# Playlist: A personal sequence of learning activities

Full report on a holistic approach towards designing an educational tool

Thesis report

by

Rebecca N. Glans

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| *Thesis committee*: | |
|---|---|
| Chair: | Prof. Marcus Specht |
| Supervisors: | dr.ir. Steven Flipse |
| | Manuel Valle Torre |
| | Dr. Éva Kalmár |
| External examiner: | Jorge Martinez Castaneda |
| Place: | TU Delft, Delft, Netherlands |
| Project Duration: | June, 2023 - July, 2024 |
| Student number: | 4305663 |

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Faculty of Electrical Engineering, Mathematics and Computer Science · Delft University of Technology

# Executive Summary

This thesis involves 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. This research contributes to the complexities of modern digital learning environments and the challenges students face in navigating vast amounts of educational content.

This report holds the full description of the integrated thesis. The first part including the chapters of ”Fostering a personal sequence of learning activities in Skill Circuits” [1].
The study uses a design-based research approach, which involves iterative development and research cycles and including students in the evaluation phases. By drawing on educational theories and addressing practical needs identified at TU Delft, the Playlist tool was designed to seamlessly integrate into the existing learning environment. The tool’s functionalities were prioritized based on user feedback provided by Computer Science students and gathered through surveys and focus group sessions.

Key findings 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 hopes to demonstrate the potential and importance of designing tools to personalize learning and support students in achieving their learning goals. It also explains why personalization tools in higher education should be implemented in an iterative manner.

The Playlist Feature, as part of Skill Circuits, can be found on the TU Delft GitLab server:
`https://gitlab.ewi.tudelft.nl/in5000/cel/rebecca-glans/skill-circuits-and-playlists`

# Acknowledgments

“Have no fear of perfection – you’ll never reach it”

Salvador Dali

This thesis report concludes a year filled with both academic and personal development. I never thought I would be taught so much about myself when I began this journey. Not only can I say that I am proud to have made it so far, with this report as a result, but I am also very thankful for all the support I received along the way!

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# Part I

## Fostering a personal sequence of learning activities in Skill Circuits

# 1 Introduction

*The current chapter is taken from the Master's Thesis "Fostering a personal sequence of learning activities in Skill Circuits" [1], and is added for a complete overview of the integrated thesis project.* 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 [2]. 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 [3] 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 [4], 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 [5, 6], 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 [3].

## 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 [3]. 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 [7].
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 [8].

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 [9]. 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 [10].

## 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.[11, 2, 10]
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 [12]. 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 [13].
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 [14] 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 **??**:

- 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

*The current chapter is taken from the Master's Thesis "Fostering a personal sequence of learning activities in Skill Circuits" [1], and is added for a complete overview of the integrated thesis project.* 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 [15]. 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 [14].
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 approach in this project

In this section, we will outline the execution of each phase of the model by Hoadley and Campos [14] 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.

### 2.1.1. 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 2.2 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.

### 2.1.2. 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 in the next phase.

### 2.1.3. Iterating, Chapters 6 - 8

***Methods used:*** User stories, self-reporting (survey), focus group activities
***Outcome:*** Answering research question
*Given the time span of this thesis project, only one complete iteration was conducted.*

**Chapter 6**, explains the design decisions made and design patterns that were used to structure the code. Design patterns were inherent to the tool's framework, JAVA Spring Boot, namely Model-View-Controller and Service Layer. The tool was developed as a feature in Skill Circuits and was to be tested in its production environment during the third quarter of the academic year. Permission to make the feature available to students was given for one Computer Science & Engineering bachelor course: Automata, Computability and Complexity. Students were made aware of the new feature in both Skill Circuits and a post on the course's BrightSpace page. Before they had access to the tool, they were explicitly asked in Skill Circuits to opt-into the research and give us access to their usage data.

**Chapter 7** describes all the data collected to evaluate our playlist feature. We have look into student's usage data, responses to surveys distributed both before and after using the playlist feature, and the output of two focus group sessions. Throughout their usage of the tool, students were also able to send feedback to the researcher. The sample sizes for each data collection approach can be found in table 2.2.
The surveys consisted of 4 different parts, each aimed at evaluating different aspects of an educational tool. The survey distributed before the playlist feature was implemented, was aimed at gaining insights into students' usage and evaluation of Skill Circuits. The second survey was aimed at gaining the same insights but now centered around the playlist feature. The surveys asked students for:

- Self-reported estimated usage of either Skill Circuits or the playlist feature
- The mental effort when using either Skill Circuits or the playlist feature

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

- Evaluation of either Skill Circuits or the playlist in terms of usability and appearance: AttrakDiff questionnaire
- Assessment of functionalities for the playlist feature in the form of user stories

The survey distributed before playlist usage was filled in by the same students who were asked to help prioritize the feature's functionalities. As these are not the same students who eventually gained access to the implemented feature, care must be taken in comparing the results, especially when wanting to assess improvements to students' experience with Skill Circuits when the feature is available. The survey distributed after the playlist feature was implemented, also asked students to fill in the Achievement Goal Questionnaire. More information on each part, including the existing questionnaires that were used, can be found in section 2.3.
After having used our feature, we wanted 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 experience using Skill Circuits. The activities used in the focus group sessions were to gain structured feedback on the playlist feature. Students were asked to fill in a Feedback-Capture grid to reflect on the present functionalities. The Jobs-To-Be-Done method was used to gain input from students on how they would improve and add functionalities to the feature. A more detailed explanation of these activities can be found in section 2.3 as well.

| | Survey 1 | Playlist feature usage data | Self-reported feedback during usage | Survey 2 | Focus group sessions |
|---|---|---|---|---|---|
| Computer Science bachelor courses | Algorithm design, Algorithm Design & Data Structures | Automata, Computability and Complexity | | | Automata, Computability and Complexity; open to master students |
| Amount of respondents | 110 | 57 | 6 | 9 | Session 1: 5, Session 2: 4 |

**Table 2.2:** The number of respondents for each form of data collection and the course they belong to. All respondents had experience with Skill Circuits and used or tested the Playlist feature at least once.

