	10/28	11/01
Ideation & Conceptualization	11/02/22	11/17/22
Ideation	11/02/22	11/09/22
Generate ideas	11/02	11/07
Choose idea (by using methods & ...	11/08	11/09
Midterm evaluation	11/10	11/10
Conceptualization	11/11/22	11/17/22
ASML required prototype	11/11	11/15
Unknown add-on prototype (outco...	11/16	11/17
Prototyping	11/18/22	02/09/23
Prototype ASML required prototype	11/18	12/19
Prototype unknown add-on 1/2	12/20	12/26
Prototype uknown add-on 2/2	01/09	01/27
Prepare presentation	01/30	02/09
Graduation	02/10/23	02/10/23
Graduation presentation	02/10	02/10

On the top the Gantt Chart of my graduation period is visualized from 09/12/22 to 02/10/23 (20 weeks). The project is divided in 4 phases; research, ideation & conceptualization, prototyping ASML's interest and prototyping outcome research. The first 10 weeks will be spent on research, ideation and conceptualization. The last 10 weeks will be spent on making the prototype (MVP). During the graduation period, I will have a 2-weeks holiday for Christmas.

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

The past half-year I did an internship at ASML, which was focused on researching user experience in several departments by creating a Customer Journey Map. I find the company and its complexity very interesting, which has resulted in me wanting to graduate here as well and to explore other departments. During my internship I've approached several departments about graduation possibilities, and I've chosen the one I found most interesting; creating a new module for the training of ASML's newest machine.

During this project, I will have 3 learning goals.

1. Learn more about ASML's machines by investigating its current training module
I want to learn more about the company and their interesting technology. Besides that, it's needed to have a complete understanding of the company and the current training module, to create a redesign that can be used in their future TC.

2. Improve my critical skills and apply them to challenge ASML's current views on training, if needed
I want to offer the company a critical view on findings during the project, to make the outcome valuable and realistic.

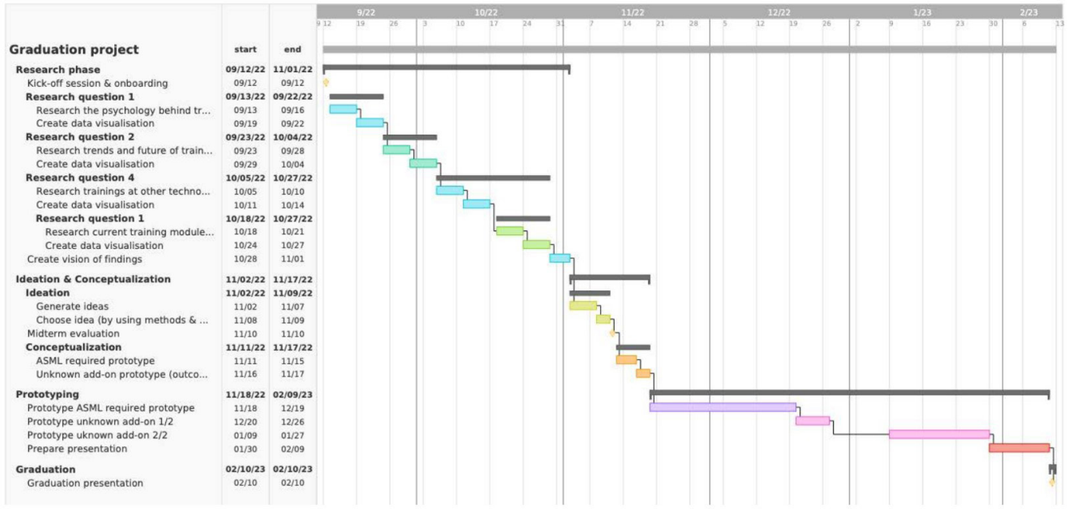
3. Improve my data visualisation skills
I want to make an impact with my research phase by focussing on data visualisation. These visuals can be used throughout the process to substantiate the prototype.

FINAL COMMENTS

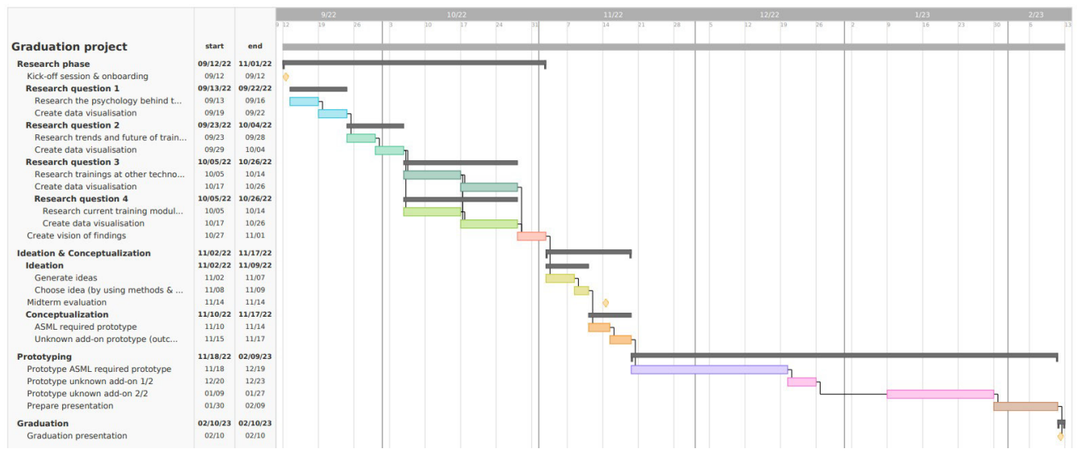
In case your project brief needs final comments, please add any information you think is relevant.

Appendix B2: Evolution of Gantt charts

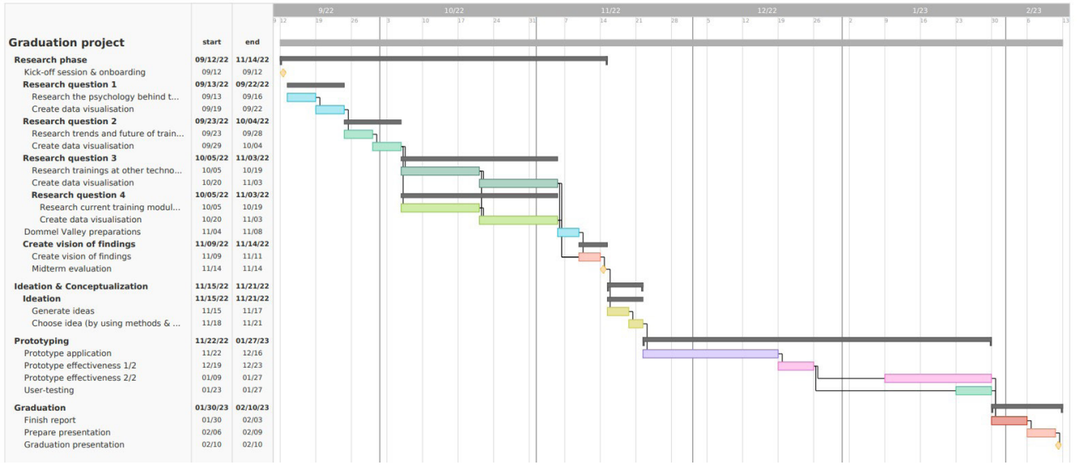
Initial Gantt Chart of kick-off, encountering the following phases: research, ideation, conceptualization and prototyping. All are typical design phases when looking at methodologies applied for the faculty of Industrial Design Engineering (IDE) at TU Delft.



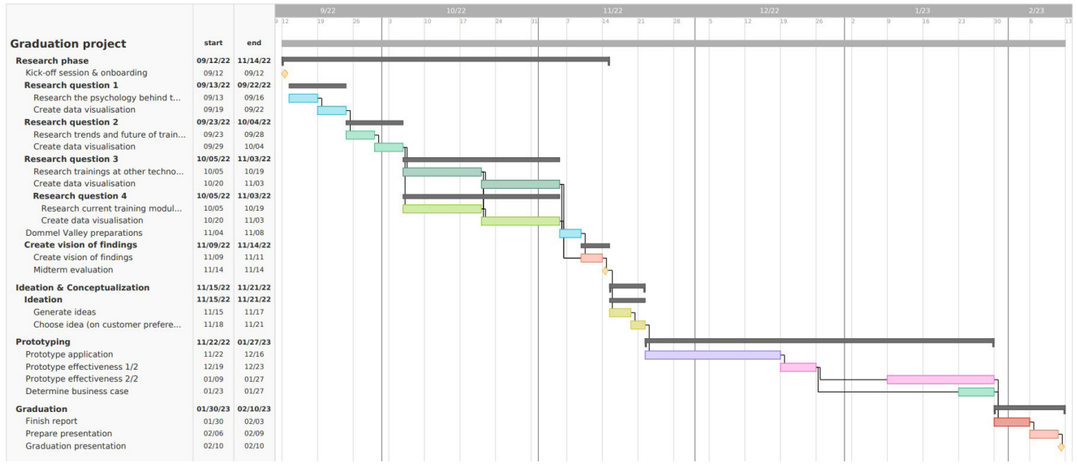
Update after first progress meeting, since the timeframe of RQ3 and RQ4 took longer than expected. This was mainly because of the analyses, and dependency on the availability of participants. Because of that, both researches found place simultaneously.



Update after midterm meeting, since conceptualization might be not entirely necessary when looking at the applied prototyping method; gather requirements, create wireframes, create design composites and integrate a scenario as an effective system. The conceptualization is seen as redundant, and therefore I had chosen to continue directly with the prototyping phase, also since the company requested to create a training planning tool.



Update after second progress meeting, since usability testing is done during the prototyping process, this single focus point can be deleted at the end of the prototyping phase. Instead of this, the business benefits will be determined, to emphasize the value of the design for the company.

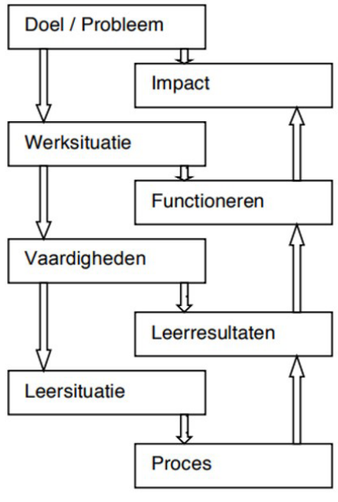


Appendix C: Kirkpatrick's evaluation tool

Extensive explanation of Kirkpatrick's evaluation tool levels according to NDSU (n.d.)

Evaluation level	Description and characteristics	Example questions	Examples of evaluation tools and methods
1. Reaction	Reaction evaluation is about the feelings of the delegates during the training, and their personal reactions to the training program or learning experience	Did the trainees like and enjoy the training? Did they consider the training relevant and engaging? Was the training a comfortable experience?	- Feedback forms based on personal response to the training experience - Analyze and note verbal reaction - Post-training surveys or questionnaires ('happy sheets')
2. Learning	Learning evaluation can be measured by the increase in knowledge or intellectual capability from before to after completing the training program	Did the trainees learn what was intended to be taught? Did the trainee gain the skills and attitude that is necessary to start the job? Does the trainee now have the required level of confidence and commitment to do the job?	- Typically assessments or tests before and after the training - Methods of assessment need to be closely related to the learning aims - Both online and F2F assessment interview assessments are possible
3. Behavior	Behavior evaluation is the extent to which the trainees applied the learning after an x period of time and whether it changed their behavior	Did the trainees put their learning into effect when back on the job? Were the relevant skills and knowledge used? Was there noticeable and measurable change in the activity and performance of the trainees when back in their roles? Would the trainee be able to transfer their learning to another person?	- Observation and interview (physical) over time are required to assess change, and its relevance - Snapshot assessments are not reliable because people change constantly - Assessments need to be subtle and ongoing, and then transferred to a suitable analysis tool
4. Results	Results evaluation is the effect on the business or environment resulting from the performance of the trainee by looking at organizational KPI's – the ultimate test	What are the effects on volumes, values, percentages, timescales, ROI, and other quantifiable aspects of organizational performance (for instance; turnover – quality ratings – attrition – failures – numbers of complaints – non-compliance – achievement – wastage – growth – retention, etc.)	- The challenge is to identify the relation between a certain input of a trainee and KPI - Good management practice is needed for this process – only linking to training input is necessary - Failure to link change in KPI to training input type and timing, will reduce the ease to adapt the training

Both methods of using Kirkpatrick's model, evaluation and creation of a training program, are combined by Kessels, Smit, & Keursten (1996) into the eight fields model. This is the model used by ASML to evaluate, and to design trainings. From top to bottom covers the training creation, from bottom to top coverts training evaluation.



Appendix D1: Additional elaboration on trends

Cybernetic maintenance-related decision processes
According to Schomaker et al. (2019), the amount of logged in decision processing data when looking at knowledge management is quite impressive. During maintenance actions, this data can be used to make certain decisions, since human-to-human interaction when selecting the correct data can sometimes be time consuming. At this point, it is not needed to only rely on cyber-physical systems, but a reduction in human labor and improvement in the quality and time of decisions can be beneficial in the maintenance field (Schomaker et al., 2019).

Real-time machine communication
During condition maintenance, several signals occur, some specific to normal operation and others related to maintenance requirements. For several errors, a deadline for reporting the issue is specified. Real-time operating systems in combination with an analysis tool can be beneficial to identify the issue in a short time-frame. However, having real-time operating systems is the easy task, and connecting it to a data-analysis tool is the difficult point (Schomaker et al., 2019).

Learning through videos
The way of learning has also evolved during the last three decades, where someone would first put a CD-ROM in a computer to watch a video on a certain topic, nowadays everything can be watched through YouTube. Video training is currently a well-used medium, and offers trainers a free platform to share their thoughts and methods. However, with YouTube content management is getting more and more important (Maity, 2019). Sharing company specific information on a platform, such as YouTube, can be a great threat to companies (Seidenberg, 2009).

Virtual maintenance
According to Rao et al. (2017), virtual maintenance is the evolution of maintainability, where you would maintain a system from a distance in a virtual environment. It improves the accuracy of a maintenance action, by creating a virtual assembly environment, and is widely used in aerospace, automobile and military fields. It will be challenging to keep up with these virtual environments, and making sure real-time machine data is up to date.

Design for maintainability
Transformations in a system are time-consuming and expensive, but can be efficient when a certain machine is build for maintenance. If one maintenance action, for example swapping a certain tube, takes 5 minutes, a domino effect can occur. However, if other actions can be done in around the same amount of time, the total process is more efficient and better to manage. This all can be done by selecting the proper granularity in the management of parts (Schomaker et al., 2019).

