Fostering a personal sequence of learning activities in Skill Circuits

Part 1 of a holistic approach towards designing an educational tool

Thesis report

by

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Executive Summary

This report holds a subset of an integrated thesis involving the development and testing of an educational tool named ”Playlist,” aimed at improving the learning experience of Computer Science & Engineering bachelor students at the TU Delft. The Playlist tool was developed as a feature for the existing tool called Skill Circuits, supporting students in creating personalized sequences of learning activities for their study sessions. The integrated research contributes to the complexities of modern digital learning environments and the challenges students face in navigating vast amounts of educational content.

The study uses a design-based research approach, which involves iterative development and research cycles and including students in the evaluation phases. This report focuses on the description and design of these phases. For each phase, it then reports on how the design of the Playlist tool utilized user feedback gathered through surveys and focus group sessions with Computer Science students.

Key findings in the integrated thesis indicate that *playlists* can improve student engagement, motivation, and overall learning experience by supporting students in finding learning activities aligned with their learning preferences and goals. The research highlights the importance of providing students with tools that improve navigating the learning environment and support them in self-directed learning. The Playlist feature not only aids students in organizing their learning activities but also promotes a holistic approach to education by incorporating supporting activities such as reflection and taking breaks.

The integrated thesis makes two contributions: it serves as an example of the design and implementation of personalization tools in higher education and provides insights into integrating such tools into an existing educational system. The thesis aims to demonstrate the potential of designing tools in an iterative manner to personalize learning and support students in achieving their learning goals.

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1 Introduction

The ubiquity of internet access and the multiple available resources because of that has impacted many aspects of society, including teaching and learning. The wide-spread use of social media, for instance, shows us the many possibilities for learning beyond the 4 walls of a classroom: learning when and where you want it [1].
Consequently, numerous educational tools have been created, with higher education institutions adopting Management Learning Systems, virtual lecture platforms and even including games in their curriculum. Using a digital environment generates a great amount of data as well, enabling institutions and researchers to use that data to improve education. Finally, accessibility of education has increased as well. Not only can students enjoy more learning activities remotely, learners not enrolled in full-time study programs can take part in high-quality courses as well. Simultaneously, experts can use the internet to share their knowledge with so many more people. Creating more (free) educational resources independent of institutions.

The amount of educational content that is virtually available enables students to personalize their learning more than ever. If they know where to look, they can use educational content from different providers and in various modalities to enhance their existing education [2] and keep on developing skills afterwards.
The many possibilities to personalize, unfortunately, also make the learning environment more complex. Without proper guidance, finding the right and correct material can be hard and overwhelming for students [3], often leading them to rely on what is readily provided for them.
While there are many studies uncovering what is needed to support students in the personalization of their learning [4, 5], institutions aren't as fast in adopting these findings. Reasons can range from not having the resources to do so to wanting to take appropriate time for choosing the right solutions. It can, therefore, be beneficial to look at what can be done to help higher education students in the meantime. Are there maybe less intrusive ways to improve the existing learning environment to better accommodate students in personalizing their learning? Providing technology that enables students to interact with their environment in a way that suits them not only helps them directly but may also accelerate the institutional changes they need [2].

1.1. Fostering personalized learning at the TU Delft

A widely adopted method of (gradually) blending traditional education with more innovative and technology-based methods is blended learning [2]. In essence, blended learning can be described as a *"mixed learning model that integrates online learning with face-to-face learning theories and practices"* in a flexible and multi-modal way, where students have opportunities to follow a personalized learning journey [6].
This model implies that a student may rely on their teacher to provide learning content in a way that is readily customizable. Keeping a course's content up to date is often already a challenge for teachers. Asking them to also provide alternative ways of engaging with that content might be unrealistic. Ideally, you would want a teacher to be able to relay to their students the steps needed for finding better learning activities without having to actually do it for them. Being able to self-direct one's learning is a skill that is very much needed in today's technology-driven society where opportunities increase but our skills to properly make use of them may lack [7].

Several initiatives exist at the TU Delft aimed at helping teachers accommodate the different students they teach. Either by providing digital tools to enhance their course or programs to keep teaching skills up to date[1]. The Teaching Academy[2], for instance, is a community for teachers to collaborate on improving the overall education at the TU Delft. The CSE-Teaching team is a collaboration of several staff members involved in the Computer Science & Engineering bachelor program to keep on improving their educational content. PRIME[3] is a dedicated program for lecturers of mathematics courses to work together to improve their lectures in a centralized way. Additionally, they are encouraged to share their course materials, reducing each other's workload and providing alternative quality content for their students.

Effort is also put into providing TU Delft students directly with the necessary learning tools and information[4] outside of course materials, but they are often scattered across different platforms. For teachers alone already several different spaces for learning could be mentioned. A central place from which students can find all their learning content would not only be ideal but could also make customizing their learning journey more straightforward [8]. Is there a way to achieve such a thing without adding to the complex learning environment of TU Delft students?
Being able to improve ones learning journey gives the student agency and instills a sense of responsibility. With this thesis project we want to uncover a way of providing that experience alongside the initiatives on an institutional level. We want to help students find and select fitting educational content and help them recognize the small yet beneficial changes they can make to improve their learning experience. What can be done to help students make beneficial choices in their personal learning journey, in an existing learning environment such as the TU Delft?

1.2. Thesis focus

The main form of higher education people engage with is through an institution. The institution and its teachers then set the boundaries of your learning environment. Traditionally, a teacher comes up with the different learning activities the student engages with, i.e. reading chapters and taking exams. Teachers also indicate in which order you are to do those activities, creating a sequence of learning activities you must complete.
Given the sequence of a course, what opportunities does a student then have to adjust that sequence with learning activities made available to them? And which of those opportunities should they take to improve their learning experience? By consulting the educational sciences, we can uncover ways to expand a learning sequence to fit a learner's needs and translate that into –yet another– a supporting tool. While this seems counterproductive because students already have numerous educational tools at their disposal, we can only determine the effectiveness of our findings by allowing students to interact with them. One requirement we therefore already have is that this tool logically fits into the existing learning environment of the student.
As the student is the intended user of this tool, they will be included in its development process. Not only to uncover the needs and use cases of such a tool but also to determine whether students would be willing to use it. Are students actually interested in taking more ownership of their learning?
Siemens states that technology, sociology, and pedagogy are some of the fields that will need to collaborate for the education of the future. In addition to consulting these fields during this project, looking at educational sources and learning solutions outside the academic field could also provide valuable insights as the internet has given learners access to both formal and informal educational content [9].

1.3. Research objective

Whether they are aware of it or not, students are very much familiar with adjusting their learning journey to better fit their needs. Wikipedia[5] is a popular online encyclopedia students use to get a quick overview of different topics. Search engines (Google) and Large Language Models (ChatGPT) help students explore topics by querying based on their existing knowledge. And even social media play a part in their education.

[1] TU Delft course for teachers to innovate in their course, https://www.tudelft.nl/teaching-support/training-events/senior-university-teaching-qualification

[2] The Teaching Lab: https://www.tudelft.nl/teachingacademy/about/teaching-academy

[3] Prime, https://www.tudelft.nl/en/eemcs/the-faculty/departments/applied-mathematics/education/prime/

[4] https://www.tudelft.nl/teaching-support/educational-tools

[5] https://www.wikipedia.org/

The increasing popularity of educational content on platforms such as YouTube and TikTok could be a sign of people tending to use their social network to navigate educational areas they are not familiar with yet. As the amount of (non-formal) educational resources grow and student's skills to properly navigate them fall behind, they increasingly rely on their social networks– which include teachers and other experts– and recommendations to help them.[10, 1, 9]
The objective of this thesis is, therefore, to design a tool that helps students navigate the educational resources (made) available to them to achieve their learning goals and improve their overall learning experience in the process. Making them aware of the actions they take to improve their learning experience might also teach them how to take these actions when a support system, such as a teacher or tool, is not available. The basis for their learning experience in this research will be the sequence of learning activities provided by their teacher. The tool will then aid the student in personalizing that sequence with activities that fit their learning preferences. The focus of this project is two-fold:

- To design an educational tool aimed at personalizing an existing learning sequence
- To design it in accordance with student's needs and their learning environment

Our research objective can thus be written as:

Research Objective

Designing a digital tool that supports the creation of a personal sequence of learning activities to help students improve their learning at the TU Delft

We limit our definition of students to those at the TU Delft. Specifically, this study includes Computer Science students.

1.3.1. Design-based research

We will use design-based research to achieve our objective. This research methodology is predominant in educational research as it emphasizes the designing and testing of an intervention in a real educational context [11]. For our tool– the intervention– we will need to establish a scientific foundation and also understand the environment in which we intend to implement it. This will not only help us translate theory into practice but also make us consider what is effective in our specific context [12].
There are many descriptions of the design-based research model, with the main characteristic being phases that are visited in an iterative manner. There is an initial order of phases, but revisiting phases upon reflection is encouraged and an important part of the process. We will use the model described by [13] as it focuses on online learning and creating actionable improvements after each iteration. The model consists of four phases which can be seen in figure 2.2:

- Grounding: understanding the problem space and scoping the project
- Conjecturing: creating an action plan
- Iteration: going through building, testing, and adjusting the action plan
- Reflecting: analysis of the previous phases

We want to make our decision-making clear so other researchers and designers can follow along and develop further. As we want to include student's feedback in the tool's design, having an iterative process ensures we have ample opportunity to incorporate their input. It also enables to test the tools effects in the learning environment and adjust where needed. This mindset ensures we keep on improving the tool to fit our user's needs and not just our envisioned functionalities. More information on the methdology of this thesis will be given in the next chapter.

The research objective is broken down into two sets of research questions: literature review questions and empirical research questions. The first set of questions will help us identify relevant scientific literature to gain an understanding of personalization and learning sequences, and work done so far. Answering these questions is also part of the first design-based research phase, grounding, and gives us literature-based input for our tool design. The empirical research questions will then guide our project –in the iterating phases– toward achieving the research objective.

1.3.2. Literature review questions

Literature Review Question 1

How does a personal sequence of learning activities improve learning and make learning more engaging?

Research shows that aligning educational content with a student's preferences helps students become more engaged and increases their motivation to learn. Educational content is consumed through learning activities and these learning activities are presented in a sequence. As we do not want to interfere with the actual educational content can we gain the same benefits by aligning the sequence with student's preferences?
With the first literature review question we want to understand what learning activities are and how they make up a learning sequence. Additionally, we want to understand how a personalized learning sequence improves the learning experience of students.

Literature Review Question 2

What methods can be used to create a personalized sequence of learning activities?

Traditionally, the teacher determines which learning activities should be conducted and in which order. To create a personalized sequence we need to understand how we can adjust that sequence without it losing its educational significance. With the fast growth of educational resources outside the classroom, it would also be wonderful to be able to properly incorporate them into existing curricula.

Literature Review Question 3

How can a personal sequence of learning activities be expanded upon to improve the learning experience in a holistic matter?

Besides learning activities, there are many supporting activities that enhance your learning without adding more educational content. Take, for instance, reviewing past material and creating flash cards. Or less obvious activities that enhance your learning but are not directly related to it, such as taking breaks and changing your environment.
With this research question, we hope to view the learning experience in a broader context. With a more holistic view, a personal sequence can hopefully cause learning to fit a student's goals and needs outside of their studies.

1.3.3. Research question

The next set of research questions will be answered by collecting new data that is specific to the project's context.

Emperical research Question 1

What are the expectations of TU Delft students regarding personalized sequences?

While a design or even an idea can sound amazing on paper, it doesn't fulfill its purpose if it doesn't get used. Literature can get us so far, so we will still need to ensure our tool satisfies actual needs of its intended users.
Students are the most important stakeholders. As we will later learn, educational tools that have students as their intended users often fail to properly include them in the evaluation and design process. With this research question, we want to ensure the student's input on our tool's design is included. Most importantly, we should ask students whether they see any potential in a tool that aids in creating a personalized sequence of learning activities.

Emperical research Question 2

How to design an educational tool to fit the learning environment of the TU Delft?

As we limit our target students to those of the TU Delft, it makes sense to explore how such a tool should be designed in this learning environment. With this final question we can hopefully identify existing channels that can support the design process.
Given that this is a design-based research project, the intervention I eventually present will be preliminary, marking the start of an iterative and open-ended process. In the literature review on personalized learning sequences, I will encounter various methods for measuring improvements in learning environments. I will use these measures to assess whether the intervention fits within the TU Delft environment in that state. We will aim to maintain or reduce cognitive load in the learning environment, achieve comparable or better Attrakdiff scores, and align the tool's design with the students' learning goals.

2
Methodology

This thesis project is guided by the Design-Based Research methodology. While there exist several descriptions of this method, they do share certain aspects such as being integrative and involving iterative cycles [14]. We will use the process model created by Hoadley and Campos as it combines several descriptions of design-based research and focuses on the model's utilization in research on online learning, which is also the context of this project [13].
In this chapter we start with a brief introduction to design-based research and the model as described by Hoadley and Campos. It is then explained how the model was used to guide this thesis project and how its process is reflected in this report. For each phase additional methods are described as well. Finally an overview is given of this project's context as part of the first phase of the design-based research model.

2.1. Design-based research

Amiel and Reeves argue that the growing popularity of design-based research in educational research is due to its emphasis on collaboration with practitioners (teachers *and* students) in an iterative and open-ended process. Design-based research focuses its efforts on solving real-world problems by systematically refining an innovation and, at the same time, producing guidelines and theories on how to do so [15]. When wanting to introduce new technologies in a learning environment, this methodology urges researchers to look at *why* the technology should be adopted, in addition to *how* and *when* it should be used [12].
This differs from empirical *predictive* research where a new form of technology is hypothesized to be an improvement to the learning environment, and this is tested by adapting the learning environment to fit the new technology and not the other way around. Essentially creating a situation that is different from reality and increasing the gap between research and practice [15, 12].
By using the design-based research methodology, we can ensure that the findings of this project, both theoretically and empirically sourced, are applied in an existing learning environment. This helps narrow the gap between research and practice by aiming for a local improvement in education, i.e. the TU Delft. The value of our research can then be found not only in how literature can be applied to our chosen learning environment but also in the process in which we do so. Our research becomes an example for other learning environments on how to use the theories and technologies utilized in this project [11].

A general description of design-based research and predictive research by Amiel and Reeves is seen in figure 2.1. Hoadley and Campos use several descriptions of the model by other researchers to fill in the process for conducting design-based research on online learning. Each phase and its main activities are visualized in figure 2.2 and we will briefly explain below.