**Chapter 8**, discusses the previously presented data to understand whether the playlist feature can address any needs students have. The process of designing and collecting user data are also discussed. New insights are presented and adjustments to the conjectures are made for future iterations and research. Chapters 7 and 8 then complete our answers to the fourth and fifth research questions.

### 2.1.4. Reflecting, Chapter 9

***Outcome: Research objective***

Our project, and thus the report, concludes by not only answering our research questions but also describing our outcome. As we are conducting design-based research and want to encourage improvements in a learning environment through iterations and constant reflection, our outcome will fall in the category of a new hypothesis. Amiel and Reeves describes technology as a value-laden process, implying it is something that is never complete and will continue to develop alongside its environment. We, therefore, hope to inspire further research in our chosen learning environment, which further develops our playlist feature and explores our adjusted conjectures.

## 2.2. 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.

### 2.2.1. 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 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.

### 2.2.2. 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.

The team focuses on developing tools that address the needs of both lecturers and students [2]. A tool developed to mainly address student needs is Answers, a Question & Answer platform [3]. 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.

### 2.2.3. 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[4].

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 2.2.3 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

[2]Find all developed tools here: `https://eip.pages.ewi.tudelft.nl/eip-website/`

[3]`https://answers.ewi.tudelft.nl/`

[4]An introduction to Skill circuits can be found at `https://eip.pages.ewi.tudelft.nl/eip-website/skill_circuits.html`

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.

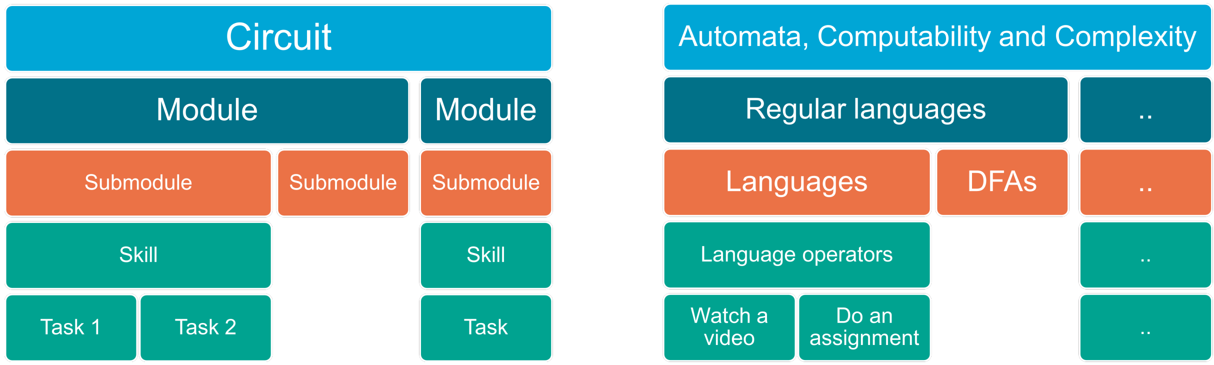


**Figure 2.1:** A visualization of how a course is broken down in Skill Circuits. On the left, the different levels are shown. On the right, the levels are filled in for the course Automata, Computability and Complexity, as an example

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. Developing a technology to assist them in this process could significantly empower students and improve the overall learning environment. Additionally, it will address the lack of systems adopted for students to improve their learning independently.

## 2.3. 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 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 2.3:** The courses where each of the surveys were distributed

### 2.3.1. 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.

### 2.3.2. 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[5], 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 2.4:** 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 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

[5] https://datainnovationproject.org/tip-tools/

- 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?

### 2.3.3. Coding student’s input

In chapter 6 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

*The current chapter is taken from the Master's Thesis "Fostering a personal sequence of learning activities in Skill Circuits" [1], and is added for a complete overview of the integrated thesis project.* 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 [5, 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 [5, 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 [3] 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 [11]. 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]:

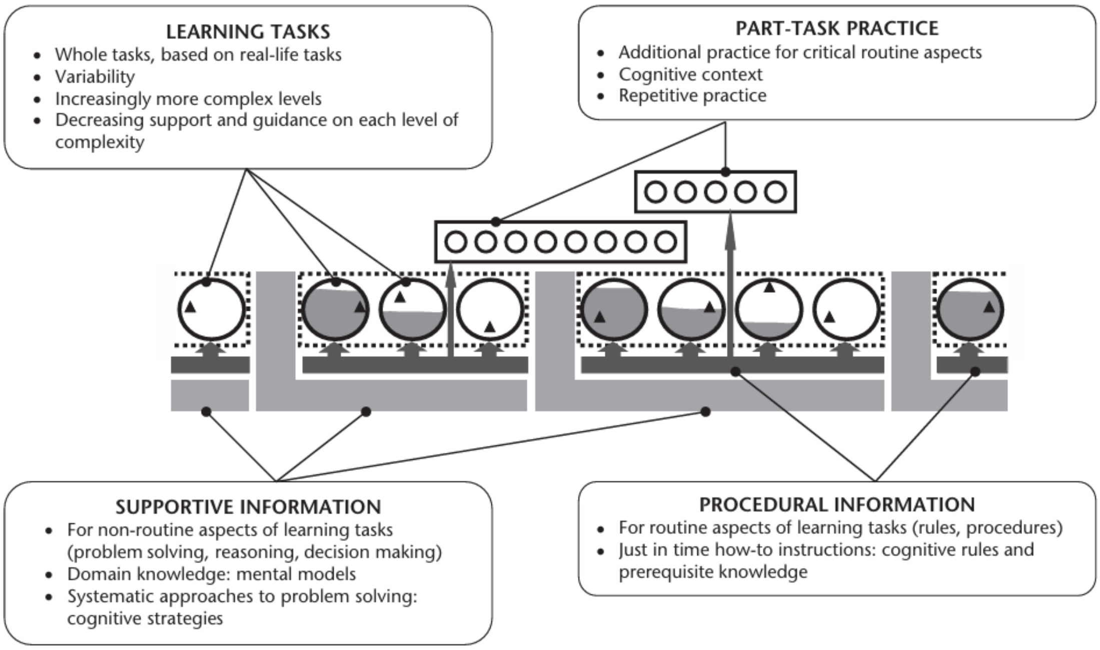


**Figure 3.1:** Schematic representation of each of the 4C/ID components [25]

- Intrinsic cognitive load: the mental effort needed to perform the learning task
- 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, [5] 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* [5]. In literature the difference between the two approaches is not always clear, especially since the terms are sometimes used interchangeably to describe educational systems [5, 6]. 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 [6]. 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 [5].
*Personalized learning*, on the other hand, is when the student is given the opportunity to change educational content to fit their preferences and interests [6, 5]. 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 [4].
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 [5]. 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 [3]. 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 [3, 8], 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 [4].
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 [11]. 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. [5].