Data driven pragmatics
Human analysis of modelling maintenance processes by using interpretable models (white

boxing), is time-consuming. Besides that, it is not always necessary for a company to understand all the details and causes of a certain relationship. New machine-learning tools can analyze certain mappings in an accurate and reliable way, focusing on economic yield and not scientific understanding. However, investing in human-based research can be beneficial for understanding important costly maintenance issues (Schomaker et al., 2019).

Service robotics
There is need for expedience, programming and man-machine collaboration in a working place. Industrial robotics are often used in these environments, while they're still mechatronics based, but difficult to program and expensive when looking at costs. Robotics can be a solution in maintenance for diversed application areas in maintenance, such as occasional removal of dirt and providing oil; routine tasks. However, human operators still are of great value to solve unknown or problematical issues, and replace complex parts in certain procedures (Schomaker et al., 2019).

SIP method
According to a research of Maity (2019), the future of training can be displayed through a SIP model; Seamless, Intuitive and Personalized. Seamless has to do with knowledge management, and making sure there is a suitable platform that everyone can access. Intuitive indicates the shift from classrooms to mobile application where physical attendance of the trainer is not necessary. Personalized indicated training programs that are specifically designed for each individual, where AI has potential to identify suitable trainers, the learning program, a location and modules.

Appendix D2: Reasoning trends clustering

1. Training phase

2. Category (Technology, Learning methods, Maintenance)
- Technology: AI, VR, AR.
- Learning methods: SIP, Workplace communities, Personalized learning, Optimize learning, Design for workforce diversity, Micro-learning and byte-sized modules, Learning through videos, Learning through real-time feedback.
- Maintenance: Virtual maintenance, Design for maintainability, Service robotics, Data driven pragmatics, cybernetic decisions.

3. Motivation (Autonomy, Master, Purpose)
- AI; Autonomy, Mastery and Purpose. Offer personalized trainings programs by having input of trainee, giving additional information whenever to improve knowledge. Measuring performance, indicating that someone did a good job (human look-a-like).
- VR; Mastery. Tool to become better at something.
- AR; Mastery. Tool to become better at something.
- SIP; Autonomy. Intuitive, seamless and personalized training program.
- Workplace communities; Autonomy, Mastery & purpose. Engineer is in charge of posts, likes etc. Engineer is able to exchange knowledge with fellow engineers. Engineer feels like he/she belongs to a large community.
- Personalized learning; autonomy, Purpose. Autonomy because someone is in charge of their learning journey. Purpose because someone can feel special that a specialized plan is made.
- Optimize learning; mastery; investigating methods to become more experienced and better in your job
- Design for workforce diversity; purpose, a designed training program, taking everyone's needs into account
- Virtual maintenance; Mastery. Gaining more experience.
- Micro-learning and byte-sized modules; Mastery. Gaining more experience, just in another way.
- Learning through videos; mastery. Gaining more experience.
- Learning through real-time feedback; Mastery and Purpose. Gaining experience, but also feeling that they belong once they are in contact with an other engineer and they're helping out.
- Design for maintainability; Mastery and Purpose. When the machine is designed well, the engineer can work better and more efficient on it, meaning more time to gain more skills. The product is designed in an efficient way, making sure the engineer can work efficiently and well.
- Service robotics; Mastery. By having service robots who take over routine tasks, engineers have more time to master the more difficult tasks.
- Data driven pragmatics; Mastery. Mainly mastery of machine but because the machine can create certain models, an engineer can use it as input for learning or to work further on and avoid unnecessary spending of time on calculations.

- Cybernetic decisions; Mastery. Retrieves data and makes certain automatic decisions. Possibility for engineer to look into data and learn.

4. Statistics of companies; this one is seen as the most important cluster. You can see on which trends the companies intend to focus, and on which ones they don't. See Appendix E2 on the transcripts of the interviews.

Appendix E1: Company interview script

Training optimization brief for technology-based company

RQ: What does the technology-based company contribute to all phases and what is their future vision on training?

Introduction

- Introduce yourself: My name is Eline and I am a master student Integrated Product Design at TU Delft. For the next five months I will be working on a graduation project about training and its optimization at ASML.
- Explain the goal of the meeting and the benefit for the company: Understand the current way of training at other technology-based companies, their training developments and their future view on training. If you are interested, findings and conclusions of the research can be shared.
- Clarify the amount of time: 60 minutes.
- Make sure the conversation is either recorded, or notes are made: Can this conversation be recorded?

Initial questions

1. Can you briefly explain your role and main responsibilities?
2. Can you give an indication on the amount of trainees per year at your company?
3. How do you envision training and development practices in your organization to evolve in the next years?

Pre-training phase

With the pre-training phase, the initial state before the training starts is meant. It includes positive training framing, selecting trainees, prerequisites, preparing the training etc.

4. Can you tell me what the pre-training phase at your company currently looks like?
5. Can you tell me about your current pre-training developments?

Training phase

With the training phase, the actual training period is meant, with a focus on the confidence and motivation level of the trainee.

6. Can you tell me about the methods you use during training programs? (Ratio Hands-On/Theory/Cases)
7. Can you tell me about the technologies you use during training programs? (AR/VR/AI etc.)
8. What has been the shift in the behavior of trainees toward your training programs?
9. Could you elaborate on measuring performance outcomes during training programs?
10. How do you boost the confidence and motivation of a trainee during training programs?
11. What is the major drawback in your existing training and development model?
12. Can you tell me about your current training developments?

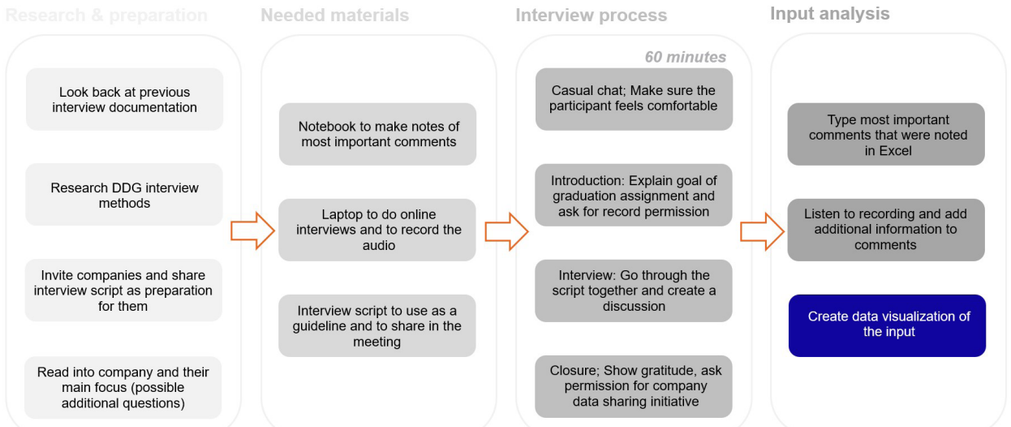
Post-training phase

With the post-training phase, the start of the employee's job is meant, with a focus on keeping a certain level of confidence and motivation throughout the tasks.

13. Can you elaborate on whether there is guidance of the employee when they are starting their job?
14. How do you boost the confidence and motivation of an employee during their job?
15. Could you elaborate on whether you measure the effectiveness and accuracy of the training once the employee has started working?
16. What does your company contribute in terms of continuing the learning journey of the employee during their job?
17. Can you tell me about your current post-training developments?

18. Can I share your answers anonymously with the other companies (7) in a complete overview? If yes, we can grant you access to the answers of these other companies as well.