2.1.1. Grounding

Researchers begin their journey by choosing and familiarizing themselves with a learning environment. By understanding the needs, constraints, and interactions in the environment, they can determine how literature can be used to improve learning in that specific environment [12]. At the same time, they explore literature to find theories, use cases, and unanswered questions. By identifying a need in an existing learning environment and matching it with theories that describe that environment, as well as research gaps that align with the need, the research becomes valuable to the learning environment and contributes to advancing theory [14]. In this phase, it is also important to clarify the scope of the project, the stakeholders

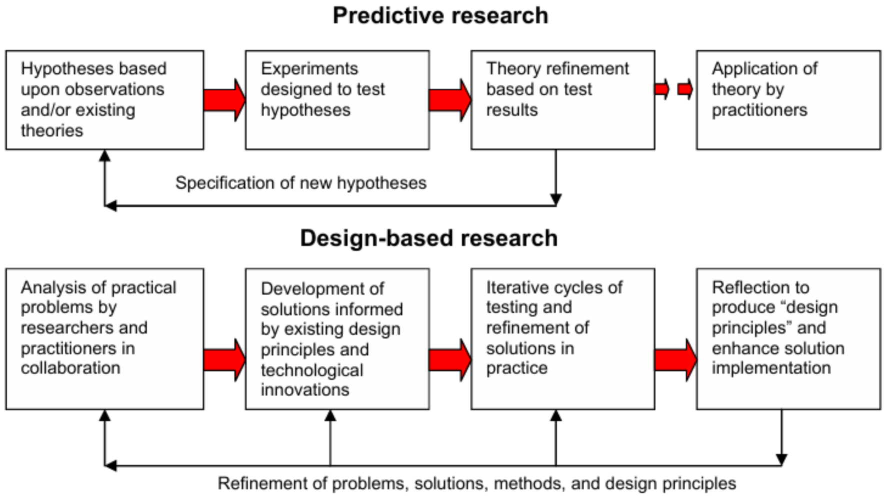

Figure 2.1: The general differences between predictive research and design-based research in terms of phases and the overall process. Taken from [15]

that will be involved and how, and what methods will be used. The ***vision*** for the project is set to guide its direction and the perspective that will be used [13].

2.1.2. Conjecturing

The next phase is creating the initial plan for answering the needs of the learning environment. We say initial, as through iterations the conjectures are updated as more information on the environment is collected. Referencing Sandoval's work on conjecture mapping, this phase asks the researchers to explain their conjectures. Conjectures are the ideas and expectations, influenced by theory and/or practice, for creating a certain effect in the learning environment [13, 16].

Based on the knowledge available at this point, the interventions to be introduced in the learning environment are designed. These interventions are the ***embodiment*** or physical representation of what the researchers have concluded to be able to impact the learning environment. An intervention can be anything, ranging from an actual tool to new materials or even using a different educational approach [13]. The importance of this phase is that researchers state what their theoretical and design conjectures are– and, in later iterations, how and why they are adjusted. Hoadley and Campos cite Sandoval again that it is not the embodiments that will lead to a certain learning outcome, but that the ***mediating process*** that ensues because of the embodiment will [13, 16].

2.1.3. Reflecting

While each iteration in the iterating phase has a reflection moment, design-based research is closed with a final reflection to determine its outcome. After analyzing all the collected data and different conjectures that were explored during the research, Hoadley and Campos suggest there are 6 possible types of outcomes.

A domain theory provides an explanation of a learning theory when applied in a specific context and using a certain intervention. It is called a domain theory as it might not be generalizable to other contexts or domains.

Design principles or patterns can be seen as general guidelines to achieve a certain outcome. Researchers describe how and when learning environments need to be designed when dealing with certain learning problems. As these are generalized prescriptions, adapting the principles or patterns to a given learning environment will always be necessary [13].

New hypotheses and ***ontological innovations*** encourage future research as through iterating new questions arose regarding the learning environment or even established design frameworks.

A design process and ***"design researcher transformative learning"*** as outcomes focus on the actual process of the design-based research. The former describes a clear methodology for achieving a certain design. The latter focuses on the researcher and the role they play in the learning environment they are exploring [13].

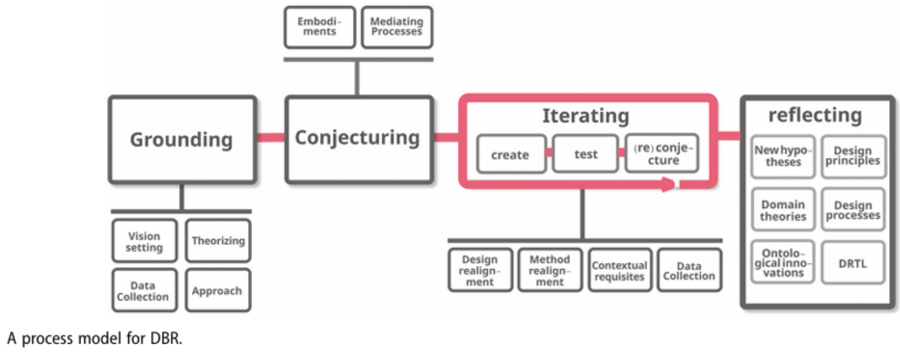

Figure 2.2: The design-based research process model as created by Hoadley and Campos [13]

2.2. Design-based approach in this project

In this section, we will outline the execution of each phase of the model by Hoadley and Campos [13] in this project. For each phase, it is explained what methods were used, the outcome, and which research question it is related to. The corresponding chapters for each phase are mentioned as well. Each phase and its activities will be described in a sequential order for better readability. In reality, phases were revisited multiple times, and their outcomes were iteratively improved.

2.2.1. Grounding, Chapters 1 - 3

Methods used: content analysis, inquiring experts, exploratory literature review
Outcome: answering the three literature review questions.

Chapter 1 sets the vision for this project by stating a research objective. We discuss today's socio-technical society and how it impacts higher education. We argue that higher education is not fully utilizing students' access to the internet and other technologies, and if it did, it could provide students with a more personalized learning experience. We choose to focus on the sequencing of learning activities and its personalization. Five research questions are formulated to help us achieve our research objective.

Chapter 2, the current chapter, outlines our approach by explaining the methods used and providing the context of our research. The learning environment that we want to improve is that of the TU Delft, which we will explore through content analysis (the TU Delft website). We are also interested in educational innovation at the TU Delft. Contacting education experts will help us find relevant spaces. Section 2.3 not only introduces the learning environment in which we will conduct our research but is also the first step in collecting data on our so-called local practice and will help ground us in practice.

Chapter 3 will provide the theoretical input for our design-based research. An exploratory literature review is performed to understand the aspects of personalized learning in online learning environments and how personalization can be achieved when focusing on sequences of learning activities.

2.2.2. Conjecturing, Chapters 4, 5

Methods used: User stories, self-reporting (survey)
Outcome: System requirements, tool functionalities

Most of our conjecturing will be theory-based and can be found in **chapter 4**. In this phase we will formulate the ways we aim to achieve personalization of sequences of learning activities in our chosen learning environment. Our embodiment will be defined in the form of system requirements for our envisioned tool. To help us choose and prioritize the several functionalities of our system for the tool's first iteration, we will ask for input from our intended users through a survey.
Chapter 5 shows the inputs collected from students. The digital learning environment in which we will test our tool with students is called Skill Circuits. This learning environment is used in the Computer Science & Engineering bachelor by several teachers. The users of our tool will, therefore, be students using Skill Circuits. As this phase was during the second quarter of the academic year, bachelor courses utilizing

Skill Circuits in that quarter were approached to distribute a survey among their students.
Qualtrics[1], a surveying platform often used for research, was used to digitally host the survey and students were asked to participate via an announcement on the BrightSpace page of their course. Data on the respondents can be found in table 2.1

	Algorithm Design	Algorithms & Data Structures
Total number of students	529	584
Number of respondents	34	76

Table 2.1: Courses where each of the surveys were distributed

Our envisioned tool was described in the form of user stories in five categories. User stories are short descriptions of different functionalities of a tool. Students could indicate if they would use the functionality by filling in a 5-point Likert scale, ranging from extremely unlikely to extremely likely, for each user story. The results were used to prioritize functionality development. We also use this section to briefly introduce how the final playlist was created.

2.2.3. Discussion and Conclusion, Chapter 6

This chapter summarizes the data collected to evaluate the playlist feature, including the key findings for the first implementation and recommendations for future developments. A full description of this process, including the complete iterating phase of the project, can be found in part 2 of this thesis. A complete description of the evaluation phase can be found in that report as well, which is available online in the TU Delft repository [2].

2.3. Project context: TU Delft's learning environment

Part of the grounding phase is becoming familiar with the learning environment we want to help improve. We will start with a general overview of the TU Delft campus and look at two aspects:

- learning opportunities
- learning design and innovation

We then narrow down our view to where students encounter their main learning sequences: a course. Looking for an appropriate opportunity for our design-based research will bring us to a digital environment called Skill Circuits. Skill Circuits is a tool used in the Computer Science bachelor's program that breaks a course down into its learning activities.

2.3.1. Learning opportunities

The TU Delft offers 16 bachelor's programs and 39 master's programs (some with different tracks you can choose from) [17]. The different digital systems you are required to interact with once enrolled vary per program and even course. Two digital environments are, however, adopted institution-wide. Brightspace is a learning management system that is used as the online learning environment for every course. Teachers are free to utilize this system as they see fit. Osiris is the official administration system where students can register for exams and view their study progress.
Having multiple tools is not necessarily the problem, as suggested by the media richness model; rather, the issue lies in not providing proper guidance on using them effectively. With Brightspace being the main online entry point for a course, is it utilized effectively to guide students towards other tools? Different tools have varied ways of communicating with their users, which is crucial for personalizing the learning experience.
Every student is unique and may require some help during their studies. The TU Delft Career & Counseling Services offer workshops to help students improve their study skills, work on their personal development, and help them make choices to better prepare for their career. The library and student-run associations

[1]Qualtrics is a platform for creating, distributing and analyzing surveys and is GDPR compliant, `https://www.qualtrics.com/`
[2]Link to repo

also provide learning support in a more generalized matter. Additionally, the university offers buildings where students can study outside of normal class hours.
The campus is not just for learning, but also to meet and connect with peers through activities that are not directly related to learning. The university agrees with this more holistic view of learning, where you need to hone more than just academic skills to make studying enjoyable and worthwhile. The culture and sport hub X is where students can engage in sports activities, learn about the different cultures at the TU Delft through social activities, and take courses in several arts.
While studying at TU Delft, students are encouraged to develop skills beyond the academic to prepare themselves as future engineers. However, this holistic approach is not always mirrored in the technologies used for learning.

2.3.2. Learning design and innovation

Identifying areas within the learning environment that are open to research and prototyping is crucial for continuous improvement. Highlighting current initiatives, past efforts, and lessons learned can provide valuable insights.
Key players in this space include the Teaching Lab, Centre for Education and Learning (CEL), individual teachers, Extension School, and the Computer Science & Engineering Teaching Team (CSE-TT) team. With both physical and virtual learning environments and a campus with over 20,000 enrolled students [3], there are many ways to improve education. Thus, many such initiatives exist on both an institutional level and on a more local level, such as within a faculty. The Teaching Academy is a community of educators at the TU Delft that aims to innovate education and teaching through campus-wide collaboration. Being a central place for educational knowledge and support, they ensure every teacher can find the resources they need to improve their courses.
Using the teaching academy as a starting point for exploring the various ways teachers at the TU Delft approach learning design and innovation, we see it happening on several levels:

- Collaborating with other institutions to share knowledge and streamline higher education in the Netherlands (Centre for Education and Learning) and even in Europe (ENHANCE).
- Knowledge sharing within the university (PRIMECH)
- Creating evidence-based solutions for educational challenges encountered throughout the university (Teaching Lab: IDEE)
- Empowering teachers and keeping their skills up to date (UTQ)
- Inclusion of general engineering skills in education at the TU Delft (Reflective Engineer, Extension School)
- Focus on improving education in a certain field (PRIME)

These initiatives offer clear entry points for teachers to collaborate and learn how to incorporate new knowledge into their teaching. While improving education has the biggest impact on the learners– students in this case– they aren't easily included in sharing their experiences and ideas.
Students are often given reactive opportunities through feedback surveys at the end of a course or by mentioning needs to various student councils. While teachers are encouraged to include their students more in their course design, this activity is solely left to them. Currently, there is no system in place for students to independently enhance the education they receive, nor is there technology that could assist them in learning how to do so. Developing such systems and technologies could significantly empower students and improve the overall learning environment.

2.3.3. The computer science & engineering teaching team

This brings us to the Computer Science & Engineering Teaching Team, a local initiative to improve the Computer Science & Engineering bachelor program. The team consists of both scientific and educational staff members who design and improve educational software and a group of developers who create and maintain that software. This might sound as another initiative where no students are included, but the developers mostly consist of (ex-) computer science students. While they fulfill a more implementing role, they are part of the development process and have the opportunity to voice their opinions on design choices.

[3] TU Delft in numbers, `https://www.tudelft.nl/over-tu-delft/feiten-en-cijfers`

The team focuses on developing tools that address the needs of both lecturers and students [4]. A tool developed to mainly address student needs is Answers, a Question & Answer platform [5]. Here, students can seek help with course materials in any computer science subject from their peers. While this functionality exists in Brightspace– which should be available for every course– this feature is separate for each course. Answers is solely used for discussions on learning material and enables student to ask for help in a central place for all courses, helping them keep track of all their inquiries and those of their peers.
A tool that aims to address the needs of both lecturers and students is Skill Circuits.

2.3.4. Skill circuits

Skill Circuits is a platform that can be freely used by teachers to support their students in understanding the hierarchical structure of their course. On the platform, teachers will visualize their course material as a circuit tho show the interconnections of topics[6].
First, teachers must identify the overarching topics in their course, called modules in Skill Circuits. Each module can then consist of sub-modules, indicating sub-topics or concepts the course will touch upon. These sub-modules are then broken down into skills, the smallest concept the course wants to teach its students. This breakdown can be seen in figure 2.3.4 as well.
Eventually, the course is represented by a circuit of skills that show how, and *why* each part of the course is connected. Each skill holds learning activities (called tasks on the platform), implying that their completion results in mastering that skill. The completion of learning tasks is tracked by the platform, which shows students their progression through the course's content.

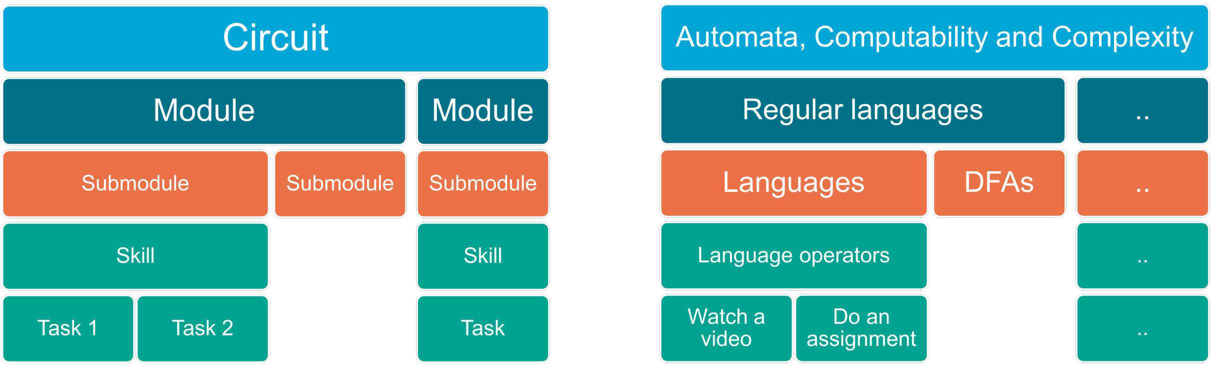

Figure 2.3: A visualization of how a course is broken down in Skill Circuits. On the left, the different levels are shown. On the right, the levels are filled in for the course Automata, Computability and Complexity, as an example

Skill Circuits is constantly improved upon, incorporating feedback from both teachers and students. Computer Science students are encouraged to actively contribute as well, be it just for the experience of developing a tool. A master's thesis on improving Skill Circuits' usability for teachers can be found in [18]. We will add to the contributions by exploring the personalization and sequencing opportunities in Skill Circuits to benefit students.