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 [5].

Four types of educational technology solutions can be identified within institutions [3]. 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 [3]. In [5], 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 [5]. 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 [3]. 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 [5, 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 [3].

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].

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

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 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 [5], 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 [11, 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. [6] 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 [9]. 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 [10].

### 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 [2]. 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 [2]. This includes integrating reflection amplifiers as described by [4] 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 [6]. Furthermore, it is essential to consider how the chosen educational technologies align with and enhance a student's overall learning experience [2]. Learning is not only about interacting with

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

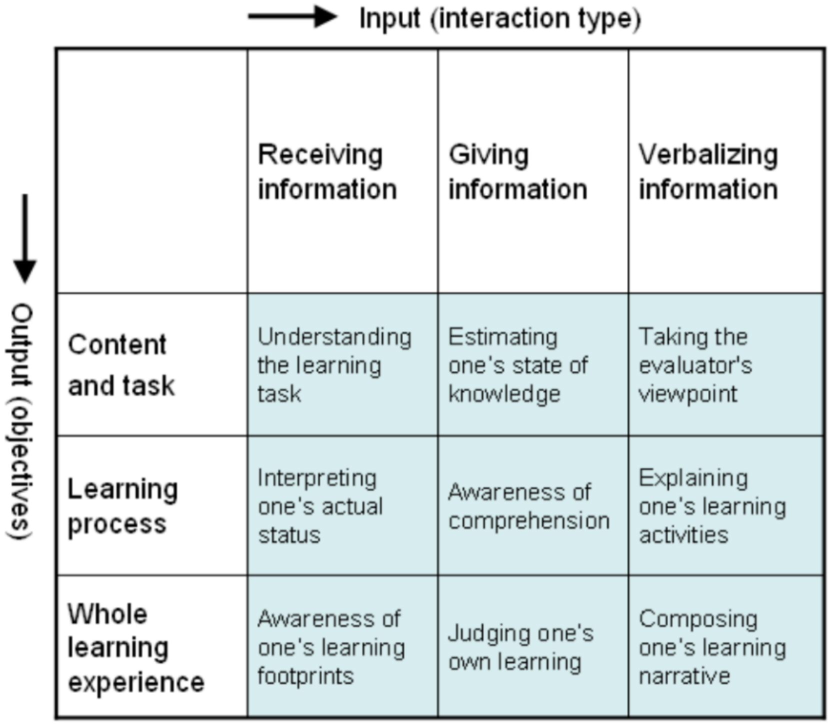


**Figure 3.2:** A classification framework created by Verpoorten, Westera, and Specht. It is based on existing reflection amplifiers and aims to support the integration of reflection activities in online learning environments, as well as promote further research [56].

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 9. 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 [5, 6].
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, 4].

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 [11, 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 System requirements

*The current chapter is taken from the Master's Thesis "Fostering a personal sequence of learning activities in Skill Circuits" [1], and is added for a complete overview of the integrated thesis project.* 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

[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`

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.

### 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.**

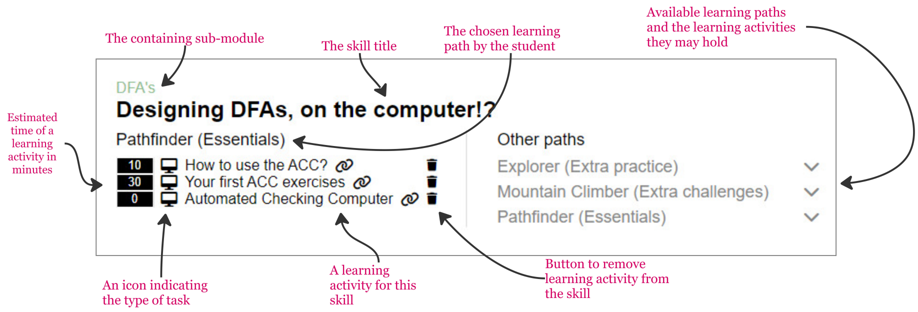


**Figure 4.1:** A skill block as displayed in Skill Circuits. Among other information, a skill holds a list of learning activities. This list can be adjusted by the student to resemble the activities they actually plan to do. In this view, the students also see any information associated with the learning 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 [4]. 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 [11]. 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 [9, 11]. 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

[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/`

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], 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 Initial design

*The current chapter is taken from the Master's Thesis "Fostering a personal sequence of learning activities in Skill Circuits" [1], and is added for a complete overview of the integrated thesis project.* This chapter marks the transition from the *conjecturing* phase to the first iteration of the *creation* phase. In the previous chapter, I created a list of categories to describe possible functionalities for the playlist feature. Before proceeding to develop these functionalities, each category was evaluated by asking students for input on a set of user stories. The results will not only inform the design choices in the subsequent phase but also 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 7.