A structural process was set-up to improve the quality of the company interviews



Appendix E2: Transcript of company interviews

					Pre-training		Training				Post-training					
	Role of interviewee	*How many trainees do you have per year?*	*What is your future vision on training?*	*What does your pre-training phase look like?*	*Can you tell me about your current pre-training developments?*	*Can you tell me about the methods you use during training programs? (Ratio Hands-On/Theory/Cases)*	*Can you tell me about the technologies you use during training programs? (AR/VR/AI etc.)*	*What has been the shift in behavior of trainees?*	*Could you elaborate on measuring performance outcomes during training programs?*	*How do you boost the confidence and motivation of a trainee during training programs?*	*What are the main drawbacks of your current training method?*	*Can you tell me about your current training developments?*	*Can you elaborate on whether there is guidance of the employee when they are starting their job?*	*How do you boost the confidence and motivation of an employee during their job?*	*Could you elaborate on whether you measure the effectiveness and accuracy of the training once the employee has started working?*	*What does your company contribute in terms of continuing the learning journey of the employee during their job?*	*Can you tell me about your current post-training developments?*	*Share answers and receive overview ?*
General conclusion		Between 250 and 30000 per year	Make use of technologies (AR/VR) On-the-job learning Focus on skills Design trainings for the new generation	Depended on training all kind of methods For all prerequisites are necessary; online	Central onboarding and virtual learning processes (which you can look back later...) (Philips/MinDef)	Mix between Hands-On/Theory/Cases (some leave theory completely out) (percentages?) Video learning/micro-learning	Almost all of them use VR; AR is sometimes too cost intensive Voith uses pneumatic tool or a small part of the machine for the tactile part	F2F to Online Individual to group learning movement	Feedback of managers; performance outcomes aren't taken well by trainees Focus on personal development/confidence during feedback	Personal development stimulation Gamification and visual elements in training On-the-job learning	No full utilization of data Train the trainer	Use data of trainings to measure effectiveness AR/VR use AI use for personal training recommendations and knowledge base Training communities	Guidance process of expert; which is mostly depended on the company/team they come in afterwards More performance support is for some of them under development	Some companies; mention it's depended on the coach or the personality of the engineer Other say they stimulate it by offering additional trainings Confidence/motivation depends on application in the field	Some companies already use Kirkpatrick's level 3 to evaluate; but for some of them it's under development 2/7 find measuring effectiveness of a training difficult and do not do it	For all of the companies the engineer is not free to choose his/her personal development path, except for KLM there are some possibilities For some companies they make the engineers aware of their skills (skill passport) Doing additional trainings is in accordance with manager and training availability; individual is not completely free to choose Engineer is responsible for own personal development; they offer trainings, but there is no guarantee they can be followed We offer the engineers the possibility to find experienced colleagues from who they can learn in the Offering a catalogue with all training offers Budget for trainee's personal development Organized personal development activities, but this differs per department	Improve the possibility to do additional trainings Use data to analyze trainings Create a network for communication and documentation between engineers More focus on guidance regarding personal development of engineer	
Company 1	Manager learning innovation	Approximately 1000	Optimization of online training and remote operation of machine Use of AR/VR technology cases during the job A main focus on skill development	Prerequisites for a training are depended on the skills employees have in the skill passport They offer e-learning modules in advance Participants have contact with trainer; to introduce as much learning materials as possible in advance		Focus on skill development through skill passport They mainly make use of on-the-job learning It consists of video learning through their private 'youtube' platform Theory will be offered as pre-learning; main focus on hands-on with some additional theory	AR/VR use Hardware & Software simulations Animations Webinars Pdf/Powerpoints	F2F to Online Acceptance of online learning methods	They don't focus on performance, but on the confidence of the engineer by integrating the skills passport During the training there are some assessments where the trainee should work on	Focus on personal development; they offer a skill passport to the engineers, where they can indicate the level of confidence for a certain skill (use is depended on demographics) Trainees are in charge of the skills they want to improve		AR/VR/AI (immersive technologies) use is under development Change management of skill passport (still an ongoing development since 2018) AI training recommendations based on assessments in the skill passport	They do not have not a lot influence on the employees when they start their job, this is team or company dependent	How to boost confidence/motivation is depended on the demographics Confidence & motivation decreases after not using the training in the field, so they make sure the employee immediately applies the gained knowledge in practice		Improve the possibility to do additional trainings During an employee's daily work Setting up a mentoring program	Yes
Company 2	Expert in learning, training and future developments	Approximately 10000	Informal on-the-job learning AR/VR technology cases during the training VR to make formal moments of learning more efficient (difficult to maintain the digital environment) Video learning and giving the possibility to trainee's to choose on options	They have a catalogue of all possible trainings Employee's can request trainings themselves or through their managers Accessibility of digital learning environment before training or they will receive an assignment of the trainer before the training	Customized recommendations for trainings	Blend of theory/hands-on/CBL and environment (simulations/classroom etc.); all depended on training Online and F2F trainings, for which the engineer can choose Focus on dilemma's, since they are powerful learning methods, by focussing on the risks and consequences of certain choices	They have an XR department who focusses on VR for all applications (not only training) They are applying VR more and more for small parts, but not completely simulated environments since the costs are too high They have experimented with AR for one project, but the costs are too high and it has no optimal workability; AR is suitable for operational functions but it has some technical complexity	F2F to Online Listening to podcasts as a learning method	No conversations with managers based on performance indicators, but focus on personal development	Communicate goals & expectations of training really clear Offer a training in accordance with the personal need of the employee, not because of KLM's preference Add gaming element and use visual aspects (video's for example) during training	No full utilization of VR/AR No full utilization of data	Use of podcasts/webinars Use data of trainings to analyze the effectiveness Skill management development regarding a skillspasport and using AI to match employee's to trainings, or to give them the opportunity to match a training with the skill(s) they want to improve Taxonomy (global?) developments regarding skills	Depends on project and target audience Give assignment where they have to work on in the field Involvement of manager and team during reflection moment	Encouraging personal development See question on learning journey	Evaluation of training Measure final performances Kirkpatrick level 3 evaluation after 3 months; and investigate these results (optional) Measuring Level 4 sometimes happens when in accordance with management	Use data to analyze training and performances for the improvement of training modules Create an intuitive learning platform for employees, by using AI for searching trainings More performance support on the working place is under development (mentor/mentee)	Yes
Company 3	Educational specialist and head of the expertise center	Approximately 3000	Personalization of courses but also in planning (AI) Online/digital trainings Retrieve more data	Intern switching jobs; or new hire Extern measurements (government) play a role	A more clear and tailored onboarding process (app)	Method 4CID model; train with the task as main driver Hands-On, give context and start (no Theory)	They have a lot of simulators and make use of this to test scenarios in certain environments They use VR to do exercises in a hall; every trainee wears a suit	VR interest F2F to Online	Trainee's receive feedback of mentor, and from other trainees They receive feedback regarding to progress of the training plan Evaluation in group of trainees; analyzing certain situations	Ryan & Dacy self determination theory Share experiences Give them the opportunity to think for themselves first Give feedback Show respect for eachother	To find a correct balance between motivating, but not overpressuring the trainee's or making them feel uncomfortable	Personalize traject & receive recommendations (AI) Measure experience/performance from simulator data in the field Find the correct balance of the previous question	First year they have guidance from a coach/supervisor	Guidance of the coach/supervisor Depended on coach/supervisor who is responsible for that Not one standard method	We use evaluation level 3 of Kirkpatrick for training improvements (after 3 and 6 months)	When employee changes job in the company When a certain training has expired (currency qualification); after x years you have to refresh the training Overview of skills specific for employee accessible in platform and available for management (not for other trainees) Focus on personal development is not in place yet; but in the portal an employee can find and request a training Evaluation and implementation of personal development in accordance with manager is still under development	Monitoring data in field and use this data to match trainings Connect data of the field to known skills Train and develop coach/supervisor	Yes
Company 4	Service education instructional designer	Approximately 10000/15000	There will be AR/VR challenges in the future, but it is difficult to keep track on these environments when looking at the speed the technology changes in the systems Mainly on-the-job learning by qualified colleague (who was a previous trainee), resulting in higher motivation levels Loss of people due to the problem that the company stopped hiring people, and the aging generation Challenge is to design trainings for a new generation (Gen Z/centennials); easy tendency to leave, less interest in money, digital & fast learning focused AR/VR developments Training communities developments	Depended on training type and training group Prerequisites are specific for each training	Making sure the trainee is compliant and the administration of this; which engineer has been trained for which system code Using automized systems with data for compliancy Pre-test to check skills of trainee, resulting in the possibility to skip certain training They are struggling with the training=job mismatch because of the managers; people can be pulled out of the training when there is manpower needed in the field Create optimal concepts regarding what training, at what level and at what time; future planning	They focus on Hands-On and reducing Theory Use virtual machines to train on IT related parts They do training by by looking at system codes, where each system code respresents a part (e.g. computer, keyboard, mouse and table in a certain situation) Determine method based on training topic E-learnings for basic education; training language and terms Classroom theory and cases training to deepen knowledge and solve problems Micro-learning implementation On-the-job learning, of which a disadvantage is that the quality is completely depended on the trainer, because it is a non-standardized approach	VR pilots are going on, but the 3D models currently only are available of the outside of the machine and not the inside AR to make the training more interactive and engaging	F2F to online, but trainees & trainer have sometimes difficulties with this Acceptance of Teams/Online learning methods	For some sectors performance indicators inbetween play a role, but in general they measured in the end of a training	The trainees are generally motivated to start working in groups and take intitiative on their own They want to create a KPI on confidence and consequently measure this in the future	Learning management system is not optimal at the moment, since they have introduced a new platform, resulting in some e-learnings being divided over the old and new one	Having one location for the system when looking at e-learnings and virtual trainings to give more structure to it	Market should put up guidance process Employee has no contact anymore with training center once the job starts	Depended on the type of person, they are generally motivated and eager to learn, and no boost is needed They invest to maintain confidence in the field, by for example making sure the engineers start immediately after a training	They only measure effectiveness at the end of a training, but not after 3 or 6 months at the customer	Create personal development evaluation with manager where the focus is on the engineer's personal development Implement level 3 of Kirkpatrick and improve evaluation	Yes
Company 5	Product manager, responsible for internal and external training	Approximately 250		Process to select trainees on educational background or university style acceptance; show portfolio of trainings and they can choose Prerequisites are based on 4 levels; 1 has no prerequisites, 2 has to prerequisites of level 1 and so on A knowledge test will be done before starting a training to conclude the level of the trainee Clear understanding of training mindset; training is a job, you have to go (and you will get paid)		Focus on skill development through skill passport They mainly make use of on-the-job learning It consists of video learning through their private 'youtube' platform Theory will be offered as pre-learning; main focus on hands-on with some additional theory	AR/VR use Hardware & Software simulations Animations Webinars Pdf/Powerpoints	F2F to Online Acceptance of online learning methods	Through e-learning it's possible to measure performance, by giving percentages after a test In a classroom it is more difficult to measure performance because it is less accepted by the young generation People learn best when they are willing to learn, and not being forced to learn; measuring performance can influence this	Personal development approach on participants by the managers; offering them the training in an inviting and motivating way Focus on the willingness of an individual to learn, which is in contrast to forcing a training on someone The amount of motivation and confidence is also depended on the company culture; confidence indicators would not work for us	Understanding culture of training; currently there is a 9 I do not have anything else to do, then I will do a training' mindset There are not enough subject matter expert's to give trainings, also not enough time and capacity Currently this their knowledge management is a phone/mind network; problem with this approach is that there is not documentation and information can be lost	Learning by communities, where they can comment and receive feedback of fellow trainees Creating a chatbot function for deepening the knowledge during training and assistance for solving problems Currently 50% of the trainings are available, we want to develop training paths further Develop/pilot new training methods; micro-learning, VR/AR, animations	There is a mentoring path/program that includes guidance for the first half year of an assigned experienced manager who helps you encounter problems (internally) At the customer sites there is no guidance, but mainly on-the-job training due to capacity (externally)	Main motivation is that they are getting paid well, and that they train the employee to be independent Motivation is depended on personality as well and how bad an employee wants to do this job	Measuring effectiveness of training is a strategic problem, because factors related to succesfulness can not be measured In e-learning/classrooms they measure if the knowledge was understood at that time	Some trainings (e.g. electronical) can be refreshed after an x period of time, if the employee requests Employee is not in charge of their personal development, because the manager decides (different mindset/cultural thing)	Create a community network where employees can share experiences or issues, and you can communicate with colleagues regarding training/work related topics (to also improve documentation) Train the trainer course to reduce to improve quality of on-the-job learning, and to prevent fear of approaching and communicating with customer	Yes
Company 6	Clinical education specialist	Approximately 150/200	Onsite to online trainings (70% Hands-On/30% remote Theory), which is a result of covid-19, even though the company does not prefer this type of training More investments in creating an optimal online training method of which the quality is equal to F2F	This is depended on educational background Create application plan (scheduled) for trainees Prerequisites that consist of e-learning modules; trainees have to fulfill these as close as possible to the start of training	They would like to improve the control of a trainer to choose the trainees, due to the fact that some are more suitable and motivated than others Possibility to check the individual's score of the e-learnings, since there are currently no tools to check their performance besides seeing that their opened	On-the-job learning of which 10% to 20% is theory and 90% to 80% is hands-on (Software/Cases) Integration of video learning; private channel where video's on trainings are uploaded	Since 3 months they use simulators to visualize situations, but they also use them to build protocols that first only could be build on the machine; benefit that all trainees can build the protocol, instead of all of them working on one machine Hololens (AR) to project 3D construction of the machine	F2F to online, of which is the challenge to optimize the concentration level of trainee (which is a factor 10 lower online than F2F) Shift is also depended on country; Netherlands is a small country so remote training is less obvious when travel time is under 2 hours	It depends, during classroom trainings they have done intake tests, but this scared the trainees During hands-on training they try to steer the trainees by feedback	Make sure the training material is manageable by sharing a right amount of knowledge, in the shortest time possible, in the most comfortable way Optimize the amount of data that is released on a trainee when looking at a certain amount of time Train in small training slots	Stories can change and knowledge can be lost per trainer of training the trainer Provide personalized training in a group, without it being at the expense of the pace of other individuals and the group process	Train the trainer (key users), by training them in a way they can transfer the knowledge as accurate as possible Hololens to train anatomy Optimally use simulators to provide personalized trainings to the trainees	For on-the-job learning the guidance is different since they immediately apply the knowledge Officially an evaluation takes place after 4 weeks; however, because of the amount of employees, this is hard to realize and it is only available on individual request	They offer a training portfolio with 23 trainings, which is differentiated to the employee during the post-training (follow-up) phase	They do not measure the accuracy of a training afterwards, due to the fact that they find the one who should assess is in the company; will you take someone out of the field when they do not comply? The trainings are handled with care and are personal, resulting in the assumption that the trainees will succeed in the field during on-the-job	Employees are not free to choose the trainings they would like to do when looking at personal development, they are assigned by the customer	The follow-up should be improved; the approach of the employees should take place consistently after 4 weeks (more performance support)	Yes
Next Learning	Next Learning Senior ImpleMentor		Future focus on the real purpose and effectiveness of training; learning at the moment when it is needed Main use of on-the-job learning method			Focus on hands-on/on-the-job learning methods No official theory trainings are given; these materials should be accessible during training & post-training According to research, after one month a trainee has remembered 6.4% of a theory training, since it only has value when you apply it immediately	Use e-learning/micro-learning/video learning as knowledge storage to access during hands-on/on-the-job learning for additional background information AR/VR should only be used when it has real benefits for the company (costs and effectiveness wise) AI can be a solution	Learning as effective as possible in the least amount of time Individual to group learning movement in training	No measuring of performance outcomes, but focus on confidence boost by on-the-job learning	Motivation is not necessary to boost once you have a suitable and intuitive on-the-job learning method and access to an additional knowledge storage Having a learning journey & planning related to personal development, will help to motivate Confidence will rise for on-the-job learning	Current drawback for a lot of companies is that they focus too much on a training structure, while on-the-job learning in combination with an additional knowledge base is the most efficient way of training Another issue is that companies often look at training from the company's view, and they should look at it through	AI to improve knowledge storage and to link certain data with eachother for knowledge and experience enrichment Communities of trainees per machine part where they can share and discuss issues and other related topics				Yes and share name as well

Appendix E3: Extensive visual of company interviews

Outcomes of training research at seven other companies

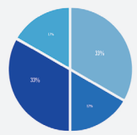
By Eline Muijters

What is your future vision on training?

- Full use of Virtual & Augmented Reality — 57%
- Mainly on-the-job learning — 43%
- Focus on personal development — 43%
- Optimization of online training — 43%
- Training communities — 29%
- Video learning or other micro-learnings — 29%
- Different training mindset of young generation — 14%
- Retrieve data of trainings — 14%

What is the amount of trainees you have per year?

- Less than 500
- Between 500 and 1000
- Between 1000 and 5000
- Between 5000 and 10000
- More than 10000



VOITH · SIEMENS Healthineers · Ministerie van Defensie · NEXT LEARNING VALLEY · ThermoFisher SCIENTIFIC · PHILIPS · KLM

01 — What are the **specifications** of the pre-training phase?

TRAINING FRAMING / SKILL SET

- Prerequisites depends on training type — 100%
- E-learning environment — 50%
- Access to catalogue with all trainings — 33%
- Training plan creation — 17%
- Training mindset alignment — 17%
- Extern regulations — 17%

Pre-training

02 — What are the current **developments** of the pre-training phase?

- Compliancy administration — 40%
- Clear and central onboarding app — 20%
- Personal training recommendations — 20%
- Knowledge test to skip training parts — 20%
- Optimization of training mindset — 20%
- Future planning of training — 20%

03 — What **methods** do you use during training programs?

LEARNING / UTILITY REACTIONS

- On the job learning — 57%
- Video learning or micro-learning — 57%
- Mainly hands-on — 43%
- Blend of theory/hands-on/cases — 43%
- Focus on dilemmas/cases — 14%
- Focus on skill development — 14%

05 — What has been the **shift in behavior** of trainees?

- Face-to-face to online attendance — 71%
- Change in generation of target audience — 29%
- Virtual Reality interest — 14%
- Individual to group learning — 14%
- Acceptance of podcast as learning method — 14%

07 — How do you boost the **motivation and confidence** during training?

CONFIDENCE / MOTIVATION / TRANSFER MOTIVATION

- Focus on personal development — 71%
- Dependent on personality/demographics — 29%
- Add gamification elements during training — 14%
- Communicate expectations clearly to trainee — 14%
- Optimize time and effectiveness of learning — 14%
- On-the-job learning — 14%

09 — What are the current **developments** of the training phase?

Training

04 — What **technologies** do you use during training programs?

LEARNING / UTILITY REACTIONS

- Virtual Reality — 83% — Of which in use 80% — Of which in pilot 20%
- Augmented Reality — 83% — Of which in use 40% — Of which in pilot 60%
- Simulations — 50% — Of which environments 33% — Of which Hardware or Software 67%
- Artificial Intelligence — 8%

06 — How do you **measure performance outcomes** during training?

LEARNING

- Not in way of working — 71% — Of which focus on confidence 60% — Of which focus on feedback in group context 40%
- In way of working — 29% — Of which during e-learning 50% — Of which at end of training 50%
- Classroom fast scares the trainees — 29%
- Less accepted by younger generation — 14%

08 — What are the **main drawbacks** of the current training program?

- Training mindset of company or trainees — 43%
- Train the trainer — 29%
- No full focus on training effectiveness — 14%
- No full utilization of VR/AR — 14%
- No full utilization of training data — 14%
- Training management — 14%

11 — How do you boost the **motivation and confidence** after training?

CONFIDENCE / MOTIVATION

- Encouraging personal development — 50%
- Dependent on personality/demographics — 33%
- Confidence decreases when knowledge is not immediately applied — 33%
- Dependent on mentor or supervisor — 17%
- Dependent on salary — 17%

13 — What do you contribute in terms of **continuing the learning journey**?

MOTIVATION / SKILL SET

Post-training

10 — Can you elaborate on whether there is **guidance** when the job starts?

CONFIDENCE

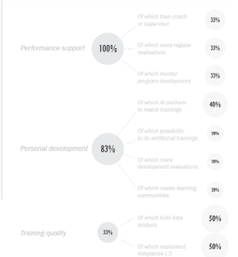
- Guidance from mentor or supervisor — 50%
- Responsibility of external company — 33%
- Evaluation sessions on request — 17%

12 — How do you **measure effectiveness** of a training afterwards?

SKILL SET

- Not in way of working — 60% — Of which use Kirkpatrick L3 after 3-6-9 months 50% — Of which use Kirkpatrick L3 after 3 months and L4 50%
- In way of working — 40% — Of which do not know how to 50% — Of which do it only immediately after training 50%

14 — What are the current **developments** of the post-training phase?



Appendix F1: ASML interview script

Training optimization brief for an engineer/trainer/knowledge manager

RQ: How did the trainee experience all three phases? (pre-training, training, post-training)

Introduction (5 min)

- Introduce yourself: My name is Eline and I am a master student Integrated Product Design at TU Delft. For the next six months I will be working on a graduation project about training and its optimization at ASML.
- Explain the goal of the interview: Understand the experience of the engineer of the pre-training/training/post-training phases, with a focus on the confidence and motivation level.
- Clarify the amount of time or the interview: 30 minutes.
- Create a safe space: This is a safe environment where you can share your opinion. This is an opportunity for you to generate positive impact in the way the High-NA training will be designed in the future. The input of this interview will be used for my master thesis, the research team at TU Delft and the KXI department at ASML, and there is no risk for sharing your data with us.
- Make sure the conversation is either recorded, or notes are made: Can this interview be recorded?

Initial questions (5 min)

1. Can you briefly explain your role?
2. What are your main responsibilities?
3. For how long do you already work at ASML?
4. What NXE training program did you complete last and when? (fabready-1, fabready-2 or advanced)

Pre-training phase (5 min)

With the pre-training phase, the initial state before the training starts is meant. It includes positive training framing, prerequisites, preparing for the training etc.