2.4. Evaluation methods

As mentioned in the previous section, students were asked for their input at several stages of this design-based research project. Each time, students who had experience with Skill Circuits were approached. As Skill Circuits is used for Computer Science mainly students from these courses were included in this research.

Through the process of operationalization we can translate a research objective or question to actual concepts or variables we can measure. Not only does this help us determine *what* we precisely want to

[4] Find all developed tools here: `https://eip.pages.ewi.tudelft.nl/eip-website/`
[5] `https://answers.ewi.tudelft.nl/`
[6] An introduction to Skill circuits can be found at `https://eip.pages.ewi.tudelft.nl/eip-website/skill_circuits.html`

measure for our research, but it also lets us think about what methods are *possible* given our resources [19]. In this research it will come down to mainly exploring tool possibilities and collecting student perspectives and ideas. Still, we must find clear (design) methods to do so. The operationalization steps can be found in the appendix, table A.1. Surveys will be the main tool for tracking students' perceptions and will include three existing questionnaires:

- the (revised) Achievement Goal Questionnaire [20]
- Mental effort rating scale [21]
- AttrakDiff Survey[22]

Two surveys were distributed. The first was to gain baseline information on Skill Circuits and students' perceptions of our feature idea. The second was distributed after students had a chance to use our designed feature for Skill Circuits.

Students were also asked about their opinions on envisioned functionalities and what they would want to see in the feature. As will be discussed in chapter 4, five categories of functionalities will be presented as user stories.

To have effective focus group sessions with students, where we both discuss the playlist's current and future design, the Design Thinking toolbox was consulted [23]. Qualitative data will be collected by engaging in the following activities:

- Filling in a Feedback-Capture grid
- Constructing user stories in the Jobs To Be Done format

To ensure a sufficient amount of participants for the focus group sessions, they will also be open to Computer Science master students. The only prerequisite is that they have used Skill Circuits before. These master students were contacted through several social channels.

	Survey 1	**Survey 2**
CS bachelor courses	Algorithm Design, Algorithms & Data Structures	Automata, Computability and Complexity
Total number of students	1113	553
Number of respondents	110	9

Table 2.2: The courses where each of the surveys were distributed

2.4.1. Survey elements

The surveys were used to collect students' input on Skill Circuits and the designed feature. Additionally, three existing questionnaires were included. The Attrakdif questionnaire was used to assess the tool's overall usability and stimulation. A measure of cognitive load was used to see if mental effort would differ when introducing the designed feature in Skill Circuits. The revised Achievement Goal questionnaire was used to hopefully discover which goals can be linked to using Skill Circuits and/or the designed feature.

AttrakDiff

The Attrakdiff questionnaire aims to gain a holistic perspective on a technological tool, which means looking beyond utilitarian aspects. Through 28 word pairs, we gain information on 4 dimensions [22]:

- Pragmatic Quality (PQ): the perceived usability of a tool
- Hedonic quality-stimulation (QHS): self-development through usage of a tool
- Hedonic quality-identification (QHI): self-expression through usage of a tool
- Attractiveness (ATT): the beauty of the tool, seen as an overall impression indicator

With a 7-point semantic differential scale [19] students could indicate which word in each pair mostly describes a tool– each word in the pair representing one end of the scale. The results will help us determine how satisfied users are with a tool in terms of usability and subjective experiences. While I aim to design a tool that students perceive as useful, it is also important that students enjoy using the tool as that increases the chances of repeated usage.

Achievement goal questionnaire
To uncover what type of goal students have for a course, you can ask them to fill in the Achievement Goal Questionnaire. The questionnaire consist of 12 statements, of which students have to indicate on 5-point Likert scale whether they agree with the statement or not.
There are four types of achievement goals: Mastery-approach, Mastery-avoidance, Performance-approach, and Performance-avoidance. An explanation of each goal type is given in chapter 3. For each goal type 3 statements are given [20].
Students' goals can be used to determine both appropriate learning activities and strategies. For the students themselves, setting a goal is an integral part of self-directing their learning, a skill that will be explained as beneficial in today's technology-driven society.

Mental effort rating scale
We use the scale created by Paas to ask student how much mental effort is required of them when they interact with an educational tool [21]. This relates to cognitive load theory and our aim not to burden students when introducing a new tool in their learning environment. More information on cognitive load is given in chapter 3. The scale is a 9-point Likert scale (1 = very, very low mental effort; 2 = very low mental effort; 3 = low mental effort; 4 = rather low mental effort; 5 = neither low nor high mental effort; 6 = rather, high mental effort; 7 = high mental effort; 8 = very high mental effort; 9 = very, very high mental effort). Students were then asked to answer one question with that scale: *" How much mental effort do you actively put in when using [educational tool X] to learn?*. [Educational tool X] is either Skill Circuits or our Playlist feature.

2.4.2. Focus group activities

After using our designed tool, we want to collect more qualitative data from the users. To ensure enough students would sign up for the focus groups, as these were planned during the exam week, registration was opened for master students as well. A prerequisite to join was having experience with using Skill Circuits.
Ideally, a focus group would consist of 6 to 10 people. The total number of registrations was 11, so the group was split into two separate sessions. These smaller groups were also envisioned to be more manageable by just one moderator.
Following guidelines provided by the Data Innovation Project[7], we set up the following focus group session:

1. Filling in a "Feedback Capture Grid" based on the first version of the Playlist tool
2. Short discussion on own expectations and ideas for the Playlist tool
3. Determining use cases and user stories that speak to you
4. Filling in "Jobs To Be Done" template for chosen use cases and user stories

	Focus group session 1	**Focus group session 2**
Bachelor students	1	1
Master students	4	3

Table 2.3: The number of Computer Science students that participated in each focus group session.

Feedback capture grid
The feedback capture grid is a method for testing a minimal viable product with its intended users. It was chosen for its simplicity and quickness of understanding [23]. After a short introduction, the students were

[7] `https://datainnovationproject.org/tip-tools/`

given at least 10 minutes to test and write down any feedback they had according to the four quadrants of the grid:

- Likes: things you like or find remarkable
- Wishes: constructive criticism
- Questions: questions that arise throughout the experience
- Ideas: ideas that arise throughout the experience

Students were given post-its to write down their feedback, which were then placed on the grid drawn on a flip-over in the room. Once all the students had finished writing, they were asked to explain their key points. Ideally, we should delve deeper into discussing the post-its on the grid to understand why students chose to write down what they did. This aspect will be captured by the second activity of the sessions.

Jobs to be done
The "Jobs To Be Done" method asks users to write the process of accomplishing a task in the format: "When <*fill in situation*>, I want to <*fill in motivation*>, so I can <*fill in expected outcome*> [23].
This method provides us with a structured way of gaining feedback on my tool's developed and proposed functionalities. Additionally, it is a clear format for students to present tasks I did not account for but that they would like the tool to help them with.

Students were asked to fill in the "Jobs To Be Done" format for:

- Tasks or functionalities they wished to accomplish with the tool
- Functionalities that were determined in this research
- Healthy learning habits

The first category also provided an opportunity for students to explain the feedback provided on the feedback capture grid in more detail.
The second category was to learn how the user stories mentioned in chapter 5 could be implemented to properly assist the student in the task.
The last category was added because the surveys did not clearly indicate whether students would appreciate the inclusion of such activities in a personal learning sequence.

Again students were given post-its to write down their "jobs", which were collected on a central flip-over.

Discussions in between
If time permit, short questions were asked to students about their inclusion in this research project:

- Is this an appropriate time to ask for your feedback on the design of an educational tool?
- What are your main impressions about the current implementation of the tool?

2.4.3. Coding student's input

In chapter 5 five categories of functionalities are defined:

- navigation
- time
- learning analytics
- learning activities
- supporting activities

Unstructured student data from both the surveys and the focus group sessions were coded using these categories. When analyzing the data from the focus groups, it was discovered additional categories were needed to better describe the feedback students gave.

3
Related work

In this chapter, we complete the grounding phase of our project by exploring literature to find relevant works to build upon and understand the concepts needed to achieve our research objective. This chapter will be guided by the three literature review questions in chapter 1.

I aim to design an educational tool that improves a higher education student's learning experience by providing them with the tools to personalize their learning. Specifically, tools that can help them navigate their learning environment to create a learning sequence with learning activities that interest them. Following the order of the literature review questions we will first look at what a sequence of learning activities is. The instructional design method 4C/ID will help us understand how a sequence best supports learning. This should help us answer the first literature review question.
We will then explore the literature to find out what personalization means in education, its benefits, and why students should have the ability to personalize their learning. The process of personalization is a part of self-directed learning, and we will therefore explore how a tool can assist a student in developing this skill as well. We now have the answer to our second literature review question.
Finally, we will take Siemens's advice on a holistic approach to education design and explore methods to enhance a learning sequence with activities that may not be directly related to the presented learning content. By considering the opportunities within the TU Delft learning environment and utilizing the four-component instructional design (4C/ID) model, we can the address the final literature review question.

The chapter closes with a recap by answering the literature review questions.

3.1. Learning sequences

A sequence of learning activities can be seen as the path a student is required to follow to consume a course's content [24]. The sequence is designed to ensure that students engage with content that matches their knowledge level, increasing the complexity of activities as students progressively interact with the learning material [4, 25]. Different strategies exist for sequencing learning activities, as the appropriate sequence is very much dependent on the content being taught, the activities chosen to do so, and the preferences of both the teacher and the student [24].

In [26], a distinction is made between main and supplementary learning content. The main content is the core material of the course, including activities centered around understanding the subject. Activities designed to help you make that new knowledge your own and apply it are then seen as supplementary (i.e., exercises and opportunities to ask for help). If given the choice, students tend to engage more with the main content of a course. Especially when the value of (supplementary) activities is unclear, or they do not align with a student's preferences, students will prioritize activities where the course's subject is at least plainly explained. If a student does not believe they are capable of achieving a certain academic performance on their own (self-efficacy) and no supplementary activities align with their preferences, this can have a negative impact on their learning experience and outcome. Which highlights the importance of personalized sequencing and learning in general.
While teachers may want to provide different sequences to accommodate the various preferences students have, doing so requires increased effort from the teacher and the support of technology to be able to cater to all students effectively [4, 26, 27].

To understand how sequences are preferably constructed in higher education, I will look at the 4C/ID model [28]. An important reason for the appropriate design of a learning sequence is managing cognitive load, which will be explained thereafter. Finally, I will define what I consider to be a learning activity.

3.1.1. The four-component instructional design (4C/ID) model

The 4C/ID model is a task-centered instructional design model focused on the development of complex skills [25, 27]. Traditional objective-based instructional design approaches focus on breaking down complex content into smaller objectives to be attained. One drawback of this approach is a disconnect between the different topics of a course, as they are mastered separately and not in an integrated manner. A task-centered approach keeps the complex content as a whole instead. Tasks are a representation of how different objectives can coexist, gradually developing the mastery of each objective in a holistic manner.

In contrast to the more traditional objective-based instructional design approaches, 4C/ID is, therefore, said to be more suited for preparing higher education students for the careers that await them. In a socio-technical society, the job market is constantly evolving, and professionals are not only required to have expertise in their respective fields but must also continually update and adapt their methods to succeed in an increasingly multidisciplinary and globalized environment [27]. When using 4C/ID to design a course, students are given instructions based on the task at hand [29]. This approach allows students to acquire the necessary knowledge, skills, and attitudes for professional and daily life situations in an integrated manner. Students begin with the least complex tasks that they might encounter as professionals and gradually make their way up to more complex tasks. Each complexity level consists of several tasks to show the variability tasks may have [25, 27].

The four components refer to the components of the learning sequence. A 4C/ID sequence contains sub-sequences. Visualized in figure 3.1, its components are:

1. learning tasks: complete tasks representative of real-life tasks
2. part-tasks: to practice a part of the complete task
3. supportive information: educational content relevant to the sub-sequence
4. procedural information: educational content relevant to each task

Each sub-sequence has learning tasks with the same level of complexity. As these are all complete tasks, each task in a sub-sequence should represent the varying nature of tasks in a professional setting. Part-tasks are needed when complete tasks do not provide enough practice to become fluent in routine aspects. Procedural information holds the instruction for these routine aspects and is gradually reduced as the student masters the routine. Supportive information is then specific to the sub-sequence and pertains to the non-routine aspects of a learning task. It explains how the tasks in the sub-sequence can be approached and builds upon previously acquired knowledge.

Implementing 4C/ID ensures that complex skills are taught holistically by ensuring both the mastery of routine skills and proficiency in utilizing non-routine skills.

3.1.2. Managing cognitive load

Learning environments are also becoming more complex as teachers are encouraged to facilitate blended-learning [2] and integrate new technologies. While these technologies are designed to improve learning, students can still get overwhelmed by all the different possible learning activities made available [10]. In educational sciences, this is often described as cognitive overload.