### 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 in Chapter 6, 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

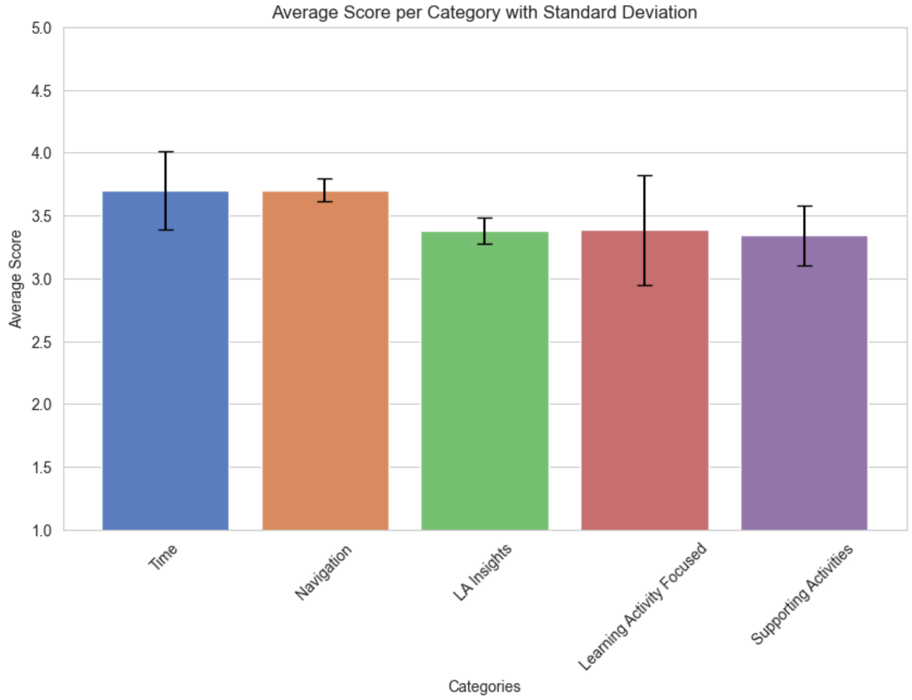


**Figure 5.1:** The average score for each type of user story presented to students in the form of 15 user stories.

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

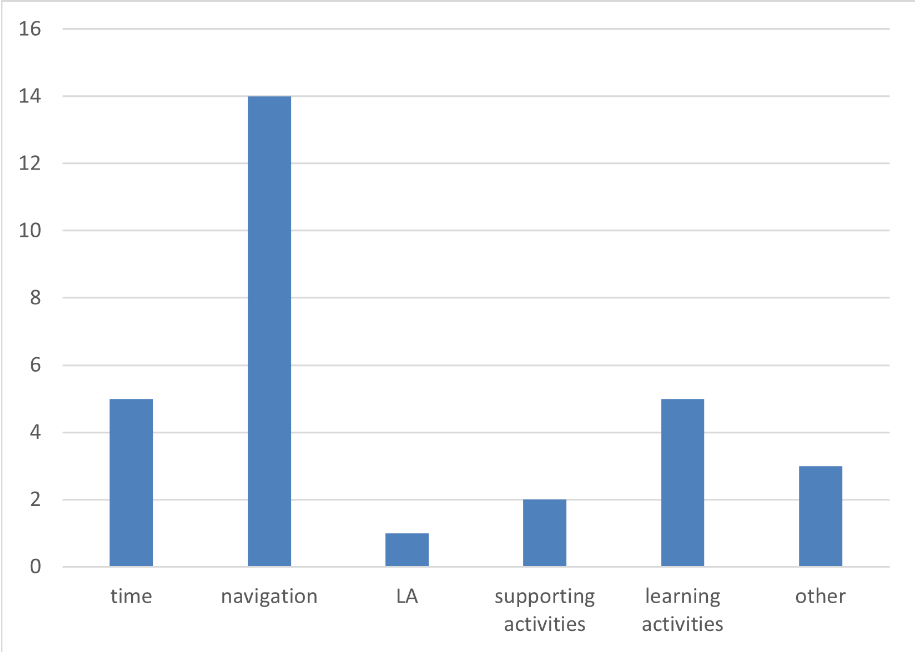


**Figure 5.2:** Student's suggestions for new features in Skill Circuits, after being coded with the functionality categories.

## 5.4. 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 conducted a survey with 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.

# Part II

## The implementation of the Playlist feature in Skill Circuits

# 6 Creating playlists

With basic functionalities described and the preferences of our intended users collected, I can now attempt to develop the first version of the *playlist feature*. Building upon the existing architecture of Skill Circuits, makes the feature accessible to students to use alongside their normal usage of Skill Circuit in a course. In this chapter, we will first explore Skill Circuits' open-source code base to identify where and how to implement the playlist feature. For each functionality of the feature, we will decide how we want students to interact with it (the front end) and what is needed to support that funtionality (the back end). Design decisions will be made with future developments in mind by ensuring that the code's structure is clear and scalable. However, if time constraints require it, the initial implementation will prioritize functionality and widespread student testing in a live learning environment over making the code fully future-proof.
The chapter concludes with a description of the initial implementation of the playlist feature.

## 6.1. The playlist feature

With a playlist, we aim to help students pick a subset of the full sequence of a course for their study session. A study session is a **time-slot** chosen by the student to work on **learning activities** of the course. The playlist feature needs to help them **navigate** the learning activities of the course's sequence and find the ones that fit the **goal** of their study session. Goals can be time-based and **achievement-based**. Creating a playlist will hopefully **lessen the cognitive load** needed to determine how to best organize a study session and increase a student's **motivation to engage with learning activities**.
Given the information that is available in a course's circuit, how can we translate it to a playlist?

The feature is visually designed to test whether the Playlist format is appealing to students. Especially when comparing it to the existing Skill Circuit representation of learning activities

- Create a playlist to become aware of your study goal
- Compile it from available learning activities to make navigating a course easier
- Start, pause, stop a playlist to be more aware of the state of your study session
- "Play" through each activity to have a sense of progression

The feature's first implementation will focus on improving the navigation of learning activities and supporting time-based learning analytics. Additionally, we want to test the playlist analogy to see if further development of the tool with that framing makes sense to students.

SDL

### 6.1.1. Ensuring feature removability

Considerations must be made in both the design and implementation of the feature to ensure it is easily removable from Skill Circuits after the thesis project is completed. The feature will be available for testing in only one course during the third quarter of the academic year 2023-2024. Specifically, only students enrolled in "Automata, Computability, and Complexity" (ACC) will encounter the playlist feature within the course's circuit. From the user's perspective, the feature should be clearly identified as exclusive to this course.
Students have the option to test and use the tool. For those who do not wish to participate, the tool must not interfere with their usual workflow within Skill Circuits.