5. What are your needs and expectations during the pre-training phase when looking at framing and previous experience?
6. Can you think of any improvements for ASML's current process regarding this phase?

Training phase (7.5 min)

With the training phase, the actual training period is meant, with a focus on the confidence and motivation level of the trainee.

7. What are your main needs and expectations during the training phase?
8. Can you tell me about your confidence level during training? (on a scale of 1-5)
9. Can you tell me about your motivation level during training? (on a scale of 1-5)
10. Can you think of any improvements for ASML's current process regarding this phase?

Post-training phase (7.5 min)

With the post-training phase, the start of the employee's job is meant, with a focus on keeping a certain level of confidence and motivation throughout the tasks.

11. What are your main needs and expectations during the post-training phase?
12. Can you tell me about your level of confidence in practice, after finishing the training? (on a scale of 1-5) What does ASML do to keep you confident?
13. Can you tell me about your level of motivation in practice, after finishing the training? (on a scale of 1-5) What does ASML do to keep you motivated?
14. Do you have the opportunity to continue your learning journey by following trainings during your job? Are you able to personalize it?
15. Can you think of any improvements for ASML's current process regarding this phase?

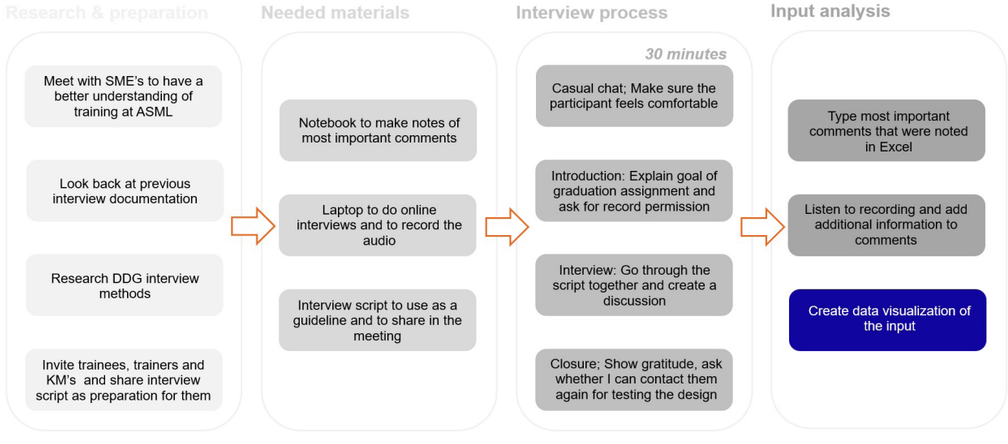
Closure

16. Are you open to also fill in an online 5-minute survey related to NXE experience?
17. Can I contact you in January again to test the design proposal I came up with?

Extra questions (when there is time left)

- Can you tell me about the contact you had with your fellow trainees? Did you help each other out? Did you have a platform to reach out to each other when needed?
- Can you explain me whether you think the training is useful to your job task? Can you explain me how you've experienced the guidance of ASML of you as a trainee putting all that you've learned into practice?
- Can you tell me about your experience with performance outcomes? Can you explain me whether you think it is valuable to know your performance in the end? Can you tell me to which extent ASML informs you about your performance outcomes?
- Can you explain me whether you are informed about the skills of your engineer colleagues? Would you like to know the skills and/or the amount of experience your colleague has?
- Can you explain me whether ASML showed you your purpose in the company? Do you feel that you belong?

A structural process was set-up to improve the quality of interviews with the engineers, trainers and knowledge managers

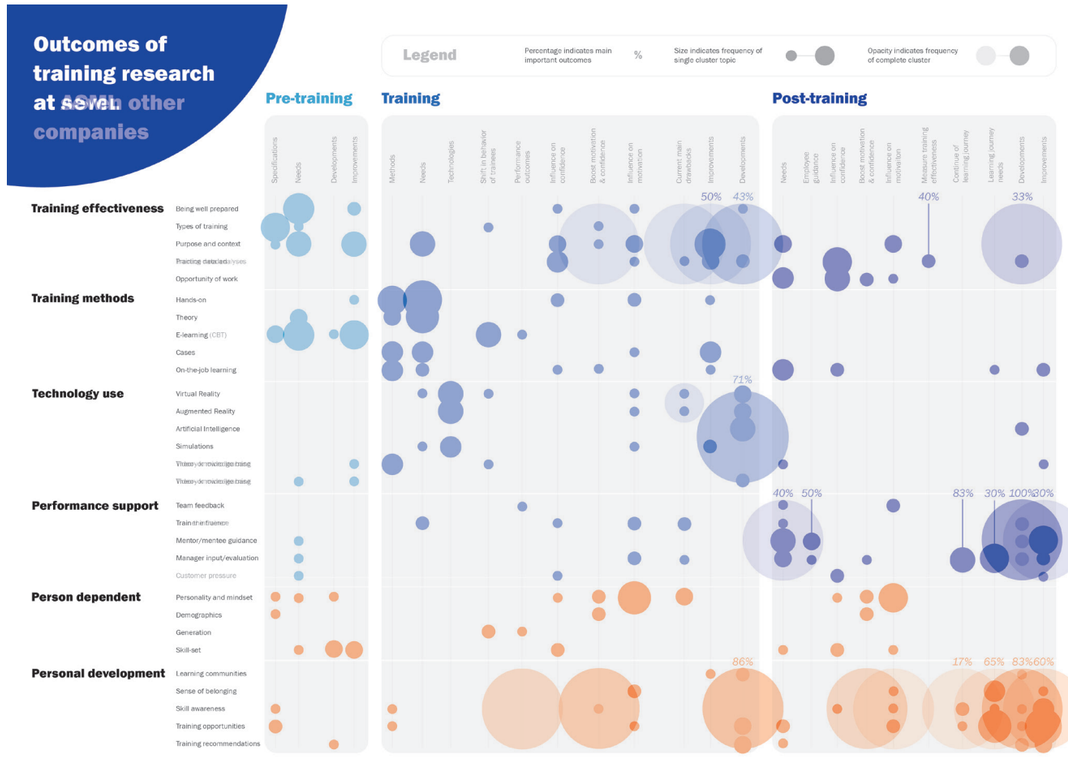


Appendix F2: Transcript of ASML interviews

Engineers				Pre-training		Training				Post-training						Further contact	
What NXE training ge	For how lc	Can you briefly expla	What are your main i	What are your needs	Can you think of any	What are your main r	Can you tell me abou	Can you tell me abou	Can you think of any	What are your main r	Can you tell me abou	Can you tell me abou	Do you have the opp	Can you think of any	Would you like to kn	Can you explain me	whether ASML showed you your purpose in the company,
Advanced	6 years	Upgrade engineer for scanner	Perform recovery actions needed for machine	Preparation for course Study relevant documents before technical training (CBT) Having a remote online training before it starts in VHN	Pre-training should be improved because the TC is overloaded and some students don't know yet how to use the tools (a big difference between skill sets)	Receive training of total package and storyline (not separate modules) Study theory	(4) Trainers do their best to train the engineers for the field and explain everything well	(5) I could follow the training in a relaxing/laid back way; he has a motivated drive	The advanced training is too big; the trainees need to 'race'. Basic/functional part can better be an individual part of the training (1 week), and the second part will be the advanced part	Check training content and link it to the field and check additional materials that need to be read Apply gained skills of training in job	(5) His confidence raises after the training since he was missing a certain skill gap; he is confident in general	(5) His motivation level is high, he has his own drive to work and is triggered by daily work and projects Compliments of managers don't have as much impact as from a colleague/peer	Without receiving new things, you will get bored. Allowing engineers to do additional trainings will motivate them a lot	GTC and engineers lose connection after training Feedback loop is not really there and helpful if we want to shar our feedback on application of the training in practice, some forms but these are not really helpful	Some people are happy to share, but some don't want to share their knowledge	Have not asked	Open
Fabready-2	3 years	Field service engineer	Maintain ASML's systems	Clear prerequisites and manager responsibility/guidance	The prerequisites are vague and often for some available training spots not known. Communication of this should improve.	Hands-on training 30%Theory/70%Hands-On	(2) More confident after a Hands-On training Less confident after Theory Clear goal and the correct training framing results in more motivation	(2) Online and Theory is less motivating (motivated engineers) instead of quantity	Make expectations of the project more clear, and make sure they are reasonable for the amount of time and complexity for the topic Make sure the content meets the expectations	End of training should align with start date of needed service (skill retention) Follow-up from trainer 1-3 months after training	(3) More confident with certain actions after doing the training As long as there is an immediate follow-up where he can use the skills gained	(3) He finds motivation depended on his personality and is in general motivated	MyLearning and SMT is not intuitive, ASML maybe offers it to engineers but you need to know what you want to learn and search for it. Currently it's not personalized and more a pain to use.	Giving training managers more resources to help engineers find their skill gapsinstead of having one training manager for a site, having a complete manager team (or AiT)	Fellow engineers skills are known mouth-to-mouth	Have not asked	Have not asked
Advanced	5 years	LTA and was previously a field service engineer	Make sure the machine is running at the customer site	CBT; online courses/videos in MyLearning	Having real experience with machine instead of CBT. English is hard to understand, and in this way you can learn the engineering language (on job learning)	Learn how to recover a part and get more experience with that Learn qualification	First the confidence is low for a first time training	(5) She is in general motivated	More CBL (cases learning) How to apply it in a fab Case sharing with other engineers	Go as soon as possible to the fab to apply skills (ideal 1 week after completing training)	(2) It's possible that you're afraid the first time in the field, since you will do recovery in favor of the customer	(5) She is in general motivated	Yes but the manager guides you to do other trainings, discusses it and helps organizing (not possible to plan herself)	She knows the routine, but needs more additional trainings in critical actions, diagnostics (advanced trainings) Personal journey; additional trainings of tasks that not have been applied in the field (and have been forgotten)	They have a table with all the team members and their skills, but these are not aware of the other teams & departments	Yes, they give us opportunities to and it's possible to catch up with the team quickly	Open
Advanced	8 years	CDP engineer, he will return to HBO to be a 2nd line illumination & projection engineer	Provide technical escalation support to the engineers on the floor working on the machine, they have a general knowledge on the tool where I have a specialised knowledge on the tool	Depended on training (fabready-1/2/advanced) CBT Have a good understanding of the context before going in; ask efficient questions	Additional reading material to CBT so you can use this later on in the field Make sure people are ready before they start a training when looking at having everyone on the same threshold (skills wise) because some people are not able to make the connection to certain tasks	Theory at the front (helps him to make the connection) Hands-On in the back or middle-to-back in a training CBL	(4) He already had some experience	(3) Relatively high, because he has the chance to network (go to HQ) and becomes a better engineer as an award	Quality of CBL cases A certain amount of technical complexity to dig in; they tend to gloss over a bit and he would like to know the details	Use training immediately (probably you won't use it in the first 3/4 months) A better post-training; a refreshment program (continual/follow-up)) to maintain knowledge Your manager expects you to know everything of the training; but this is not realistic	(3) Should be higher, but is actually lower because when you go back to the field, your manager assumes you can do it but it sometimes takes some time before you will use the training Utilization of skill depends on machine specific error, and can't be determined time wise after a training Theoretical knowledge stays but hard skills can decrease after x amount of time	(4) After training I'm motivated; I've learned a lot and can use this opportunity now	You have to be driven to speak up of additional trainings Additional trainings and soft skills developments should be more clear; in VHN they are because it's there but in the field it's less clear and available	Work with expert (mentor/mentee) immediately when you go into the field Remain GTC contact; for follow-up of trainings but also for doing additional trainings Make trainings more visible that are available to you (definitely soft skills) in VHN they are more aware of possibilities than in the field Make expectations of engineer after training more clear	He is aware but on mouth-to-mouth You can track skills in SMT but it's on management level He would like to see (sees value), but understands if people are private on it	Not asked	Open
Advanced	5.5 years	LTA to become a proto 1st line engineer at HBO	Improve CS service mix related to procedures, hardware etc. Build knowledge for new system	Currently there is no pre-training yet for the new system; you need to go to several people to retrieve all the information/documents	Centralized way to receive all the pre-training information on High-NA	Hand-on training with some additional Theory training did a great job on the combination on those two and additional simulations/mock-ups/VR NXE was mainly CBL based	(4/5) There is a lot of focus on confidence during High-NA validation trainings, but for NXE there was not a lot of confidence since there as a ramp-up and there must be O.I.	High-NA training is motivating, he is really enthusiastic and the modules and the current training program	Nothing yet for the High-NA training, they did a great job until now	Validation of training into the field Have the resources to schedule a time and refresh a certain training when it's not immediately applied in the field Personalize trainings	Confidence level will become lower if you can't troubleshoot immediately	It's motivating to schedule your own resources and trainings when you start working in the field as well	I hope I will get the opportunity to schedule my own trainings and to book timeslots	Also make sure the resources will be possible in HBO and not only in VHN Possibility to plan timeslots (I know they're on it, but don't know yet when it's available)	SMT we're supposed to be using for management He does not see the value for a 1st line engineer to see the skill sof colleagues (for escalation it might be useful for the 2nd line engineer)	He thinks this is a manager dependent, and doesn't have a lot of experience with this Sometimes he feels like a needle in a haystack	Open
fabready-2	4.5 years	LTA for the customer support site (D&E)	Maintain resources for different D&E projects for first integration Make sure Hillsboro is ready for new system	Exposure to the job before you dive into the training (training right away you don't know what you need to know) Become comfortable	Onboarding deal; it's currently stressful and it might help to widen the timeframe	Background story of tasks; full understanding but not all details 50/50 Hands-on and theory	(3/4) But not confident enough to do it immediately in the field after, takes some x amount of tasks	(3/4) I enjoy training; the atmosphere is nice and everything that ASML arranges	Improve the sequences of the HW-riggs to make it more realistic to the real situation (currently the main focus is on the swap itself and not the situation before and after)	Training should be consistent to practice Start doing the tasks you've learned Having a mentor/mentee; still not applied everywhere (increases confidence)	(2/3) In the end it will be lower because there are still a lot of gaps and you have not learned everything	(2/3) Great to apply knowledge in field	[redacted]	Improve the purpose of each engineer and make sure they feel like they belong; [redacted]			
Fabready-2	10 years	LTA and was previously a technisupport engineer	Share knowledge and experience with D&E	CBT and share others materials	Not enough time for prerequisites, more times needed due to individual's different paces	Theory you learn by CBT, so he needs CBL and training on real machines	(4) During the training you think you can do everything afterwards in the field	(4) He is a motivated person	His main point of improvement is working/training on a real machine Try to include more types of cases in a training and specific ways of doing diagnostics	The training should be useful and prepare you for the field. However the training is too theoretical so it can't prepare you for everything	(2) Training focuses more on Theory, therefore your confidence will get lower because you did not have a sufficient amount of cases	(4) Stays the same	ASML's advantage is that they provide a lot of trainings, request is easy, but scheduling for senior engineers is hard (time/money) Scheduling for new hires is easy	No	We know it when we work together with eachother	Yes	Have not asked
Advanced	5 years	Local customer support engineer	Provide customer support to customer (tsmc)	CBT and safety prerequisites	Some CBT materials are not up to date CBT video training is not interesting, should be more intereactive and more clear in the main topic (F2F CBT?)	Hand-on training Experienced trainer who has a lot of knowledge on the machine	(4) Good level of confidence due to the fact that there was a real machine in the TC	(4) Also motivated because she could work on the machine	There is an early (7-1) and late (3-11) shift, but it's not efficient to have the late shift More focus on diagnostics in the field	1 month guidance of an experienced colleague (mentor/mentee) to know field issues since there is a lot of difference between training and real troubleshocting (sometimes depends on department)	(2) You learn most from experience that the training can't provide to you	(4) She is motivated to work in practice	Yes but it's more related to the development of soft skills Manager will help to arrange	It would be helpful to have a skill validation test at the end of a training, where it shows you the insufficiencies and recommends you additional trainings that you can do	You know it from talking to your colleagues, and it's good to known eachother's skills when you work in a team	There are monthly employee meetings where they show you the roadmap and they involve you during this	Open
Advanced	4 years	LTA Optics	Learning on Optics competency (POB etc) and use this knowledge for the new system at tsmc in Taiwan	Purpose, functionalities and abrevaiation of module CBT	CBT should be better up to date but I imagine that this is hard Hard to connect module to module in CBT, they should focus more on this correlation /connection	Depended on training but he prefers Hands-On Theory combination CBT is not sufficient for Theory Trainer should have a sufficient background before giving training (sometimes it seems like the ppt was made by someone else)	(4) I'm able to explain issue and what I've learned	(2) Issue is hard to distinguish and hard to do it right on the first time	Work more with HW-riggs/simulations to see it more visually in the whole system, because currently you don't see the whole picture	To know how to write down the most clear problem description, also enables me to solve it better A mentoring system, people are currently guided by the issue	(4) Confidence is relatively high after you have experience with some of the issues though (x amount of times)	(5) Motivation is high because you have more experience and you can solve issues with the team	They plan it, but it depends on your engineer label; freshman is easier to arrange but senior is hard because they need to control manpower and duty	A standard mentor/mentee system, currently it's depended for the site and he was guided by the issue Mentor/mentee guidance on distinguishing the key problem, how to write down issues and do diagnostics	He is not aware of the skills	Not at all. He needs more recognition; pay me more	Open
fabready-2	4.5 years	LTA 1st line engineer in Taiwan	Know how to do service actions & maintain system in Taiwan	CBT and safety prerequisites, general skill set	CBT should be better up to date (revise checklist); important because then I have the wrong types/explanation in my brain when I go to training	Hands-on training, but also theory because you need to recover the system Know how to find rootcause and use analysis tool	(3) Step by step they tell us what to do and we don't have the pressure of the customer	(2) Link between task & situation in the field was not clear and decreased her motivation	Content of fabready-2 training (Source/Scanner label 2) needs to be more extensive since it's not suitable for in the field and it's difficult to perform	On-job training Mentor/mentee guidance	(1) Confidence level is really low when you start working in the field because you need more experience	(3/4) Motivation is good in the field	Two options; request (simple) or your manager chooses you to receive a training They always say training slots are too tight; and focussed on newhires and not senior engineers	Give more opportunities regarding personal development and do more additional trainings	It will be useful, normally I ask on the trainings my colleagues have done	[redacted]	
Trainers														[redacted]				
Trainer	22 years	Became an Advanced optics trainer 3 years ago	To train the future engineers of ASML	Clear prerequisites	There are not enough prerequisites (CBT) for Advanced training	CBL is really important Combination of Hands-On and Theory Metreology + combo of these 3 CBL looks like Hands-On	To boost confidence he gives the trainees the opportunity to first look at the problem his-/herself	To boost motivation he uses real life situations Advanced class is motivated in general He asks them to bring an example before the training course starts	More CBL and more real cases (also quality of it) Reduce theory time	Evaluation should be done after a training phase after 1-6 months working in the field (currently immediately after training) To know: How do the engineers use their knowledge?	Confidence level can decrease after +- 2 months when not working on that specific issue	Motivation level is also dependend on engineer	SOJT can be the solution for this	Refreshment program during the post-training phase to refresh certain skills; focus on personal development and skills maintainability Optimise use of SOJT to maintain confidence in field (guidance in the field)	Have not asked	Have not asked	Have not asked