> "Cognitive load theory aims to explain how the information processing load induced by learning tasks can affect students' ability to process new information and to construct knowledge in long-term memory." [30]

The theory is used in instructional design to help teachers keep in mind the mental effort they are asking of their students. As students encounter new pieces of information, they make use of their so-called working memory to process this information and eventually store it in their long-term memory. Working memory can only process a limited amount of information at a time, meaning how you are asked to use your working memory directly impacts your learning [31, 32]. There are three types of cognitive load to be managed [33]:

- Intrinsic cognitive load: the mental effort needed to perform the learning task

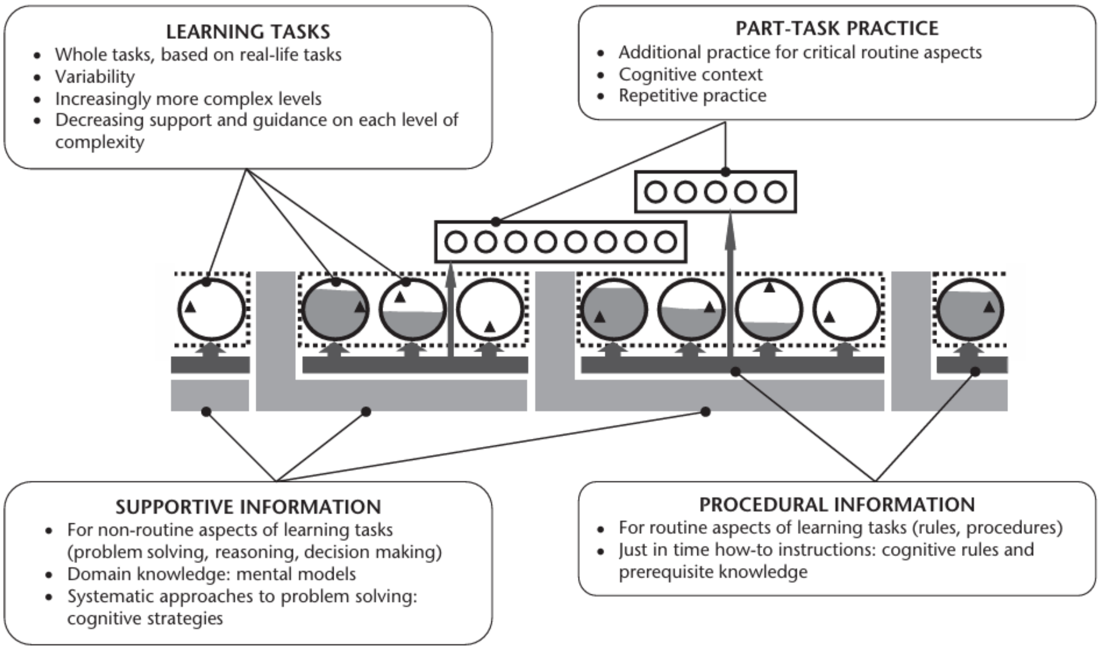

Figure 3.1: Schematic representation of each of the 4C/ID components [25]

- Extraneous cognitive load: the mental effort required to process information related to the learning task
- Germane cognitive load: the mental effort put into actually understanding the learning content for future reference

The utilization of cognitive load theory in 4C/ID is reflected in the four components. Intrinsic cognitive load is managed by gradually increasing the complexity of tasks through sub-sequences. Extraneous cognitive load is minimized by providing supportive information at the right time and in the right amount. Germane cognitive load is increased by task variability within sub-sequences. And lastly, cognitive overload is limited by providing appropriate supportive information for each sub-sequence [30, 34, 33].

Proper sequencing of learning activities improves learning by effectively managing a student's cognitive load.

3.1.3. Learning activities

The terms ”learning activity” and ”learning task” are often used interchangeably in the literature. Does a learning sequence consist of learning activities, learning tasks, or both?

Merriënboer and Kirschner provide examples of learning tasks such as a case, project, or assignment, indicating a task results in an outcome [25]. In Çebi and Güyer's work on online learning activities, examples of learning activities include tutorials, engaging on forums, and doing exercises. It would seem learning activities are slightly different and more objective-related, as they are focused on knowledge acquisition [26].
In “What is task-centered learning?”, however, task-centered learning is described as being a way of making learning activities *”more relevant to performance outside of school and foster the skills needed in workplace and lifelong-learning settings”* [29]. When comparing with the implementation of 4C/ID in [33], both studies suggest that learning activities are components of learning tasks.

Skill Circuits, the environment in which I will develop the resulting intervention (more in chapter 4), uses the term task for units that could fit both descriptions. Moreover, [4] observed that studies on personalized educational systems often use both terms interchangeably. A proper distinction in the context of this thesis is therefore not possible, so I will mainly use the term ”learning activity” for any unit of work within a course. ”Learning task” will still be mentioned when a referenced work uses that term.

3.2. Personalized learning

There are two main approaches for tailoring educational content to a student's needs: *adaptive learning* and *personalized learning* [4]. In literature the difference between the two approaches is not always clear, especially since the terms are sometimes used interchangeably to describe educational systems [4, 5]. I believe that understanding the difference in this case is important as opposed to the previous case (learning activity and learning task). Thereby, I will attempt to explain how I differentiate between the two before moving into summarising literature about personalized learning.
Adaptive learning is when the educational content is (automatically) tailored to fit a student's preferences and knowledge level [5]. A student's learning behavior is constantly monitored and analyzed to support their learning throughout the whole learning process, and when this process is carried out by technology, they are often called an intelligent tutoring system [4].
Personalized learning, on the other hand, is when the student is given the opportunity to change educational content to fit their preferences and interests [5, 4]. Adaptive learning focuses on supporting the learner in achieving a certain (predefined) educational outcome, whereas personalized learning aims to make the educational outcome personally relevant [3].
The aim of this thesis is personalization, as I aim to align educational content with a student's needs rather than shaping their education toward a specific outcome. [24, 35].
In the context of educational technology, the difference between the two approaches is often unclear [4]. It is, therefore, beneficial to look at both types of systems to gain an idea of past work on personalized learning systems.

Personalization of the learning experience is one of the most common goals in the development of educational technology. It is even seen as an antidote to our current education systems that are built to accommodate masses rather than individuals. Personalized learning happens when students have the ability to take ownership of their learning and adjust it to their needs [2]. With access to appropriate tools and guidance on how to use them, students can create their own personal learning environment[36]. As learning becomes more technology-based, we gain access to a lot of (personal) data about learners. Utilizing this data to improve the learning experience can make education more learner-centered and learning-based [2, 7], instead of the more traditional focus that is on teaching.

3.2.1. Increasing motivation

One of the key factors in education is motivation. Personalized learning content can help students learn the subjects they are interested in, in a way that is motivating to them. Assuming motivation is associated with the student's engagement with the learning material, we want to be able to ensure that engagement as much as possible [26]. That means putting effort into helping students find what they need, when they need it. This is especially important in online learning environments where information can be abundant and overwhelming.

Motivation is not only a studied topic within the learning sciences but a field of study in its own right. Motivation is a key driver for engaging in any activity– not just learning– and maintaining that motivation is beneficial to seeing that activity through until the end [37]. Through personalizing, we would therefore want to at least maintain and potentially increase a student's motivation.Verpoorten et al. explain that a student's motivation to learn is dependent on their perception of 3 factors: the amount of control they have, the value of the learning task/activity, and self-efficacy or confidence in their ability to complete the activity [3].
In providing a personal sequence of activities to students, we don't want to take away any form of control they already feel they have. Instead, we want to increase their perceived control by allowing them to navigate better and choose among the learning activities presented to them [10]. The perceived value of a learning activity is personal but could be increased by making its connection with the student's goals clearer. This can be done by showing the student how the activity fits in their personal sequence, which in turn is based on the goal the student set.
To increase students' self-efficacy, we can help them become aware of their progress. When they work through the learning activities of a personal sequence, the tool should emphasize the learning activities they've completed and how far they have already progressed. This can be achieved by collecting Learning Analytics; which will be discussed in section 3.4.3.

3.2.2. Related educational systems

Xie et al. reviewed a decade's worth of both adaptive and personalized learning systems. They found that the majority of systems were designed for higher education students, to be used on a computer, and focused on engineering learning content. Personalized learning content and personalized learning paths were mostly supported by these technologies. Learning achievements and learning preferences are among the most popular parameters for personalization, with the sequencing of learning activities being more conventional. [4].

One of the gaps Xie et al. identify is related to the readiness of a tool, which considers what experiences and contexts increase a student's willingness and ability to learn. They explain that studies that have attempted to enhance learning experiences in this aspect either have too limited data to make an impact or the data collection methods required are intrusive to users [4].

Four types of educational technology solutions can be identified within institutions [2]. A system that personalizes learning for the student falls into the category of human-machine interaction. Key takeaways are that mostly student's performance and motivation are affected. Such tools focus on matching a student's cognitive style and automating recurring tasks such as tutoring, assessment, feedback, and content delivery. The most adopted tool in institutions, a Learning Management System, often lacks in this regard as it has very basic adaptive functionalities. Additionally, these systems are often solely used as a means of managing and delivering educational content to students [2]. In [4], it is shown that personalization is often dependent on technical and platform support. Finding a way to introduce personalization functionalities in existing technologies adopted in higher education institutions might be more feasible than trying to encourage the adoption of newer, more sophisticated systems.

[35] designed an Adaptive Course Player. While it is a fairly old system, it is an example of using learning preferences to adapt a sequence of learning tasks. Using Felder and Soloman's "Index of Learning Styles Questionnaire"[1], the system determines the learning style of the student and adapts its learning content accordingly.

The Adaptive Course Player adjusted both the learning content and the sequence in which it was presented to the student's learning style. A problem that occurred was providing content for learning styles with a visual preference. Most visual learning content supported textual content and could not be understood without text. Although the student with this preference was presented with less textual content, not everything could be visualized. This problem might explain another gap identified by Xie et al., where a system that both adapts the educational content and sequence was a rare find among the 70 studied systems.

These works highlight the importance of considering a student's context and readiness when personalizing learning to ensure it is effective [4]. Within existing educational environments, the adoption of more sophisticated personalization technologies is not expected soon, indicating that finding a way to integrate personalization into existing systems is crucial [2]. Sequencing of learning activities is a common way of personalizing learning content, but systems often do this in a domain-agnostic way. While learner information, such as learning preferences, provides greater opportunities for personalization, the extent of what is achievable still relies on the available content and platform capabilities [4, 35].

3.2.3. Considerations

While personalization is beneficial, Selwyn et al. [38] argue that technology may demand it excessively and in an unhealthy manner. With mobile devices always being connected, students might be tempted to engage with educational content at times when it negatively impacts other areas of their lives. Providing students with tools that can enable them to personalize their learning is therefore not without a responsibility of teaching them how to use those tools properly and responsibly. Especially when studies show that only a small group of students know how to use such tools [2].

The founder of instructional design method 4C/ID suggests that not only should education be adaptive to students' preferences, but students themselves should be taught how to choose and define their own learning activities [25].

While my goal is to foster personalization in an existing learning environment, I do not want to make students dependent on a teacher or tool to personalize their learning. I also do not want to focus on a

[1] The questionnaire can be accessed online: `https://learningstyles.webtools.ncsu.edu/`

student's learning outcome in terms of performance. Instead, I aim for personalized learning environments to improve a learning outcome Xie et al. dub "affection". Studies with this focus measured several things, including learning motivation, self-efficacy, cognitive load, and learning intention [4], which are all affected by self-directed learning.

GOAL is an example of a tool that is designed to both support and monitor students' self-directed learning ability within an existing learning environment. Focused on the learning activity "extensive reading", the tool holds different functionalities likely needed for this activity. By collecting data on student's behaviors, it also provides feedback to improve self-directed related skills. A higher self-directed learning ability was associated with higher performance, indicating it is a skill worth developing but may require domain knowledge to support properly [39].
The next section will look at self-directed learning, why that is an important skill to have, and how we can foster that skill with a tool.

3.3. Self-directed learning

As much as we want to support a learner in their journey, we also want them to have agency and take responsibility for their learning. If a tool can deduce what a student's learning preferences are, it should share those findings with the student. Not only to verify if the analysis is correct but also to make the student aware of their preferences and tendencies. This type of information empowers students and enables them to, eventually, be able to personalize their learning on their own terms. This not only enables them to better navigate the technology-based society we live in but helps them to become self-directed learners.

> Self-Directed Learning (SDL) is the process wherein individuals take the initiative, with or without others' support, to diagnose their learning needs, formulate their learning goals, identify human and material resources for learning, choose and implement appropriate learning strategies, and evaluate their learning outcomes (Knowles, 1975) as cited in [39]

This is a much-needed skill in the 21st century as technology is encouraging a shift from teaching-centered education to learner-centered. While most students nowadays have ample experience using technology and web-based resources, this does not necessarily mean they know how to utilize them for their learning [10, 39, 40].

The most cited description of SDL is that of Garrison which explains SDL as a model with three overlapping dimensions: self-management, self-monitoring, and motivation [41]. This model shows how self-directed learning relates to the cognitive and motivational dimensions of the learning process. In more recent studies, the model has been translated into phases that students cycle through. These models attempt to translate SDL behaviors into a more comprehensible process.

3.3.1. Self-directed learning phases

Using SDL helps us determine holistic ways of personalizing a student's learning experience as it focuses on how a learner wants to retrieve information meant for learning [42]. It lets us look at the learning environment from the learner's perspective and helps us design better ways for them to interact with that environment [39]. In this case, designing the environment in a way that supports the phases of self-directed learning.

Li et al. describe SDL having the following 4 phases [39]:

- Task definition
- Goal setting and planning
- Strategy enactment
- Monitoring and reflecting

These resemble the phases of Self-Regulated Learning (SRL), and as a consequence, these terms are often used interchangeably. The key difference is that SRL focuses on the internal processes of a learner (i.e., meta-cognition and emotions) and how they aim to regulate those to achieve a learning goal. SDL is about a learner taking control over external factors in their learning and achieving a learning goal that is intrinsically motivated[43, 39].

I will use the phases as described by Li et al. and explain them according to Garrison model Li et al., Garrison.

Task definition is related to both motivation and self-management. Motivation is needed to both choose a task and proceed to put effort into completing the task. Self-management pertains to how the student decides to take control of the tasks that the learning environment asks of them, and managing the resources available to them.

Goal setting and planning touches all 3 dimensions. To effectively manage your learning environment, you need to set a goal to guide your actions. Monitoring of ones learning process is then needed to plan and adjust that planning if needed . This induces a sense or responsibility. The process of setting a goal is based on what the student is motivated to do and thus willing to commit to. This can be both intrinsically and extrinsically motivated. Intrinsic motivation is increased by a planning process as it gives a sense of control of the learning process.

Strategy enactment is linked to both self-management and self-monitoring. In SDL, students must manage their learning strategies to fit the learning activities they must do and the learning environment they are situated in. Monitoring your strategies means taking responsibility in assessing whether your strategy will result in personally meaningful knowledge. Self-directedness is highly dependent on the learning strategies available to the student, including a strategy to ask for support when available strategies are lacking.

Monitoring and reflecting is naturally related to the dimension of self-monitoring. Both critical and reflective thinking are needed to help a student improve their ability to self-direct. As a teacher, this phase might be the most important one to pay attention to, as it requires strategies that will improve all 4 mentioned phases.

If a student is proficient in self-directed learning and has the tools to find the learning activities they require, they can produce a sequence which:

- contains learning activities the student is motivated to do
- works towards a personal goal that the student believes is achievable
- contains learning activities a student can carry out
- helps a student become aware of their learning process to be able to improve upon it

Self-directed learning is a complex skill that demands practice and a supportive learning environment, which involves gradually reducing scaffolding, as outlined by 4C/ID. To achieve a personal sequence as described above, while fostering the development of self-directed learning, a supporting system must align with the four phases. Based on the systems mentioned in section 3.2.2, the next section will look at several ways of personalization that support the four phases.

3.4. Personalizing a learning sequence

Assisting students in both personalizing their learning sequences and developing self-directed learning skills requires appropriate support in each of the four phases of self-directed learning. In this section, I will outline several methods for identifying students' needs and leveraging that data to facilitate their personalized learning experiences.

Many studies try to determine a learner's previously acquired knowledge to build upon with personalized content [44]. While previous knowledge has a significant impact on a student's learning success [24], there are many other factors to consider when trying to personalize learning; cognitive styles, learning preferences, and even a learner's context are things a system might need to know to personalize educational content properly. Considering these many factors to filter the growing offer of educational content online, makes recommendation systems essential [45]. Solely relying on teachers to filter the vast amount of resources out there may ensure a certain quality of educational material but it is at the cost of personalization as you are limited by the resources the teacher is able to collect [46].
While we will briefly look into recommendation systems, personalizing a given sequence is already possible with the educational content already present [35]. In both cases, the key is to infer students' needs to determine suitable methods of personalization.