In the back-end, the playlist implementation must be as loosely coupled as possible. This approach will involve creating separate database tables for the playlist feature rather than modifying existing tables and entities, resulting in some duplicate entries. Additionally, any code necessary for the playlist feature will be isolated where possible to facilitate smooth removal at the end of the project.

### 6.1.2. From circuit to sequence

To introduce personalization of a sequence of learning activities, we must first retrieve a course's complete sequence from Skill Circuit as described in chapter 4. The playlist feature must access the tasks in Skill Circuit to assemble this complete sequence. Within Skill Circuit's backend, these are represented by a `Task` entity.
To maintain loose coupling between Skill Circuit and the Playlist feature, I will introduce a counterpart entity named `PlaylistTask`. The `PlaylistTask` will only contain information relevant to the playlist feature. Details specific to a task will remain stored in the original `Task` entity as much as possible and will not be copied. This setup will allow me to explore the best ways to manipulate the tasks as learning activities in a personalized sequence.

### 6.1.3. Navigation

Transforming the circuit to a complete sequence is in itself a new way for students to navigate the learning activities of a course. The ordering of the complete sequence is derived from the circuit as follows:

- Learning activities are sequenced as they are within skills in the circuit
- Learning activities are visually grouped by skill
- Skills are sequenced as they appear in the circuit: from top to bottom, respecting the hierarchical relationships, and then from left to right

Circuits include checkpoints, which are (recommended) deadlines for completing the learning activities within a skill. These checkpoints typically correspond to lecture dates. In the complete sequence, skills are grouped per checkpoint to show how many activities remain before students are on track for the next checkpoint.

With the circuit transformed into a sequence, students can then select the learning activities they want to complete during their study session.

### 6.1.4. Time

Students want to understand how many learning activities they can complete within their allotted study time and, conversely, how long their study session should be to complete a selected set of learning activities. To help with this, teachers set an estimated completion time for each task. However, students report that these estimates are not always accurate and are seeking a way of providing feedback to adjust them. This feedback not only helps teachers and other students to get a better sense of how much time is needed to complete each task but is also essential for a students own progress tracking.

Therefore, the initial implementation of the playlist feature will focus on enhancing the accuracy of time estimates in Skill Circuits. This is also a prerequisite to be able to introduce more time-based functionalities later on.
The Playlist feature will:

- display an estimated duration of a study session, based on the chosen learning activities in the playlist
- display and track the time spent studying in the session
- display and track the time spent on a learning activity
- Ask student confirmation on the tracked time of a learning activity

### 6.1.5. Playlist emulation

While the overall flow will mirror the phases of self-directed learning, user interactions will draw inspiration from the familiar controls found in traditional playlist interfaces.
Functions such as *Starting* and *pausing* will represent the start and temporary interruption of the study session. The playlist and its contents, the learning activities, can have several states:

- *"playing"* indicates a student is engaged in the study session and which learning activity they are currently working on
- *"paused"* signifies the study session or particular learning activity is set on hold
- *"queued* is to indicate a learning activity is scheduled

The title of the playlist will be auto-generated for this implementation and set to "Study session *[date of creation]*".

## 6.2. Implementing the playlist feature

In this section, I will outline the initial implementation of the playlist feature. Skill Circuit is developed using the JAVA Spring Boot framework, which is designed for building web-based applications[1]. The framework enforces several design patterns to which we will have to adhere when adding the Playlist feature. A design pattern can be seen as a best practice for effectively structuring your code.

The core design pattern is the **model-view-controller** design pattern, which ensures a separation of concerns [2]:

- The model: includes data management and business logic
- The view: handles the layout and presentation of the interface the user interacts with
- The controller: facilitates the communication between the model and view

Within the model part, two additional design patterns are utilized. Having a **repository** for each entity– such as `PlaylistTask`– ensures structured data management. This is fully supported by Spring Boot and requires minimal setup. A **service layer** separates the business logic from direct data manipulation. It provides controllers with a defined pathway to interact with models and retrieve the data needed by the view.

Using the structure provided by the design patterns, I will walk through the code of the Playlist feature.

### 6.2.1. Model: playlist entities

First, we must create the entities to store all the necessary data. For each study session, students will create a playlist: their personal sequence of learning activities. We will take inspiration from the memento design pattern[3] to make playlists editable without requiring the creation of a new Playlist object each time a student wants to modify their sequence. This approach allows us to separate general information about the playlist from the details of the specific learning activities it contains. Consequently, this requires the creation of two entities: Playlist and PlaylistVersion.

- Playlist: contains metadata about the playlist, such as the owner, creation date, and current state
- PlaylistVersion: contains details about the learning activities selected, including their sequence and total estimated completion time

To maintain a loose coupling with the Skill Circuits code base, we introduce another entity called PlaylistTask, which will be the learning activity contained in PlaylistVersion. PlaylistTask holds a reference to the Task it represents in Skill Circuits, to prevent redundant duplication of task information. PlaylistTask then has several fields related to tracking a student's progress on the learning activity.

Finally, the entity ResearchParticipant was created to store information about students who used the Playlist feature. As the feature is part of a research project, in which I collect and analyze student's usage data, I had to explicitly ask students to join the research. Only after they agreed to the terms, were students marked as a ResearchParticipant, granting them access to the functionalities of the Playlist feature.

### 6.2.2. View: what the students interact with

Several views were created for the Playlist feature. They could all be accessed through a button titled *Playlist*. This button was always located at the top right corner of pages related to the ACC course. The

[1] The official documentation on Spring Boot can be found at `https://spring.io`

[2] https://developer.mozilla.org/en-US/docs/Glossary/MVC

[3] Memento design pattern: `https://refactoring.guru/design-patterns/memento`

playlist button was not visible on other pages in Skill Circuit. The different views students would interact with, can be categorized by 3 different user flows:

- Opting in and out of the research
- The playlist feature
- Task completion confirmation

**Opt-in and Opt-out views** were created to let students either join and leave the research study. The opt-in view provides information about the playlist feature, including the reasoning behind it, what data will be collected, and assurances that students can withdraw from the study at any time.
The opt-out view allows students to leave the study while revoking their access to the Playlist feature. Students could also indicate if they preferred their data collected so far to be excluded from the research.