Trainer	22 years	Trainer fabready-1 and 2 in Taiwan	To train the future engineers of ASML	Introduction of engineers Know expectations of engineers Explain houserules Give them number to contact for help	Have not asked	Engineer want to know how to troubleshoot and to face real issues CSTO; 4 days training contents (just onboarded) 70% Hands-On (HW riggs or real machine)/ 30% Theory Specifics of interface and differences	Confidence during training is higher than after training, but they test on test-riggs which do not represent the real life situation	Depended on manager and not on trainee, because they decide on the training	[redacted]	OIL will benefit the engineer regarding confidence KM will ask for feedback on training after 2-3 months in the field; should be around that time but it's earlier (not accurate)	Confidence will decrease but OJL will help You have to fill in a skill matrix after a training (which has to do with how confident you are after a training regarding some skills)	Have not asked	Manager decides in accordance with KM what training the engineer needs to get in the future	Improving OJL can result in higher confidence of the engineer	Have not asked	Have not asked	Have not asked
Managers																		
CS field Knowledge	12 years	CS field Knowledge	Development paths of engineers in the field												Confidence level is mainly dependent on applying the skills of the training in practice. After at least 3 times a good level of confidence is gained. Depends also on time pressure, and different kinds of pressures.	Motivation is boosted by giving the engineer personal development opportunities, having the thank you program, and having motivational morning sessions	TCD program, in mylearning they can request trainings but this is mostly not used. It's preferred to contact manager on possibilities, he/she is the first stsarting point.	Mentor/mentee connection; making sure the mentor program is updated regarding giving an experienced engineer the possibility A. to be a mentor and B. offer them additional trainings to be one (also not obligatory and only optional)		Have not asked	
EUV Knowledge		Responsible for fab-ready 1 and SMT.	Find the right balance betweem a high amount of trainees and the available resources	Engineers jump to class without prerequisites; because they have not enough of time and have to be trained as quick as possible. Besides that they don't take it too serious, see it as a relaxing time; no pressure of customer	Prerequisites as KPI is under development	Hands-on training is important to shorten ramp-up time OJT is best learning method; but there are too many engineers and some of them are less experienced (high risk to place them immediately in fab)	(4) They are confident because they can work on a machine	(5) They are motivated because they don't have to work in the field and they see it as a relaxing time	They already did a lot of impeovements but OJT can be improved	Transfer knowledge/learning points into rest of the team (helps to memorize and avoid basic mistakes) SOJT Mentor/mentee program; however currently a whole group is assigned to one mentor/mentee and not everyone can work on machine (1). Besides that, the mentors/mentees are more experienced and needed to execute tasks (2)	Increase or decrease. Confidence level is mainly dependent on opportunity of work and whether you can apply them; (1) depended on team and x amount of machines. (2) depended on operational schedules.	(5) They are motivated	She has a ppt with all trainings; but doesn't show it to engineer to often because they need manpower in the field EUV curriculum is complex and new skills are incoming Engineers have 1-on-1 meeting with manager to discuss advanced trainings Depended on ambition of engineer; 1st line don't want to learn more troubleshooting	SOJT program is under development SMT should be improved, currently engineers can indicate their level of a certain skill (due to certain targets), however there is a gap in what engineers say they can do and what they actually can according to the management; better validation needed of skills	It will be useful to see skills of fellow engineers; stimulates to learn skills of fellow colleagues She doesn't know why they do not share this information in the team	Yes	Have not asked but open for further questions

Appendix F3: Comparison of ASML and company data visualizations



Appendix F4: All outcomes of survey on NXE training experience

Appendix F5: Notes on training observations

NXE hands-on training observation notes

Hands-on training 18/10
Context: 6 participants

- They work on a specific part of the machine, however the size (and costs) of the complete module is to another extent. Benefit is that they can see part placed in the module (which enables them to see the total picture); however, this can also be achieved by placing a module part in VR environment. In their new way of working, HW-riggs will be mainly used.
- Engineers are rushed in their learning journey, because a lot of manpower is needed in the field in the future. Trainer requires trainee to have 1.5 yrs experience, but some of them have less experience; best for them would be to send them immediately to the field. One trainee didn't complete prerequisite trainings, and has no sufficient knowledge base for this training; OJT is needed according to the trainer.
- Current focus is on planning trainings, admission of new hires; but on the other hand the training rooms have not been cleaned and there is still materials left of one month ago
- Theory training (no CBL) related to this hands-on training is given Friday (hands-on is on Tuesday), this means this knowledge is not immediately applied and can be seen as not effective, micro-learning that can be accessed at any time /or a short cases theory training right before the action, could be the solution or this. The hands-on training needs to have to related theory at the same time when you apply it. Trainer is looking into methods to print the image of the theory training and place it at the wall during hands-on, to refresh the theory knowledge that was provided.
- During the hands-on several pre-actions need to be done before the main action can be executed. In this case, one of the trainees had not done of these pre-actions before, so it was no lost. But by focusing only on the part during the hands-on, and possible simulations of the whole system besides that, the hands-on can be way more effective when looking at the concentration of the engineer, but also time wise.
- They offer a platform, where the engineers can watch videos of action during training (without goal, why and context?) Possibility to make full use of it during training.

Process:
1. Planning of training and sending emails (should this be done by trainer? How to make this more standard and generic?)
2. Preparation of materials by trainer
3. Change into cleanroom clothes
4. Walk to training room
5. Get-to-know; trainer and trainees. Also get-to-know for only trainees for team bonding?
6. Introduction; what they are going to do, how they do this, expectations of trainees. Why they need to do it is missing; no case is given.
7. Theoretical example of hands-on training (classroom learning on big screen) and discussion; how to make this engaging? (micro-learning in groups) How do you make sure everyone joins and speaks up?
8. Trainer divides groups on; (1) Who has not done this before? (2) What is your preference?/ (What skill do you want to improve?)
9. Two groups work on two separate parts (3 persons per part) Teamwork! Group instead of individual learning

- They use a platform for machine procedures during the work; however 'why' you do certain steps is missing in this procedure; they are very cryptic steps in an order and without any additional explanation. Sometimes a procedure should be updated, and steps are incorrect; they can communicate this through the platform by adding a comment on the mistake and a suggestion on how it should be.
- Trainer walks around, answering questions and checking upon the groups
- A team session finds place to evaluate the issue. Trainer explains what happens and effect of another part; expression with hands to show phenomenon. VR might help to simulate.

NXE Theory training observation notes

Theory training 21/10
Context: 6 participants

Process:
- The powerpoint presentation is showing different parts in visual model, trainer explains what part is each number
- Trainer shows the real-life pictures next to the 3D model
- Small parts go around the classroom, which were shown in the powerpoint
- Sequence is the same; showing part numbers, with part in drawing, and additional picture of part (what if the parts where shown in a 3D/cad model of the whole system? To make the theory training more interactive as well)
- Trainer introduces a dilemma; "What are you going to do? And why?" Focused on procedure, because trainer implies on a step.
- Trainer mentions they can check a certain video related to a procedure on certain platform. Micro-learning?
- The exercises start; they are placed in one-note. Individual way of working for making the exercises, is this usual? Or do they also sometimes make them together in groups?
- After having some time for the questions, they go through the answers together and have a discussion.

General notes:
- Classroom style teaching; trainer explains and they ask questions. Is it possible to make the theory class more interactive? Will a CBL class be more interactive?
- Still procedural & part based (using tables with sequences and pictures); showing part numbers and images and mentioning the functionality; or showing numbers and showing sequences. Not the 'why, how, what' you use it in the complete system. On the other hand; it is possible that this theory training suits very well to the hands-on training after that.
- Use a lot of pictures to make it more visual.
- Use dilemma's/multiple choice questions? It is currently showing mainly theory and explaining, but will it make more impact, and the trainees will remember it longer, when you

give them the option to choose?

- They introduce the procedure of the company specific platform during reviewing the answers. It is good that they use this during Theory and Hands-on training as a guideline, but will these trainings not look too much the same? Add the focus on the why?
- The trainer is teaching in a really calm and comfortable way.
- Is it good to have a specific skill? Will not this person who is skilled at that task will be assigned to everything?