3.4.1. Goal setting

When looking at students' online behaviour, studies have found different behavioural patterns depending on the type and complexity of the students' goals. The frequency, total usage time and preferred learning activities all affect a student's learning performance. Students (sub-) consciously try to personalize their learning and choose activities that align with their (strategic) goals [26]. To be able to personalize the learning experience, we must therefore find a way to determine a student's learning goal(s) and how they prefer to achieve them.

One of the ways we can uncover a student's needs during studying is by asking them what goal they want to achieve with their learning activities. Learning activities that align with their goal can be given a higher priority in their personal learning sequence. Additionally, asking a student to set a goal, lets them think about what they want to achieve within their study session. [5] suggests that a student's goals are closely related to how they wish to perform.

Setting a goal can require some practice from students to get it right. How students choose to formulate their goal can also differ, meaning it would require additional methods to properly process a goal that was freely written by students. It would therefore be better to ask the student to describe the type of goal they have and then determine associations between learning activities and goal types.
A simple and proven way of determining a student's goal type is with the Achievement Goal Questionnaire [20]. This questionnaire consists of 12 questions that help you determine which of the following 4 goal types you have for a course [47]:

- Mastery-approach: you aim to master the course's material as much as possible
- Mastery-avoidance: you aim not to misunderstand the course's material
- Performance-approach: you aim to get better results than your peers in a course
- Performance-avoidance goals: you aim to not perform worse than your peers in the course

A student does not just have one type of goal for a course and can even have conflicting goals; within the course or with goals outside of their studying [48]. Making students think of the goal(s) they have for a course, or just a study session, can make them aware of these mismatches and motivate them to better align these parts in their lives. In addition to our tool providing learning activities that better align with their goal, a goal-setting activity might be a learning improvement in itself [49]. It can give a sense of control over learning and gives students perspective on how their learning activities fit into the broader scope of their lives. This can also contribute to their motivation to learn.

3.4.2. Learning preferences

There are many types of data you can choose from to collect for a personalized experience. If we take a look at instructional design, teachers sometimes use learning preferences to determine how they can best prepare their material for students. If you know the learning preference of your students, it becomes easier to provide matching learning activities. The outdated term "learning style" is misleading as it implies students can have distinct ways of learning. Students may however have a preferred way of learning and are likely to switch between different ways of learning. Learning style models are therefore being repurposed to uncover preferred ways of learning without unnecesarily categorizing students. The way student's learn is not set in stone and changes over time for varying reasons.
Identifying learning preferences can be a starting point for a personalized learning tool. The tool should not solely recommend content that adheres to the identified style, but can use it as a form of prioritization of learning content.

Determining the preferred learning style can be done according to different models and their identification method [2].

Eventhough the learning style models, such as by Felder & Solomon [50] are oversimplifying learning processes, they can still help us determine different learning activities our students might prefer, and in which order. We do not want to categorize students, but merely be able to adapt to their different ways of learning at any point in time. Felder and Soloman's learning styles are based on four dimensions of preferences [35, 50]:

[2] https://help.open.ac.uk/applying-yourself-to-the-learning-cycle

- active - reflective: a preference towards theoretical or practical learning elements
- sensitive - intuitive: a preference towards interactive or less interactive learning elements
- visual - verbal: a preference towards learning with picture-based or text-based contents
- sequential - global: a preference towards learning in small linear steps or larger holistic steps

By identifying a learner's preferences, a teacher can recommend more appropriate learning activities or a different sequencing of learning activities. Some examples are given in figure 3.1.

Model	Style	Preferred Activity	Preferred Order
Felder and Soloman	Active learner	Group activities, application of theory	
	Reflective learner	Summarizing, reviewing past materials	
	Sensing learner	Connecting theory to the real world	
	Intuitive learner	Innovate with existing theory	
	Visual learner	Learn from visual material, concept mapping, color-coded note-taking	
	Verbal learner	Summarizing, group discussions	
	Sequential learner	Build upon previously gained knowledge	Linear progression through material
	Global learner	Build upon previously gained knowledge	Bigger picture first

Table 3.1: For each learning style, the learning activity that is preferred. If applicable, order of learning activities is given as well [51]

3.4.3. Learning analytics

Personalizing education on demand is a difficult feat. You need a system that is able to collect data about a learner, infer from that data what the needs and preferences are, find learning content that is a match, and then return that to the learner in a timely manner [44]. If the system wasn't complex enough already, it should also keep adapting its recommendations as a learner evolves their learning both in strategies and content. In the previous section we learned that determining a student's preferences and goals is a starting point. There are a couple of ways to gather this information. One is through using specific questionnaires. Another method is to collect learning data from students and then use tools to analyze it. This leads us to the emerging field of Learning Analytics (LA).

Learning Analytics (LA) is a scientific field aimed at improving teaching, learning, and the environment in which these occur, using analytics and human-centered design. After collecting, measuring, and analyzing data about learners and their context, researchers develop tools and methods to support both teaching and learning[52]. The end-users of these LA-based tools and methods are often teachers and educational institutions, who then use these tools to improve learning (environments) for their students. Researchers and practitioners have fortunately realized that proper development of this field needs more direct involvement of students [8]. This not only means developing artifacts catered to students' needs but also involving them in the design process. Something we are trying to achieve with this thesis.
There are 3 ways you can utilize LA: to describe, predict, and prescribe.[53] That order also reflects the different levels of complexity in LA.
The most basic form is descriptive insights, where LA enables you to describe the learner and their environment. The system is usually tasked with presenting the data in such a way the user can easily draw conclusions. When presented with descriptive insights, a teacher– or the learner– can make more accurate decisions on how to improve the learning journey. Predictive insights are when an LA system

uses the data to formulate a prediction. This is often a performance indication: ”*this learner will probably get grade X*”. Prescriptive is then the most complex, where a system can interpret descriptions of the data, the (performance) outcomes they predict, and recommend what the learner should do to improve that outcome [53]. From a learner’s perspective, such a system is very much desired as it can help them plan, monitor, and evaluate their learning[46].
Prescriptive LA is what we would eventually need to fully aid in personalizing a learning experience. To be able to provide that, we need to start with descriptive analytics, which is the type of LA our tool will try to implement.
By designing such a tool in an academic setting, this project can aid in progressing the LA field [9].

3.4.4. Recommendation systems

For recommendation systems, the context matters and what type of content you want to recommend. In educational recommender systems there are 3 major contexts: formal education, non-formal education, and informal education [45]. The latter referring to what is acquired in day-to-day life through interaction with individuals and their environment. Recommendation systems require sufficient amounts of data [46]. As mentioned before, in this project we want to focus our LA efforts on describing first. This will enable us to create a reliable tool that iteratively works towards predicting and prescribing learning activities to include in a learning sequence [54]. Feasible recommendations can then be added and adjusted in each iteration.
Recommendations can start as simple as presenting formal learning activities that have already been provided by the teacher or institution. Informal learning activities or content can be added once they have been approved by the course’s staff or many students in the course find it is of good quality [45, 55]. This collaborative approach to recommending is seen in educational systems but is very prominent in social media. Social media have so-called “feeds”— which can be seen as a sequence of entertaining content—- that cater to the user’s (social) preferences and therefore keep them “hooked” on the platform. Whether this is an approach educational platforms should fully adopt to engage their users/students, it does showcase how to use LA to present learning materials in an engaging and flexible way [1]. Additionally, educational platforms would be able to compete with these content providers as students might choose to spend more time learning than consuming entertainment.

3.4.5. Holistic approach

Personalizing a sequence of learning activities in a holistic manner requires us to look beyond the learning activities typically expected in a course. The phases of self-directed learning indicate the inclusion of activities that support meta-learning: setting a goal, planning accordingly, managing the resources needed to achieve the set goal, and reflecting on the process to improve. In [56], it is even suggested that meta-learning activities such as reflection are needed for students to perceive learning as personalized.

Since reflecting is a part of self-directed learning, we can further personalize a sequence by including so-called reflection amplifiers. Despite growing evidence of reflection’s positive impact on learning, both teachers and students often struggle to make it an integral part of learning. Adding reflection amplifiers to a sequence can hopefully foster this behaviour [56]. Verpoorten, Westera, and Specht have created a classification framework to guide future work on reflection activities in online learning environments (see figure 3.2).

We must also consider where, when, and with whom students learn. By including learning activities that connect formal learning activities with informal ones, we can personalize learning and foster stronger connections among students and with their environment [1]. This includes integrating reflection amplifiers as described by [3] and encouraging healthy study habits prescribed by experts [57] and teachers [3].
Learning analytics can provide insights into student performance, behaviors, and learning preferences, offering a more holistic view to accommodate their learning needs. In turn, students can gain access to more comprehensive analytics than just their progress on isolated parts of a course. A holistic view of their progress gives them a greater sense of control as they can choose which aspects of their learning to focus on [5]. Furthermore, it is essential to consider how the chosen educational technologies align with and enhance a student’s overall learning experience [1]. Learning is not only about interacting with

[3] https://www.learningscientists.org/podcast-episodes

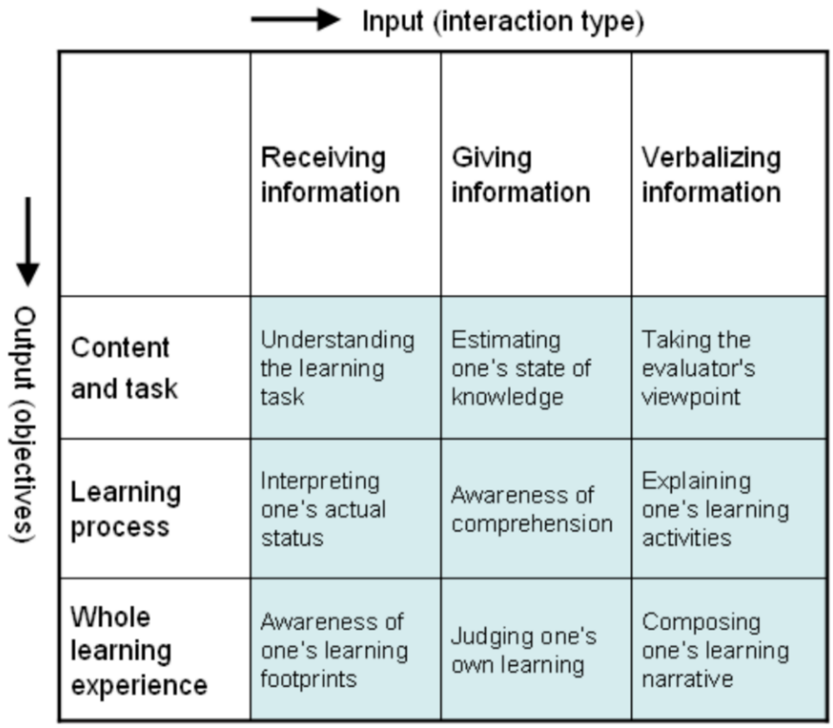

Figure 3.2: A classification framework created by Verpoorten, Westera, and Specht. It is based on existing reflection amplifiers and aims to support the integration of reflection activities in online learning environments, as well as promote further research [56].

learning activities. It is also about integrating learning with the rest of your life. Learning does not happen in isolation, and it is even suggested that most of our learning happens informally through interactions with people and our environment [46].

3.5. Answering literature review questions

As a recap of the chapter, the literature review questions are answered in a concise manner. More elaborate answers will be provided in chapter 6. In the next chapter, we will apply the information discussed here to develop effective personalization methods for the learning environment of this thesis. To address the student's readiness, our focus will be on personalizing a learning sequence for student-initiated study sessions. In these sessions, students have already decided they are ready to engage with the course's learning activities. We will then identify suitable opportunities to support personalization and promote the development of self-directed learning skills.

3.5.1. How does a personal sequence of learning activities improve learning and make learning more engaging?

A personal sequence of learning activities takes several things about the student into account. The order in which they prefer to do their learning activities, the learning activities that are appropriate to their skill level, and even their preferences regarding learning activities and learning strategies [4, 5].
If executed properly, this personalized learning sequence helps manage a student's cognitive load during learning. When personalizing in a domain-agnostic manner, especially extraneous cognitive load can be managed and even reduced as students would need less effort to find and understand learning resources [30, 34, 33]. Better alignment of a learning sequence with a student's preferences and goals also increases their motivation to stay engaged with learning activities [26, 3].

Personalizing a learning sequence *for* a student takes away a valuable opportunity for them to develop a skill called self-directed learning. This skill is very important in today's technology-based society as it ensures students know how to properly navigate the growing number of resources available to achieve their learning goals. This ability also translates to their future careers, helping them stay adaptable in a constantly evolving professional landscape [10, 39, 40].

3.5.2. What methods can be used to create a personalized sequence of learning activities?

To personalize the learning experience, we must find a way to determine a student's preferences and learning goals. Collecting learning analytics and mirroring back descriptive insights can help students make better decisions when personalizing a sequence. Learning analytics can also be used to predetermine a preferred order and type of learning activities to do. These suggestions help align the sequence with the student's goals and can introduce activities from the learning environment that the student may not be aware of.

The 4C/ID method of building learning sequences demonstrates how a tool designed to aid students in learning the complex skill of self-directed learning can gradually reduce the amount of guidance provided. Taking inspiration from the four components of the 4C/ID method can help us determine how to support each phase of self-directed learning in terms of supportive and procedural information.

3.5.3. How can a personal sequence of learning activities be expanded upon to improve the learning experience in a holistic matter?

Introducing personalization to foster self-directed learning is a holistic approach that views the personalization process as a learning opportunity in itself. Including meta-learning activities, such as reflection, not only fosters self-directed learning but is also essential for experiencing personalization [56]. Activities that consider a student's environment and promote healthy learning habits[57] also contribute to a holistic, personalized learning experience.

4 Design requirements

In this chapter, we enter the conjecturing phase in which the first steps are taken towards answering our second empirical research question: *How to design an educational tool to fit the learning environment of the TU Delft?* Based on the knowledge presented in the previous chapters, I will construct the ways in which I believe personalization can be introduced in a learning environment at the TU Delft.
A digital environment called Skill Circuits is chosen as the location for our intervention. I will begin the chapter by explaining what Skill Circuits is and how it gives us access to a course's sequence of learning activities. I will then propose several ways to personalize that sequence and describe their potential effects. These proposals can be seen as my conjectures.
The intervention will be introduced as a feature called *playlist*. This will be the embodiment of the conjectures, and I will explain why I chose for this analogy. The chapter concludes with high-level conjectures that will guide the implementation of the embodiment towards the effects of fostering self-directed learning and reducing cognitive load.

4.1. Blending the tool into the learning environment

To improve the learning experience of students through a personal sequence of learning activities, we need a way of accessing and manipulating the sequence set by the teacher. To avoid increasing the cognitive load of students using the tool or making their learning environment more complex, it would be best to expand upon a tool they are already using. A tool that meets these criteria is the website called Skill Circuits[1]. This is an open source[2] project created by the Computer Science & Engineering Teaching Team (CSE-TT) at the TU Delft. This team of lecturers, developers, and PhD candidates has the goal of improving the Computer Science Bachelor program through high-quality educational content and the in-house development of education-supporting tools. A perfect environment for us to develop a tool focused on personalization.