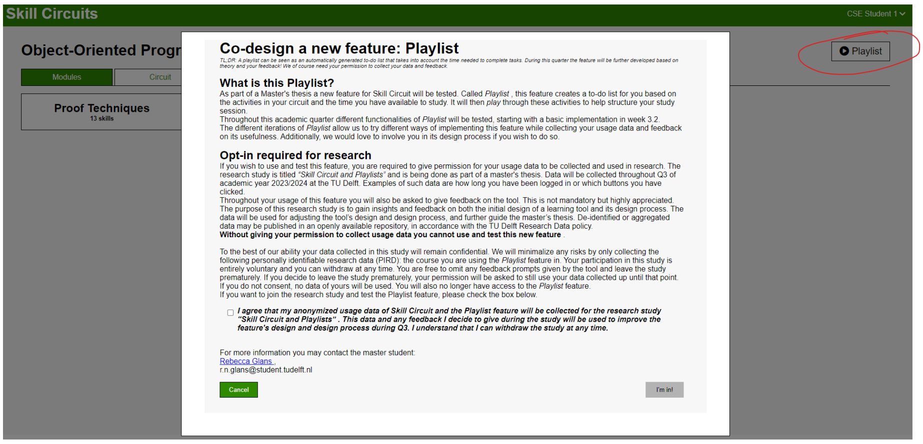


**Figure 6.1:** Students were required to opt-in for access to the playlist feature as their date would be used in this thesis project.

Once access was granted to the Playlist feature. Student's interactions with the Playlist feature will be contained in the playlist window. **A "first-time" view** is shown when students click on the playlist button. In this view a short description of the feature is given and an explanation on how to use it. After students have created their first playlist, this view is never shown again. Instead, the subsequent views hold different tool-tips that students can click on to gain information of different functionalities. This declutters the views and gives students the opportunity to access information only when they need it.

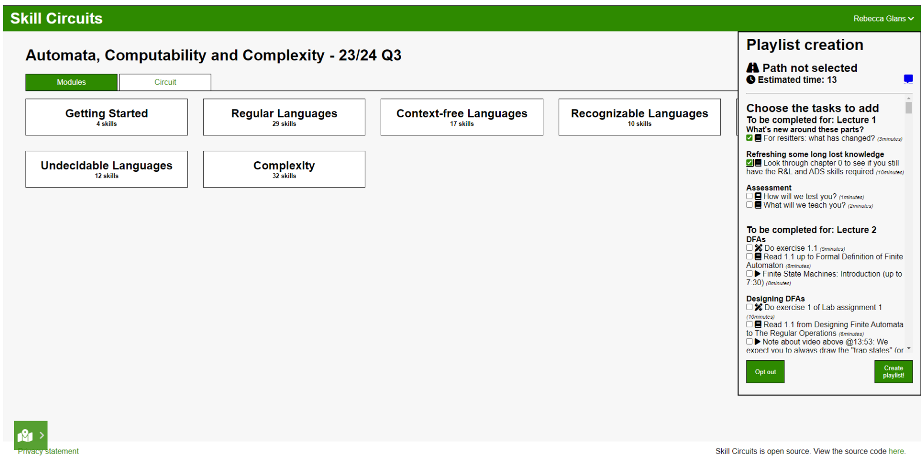


**Figure 6.2:** Creating a playlist in Skill Circuits

Next up are **two views for creating and playing a playlist**. Both views were contained in the playlist window. This window can be seen in figure 6.2.

Students go through two different views that represent the first phases of self-directed learning as described in [39]. The first view concerns the first two phases of self-directed learning: task definition, and goal setting and planning.

**Creating a playlist.**
Task definition is supported by displaying the complete sequence of the course and giving students the ability to select which learning activities they wish to include in their playlist. By displaying learning activities grouped by both skills and checkpoints, students can determine if they want to work on completing skills, checkpoints or both.
Goal setting and planning is mainly supported by indicating the estimated time per learning activity, and calculating the total time of that playlist each time a learning activity is selected.

*The strategy enactment phase would be supported if the students were given the opportunity to edit the order of the chosen learning activities and add additional activities that align with their strategy. This way, the playlist would more accurately represent the structure of their study session. This functionality will be introduced in the next iteration, as described in chapter 8. Implementing support for the strategy enactment phase would significantly reduce the time available for students to test and integrate the playlist feature into their study routines.*

**Playing a playlist**
The second view is where the created playlist is displayed and students can use it to track their progress during a study session. This view pertains to monitoring and reflecting, primarily monitoring. The view enables the student to track the total time spent studying, and the individual times they were busy with individual learning activities. To start a study session, a student can press *play*. Each learning activity can be started independently to signify engagement, and multiple activities can be in progress at the same time. Learning activities can be paused individually or collectively if a student needs to put the session on hold.

T**he task confirmation view** was triggered when students completed a learning activity. Completion could not be done in the playlist window but had to be done in the circuit ”as normal”. This was a conscious design choice to separate the enhancing functionalties of the Playlsit feature from existing functionalities of Skill Circuit.
Once a student completed a task in Skill Circuit and it was a part of the currently playing playlist, a view popped up with the tracked time of that activity. In figure 6.3 it shown that students were either asked to confirm the tracked time or input the time they estimated the task took.