High-NA Theory validation training observation notes

Theory training 24/10
Context: 9 participants

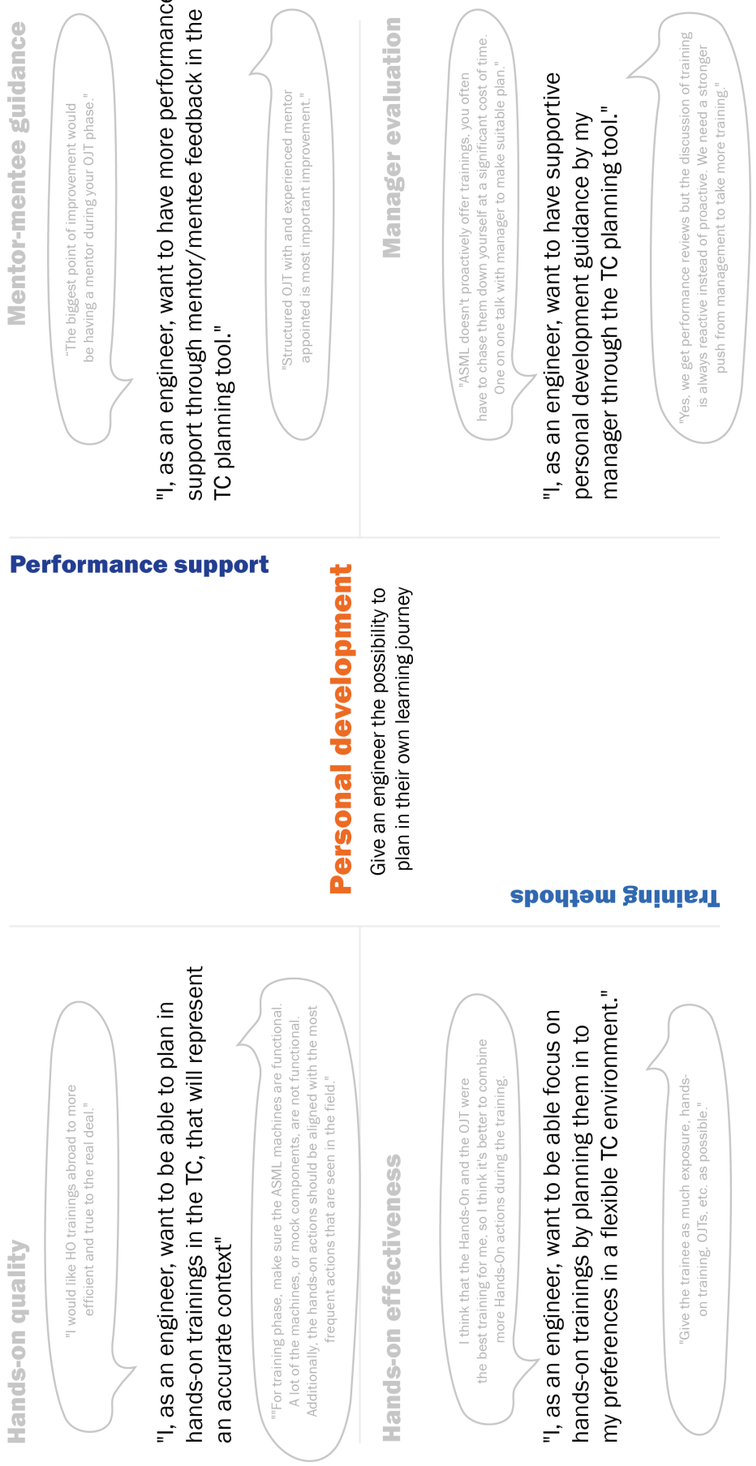
Process:

- Safety rules
- Content
- Introduction of trainer/engineers
- Goals of training & content; this training is for validation purposes.
- Training slides based on specifications

Notes:

- All participants have NXE experience; they are first explorers of this course, and some of them are in Veldhoven for a Long-Term Assignment (LTA).
- Materials shared upfront on platform; Teams.
- Optics/Illumination; related to mirror which reflects the light.
- I already notice that this training is more focused on theory and explanation ('why'), then the NXE training, which was mainly focused on procedures. Also quizzes are integrated during theory class, which makes it more interactive. This also was not the case for NXE.
- Training is focused on comparing NXE with High-NA; use understanding and insights of their current NXE experience, to learn more of and prepare for High-NA.
- More integration of cases for which you need this theory, the context and 'why' is often still missing.
- No CBT, he does recommend some NXE CBT to do on forehand.
- High-NA TC; focus on 4 factors; VR, HW-riggs, Theory and Software to obtain the most real-life experience.

Appendix G: Supportive quotes on vision directions



Appendix H1: Set-up of co-creation session with engineers

Together with an UX colleague, this co-creation session was prepared and set-up. The structure of the brainstorm session is as follows:

- Introduction: Since I have already got to know the engineers that will join the session through the interviews and observations, I will not go in detail regarding introducing myself and each other. I will start off with explaining why we're here today; what is the goal, what are the outcomes of the research I have done, and why the planning tool will be created and how this will benefit them. Last, I will show them the planning of the brainstorm session, explain how it will work and will make sure they feel comfortable to ask any questions. For each brainstorm topic they will have 5 minutes individual time to brainstorm, after that we will have a group discussion on the input, and for some of the brainstorm topics the participants have the chance to vote on the three post-it's that they think has priority. This voting will take place after the discussion, while there is a possibility that some individual's will change their minds having a group discussion on the input.

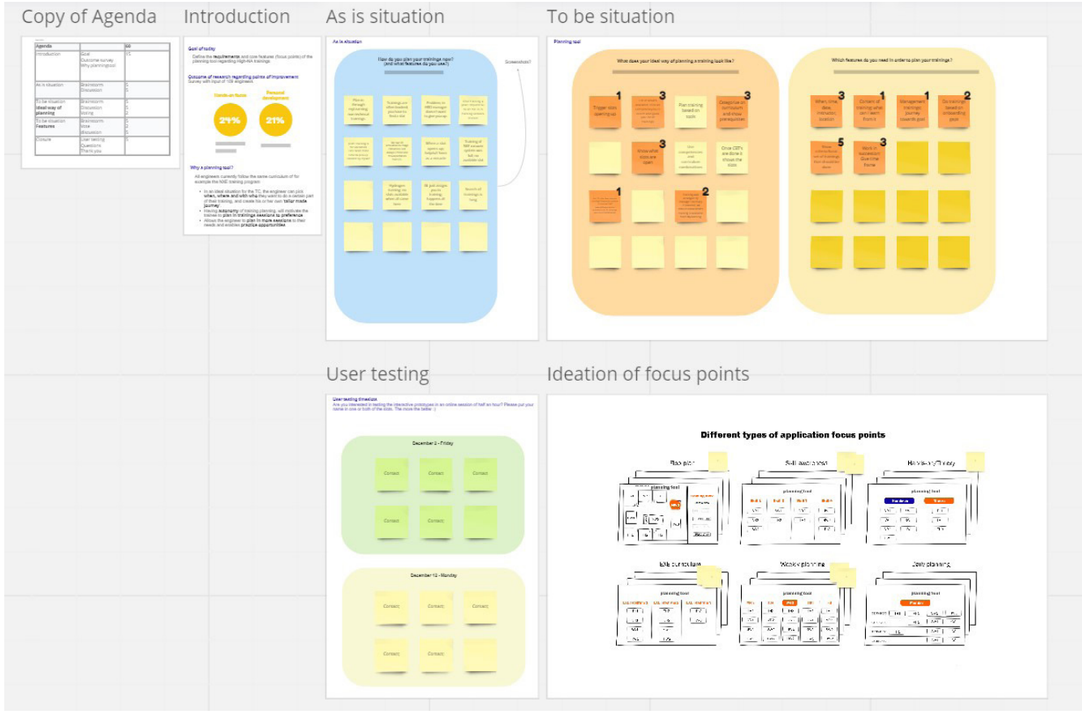
- Brainstorm on current situation: We will first start by looking how they experience this current situation regarding training planning. What do the participants like or dislike, triggering them on thinking what aspects should stay and what should be changed. By this brainstorm topic, I want to prepare them for the next one, which is about how they want the planning to become.

- Brainstorm on ideal situation: For the second topic the participants will think about how they would like to plan in their trainings and what should be the main focus points according to them. The intention of this topic is that it will be an intermediate step to linking the needed features for the wanted effects.

- Brainstorm on features specifying the ideal situation: For the last topic the participants will think about what should be the core features of the tool, they're asked to give examples and the information needed for these features. In the end there will be a voting round again, implying on deciding what should be the focus points of the tool.

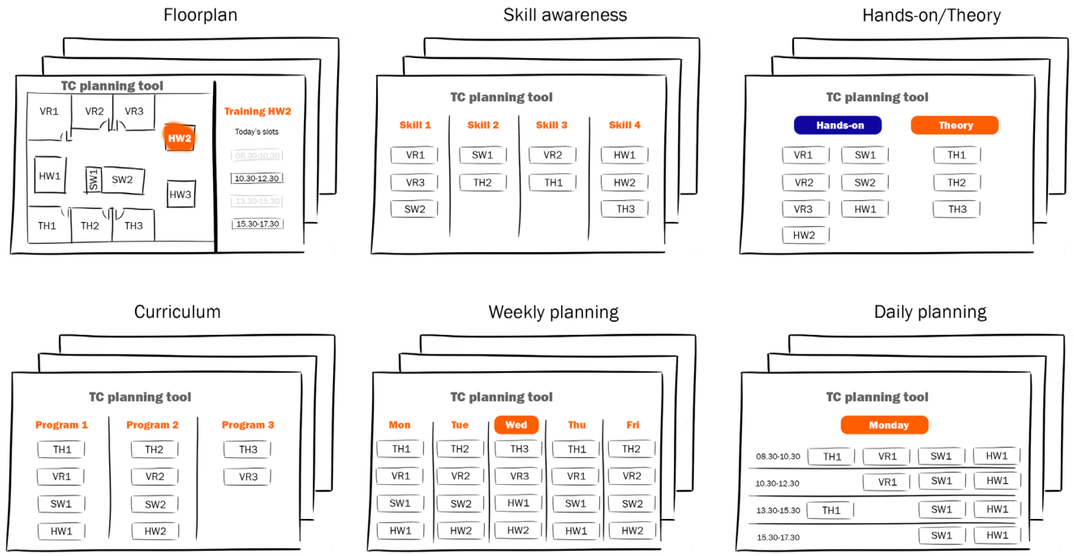
- User testing request: After the co-creation session, I will ask the engineers to help me to validate and iterate the design by joining the user testing, which will be half an hour online sessions. I will give them the opportunity to write down their names for two possible sessions: the 2nd of December, which refers to the wireframes testing, and the 12th of December, which refers to the design composites testing.

- Closure: For the closure phase, the participants are asked if they have any questions regarding the topic or the session itself. Finally, I will show gratitude by thanking them for contributing to the planning tool prototype and make sure to keep them in the loop when interested.

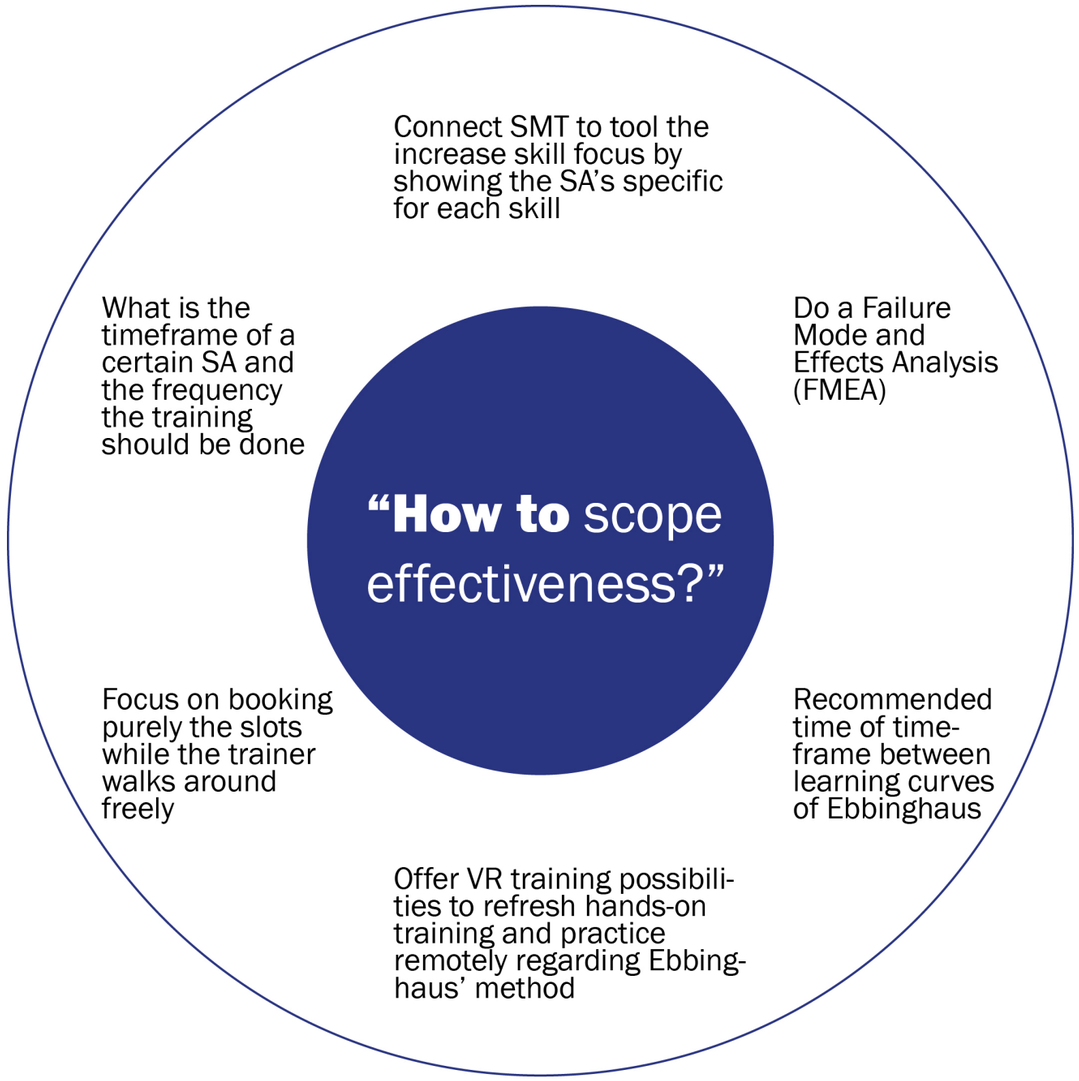


Appendix H2: Core feature exploration

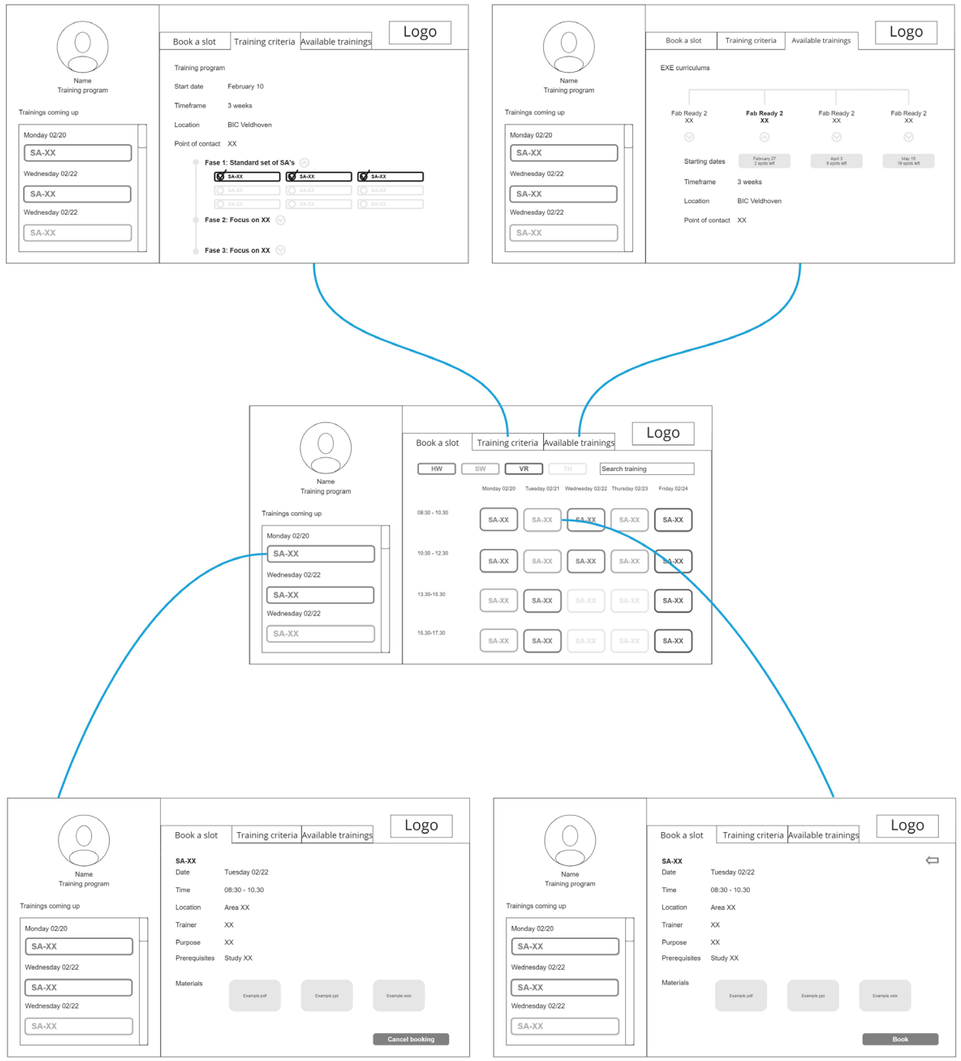
Different types of application focus points



Appendix H3: Brainstorm on effectiveness scoping



Appendix H4: Wireframes sketches



Appendix I1: Usability testing protocol (1)

Usability testing of wireframes

RQ: How did the trainee experience performing the activities when looking at ease of use and intuitiveness?