4.1.1. Skill circuits

As mentioned in chapter 2, Skill Circuits is a platform that enables teachers to visualize their course as a skill tree. This representation guides students through a course and helps them understand why they are asked to engage in certain learning activities [58]. A circuit can hold different modalities of learning content and enforces blended learning by containing both remote and in-class learning activities.
Students can personalize the circuit by choosing which tasks they wish to complete to acquire a skill. They can make this decision independently or follow a ***path*** provided by the teacher. A path is a subset of learning activities tailored to a specific level of knowledge, designed to help students complete all required skills effectively.

Skill Circuits has the goal of improving the learning experience by making students more aware of their learning journey. The sequence of learning activities the teacher has created is visualized and made customizable by letting students choose, to an extent, which learning activities qualify to complete a skill. The sequence in which the learning activities appear in the circuit is not personalizable.

[1] Skill Circuits can be accessed at `https://skills.ewi.tudelft.nl/`

[2] Skill Circuits' repository on GitHub: `https://github.com/eip-ewi/Skill-Circuits`

4.1.2. Circuit to sequence

The Skill Circuit of a course is a tree-like structure with three levels of elements, in the form of blocks [18]. The course's highest level shows the main topics with blocks called modules and shows how they are linked to each other and in which order they will be addressed in the course. The second highest level shows the submodules, which are the sub-topics, and how these are linked to each other. Each submodule then consists of skills, the smallest piece of knowledge a student is asked to master to be able to understand the bigger topics. Skills are then filled with tasks, which are the learning activities of the course.

The sequence

The tree-like structure resembles a hierarchy and shows the sequence of the course and its sub-sequences. Two elements linked vertically indicate that the higher skill is a prerequisite for the lower one, and thus, the teacher recommends doing the associated learning activities in that order [18]. Elements can not be linked horizontally. However, when displayed horizontally (next to each other), that indicates these topics are best studied at the same time.
The connections and how skills are aligned vertically are the course's sequence we want to personalize.

Personalization: Learning paths

Learning activities are always part of a skill, indicating that completing them helps the student master that skill and, therefore, progress the course. Unless obligatory for the course, students can choose which learning activities to complete for each skill. A type of personalization already present in Skill Circuits.
The teacher's selection of learning activities is how they think you will master the skill. But depending on your knowledge of the topics or your goal for the course, you may want to deviate. A teacher may already anticipate a difference in knowledge among their students and have prepared *learning paths*. When selecting a learning path, skills are pre-filled with different learning activities. Figure 4.1 shows what a skill looks like to a student.
The chosen learning path and any customization done within a skill is a personalization we must reflect in our intervention.

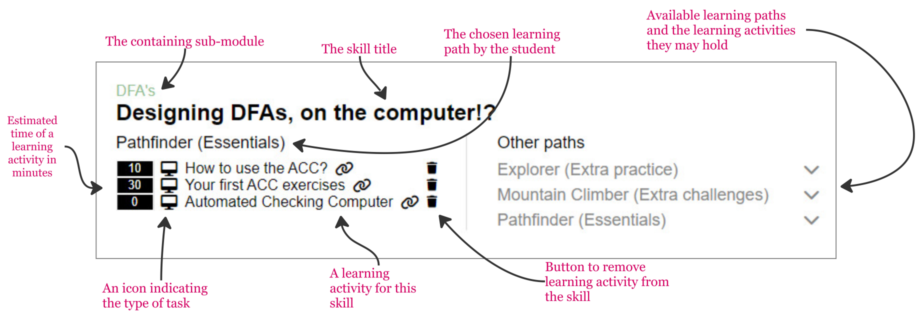

Figure 4.1: A skill block as displayed in Skill Circuits. Among other information, a skill holds a list of learning activities. This list can be adjusted by the student to resemble the activities they actually plan to do. In this view, the students also see any information associated with the learning activities.

Learning activities

Once the student has personalized a skill in the circuit, they have decided which learning activities they wish to do to master that skill. **These are the learning activities part of the student's sequence.** Learning activities (the tasks in Skill Circuits) have the following properties:

- Type
- Estimated time needed to complete it
- The skill it belongs to
- A recommended deadline to complete it by, called *checkpoint*
- Information on where to find the learning content to complete the activity (often in the task's name or a link)

With these properties, we can attempt to personalize the course's sequence for a student.

4.2. Personalizing a sequence in skill circuits

To tailor the sequence to the student's current environment and needs, I opt to personalize the study sessions initiated by the students themselves. These sessions involve selecting a subset of the full course sequence, resembling the sub-sequences found in the 4C/ID model. We want to add to their control of choosing how and when to study by providing a tool that helps them better determine the learning activities they wish to engage with. We choose to build upon the existing tool Skill Circuits which gives us access to the learning activities a student can and wants to do for a course.
In this section I list several ways we can improve the personalization aspects in Skill Circuits.

4.2.1. A course's full sequence

Ideally, we want our tool to be easily applicable to any course and have a domain-general approach [25]. We, therefore, want to implement personalization methods that are not dependent on understanding the actual contents of a course. Of course, some domain knowledge is still needed to understand how learning activities are connected to be able to support them with learning strategies. For this project, I will assume that the location of the "Skills" in a course's Circuit appropriately represents this connection. The circuit created by the teacher is seen as **the default sequence** we can then build upon. Personalization can then be introduced by using the type of a learning activity and how it is connected to other learning activities.

First, we are required to retrieve that default sequence by putting the learning activities in an ordered list. Learning activities are ordered in the list based on their position within the corresponding skill, and then in accordance with the skill's vertical hierarchy in the circuit. The learning activities of skills that appear next to each other in the circuit are added to the list from left to right. Adding this form of displaying learning activities alongside the circuit can already be beneficial to students as it gives them a different view of the learning activities that must be done.

4.2.2. A study session's sequence

In addition to the student's goal and upcoming deadlines, the amount of time a student has for a study session is also a factor in choosing fitting learning activities. We can therefore use the time the student wants to spend studying to determine a subset of learning activities for the study session. Given the amount of time a student wants to study, choosing a subset of the default sequence is the first step of personalization.
While the argument can be made that students can already do this by themselves, a tool that supports them in this activity saves them (mental) effort and places this activity within the learning environment. It gives them an additional way of navigating the learning activities.
More control is also given to the student by providing a filter for learning activity types. What if a student wishes to fill their study session with learning activities of a certain type– i.e., only reading? The tool can help them easily find and choose these activities.
This can also be helpful when revising study material. Either as a suggestion or as a filter to help students find and study past material more easily.

4.2.3. A different order

Continuing to build upon the information in section 3.4.2, a simple reordering of learning activities can also impact the learning experience. This is where considering the connections between learning activities is important, as learning activities that support each other should be ordered accordingly. I assume that learning activities within a skill can be ordered freely among each other to support an inductive or deductive approach [59]. How the skill is ordered within a submodule then indicates which prior knowledge each learning activity might need. Learning activities for a skill that depends on another should be scheduled after learning activities for the prerequisite skill. With these rules, we can introduce two types of personalization for the order of the chosen sub-sequence. Reordering the sequence based on learning analytics collected on the student and reordering the learning activities based on a learning strategy. Using learning analytics to order learning activities allows us to mirror to a student how they typically order their own learning activities, thus increasing the awareness of their learning process [3]. Using a learning strategy to order the learning activities gives them the opportunity to try something new.

4.2.4. Adjusting the personal sequence

We can further support the creation of a personalized sequence by recommending adjustments. For example, if the sequence that fits the allotted time does not include any practical activities, the tool can suggest incorporating one. This is, of course, only possible for activities that do not require knowledge that do not require knowledge beyond the selected learning activities. Including an explanation of the benefits will not only help the student understand the suggestion but also empowers them to decide if they agree or not. We can create rules from the links between learning activities as described in 3.4.2 to do so. This may help the student create a sequence that may be more engaging.

4.2.5. Adding supporting learning activities: reflection

If there are learning activities that would fit the student's needs but are not present in the course's circuit, it would be beneficial if the tool could still recommend them. Since the tool does not know the actual course's content, these can only be domain-agnostic activities.
Reflective activities are a commonality when looking at the activities linked to learning preferences. By connecting each type of activity in Skill Circuits to a generalized reflection amplifier as mentioned in [56], we can suggest an appropriate reflection activity to be added.

4.2.6. Adding supporting learning activities: holistic approach

Finally, personalization can occur by incorporating activities that make the sequence a better fit in the broader learning experience of a student. Think of including non-learning activities such as breaks or encouraging physical exercise. Healthy learning habits such as looking away from the screen every 20 minutes [60], stopping at a certain time, or spacing out study session are also examples. The reflective activities we added in the previous paragraph also fit this category but have a clear relation to learning. Including activities or strategies that promote healthy learning habits may show students that a learning process extends beyond learning activities.

4.2.7. Learning analytics as a means to an end

One of the ways to infer a student's needs with the help of learning analytics, is to look at the type of learning activities they have engaged with in the past. This might be an indication of activities they prefer or enjoy more and can allow our tool to give these types of learning activities priority in the recommended sequence. Together with uncovering what learning preference is associated with these learning activities, a personal sequence can then include other types of learning activities that have a high chance of being accepted by the student. Presenting "preferred" activities may not improve a student's learning in the sense of greater performance but may improve their enjoyment and motivate them to stay engaged with the learning content. It also enables us to find an entrance for LA in this tool and test whether this type of data collection has any future benefits for the tool. We can determine, during the testing phase of this tool, if students are, for instance, interested in seeing some of their analytics. Whether to gain insight into their learning habits or to help them better plan their study sessions. If so, we can proceed to improve their learning by encouraging a reflection process because of the insights these analytics give [53] by presenting more of them in the future.

In chapter 3 cognitive load theory showed us that presenting students with more information is not always a good thing as it can be overwhelming and can even discourage learning [10]. Even if we are certain the added information is helpful, we will have to make sure the information presented fits the student's needs and does not add to them [8, 10]. If we manage to align LA with student's needs and ensure it is interpretable, it can increase their motivation and, thus, their learning experience. In addition to collecting learning analytics to determine a student's learning preferences, the tool can mirror completion rates for each type of learning activity back to the student. Showing a student their past progress on a type of learning activity might encourage them to do an activity they would rather not have in their personal sequence– the self-efficacy aspect of motivation. Conversely, after they have completed an activity type they usually do not engage with, making them aware of this accomplishment can also increase motivation to complete the rest of the sequence.

The objective of our intervention will be to identify an entry point for these personalization approaches. By establishing the essential infrastructure required to support these methods, we can determine whether they genuinely enhance students' learning experiences. Achieving this in an already adopted system, such as Skill Circuits, also fosters future advancements toward learner-centered learning.

4.3. Transforming a study session to a Playlist

A study session is characterized by a clear beginning and end, with a sequence of learning activities tailored to fit the timebox and available resources. The sequence is created by the student to address both their own needs and the environment they might be in. If we wish to design a tool with a holistic approach towards learning, it might be worthwhile to look for other sequences students may encounter that have similar characteristics. We can look for an informal sequence to relate to, especially if we would like to find a connection between formal and informal learning. We will follow Lamb's proposition of using a playlist to explore and possibly improve learning in higher eduction [61].

A playlist is a list of items where each item is automatically iterated or played. The term was first used on the radio to describe the list of songs that would be played[3]. Nowadays, it is still mostly used to describe a list of songs but also other types of media such as videos[4].

A playlist is both flexible (can be adapted) and has a robust structure (fixed items can be part of the playlist) [62]. Playlists can be made by yourself, automatically generated based on your preferences, or a collaboration between you and the application[5].
Although playlists are used to order and "play" entertaining content, their format is usable for any sequence of items [62]. Whether these playlists provide you with items that are to be passively or actively consumed might then not matter. The sequence in which you go through them is fixed and even time-constrained– a song has a fixed duration. To students, they are a familiar form of sequential items that can be translated into the context of learning. So, what happens if we use the playlist format to support learning?

Playlists with educational content are already widely used to help students personalize their learning [61]. These playlists are often created by their teachers and contain content created by the teachers themselves or carefully sourced from other parties. Providing students with playlists tells them in which order the content should be consumed and enables them to learn at their own pace.
Traditional playlists are already used to personalize learning environments in an ethnographic matter. Students use music playlists to change their physical environment, ensuring it better supports the learning activities they are engaged in [60]. Lamb suggests that playlists holding instructional content are only fully effective if they are paired with other learning activities [61]. Using these findings to inspire a design, employing the visual and interactive characteristics of a playlist for a tool that personalizes a sequence of learning activities, could be a valuable approach.

4.3.1. Elements of the Playlist

Now that we know the effects we want to create with a personal sequence, we should take a closer look at the elements of the sequence: the learning activities.

> "..the purpose of any learning activity pursued throughout one's life is to improve knowledge, competences, and skills from a personal, civic, social, or work-related standpoint. [45]"

Many learning activities are out there, often categorized based on the learning skill they aim to convey. Teachers may choose the learning activities for a course based on an instructional design method such as 4C/ID[6] or Bloom's Taxonomy– both aimed at training certain learning skills [30, 63]. Additionally, the course's subject or domain can also dictate which learning activities should be chosen [26, 56, 64] and even the location of the course can play a role [61].
It is then also advised to have a combination of different modalities (images, text, video, real experiments) among your learning activities to enhance learning. Again, it is key not to cause cognitive overload when introducing new modalities and make sure the added value is clear to students [60, 65].

Chetty et al. show that a mismatch between students' learning preferences and the teacher's teaching "style" negatively impacts the student's performance [66]. This study, in agreement with others [67],

[3]https://www.etymonline.com/word/play-list

[4]https://www.youtube.com/@kurzgesagt/playlists

[5]https://newsroom.spotify.com/2021-09-09/get-perfect-song-recommendations-in-the-playlists-you-create-with-enhance/

[6]Official website for 4C/ID: `https://www.4cid.org/`

therefore suggests to have multiple types of activities available to students to improve their learning. As this is not always feasible for a teacher and Rogowsky, Calhoun, and Tallal even argue that always complying with students' needs can have counterproductive effects, our tool should focus on learning activities that can be easily added to the existing sequence. As it is out of scope for this project to add learning activities that require in-depth knowledge of a course's topic, we look for more general or supporting learning activities. In table 3.1, a list of such activities is given based on activities linked to learning preferences.

As we want to personalize an existing sequence with provided learning activities, we will let the learning environment take the lead in determining the base set of learning activities for our tool. Skill Circuits supports 7 types of learning activities– called *tasks*.

- reading
- video
- quiz
- implementation
- exercise
- collaboration
- experiment

Students are our main users, and while the envisioned tool may help lower a student's cognitive load by helping them make study decisions [46], we must be careful not to add any load by introducing a new tool. As with any new technology students are asked to deal with, we must ensure the functionality is clear, easy to use, and, in the case of mirroring learning analytics, interpretable [53]. Luckily, Wang [in 69] suggests that when new technology is introduced in the classroom, it is met with enthusiasm that, initially, causes an increase in engagement and motivation.