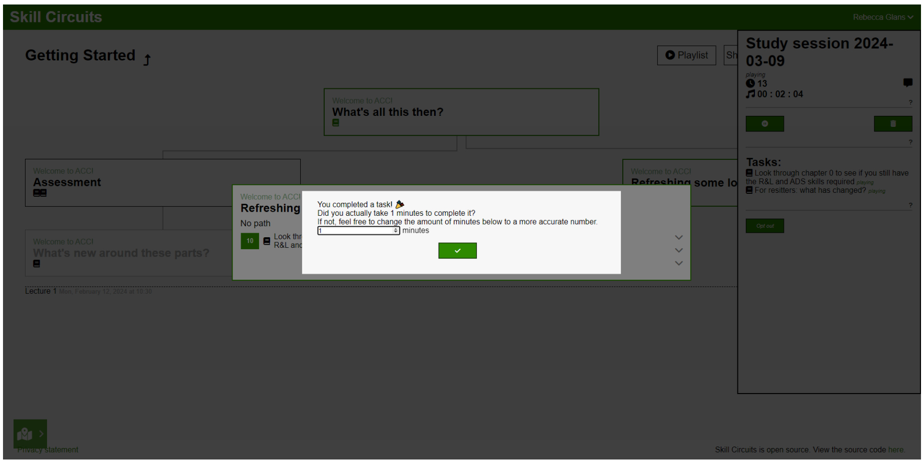


**Figure 6.3:** Pop-up when completing a skill to verify if the time taken is correct.

Two buttons were available on all the created views: the opt-out button and a feedback button. The latter could be used to send any form of feedback.

### 6.2.3. Controller: the connection between front- and back end

To properly process all the interactions with the view of the feature, the PlaylistController was created. This controller holds all the endpoints with which the front end can communicate for data access.

`POST, PATCH /playlist/optIn`
Handles students opting in and out of the research study. Opting in creates a ResearchParticipant object to represent the student.

`POST /playlist`
This endpoint is called when a student creates a playlist. As a result, it creates the relevant Playlist, PlaylistVersion, and PlaylistTask data objects.

`PATCH, DELETE /playlist/playlistId`
This endpoint is used when a playlist is completed (patch) or deleted. If successful, the front end is updated, and the student is navigated back to the playlist creation view.

`GET, PATCH /playlist/{playlistId}/times`
The front end uses this endpoint every minute to send the tracked time to the back end. This continuous update ensures that the database remains current on the time spent on playlists, and it also allows students to resume their study session on a different device at another time. Additionally, every 25 minutes, the times recorded in the student's browser are verified against the saved times in the back end to ensure both are synchronized.

### 6.2.4. Service layer: the logic of the tool

To delegate several actions from the controller, the server layer holds the main logic of many functionalities. This is also where communication between entities happens. This layer also contains the methods needed to perform personalized sequencing. The first implementation of the Playlist feature focuses specifically on correctly retrieving a course's complete sequence.

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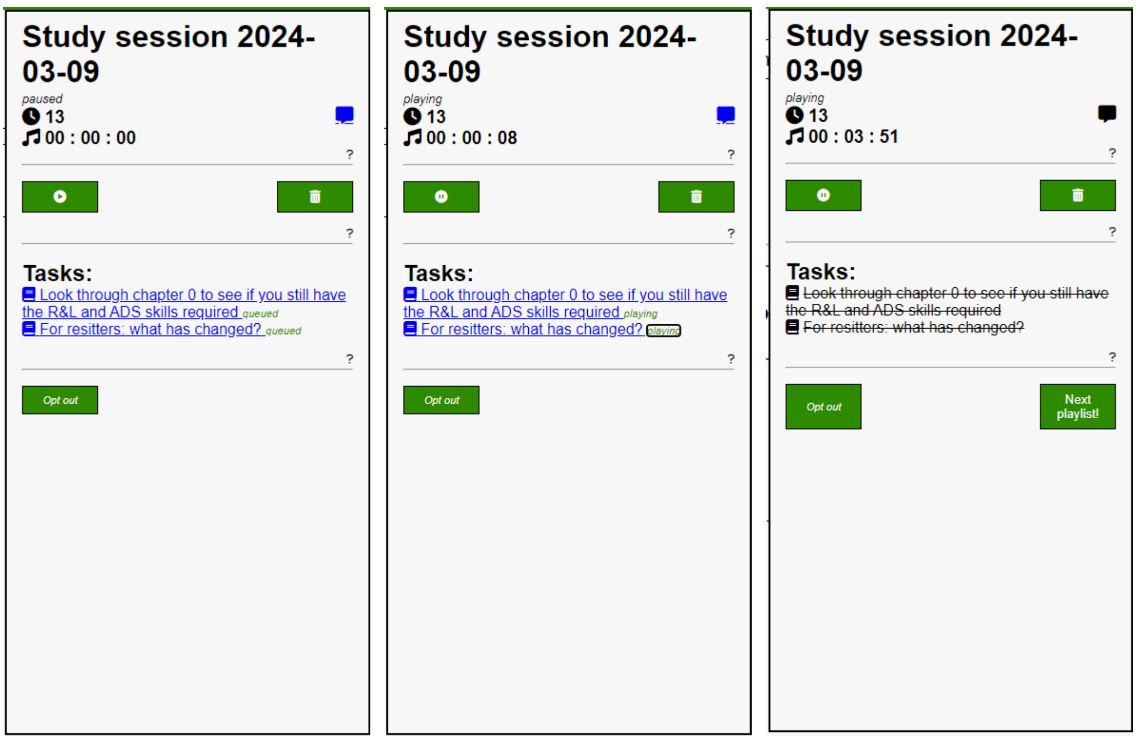


**(a)** Playlist has been created **(b)** Playlist is playing **(c)** Playlist has been completed

**Figure 6.4:** Playlist views

### 6.2.5. Playlist 1.0

The first iteration of the playlist feature is fairly basic. Even though basic functionalities were expected, the amount of functionalities implemented was lower than planned. Due to the feature being deployed to a live

environment, extra care was taken to ensure functionalities were clear and made sense visually.
The feature has at least three phases of self-directed learning represented in 3 views. ”Strategy enactment” being the phase not represented as the feature does not yet had the option to add learning activities not present in the circuit. Per students’ request the time spent on a task is now collected. In a next iteration, this can be used to both improve estimates of tasks for future versions of the course, and mirror this type of learning analytics back to the student.
Navigating tasks can now be done in the circuit as well as sequentially in the playlist feature. Additional usage data is collected on students using the playlist feature, and a they have the ability to send feedback on the feature at any time.