Introduction (5 min)

- Explain the goal of the usability testing: Today we will go through the interactive prototype of the wireframes of the TC planning tool. I want to understand your view on whether the activities proposed are easy and comfortable to do and the interfaces are intuitive in use, not on the looks and colors of the tool.
- Clarify the amount of time or the interview: 30 minutes.
- Create a safe space: This is a safe environment where you can share your opinion. There is no right or wrong, and I want to ask you to share your thoughts, think out loud, while performing the activities. You can ask questions anytime you want.
- Make sure notes are made and consent is given: Can I use the notes of your comments in the research?
- Sketch scenario: Imagine you're in the TC for training purposes. You've been following a curriculum for some time now and you want to continue your journey by planning in new slots, but also explore other curriculum possibilities.

Task 1: Check training criteria (5 min)

Can you check in the criteria what SA's you need to complete next to fulfill your basic set? Can you tell me the timeframe given to fulfill the Scanner curriculum?

1. Can you explain me how intuitive this activity was?
2. Was everything clear?
3. Is the set-up correct of all the information you need?

Task 2: Book a slot (5 min)

Once you've found the SA type (0009), can you book this slot for Tuesday the 21st of February at 8.30?

4. Can you explain me how intuitive this activity was?
5. Was everything clear?
6. Is the set-up correct of all the information you need?

Task 3: Cancel a slot (5 min)

Oh no, you've booked the slot, but forgot that you have an appointment at the dentist. Can you try to cancel it?

7. Can you explain me how intuitive this activity was?
8. Was everything clear?
9. Is the set-up correct of all the information you need?

Task 4: Find other training opportunities (5 min)

You're interested in doing also the Fab Ready 2 BOTTOM training, can you check the slots

available for the coming months?

10. Can you explain me how intuitive this activity was?
11. Was everything clear?
12. Is the set-up correct of all the information you need?

Evaluation (10 min)

We will go through the NASA Tasks Load Index to evaluate the tasks and the create a general view on your experience of using the tool.

13. How mentally demanding was the task?
14. How physically demanding was the task?
15. How hurried or rushed did you feel when performing the tasks?
16. How successful were you in accomplishing the tasks?
17. How hard did you have to work to accomplish the tasks?
18. How insecure/discouraged/irritated/stressed/annoyed were you when doing the tasks?

Closure

Thank you for your contribution and helping me out with the user testing.

19. Are you available for a second round on the look & feel of the prototype on the 12th of December?

Appendix I2: NASA Task Load Index

NASA Task Load Index

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point results in 21 graduations on the scales.

Name | Task | Date

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Very Low — Very High

Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed and annoyed were you?

Very Low — Very High

Appendix I3: Usability testing (1) outcomes

	Participant 1	Participant 2	Participant 3	Comments company mentor (Henri)
Task 1: Check training criteria	What does point of contact mean? The Basic set shows me to finish 1-8 first. Use color to show completion.	Tells me it's completed checkmarks, but use colors to show completion. I don't see the ones I have to complete, color is too light.	Prerequisites courses to complete before the training? I would be helpful to have definiton next to SA, description of training.	Phase 1 should be CARS scenarios, phase 2 should be SA. It's important to practice CARS scenarios.
Task 2: Book slot	Show description of SA in book slot. How do I see if I've booked the training? (Dashboard only is not clear)	I need a link to Mylearning for prerequistes (CBT), saves search time Looks pretty good, put coach procedures as pdf. Map/floorplan should show location.	I need a description of SA in slot. Interesting to see whether it's individual or group, would influence my choice. Likes that there is a purpose. Is very intuitive. I like the links having access to the materials. Link to myLearning for prerequisites could be helpful.	Show as prerequisites not MyLearning link, but the dependencies of CARS/SMS/SA. CBT would be too repetitive and of a higher level.
Task 3: Cancel booking	Giving prerequisites link to MyLearning would be most useful.	Normally we don't book our own slots. I want to see if it's a classroom/group/individual training in booking a slot.	Doesn't notice anything different appearing. Change color to show that it's new. Flash could help, pulls your attention. Convenient that you can cancel training,	Show individual/group way of learning in booking.
Task 4: Find other training opportunities	Are the EXE programs correct?	Likes spots & slots.	I like it. The visual hierarchy is nice. Compared to the myLearning way. This is the only slot; I will make sure I'm available. In the past I would also give priority to a slot.	Categorization is incorrect. Should be a three separate training programs; Scanner, Source and Co2. And underneath Scanner there would be BOTTOM, TOP, ILP.
Extra comments	Timeframe issue: What if I have already something on Tuesday and planning is 3 weeks? Will there be enough slots? What if you're late and some people prefer morning or afternoon slots?	Wonder if it can be personalised, what if I'm here for three months? It needs to be tailored to how long you will be here; what if I can't take this slot? I want to click on link for more information about the SA. Not all trainers have all knowledge. SA's have different timeframes, not always 2 hrs. Integrate CDP, would be great.		

Outcomes	Participant 1	Participant 2	Participant 3
Mental demand	8: He needs the meaning of SA's in booking page.	5: Without your help it will be not okay.	3: Without instruction would be 5, but it still would be low.
Physical demand	3: Only clicking. Only demand is from customer/manager.	1	0
Temporal demand	0	4	0
Performance	5	5	20
Effort	8: Without guidance I was not able to do it. Could there be a guidance option on the homepage?	10: Depends on task.	2
Frustration	1: Currently it's fine, but wat if slots are full and people take your place?	1	0

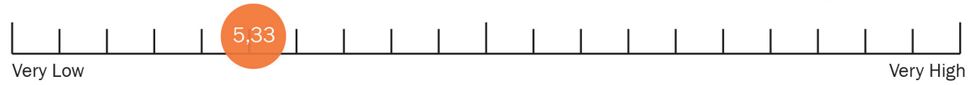
Average

NASA Task Load Index

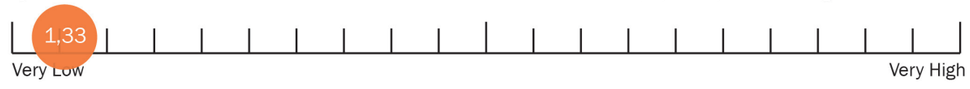
Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point results in 21 graduations on the scales.

Name | Task | Date

Mental Demand — How mentally demanding was the task?

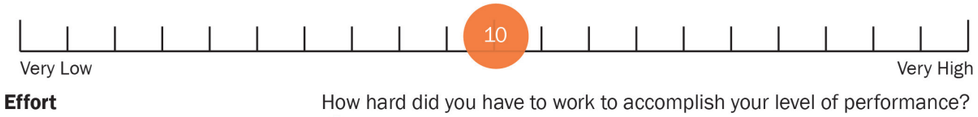


Physical Demand — How physically demanding was the task?

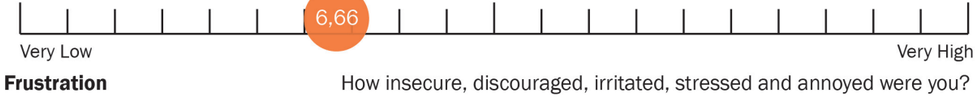


Temporal Demand — How hurried or rushed was the pace of the task?

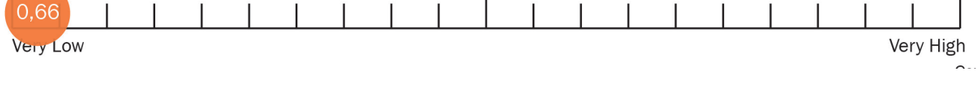
Performance — How successful were you in accomplishing what you were asked to do?



Effort — How hard did you have to work to accomplish your level of performance?



Frustration — How insecure, discouraged, irritated, stressed and annoyed were you?



Appendix I4: Usability testing protocol (2)

Usability testing of design composites

RQ: How did the trainee experience performing the activities when looking at ease of use and color recognition?

Introduction (5 min)

- Explain the goal of the usability testing: Today we will go through the interactive prototype of the design composites of the TC planning tool. I want to understand your view on whether the activities proposed are intuitive and on the meaning of the colors?
- Clarify the amount of time or the interview: 30 minutes.
- Create a safe space: This is a safe environment where you can share your opinion. There is no right or wrong, and I want to ask you to share your thoughts, think out loud, while performing the activities. You can ask questions anytime you want.
- Make sure notes are made and consent is given: Can I use the notes of your comments in the research?
- Sketch scenario: Imagine you're in the TC for training purposes. You've been following a curriculum for some time now and you want to continue your journey by planning in new slots, but also explore other curriculum possibilities.

Task 1: Check training criteria (4 min)

Can you check in the criteria what SA's you need to complete next to fulfill your basic set? Can you tell me the timeframe given to fulfill the Scanner curriculum?

1. Can you explain me how intuitive this activity was?
2. Was everything clear?
3. Is the set-up correct of all the information you need?

Task 2: Book a slot (4 min)

Once you've found the SA type (0009), can you book this slot for Tuesday the 21st of February at 8.30?

4. Can you explain me how intuitive this activity was?
5. Was everything clear?
6. Is the set-up correct of all the information you need?

Task 3: Cancel a slot (4 min)

Oh no, you've booked the slot, but forgot that you have an appointment at the dentist. Can you try to cancel it?

7. Can you explain me how intuitive this activity was?
8. Was everything clear?
9. Is the set-up correct of all the information you need?

Task 3: Notify me (4 min)

You also would like to book SA-0007 on Tuesday at 10.30. Could you book it? (Slot is full, notification box pops up)

10. Can you explain me how intuitive this activity was?
11. Was everything clear?
12. Is the set-up correct of all the information you need?

Task 4: Find other training opportunities (4 min)

You're interested in doing also the Fab Ready 2 BOTTOM training, can you check the slots available for the coming months?

13. Can you explain me how intuitive this activity was?
14. Was everything clear?
15. Is the set-up correct of all the information you need?

Evaluation (10 min)

We will go through the NASA Tasks Load Index to evaluate the tasks and the create a general view on your experience of using the tool.

16. How mentally demanding was the task?
17. How physically demanding was the task?
18. How hurried or rushed did you feel when performing the tasks?
19. How successful were you in accomplishing the tasks?
20. How hard did you have to work to accomplish the tasks?
21. How insecure/discouraged/irritated/stressed/annoyed were you when doing the tasks?

Closure

Thank you for your contribution and helping me out with the user testing.

22. Are you open for the third and final round of user testing that will contribute to the design evaluation?

Appendix I5: Usability testing (2) outcomes

	Participant 1	Participant 2	Participant 3
Task 1: Check training criteria	Clicks first on cars scenario. I need to finish SA - 0009. Orange color means I still have to finish it and is not on my plan. Green means it still needs to planned. I think this is good. Because blue color also shows the good sign. Orange means warning sign so I need to take action. Phase 2 needs to have the color of the in planning.	Steps are clear. Normally green means everything is fine, also regarding customer. Green showing complete is better. Yellow; means I already scheduled but I need to follow up. Completed should be green. Exchange green and blue.	What does SA - 0009 mean? What is subject. Can I click on it. As a new hire I'm not familiar with number. Move mouse and show short description of scenario. Color like this is fine.
Task 2: Book slot	Integrate link to CARS scenarios to check it immediately. Show link to CBT.	Material is about finish CBT? Attach CBT to link; easy to prepare. Before a training I always look back at the CBT. Ohhh you will add something special for the SA? That will help a lot. This page is perfect. I would like to click on the map to see clearly the location.	Zoom in the map; that would help. I want to see the location. Highlight the room as well would be helpful.
Task 3: Cancel booking	To me it seems all straightforward. It's okay. I can see differences clearly.	Worked well! Yea.	None
Task 4: Notify me	Why is the color different? Also propose other slots for notification; have recommendation. Latest time available would be a day. Because you have to make time for that.	It's clear; would help. I like that I also can search for a slot. It's so nice!	Perfect, clear. Would like to be notified. Flexibility to join part we need but this depends on working schedule; I would like to receive notification before one month so we have enough time to adjust.
Task 5: Find other training opportunities	To book a slot for bottom I need to email Henri, and can not book in this page. Does Henri determine the prerequisites? Or does he assign me immediately? Be more clear.	That is really nice for us, because before our manager just signs us in. In this way we can discover and check ourselves. Really nice! In this way I can see it as well and influence as well. Make sure manager sees this as well.	I think it's perfect, because normally manager will assign and now I can discuss in a more suitable timing for me. Currently it shows for coming 6 months, I think it's fine. But I'm not sure for manager, would year also be okay? (12 months)
Extra comments			Is there a maximum of booking per year? Can you cancel a max amount of time? Because it's not okay to cancel a training and impact available staff.