4.4. The conjectures of the playlist feature

The playlist feature aims to empower students in their learning, specifically during their individual study moments. Given their access to learning activities of a course through Skill Circuits, I want the students to become (increasingly) aware of their needs when choosing which learning activities to engage with during their study session. This awareness will hopefully encourage them to try and address those needs to improve their learning. To encourage students to take ownership of their learning, a tool that simulates the four phases of self-directed learning might help.
In the task definition phase, the student should be able to properly **navigate** a course's content to find the learning activities they want to do. Goal setting in itself is an activity that benefits learning, planning the study session in accordance with that goal requires creating a personal sequence of learning activities. A study session is often time-bound, meaning **time-related** information is key to creating a realistic plan. A personal sequence not only adheres to a goal but also a strategy a student employs. Representing that strategy in a tool involves the ability to **adjust existing learning activities and add new ones**. Finally, to monitor your learning in a digital environment to improve for the next session, some **insight into your learning data** and how you progress is needed.
Not every student knows what to do, and what they can do, in each phase of self-directed learning. The playlist feature will hopefully be able to cater to each proficiency level in self-directed learning. In doing so, the feature will hopefully reduce extraneous cognitive load during a study session, leaving as much working memory as possible to be used for learning. Additionally, it may improve self-directedness and promote the adoption of personalization tools at the TU Delft.

For the design of the playlist feature, we can use the conjectures to describe five categories of functionalities, indicated in bold:

- **Time** management or allocation during studying to facilitate planning and goal-setting
- **Navigating** the learning activities set by the teacher to find the learning activities that interest them and lessen cognitive load
- Access to (personal) **Learning Analytics** to gain insights in the learning proces
- Adjusting or expanding on **learning activities** to align with a students strategies

- Incorporating **supporting** learning **activities** to make the study session more holistic

In the iteration phase, we will attempt to design functionalities that are appropriate for the learning environment and in accordance with what students say they need.

5

From Theory to Design: Initial Development of the Playlist Feature

This chapter marks the transition from the *conjecturing* phase to the iteration phase. Before proceeding to develop the functionalities described in the previous chapter, each category of functionalities is translated into user stories. Students familiar with Skill Circuits were asked for feedback on these user stories. to inform the feature's design choices and provide an initial indication of students' likelihood to use the Playlist feature.

5.1. Study setup

A questionnaire was distributed among students of two Computer Science Bachelor courses to collect feedback on both Skill Circuits and the playlist concept. In this chapter, only the results regarding the user stories will be discussed. The remaining parts of the questionnaire are part of the playlist feature's final evaluation, and their results are presented in chapter 6.

5.1.1. Survey sample and course selection

Students of two Computer Science Bachelor courses were asked for initial reactions to the playlist concept to help prioritize and inform development efforts. These courses were chosen because they actively use Skill Circuits, the platform where I plan to implement the playlist feature.

- Algorithms and Data Structures, first year course: 41 valid responses
- Algorithm Design, second year course: 28 valid responses

By targeting students familiar with Skill Circuits, we aim to assess if they can envision the playlist feature improving their learning experience when using that educational tool.

5.1.2. Creating the user stories

Fifteen user stories, listed in table 5.1, were created to encompass the different functionalities around:

- **Time** management or allocation during studying
- **Navigating** the learning activities set by the teacher
- Access to (personal) **Learning Analytics**
- Adjusting or filtering set **learning activities**
- Incorporating **supporting** (learning) **activities**

They were created by considering Skill Circuits' current functionalities and the conjectures, incorporating feedback from consultations with the members of CSE-TT, addressing the project's constraints, and outlining the initial steps needed to achieve these future objectives.
Using categories can provide a clearer understanding of what each type of functionality entails. Additionally, focusing on categories rather than on individual user stories may help the development phase by allowing me to work on similar functionalities together. Especially when we want to ensure the playlist feature appears as an integrated feature in Skill Circuits rather than a separate tool.

After an introduction to the playlist idea, students could rate each user story with a 5-point Likert scale: 1 = Extremely unlikely, 2 Somewhat unlikely, 3 = Neither likely nor unlikely, 4 = Somewhat likely, 5 = Extremely likely.

Students were also asked to propose a functionality they would like to add to Skill Circuits. I did not ask students to provide a functionality for the playlist feature as the 15 user stories might steer them in a certain direction. I instead wanted to let them focus on their own experiences within Skill Circuits and think of what they would want it to do for their learning experience, with the Playlist tool acting as a possible inspiration. In figure 5.2, the proposed functionalities are coded to fit the functionality categories. The actual proposals can be found in appendix C.

Category	User Story	ID
Time	I want to know what activity I can do in the coming 10 - 30 minutes	T1
	I want to work on a subject/course in a fixed timebox	T2
	I want to plan a study session of at least 1 hour	T3
	I want to know how far I can progress with X amount of studying time	T4
Navigation	I want help in determining where to start in the circuit	N1
	I want a study plan to be made for me	N2
LA Insights	I want to know how much time each module took me	LA1
	I want to know how much time I spend on different types of learning activities	LA2
	I want to keep track of time spent on individual learning content	LA3
Learning Activities	I want to transform learning content into a modality I prefer (i.e., text to audio)	LE1
	I only want to do activities of a certain type (i.e., reading material, watching videos, exercises)	LE2
Supporting Activities	I want to switch between subjects/courses during my study session	S1
	I want to plan out regular breaks during studying	S2
	I want to plan to reflect more on what I have learned	S3
	I want to plan to revisit past content more	S4

Table 5.1: This table shows the 15 user stories about the Playlist feature students were asked to rate.

5.2. Findings

5.2.1. Students' ratings

From the responses, there is no clear indication of whether one category is preferred over another. In figure 5.1, we can see that each category scored between 3.3 to 3.7 on a 5-point scale. Which, on average, is just above a neutral rating. The time (M = 3.70, SD = 0,31) and navigation (M = 3.70, SD = 0.09) user stories received slightly higher preferences. The LA insights (M = 3.38, SD = 0.10), learning activities (M = 3.38, SD = 0.44), and supporting activities (M = 3.34, SD = 0.23) had slightly lower averages. Since the differences are so small, no definitive conclusion can be drawn regarding preference for one user story category over another.
However, when considering the number of user stories per category, time and navigation user stories have higher scores on average. While not a fair comparison, I would opt prioritizing these two functionalities based on the user story results.

5.2.2. Students' suggestions

When looking at the functionalities students proposed to add, we can see a clear preference for navigational functions in figure 5.2. During categorizing (essentially coding the students' input), I wanted to adhere to

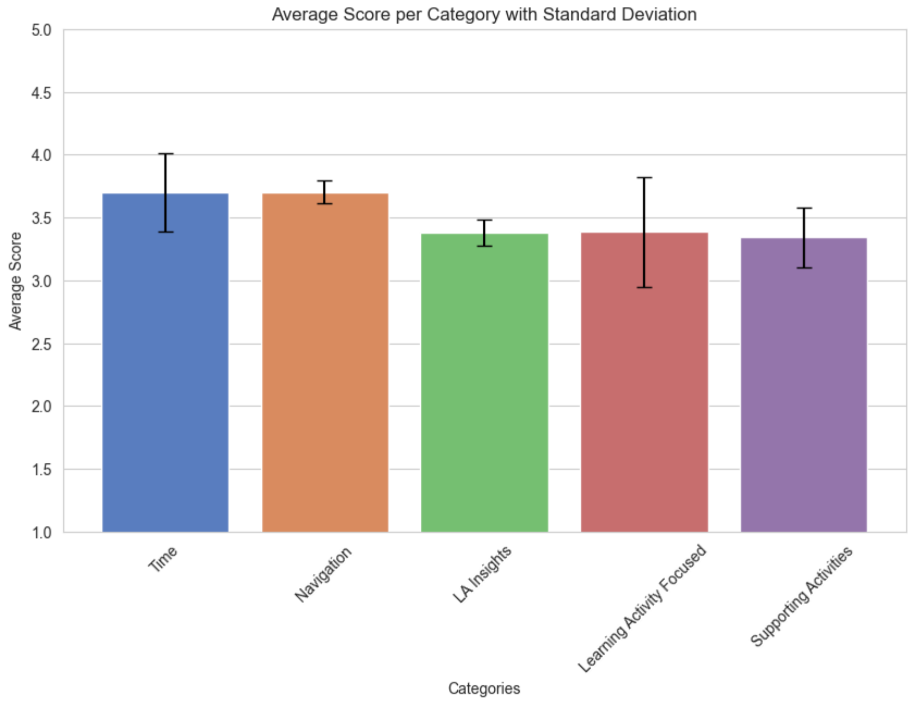

Figure 5.1: The average score for each type of user story presented to students in the form of 15 user stories.

the categories established in chapter 4. This, however, led to the navigation category becoming rather broad. Any functionalities that students explained would aid them in understanding the course's structure, finding information relevant to them, and helping them determine what to do were assigned to this category. The "other" category was mostly user experience related, i.e. better use of colors and highlights in Skill Circuits, and thus not necessarily a functionality. However, if students explained these improvements would aid them in better understanding the course's structure they are categorized under navigation instead.
It would seem that students are not very much interested in learning analytics. Three out of five time-related proposals could have been categorized under learning analytics as well. I chose to put them in the time category as students explained these analytics were to help them better manage their time, i.e.: *"to create an overview of time spent and time expected to spend"* .
Proposed supporting learning activities were, in both cases, about automatically creating quizzes or mock exams. While these could have been categorized as a learning activity (adjustment), I chose to put them in the supporting category as they were described as an active decision of the student to add an activity that supports their learning.

Combining these results with those of the user stories, navigational functionalities seem to be highly preferred. Any time-related functionalities or insights come in as a clear second.

5.3. Guiding the playlist feature's first design

- Focus on navigation and time user stories
- As students also mentioned improvements to the usability of Skill Circuits, the appearance of the playlist feature is also important
- As the feature will be deployed on the live Skill Circuits, correct implementation of simple functionalities is preferred over unpredictable functionalities that are more complex
- We also want to test the idea and framing of the feature: A playlist is a personal sequences of learning activities for a study session

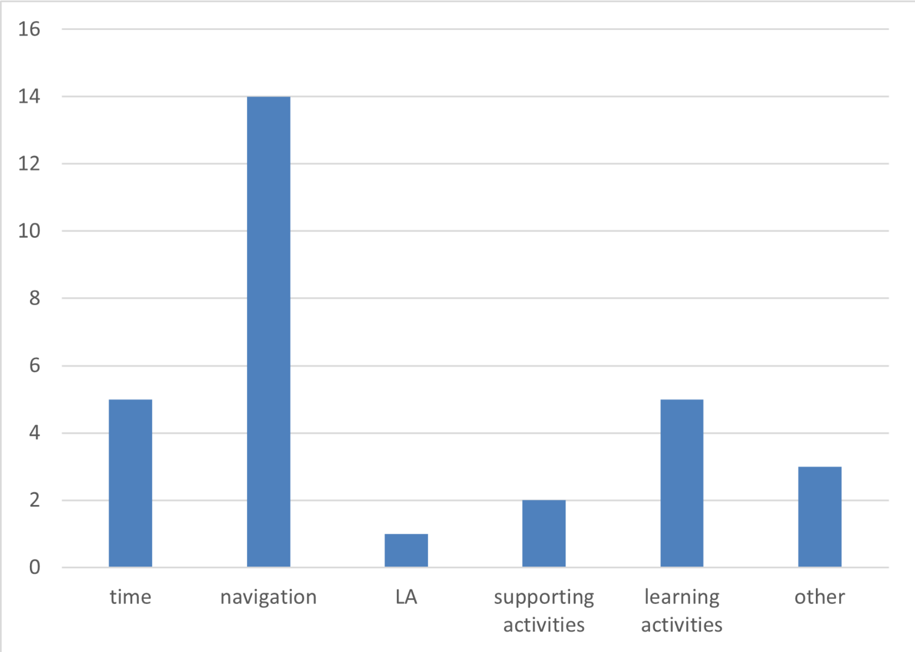

Figure 5.2: Student's suggestions for new features in Skill Circuits, after being coded with the functionality categories.

5.4. Creating Playlists

The playlist feature was developed to help students organize and navigate their course activities efficiently. The primary goal was to reduce the cognitive load associated with planning study sessions, thereby increasing motivation and engagement. The chapter outlines the process of integrating this feature into the existing Skill Circuits architecture while ensuring scalability and future development potential.

Design Decisions

Key design decisions included:

- **User Interaction:** Emphasis was placed on making the feature user-friendly. Students can create playlists to set study goals, compile learning activities, and track their progress.
- **Backend Support:** The backend was structured to support the playlist feature without disrupting existing functionalities. This involved creating separate database tables for the new feature to ensure loose coupling and easy removal if necessary.
- **Navigation and Time Management:** The playlist feature provides a new way to navigate course activities, presenting them in an ordered sequence derived from the Skill Circuits framework. It includes time estimates for tasks, helping students manage their study time more effectively.

Initial Implementation

The first implementation of the playlist feature was simple but functional, prioritizing user testing and feedback. Students in the "Automata, Computability, and Complexity" course were invited to test the feature, with their usage data collected to inform future iterations. The feature included:

- **Playlist Creation and Management:** Students could create, start, pause, and stop playlists, helping them stay aware of their study session status.
- **Time Tracking:** The feature displayed estimated and actual study times, with feedback mechanisms to improve time estimates.
- **Opt-in Participation:** Participation in the research was voluntary, with clear options for students to opt-in or out.

A detailed version of the implementation of the playlist can be found at[1]

[1]tu delft repo

5.5. Summary

In this chapter, we made some decisions to transition from theoretical conjectures to the initial design phase of the playlist feature for Skill Circuits. I surveyed students from two Computer Science courses to gather feedback on user stories representing potential functionalities for the playlist.

The survey results showed that the students had no strong preference for a particular user story category. The categories time and navigation were slightly higher than the other three and the only categories with an average score that was higher than 3.5 . From the qualitative aspect of the study, the preferences were more clear - students emphasized the need for navigation and time-related user stories, leading me to prioritize these stories for the development process. These insights helped in developing the final version of the playlist.

6

Discussion and Conclusion

6.1. Discussion

6.1.1. Reflection on Literature Research Questions

The literature research questions aimed to uncover how personal sequences of learning activities improve learning and make it more engaging, the methods to create such personalized sequences, and how to expand these sequences to improve the learning experience holistically. The findings from the literature provided a foundation for the design of the playlist feature and informed its development.

6.1.2. Key Findings from Literature Review

- **Improving Engagement and Learning Outcomes**: Aligning educational content with students' preferences enhances engagement and motivation. The literature indicated that personalizing the sequence of learning activities, rather than just the content, could yield similar benefits by providing a structured yet flexible learning sequence.
- **Methods for Personalization**: Traditional sequences determined by teachers can be adapted using a variety of methods. In this study, I focused on providing students with an additional way of navigating learning activities to find what aligns with their interests and goals.
- **Holistic Improvement of Learning Experience**: Beyond educational content, supporting activities such as reflection, time management, and breaks contribute significantly to the learning experience. The literature highlighted the need for tools that support these activities to create a holistic and effective learning environment.