	Participant 4	Comments company mentor	Comments UX designer	Comments university mentor
Task 1: Check training criteria	Click and link when you click on SA and open planning	Change curriculum name underneath Jake Change picture of Jake to more general and trainee resembling picture	Change blue and green colors Give specific icons for book a slot, criteria, explore trainings	In this overview she finds that green is completed and blue is in planning
Task 2: Book slot	Select HW and filter Use lightbar through it Make more differences in grey colors Clear that blue means it's in planning Turn Sa-0009 blue in training criteria blue after booking Connect bookings to Outlook and Teams		Put go back button on the right top Highlight room of training and possibility to click and zoom out Repeat and be consistent in type of training Make prerequisites clickable (CARS/SA) Book a slot icon en go back icon	In this overview she finds it clear that green means a training is booked, but when looking at the colors in training criteria she thinks blue suits better. However, the colors are taken from an existing ASML application, so it's possible that the engineers think it already works intuitive
Task 3: Cancel booking	It works intuitive		Pop up are you sure you want to cancel? Confirmation.	
Task 4: Notify me	Will it notify me by email; or how? I assume by email		Make full slot red and write text in there; not clear that you can be notified	What is the notification limit (hrs)? I imagine they still want to prepare. Possible to add in timeframe of notify me (dropdown) Show subject as well? Type of training? (HW/SW/...) and show grouped/paired?
Task 5: Find other training opportunities	That works; could you show the trainings I can book?			
Extra comments			Grey shows it's inactive? Can you use different colors?	

Outcomes	Participant 1	Participant 3	Participant 4
Mental demand	1	8	2
Physical demand	1	0	1
Temporal demand	8; I would feel hurried to book timeslot before my colleagues in real situation	2	1; Because it was easy migrate/navigate,very simple
Performance	19	20	20
Effort	2	8	1
Frustration	0	5	1

Average

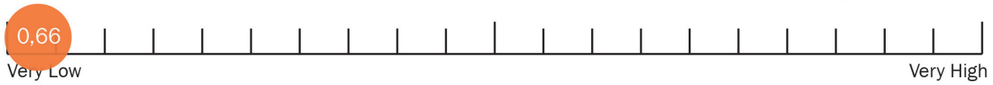
NASA Task Load Index

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point results in 21 graduations on the scales.

Name | Task | Date

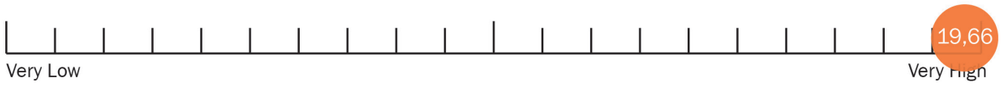
Mental Demand — How mentally demanding was the task?

Physical Demand — How physically demanding was the task?



Temporal Demand — How hurried or rushed was the pace of the task?

Performance — How successful were you in accomplishing what you were asked to do?



Effort — How hard did you have to work to accomplish your level of performance?

Frustration — How insecure, discouraged, irritated, stressed and annoyed were you?

Appendix I6: Suitable tool name of Usability testing (2)

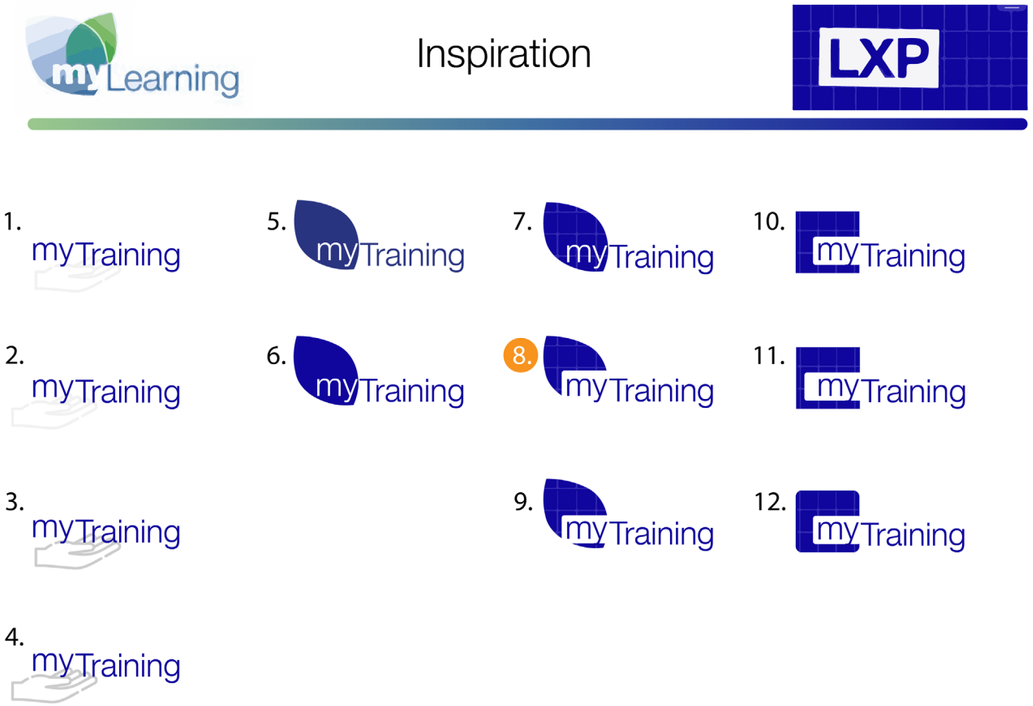
Requirements

- Name in ASML style to create familitarity

- No use of existing abbreviation to prevent confusion

Names	Votes
MyTraining	|||||
MyPlanning	|
MyTrainingPlanning	
MyTrainingSchedule	
MyWeek	
EXE Planning Tool (EPT)	

Appendix J: Logo exploration



Appendix K: Usability testing (3) outcomes for design evaluation

	Participant 1	Participant 2	Participant 3	Summary of comments & recommendations
Task 1: Check training criteria	Subjects and SA's are now more clear He would like to click on it and it will take you there	So red means it's full. I do think it's clear. Before somebody wil be introduced to this, do we get an introduction session on this tool? It does work really intuitive when you explain it, but an introduction would be useful. It's really intuitive already, when comparing it to MyLearning. MyLearning is not visual, here you can visually see	Yes, I will check blue item. I would like to know when I will do the blue training. Yellow means I need to request training. Yellow could also be not planned instead of not completed.	Subjects and Colors are clear Really intuitive compared to MyLearning Add click function to SA/SMS/CARS in planning guidance Change not completed to not planned
Task 2: Book slot	Clear	Search bar would definitely help. Would you search through categories, SMS type or subject? I would like to search through subject, since I will not know the short ID. In MyLearning it's difficult to find trainings. I Like how to prereq's show up, and then it would be red or	It's nice, clear. It's also complete.	Clear and complete Add possibility to search either on training ID or subject in search bar
Task 3: Cancel booking	Works well. Add dropdown function.	Worked good!	It works fine. Planned trainings will automatically link to calendar, that's great.	Works good Make sure training is connected to Outlook calendar
Task 4: Notify me	Clear. Advice on ideal timeframe to be notified.	Notification would be popular!	Notify me on the slot, that means it's full. I would like to know some time before. Acceptable timeframe would be at least one day	Popular function and clear in use Define notification time
Task 5: Find other training opportunities	You wouldn't schedule anything here right? Refer to MyLearning when clicking on it. Because I think I want to schedule it here. It should have some sort of attack.	It seems functional. It's an option that I would enjoy. Click on starting date to be redirected to MyLearning.	Direct to MyLearning that's great. Now we know clearly the training agenda, it's transparant and we know the opportunities.	Seems functional and they would enjoy this option Transparancy towards trainees Direct to MyLearning when clicking on training dates
Extra comments	It's pretty concized, simple to use. Low stress factor. Matter of navigating around and scheduling anc cancelling it.	The graphics are really appealing to me. It works intuitive to me.	Search box is useful. Depends if I work in Veldhoven, sometimes I have some time. Would be nice to search on a training and assign for 1 or 2 trainings in a week. In comparison to if you come from Taiwan, you would assign to one whole package.	Simple to use, pretty consized Simple to navigate around, low stress factor Graphics are appealing Great if you could also schedule a training for just some practice opportunities
Logo	Number 8	Number 8	Number 7, 8 or 9	All engineers find number 8 most suitable

Appendix L1: Benefits and limitations according to company mentor

Benefits and additional comments

- Utilization implementation plan; the effective hands-on time of an individual for a group of 6 people who work on a HW module, is estimated at less than 20 percent (1/6). Considering they can not work on a SA all at once, they have to switch turns. By having these HW focused modular slots, it will probably go up to 80%. Which means the effectivity if doubled. Greatest difference is that you can work on a HW-rigg in pairs and not in a group, meaning you do not have to wait.
- This tool doesn't not fit in MyLearning, since that one is on macro-level. If someone joins the TC for 4-weeks, they still have to assign through MyLearning. This planning tool covers micro-managing, and approaches smaller training groups. MyLearning is not suitable for this.
- The tool will be difficult to implement, a lot of change is necessary. It will be needed around 2025, when the first systems are in operation. The TC will be booming by that time, and the tool will be needed to structure the training slots through modularity. This also results in ease of booking trainings. However, if you need the tool by that time, and it has not been implemented yet, you will be too late.
- What if slots are full? If one slot is full, you can go to the next one. Sometimes the sequence might be less logical, however, you will not have to wait.
- Pilot testing will showcase what would be the optimal amount of slots. Also when looking at the training type timeframes.

Possible limitations

- Limitations of the design can not be determined yet. Can the complexity of the EUV curriculum be captured in this tool?
- The design is not suitable yet for any other applications outside the TC. OJT support etc. are out of scope.
- The two limitations mentioned above are also opportunities, to base future requirements on for integration.

Appendix L2: Benefits and limitations according to trainers

Goal: receive indication of decreased training preparation time

Questions:
- How long does it take you to arrange a training when looking at sending email invites, updating the trainees on location and preparation materials?
- How many trainings do you give per year?

Trainer 1 (NXE training)

Feedback;
- Link materials to SharePoint site; more efficient.
- Encounter flexibility and possibility to change sequence; is it possible to move slot if trainer is suddenly not available anymore.

Benefit:
- The actual training starting time, ending time, location etc.; will definitely deviate from what's stated in MyLearning. In MyLearning a training is blocked, but no details are given, which will be done by the trainer. This tool will definitely save time for me. It has minimal influence on the planning team of Nadine, since they are responsible for the slots in MyLearning, but they don't update this day to day, since it is a generic overview.
- It wouldn't only save time regarding sending emails, but also on creating daily plannings. It would take around 1-2 hours to create a training program, including who is the trainer, where should we be, what will the day look like etc. For some trainings there is already a schedule, but for most you have to create it yourself.
- For my situation, when looking at NXE trainings, 7 hands-on trainings are given per quarter, and 10-12 trainings in total. Around 50 NXE trainings are given only in Veldhoven per year (there is also Taiwan etc.). 1.5 hours x 50 = 75 hours = 10 working days = 2 weeks of work does the extra training planning require.

Trainer 2 (NXE training)

Feedback:
- Personalized options; what if a trainee doesn't want to do a certain training because he/she already knows it.
- Give names of SA subject
- He thinks my training planning more; more professional. If he would use my format in a web version this would be better. More detail.
- Add description tab; to prepare training and add links. E.g. install of specific tooling. In line with the one note recommendation?

Benefit:
- This tooling is also easy to maintain, instead of each trainer having a separate Excel file. It is a more generic way of working with this standard format, where more trainers can

work in. This would be the main benefit.
- You can not save time on knowledge; preparing the training. Now I would write down email, what we learn and what we need, recommendations on what to learn and install. If I would use your format it would save around 1.5 hour. He has 6 trainees in a class 4 times per year: 1.5 hours x 4 = 6 hours of work. This coming year will be doubled because of more demand.

Trainer 3 (NXE training)

Feedback:
- Write down the purpose in bullet points; engineers want to quickly read over it.
- Make the material boxes smaller; they take a lot of room.
- Disadvantage of modular trainings slots: You give a lot of freedom to the user to cancel or change the planning. For trainees who are coming to VHN for a training, it will be no problem. But for trainees who are already here, it can be a problem. When looking at planning, it can be quite a challenge to plan in these trainings.
- Timeframe of notification should be determined; 1 day is too short when looking at preparation time.
- It is challenging to set-up the 'blocks' of the training. If trainings slots have a relationship, how are you going to make sure that this is established.
- These modular training slots, nuggets, should be automized. You can make them more user specific. When trainees are here for a longer time, they can prepare the training and plan in slots a long time before they start. But is this possible when looking at utilization? If the sequence of training doesn't matter, this method is beneficial.

Benefit:
- You will easily spend an hour on checking the agenda, making sure trainees are assigned, informing them on the location. These are all separate tasks, and are spread over a day, with a total time of an hour. Micro-managing is often needed to arrange the training and its trainers. At this moment we make use of long training blocks, in comparison with the proposed nuggets of this training planning tool. These small training slots are more efficient regarding preparing time when looking at the greater sizes of training slots.
- This tool enables you to plan in the whole curriculum and create your own journey.

Appendix L3: Possible SMT connection to MyTraining

Notes of meeting with SMT product owner

Feedback:
- Who owns the tool?
- What database is integrated in the tool? SMT uses SAP, this could be suitable for the planning tool as well.
- Wat if a slot is full? And you have to round-up the training?
- What is the business reasoning behind this tool? Why can not it operate inside MyLearning?
- Give 5 moments of need.
- Define process, information, technology, people of capability plan/hexagon.

Benefit:
- Main benefit of this tool: eliminates documentation time of completed SA in SMT
At this moment the engineer has to fill in manually which CARS/SA were executed during a training. Because this planning tool registers when the trainee has completed a certain CARS/SA, this can be given as input to SMT. This means that the engineer doesn't have to document the completed CARS/SA's after a training, which saves around 15 minutes after every training day (business benefit). Besides that, an automatic reminder can be installed, to remind the engineer to change the proficiency level from 'can not' to 'can', if the system reads that the engineer has completed a certain CARS/SA an x amount of time. This tool will make it easier to update SMT and to show capability details.
- It is possible to create a API link from SMT to this planning tool. However, IT architects have to sit with us to determine system.
- For this connection a budget is needed, just as IT architects.

Appendix L4: Five moments of need

Translation of five moments to need to the MyTraining tool, according to a SME on learning & knowledge exchange.

1. Introduction: Introduce in general the function of the tool, aiming at the main functionalities. How will it benefit the user?
2. Apply: The utilization of the tool, explain the three main functions of the tool in a simple way, by for example showing videos. What are the possible interactions? What is the hierarchy?
3. Learn more: Link to a file with extensive elaboration on the tool, encountering the rules and functionalities. The thesis can be suitable for this.
4. Support: The user needs help, who to approach? Who are the experts? Create a FAQ, to prevent panic and escalation.
5. Feedback: Create a form or tool through which the users can give feedback, e.g. a scale or stars. Best would be to create a form, where they can give openly comments on their pain points when using the tool, and possible recommendations for improvement.