6.1.3. Insights from Initial Design and User Feedback

- **User Feedback and System Requirements**: The feedback collected from students through surveys and focus groups was crucial in defining the system requirements and functionalities of the playlist feature. Students expressed a strong interest in functionalities that aid in time management, navigation of learning activities and access to personal learning analytics.
- **Impact on Learning Experience**: The playlist feature was designed to reduce cognitive load and promote self-directed learning by aiding students in choosing the learning activities for their study sessions. This aligns with the findings from the literature review, which highlighted the importance of self-directed learning in a technology-driven educational environment.
- **Improving time estimates**: Incorporating time tracking functionalities into the tool provided students with valuable insights into their learning behaviors, helping them make informed decisions about their study strategies. This feature was well-received by students, indicating its potential to enhance the learning experience by making it more data-driven and personalized.

6.1.4. Challenges and Limitations

- **Sample Size and Generalizability**: The limited sample size poses a challenge to the generalizability of the findings. Future research should involve a larger and more diverse group of students to validate the findings on the playlist feature.

- **Implementation Constraints**: Integrating the playlist feature into an existing digital learning environment limited the amount of functionalities that could be implemented in the time given. Ensuring seamless integration without disrupting current systems requires careful planning and execution.

6.1.5. Future Research Directions

- **Iterative Design and Testing**: Future research should continue refining and testing the playlist feature through an iterative design process. Continuous feedback from students will be essential in improving the tool's effectiveness and usability.
- **Expanding Functionality**: Exploring additional functionalities, such as advanced learning analytics, could further personalize the learning experience and provide more targeted support to students.

6.2. Conclusion

This report forms the first part of a holistic approach toward designing an educational tool aimed at fostering personalized learning sequences. It demonstrated the potential of personalized learning sequences to enhance the educational experience for students at TU Delft. By leveraging insights from the literature and user feedback, the designed playlist feature offers a promising approach to support self-directed learning and reduce cognitive load. While challenges remain, the findings provide a solid foundation for future research and development in personalized education tools. Ongoing refinement and testing of the playlist feature will be crucial in realizing its full potential and ensuring it meets the diverse needs of students.

6.3. Link to Part 2: Implementation

Part 2, detailed in the linked report, extensively covers the implementation of the playlist feature, including the iterative development process, user testing, and comprehensive analysis of the results. The insights and findings from Part 2 further validate the design decisions made and provide a roadmap for future enhancements. For a detailed account of the implementation phase, refer to the second part of this thesis available at *[insert repository link here]*.

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A
Operationalization

Table A.1: Operationalization table

Research question	Main concepts	Concept definition in this context	Proxies	Methods	Operationalization
How does a personal sequence of learning activities improve learning and	improvement of learning	A subjective improvement in one's learning experience by aligning learning activities with a student's preferences	cognitive load, goal setting	existing questionnaire, feedback collection through survey	Pilot testing
make learning more engaging?	Personal sequence	Personalizing the order, type and amount of learning activities a student must engage with	-	pilot testing, feedback collection through a survey and focus group session	Students are given access to the Pilot version of the Playlist tool and asked to give any feedback during their usage. Afterwards they are asked if and how they feel this tool can improve their learning through both a survey and focus group
What are the expectations of TU Delft students regarding the use of personalized playlists?	expectations	expectations in terms of functionality and interactivity of the tool	AttrakDiff	Survey and focus group	Through a survey students are asked to fill in the AttrakDiff questionnaire on both SC and the Playlist tool. They are also asked to rate (possible) functionalities for the Playlist tool in the survey. In Focus group sessions students are asked to describe functionalities they wish to see
How can a personal sequence of learning activities be expanded upon to further improve the learning experience?	learning experience	the experience of students when interacting with educational tools at the TU Delft	-	Discuss experience in a guided way. Less room for creativity but does yield data in a controlled matter	Ask students about their experience with SC and the Playlist tool through a survey, ask for additional feedback on the Playlist feature during a focus group
How to co-design an educational tool to fit the learning environment of the TU Delft?	co-design	The researcher facilitates opportunities for stakeholders to partake in the design[70]. In this case end-users (students) are invited to participate in the design process at set times.	-	Use different activities to involve students in the design: survey and design-based activities	Through a survey students are asked to rate potential functionalities and provide a desired functionality of their own. In focus group sessions students are asked to do the same by using two design-thinking tools: Feedback-Capure Grid and Jobs To Be Done

B

Data collection methods

B.1. Survey before implementation

Introduction

Hi!
This survey is part of a Master's thesis and will be used to assess the usage of learning support tools such as Skills Circuit.
By filling in this survey you agree that the anonymized results will be used in a Master's thesis report and possibly a publication.
The survey has 4 components. First up are questions about your general usage of Skills Circuit.
Thereafter questions will be asked on how much effort Skills Circuit asks from you, how you view the tool, and a potential new functionality.
If you have any questions or feedback, feel free to t

Thanks in advance,

General usage of Skills Circuit

Is this the first course in which you are using Skills Circuit?

- ○ Yes
- ○ No
- ○ I am not using Skills Circuit in this course but have used it before
- ○ I am not using Skills Circuit in this course and have not used it before

How often do you use Skills Circuit for this course?

- ○ Less than once a week
- ○ 1-3 times a week
- ○ More than 3 times a week
- ○ I do not use Skills Circuit at the moment

Have you filled in this survey already for another course?

- ○ Yes
- ○ No

Why do you use Skills Circuit for this course? Please choose all that apply.

- ☐ It was recommended by my teacher
- ☐ I find it useful
- ☐ I'm trying it out

- [ ] I use it to plan my studying
- [ ] I use it to explore the course's content
- [ ] I use it (mostly) instead of Brightspace for this course
- [ ] Other:

Why do you not use Skills Circuit at the moment?

- [ ] Too much effort
- [ ] Not useful for me
- [ ] It is confusing
- [ ] Other:

Cognitive load

How much mental effort do you actively put in when using Skills Circuit to learn? This is not about the mental effort the learning content requires, but just using Skills Circuit.

	Very, very low mental effort	Very low mental effort	Low mental effort	Rather low mental effort	Neither low nor high mental effort	Rather, high mental effort	High mental effort	Very high mental effort	Very very high ment effor
Using Skills Circuit generally costs me:	○	○	○	○	○	○	○	○	○

Technology acceptance

With the help of word pairs we would like to know how you view Skills Circuit.
Don't think about it too long and try to make your choice as spontaneous as possible. Even if you feel the word pair does not fit Skills Circuit.

How would you describe Skills Circuit?

human	○	○	○	○	○	○	○	technical
isolating	○	○	○	○	○	○	○	connective
pleasant	○	○	○	○	○	○	○	unpleasant
inventive	○	○	○	○	○	○	○	conventional

simple	○	○	○	○	○	○	○	complicated
professional	○	○	○	○	○	○	○	unprofessional
ugly	○	○	○	○	○	○	○	attractive
practical	○	○	○	○	○	○	○	impractical
likeable	○	○	○	○	○	○	○	disagreeable
cumbersome	○	○	○	○	○	○	○	straightforward

How would you describe Skills Circuit?

stylish	○	○	○	○	○	○	○	tacky
predictable	○	○	○	○	○	○	○	unpredictable
cheap	○	○	○	○	○	○	○	premium
alienating	○	○	○	○	○	○	○	integrating
brings me closer to people	○	○	○	○	○	○	○	seperates me from people
unpresentable	○	○	○	○	○	○	○	presentable
unimaginative	○	○	○	○	○	○	○	creative
good	○	○	○	○	○	○	○	bad

How would you describe Skills Circuit?

confusing	○	○	○	○	○	○	○	clearly structured
repelling	○	○	○	○	○	○	○	appealing
bold	○	○	○	○	○	○	○	conservative

dull	○	○	○	○	○	○	○	captivating
undemanding	○	○	○	○	○	○	○	challenging
motivating	○	○	○	○	○	○	○	discouraging
novel	○	○	○	○	○	○	○	ordinary
unruly	○	○	○	○	○	○	○	manageable

Playlists: an extension idea for Skills Circuit

For the next question we want you to envision an added functionality of Skills Circuit called "Playlists". A playlist is an automatically generated list of learning activities you are able to complete in the amount of time you have. The learning activities are taken from the course's circuit and chosen based on your progress and the estimated time they would take you. Instead of you determining what to do during your study session, the playlist does it for you! It can also incorporate several preferences such as a 5 minute break every 20 minutes, alternating between reading activities and watching videos, or picking only certain activities such as exercises.

Below is a list of use cases for the Playlist functionality. Please choose how likely it is you would use the Playlist functionality to assist you in that situation, assuming it can do that.

	Extremely unlikely	Somewhat unlikely	Neither likely nor unlikely	Somewhat likely	Extremely likely
I want to know what activity I can do in the coming 10 - 30 minutes	◯	◯	◯	◯	◯
I want to plan a study session of at least 1 hour	◯	◯	◯	◯	◯
I only want to do activities of a certain type (i.e. reading material, watching videos, exercises)	◯	◯	◯	◯	◯
I want to know how far I can progress with X amount of studying time	◯	◯	◯	◯	◯
I want to plan out regular breaks during studying	◯	◯	◯	◯	◯
I want to plan to reflect more on what I have learned	◯	◯	◯	◯	◯
I want to plan to revisit past content more	◯	◯	◯	◯	◯
I want to keep track of time spent on individual learning content	◯	◯	◯	◯	◯
I want a study plan to be made for me	◯	◯	◯	◯	◯

	Extremely unlikely	Somewhat unlikely	Neither likely nor unlikely	Somewhat likely	Extremely likely
I want help in determining where to start in the circuit	○	○	○	○	○
I want to know how much time each module took me	○	○	○	○	○
I want to know how much time I spend on different types of learning activities	○	○	○	○	○
I want to transform learning content into a modality I prefer (i.e. text to audio)	○	○	○	○	○
I want to work on a subject/course in a fixed timebox	○	○	○	○	○
I want to switch between subjects/courses during my study session	○	○	○	○	○

Improving Skills Circuit

If you could add any functionality to Skills Circuit what would it be?

Briefly explain why you would add that functionality

Block 6

If you wish to join a focus group to help design the Playlist functionality mentioned previously, please enter your TU Delft email address below. The session will be held in the last week of Q3 and we will contact you as soon as possible.

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C Data collection results

C.1. First survey results

Table C.1: Table containing all functionalities proposed by students in the first distributed survey. Students were also asked to elaborate on why they would want to add that functionality. Both inputs were used to code the proposed functionality.

Proposed functionality	Elaboration	Category
Embedded content not redirection links	Improves productivity	navigation
A reward / quest system	Because then it feels rewarding completing a lesson / section (like in Duolingo)	Learning Analytics
Add quizzes of some sort in skills circuit	Right now when I go to skill circuits I am overwhelmed by the chaos. I can't find what I'm supposed to do and when. A list or general overview would help me a lot I think.	learning activities
Module digest - short but detailed explanation of the module	I'd like to see what I did where in the tree	navigation
The whole course in one tree, not different chapters	Would be a little clearer and more like a game	navigation
Library	Show all pdfs that are used/link them for each specific skill, since in some cases, like ads the chapter numbers differ	navigation
compare your time to estimated time and more statistics	to create an overview of time spent and time expected to spend	Time
A feature where it combines certain practice assignments and makes a mock exam for you to practice with	That would make it even easier to study and also see how good you are at managing different concepts in the same test, the current skill circuits groups everything on subject and this would ramdomize that making it more difficult when studying and thus making you learn more	learning activities
Connections between courses	This would help show why some thing are important or what something is used for	navigation
Prettier UI, Maybe highlighted suggested paths?	UI: it would be more pleasant to navigate the website, Suggested paths: clearer way to traverse the circuit	navigation

Maybe integrate videos or parts of the book, so i dont have 5 tabs open at the end	-	other
When I select an activity, it would be helpful for the other paths (Mountain Climber etc.) to be already dropped down (one does not know if there are activities if they don't click on the different paths)	It would help with seeing extra material more easily	navigation
Many more resources	Give the student more options while learning (from books, videos from collegerama, the exercises on weblab etc.) And separate brightspace for important messages, assignments and groups.	learning activities
Ability to save/bookmark selected nodes and access them in one place later.	(Maybe better to create a link to each course that has a skill tree?)	navigation
I would add an option to revert to the previous view where you could instantly see what the different skills are	When I open a given module view, I see all the skills but I am not really sure what each skill is at a glance. With reasoning and logic, I used to be able to instantly tell what the tasks were and it allowed me to have a greater view on all the things I had to do. Now I only see the types of tasks so it is more unlikely that I do all the parts.	navigation
Course suggestions	I like using the skill circuits, so I think it would be a good idea to extend them to more courses. I think it would be useful to let students suggest courses to add to the Skill Circuits, and maybe have a functionality to let students suggest a basic layout and work on it together, which can then be used by the course staff to build the official Skill Circuits for that course.	navigation
The option to get an overview of all activities for a certain week	Right now when I go to skill circuits I am overwhelmed by the chaos. I can't find what I'm supposed to do and when. A list or general overview would help me a lot I think.	navigation
Deadline calendar integration	It's nice to automatically keep track of the deadlines (lecture dates mostly).	time
Specifying how long a task actually took you	Because the time is not really accurate for me	time
Feedback on time spent on certain activities	I think the time estimates given are very often wrong, and feedback on them could be useful for the lecturers to know what we struggle with and to plan time allocation for outside of lecture activities.	time

(A lot of the suggestions on the previous page would be very nice, but for the sake of adding something new)A clearer connection between blocks, as in why knowing something from a previous block helps understand the next	It helps me if I can understand the connections between blocks and material, it creates a greater understanding of the whole	navigation
Dark mode, clicking on ”Read chapter X” opens a pdf	It’s too bright for my eyes at 3 AM. Also, finding where I downloaded the PDF and going to the correct page take a long time.	other
please please please sometimes it wants me to login again but it doesn’t tell me so when I refresh the page all my progress Has been undone	The bug is annoying. Other than that, skill circuit is pretty good I’d say	other
It already does this, but I’d add a clearer distinction between unvisited, partially finished nodes and completed nodes.	I would like to see at a single glance without effort where there is work to complete. Also adds to gamification aspect etc.	learning analytics
The previous version of skill circuit had a better view of which path to take to complete certain tasks or modules, it had a progress bar of sorts or a different color for the path you have finished and then next one you should take. That helped me more to know what to do next.	Because right now it’s still a bit confusing for AD which paths to take to complete something	navigation
I would add a way to interact with other people, or at least keep track of who has done which part of the circuit	There is no interaction with others in the skill set, making it hard to compare with other students. Think of it as ”achievements”, if 90% has done a part, you’re more compelled to do it as well	learning analytics
A reset button to reset progress	Might be useful for students retaking a course	learning analytics
Color customisation	Just for fun :))	other
More attention paid to time estimates	-	time
I would add the ability to give feedback on the actual amount you spend on an exercise. Then the estimate can be extrapolated from the submitted times. I would really like this feature, because I find the estimates to usually be wildly inaccurate.	-	time