## 6.3. Summary

In this chapter, we completed the first development iteration of the playlist feature for Skill Circuits. I began by exploring the existing Skill Circuits code base, focusing on integrating the playlist feature in a manner that is both user-friendly and scalable for future updates. This involved careful considerations of how students would interact with the feature on the front end and the necessary back end support.

The first version of the playlist feature offers a different way of navigating the learning activities in Skill Circuits by presenting them in an ordered list. The interface lets students select learning activities to create the sequence for their study session. Only the ordering set by the original circuit is supported. During selection, the interface shows how long the activities would take to complete. Once the playlist is created, the interface allows students to monitor their time spent on the session and individual learning activities.

The feature was made available to students in a live learning environment, with an opt-in approach to ensure students were aware of their usage data being collected. This initial implementation ensures that basic functionalities are in place while keeping an eye on future expansion and refinement.

While the resulting implementation is a rather simple version of the envisioned feature, it was ensured that the feature blended into the Skill Circuits environment as much as possible. Being visible to students who would want to test this feature and not disrupt the user flow for students who did not wish to partake in this research. As the feature would be deployed to the live version of Skill Circuits, extra care was taken to not disrupt the live environment and deploy simple but working functionalities. In addition to the added functionalities, we would also like student’s input on the playlist framing of learning sequences.

# 7 Testing and user feedback

After designing and creating the first version of the Playlist feature, we can attempt to evaluate its potential impact on the learning environment based on students' perceptions and feedback.

In this chapter, I begin with an explanation of how the different ways of data collection were determined. I then present the results of a survey distributed to students before the playlist feature was implemented. Part of the results of this survey were already shown in chapter 5. The remaining parts of that survey will be presented here to see how well the Playlist feature integrates with the existing learning environment in Skill Circuits.

The first version of the Playlsit feature was made available to students of the Computer Science bachelor's course "Automata, Computability and Complexity". The usage data and feedback collected during the six weeks students had access to the feature will be presented next.

At the end of the course, students were asked to provide more structured feedback on the playlist feature by filling in a survey and joining focus group sessions. These results will be presented as well. This chapter, in combination with the next, significantly contributes towards answering the first empirical research question.

## 7.1. Evaluation setup

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 measure for our research, but it also lets us think about what methods are *possible* given our resources [19]. In this research it boils down to exploring possibilities for personalizing sequences of learning activities and, in that process, collecting student perspectives and ideas. Still, we must find clear (design) methods to do so. The operationalization steps can be found in 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] (explained in chapter 3)
- Mental effort rating scale [21] (explained in chapter 2)
- AttrakDiff Survey[22] (explained in chapter 2)

As outlined in chapter 4, literature and the capabilities within Skill Circuits have highlighted five ways in which a sequence can be personalized:

- **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

Students are also asked to share their opinions on proposed functionalities and what they would like to see in a playlist-like feature by rating user stories and answering open-ended questions.

To have effective focus group sessions with students, where we both discuss the playlist's current and future design, we will consult the Design Thinking toolbox [23]. Qualitative data will additionally be collected by letting students engage in the following activities (explained in chapter 2):

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

## 7.2. Baseline impressions

Bachelor students of two Computer Science courses that use Skill Circuits were asked to fill in a survey about Skill Circuits and the envisioned playlist tool. This was halfway through their courses, to ensure students had at least tried out Skill Circuits before. They were asked to fill in a survey to assess the following:

- Cognitive load during usage of Skill Circuits [21]
- User experience with Skill Circuits (Attrakdiff questionnaire[22])
- Input on user stories for the playlist feature

These results will be our baseline for determining the improvement the playlist feature may have on the learning environment. It was also the first opportunity to gauge students' acceptance of the playlist tool. The full survey can be found in Appendix B.1.
Student's responses to the user stories have already been presented and discussed in chapter 5. In this section, we will focus on the other parts of this survey.

General info on the participants of this survey is in table 7.1. Unfortunately, respondents did not always complete all 3 parts of the survey. We will, therefore, treat the results of each part separately. Of the 110 valid responses, only 99 responses will be used. Respondents who did not use Skill Circuits in the course are omitted from the results as we did not ask them to fill in the remaining 3 parts of the survey. They are still mentioned in table 7.1 to give an impression of how many respondents decided not to use Skill Circuits in this course.
One thing that can be observed from table 7.1 is that the majority of the group that stopped using Skill Circuits in the course, had used Skill Circuits before.

| | Using SC in this course | Stopped using SC (briefly) | Not using SC |
|---|---|---|---|
| **Amount of respondents** | 91 (91% \| 100%) | 8 (8% \| 100%) | 11 (-\|100%) |
| **Has used SC before** | 71 (72% \| 78%) | 7 (7% \| 88%) | 7 (-\|64%) |
| **Filled in Cognitive load** | 91 (91% \| 100%) | 8 (8% \| 100%) | - |
| **Filled in AttrakDiff** | 74 (75% \| 81%) | 3 (3% \| 38%) | - |
| **Playlist user stories** | 66 (67% \| 73%) | 3 (3% \| 38%) | - |

**Table 7.1:** Amount of respondents for the first survey, if this is their first time using Skill Circuits (SC), and which parts of the survey they have completed. Percentages are given for the number of respondents in relation to the total results and in relation to their category (used SC or stopped using briefly), in that respective order.

I was also interested in knowing why students used Skill Circuits to determine whether they were using it of their own accord and how often they did so. Figure 7.1 shows which reasons student chose (multiple answers were possible) for using Skill Circuits. The majority of students (81%) that had used Skill Circuits in the course indicated that their teacher recommending the tool was a factor in their usage, despite the majority having used Skill Circuits before. The next most chosen reasons are exploring the course's content and finding Skill Circuits useful. Using Skill Circuits to plan their studying was chosen by less than half of the students.

Students were also asked to indicate their frequency of using Skill Circuits in the course by choosing from four options. One option was to indicate they were not using Skill Circuits at the moment. Responses that chose this option were interpreted as students who (briefly) stopped using Skill Circuits (the second column in table 7.1). Among the students who presumably used Skill Circuits in a continuous manner, the following usage frequencies were determined:

- More than 3 times a week: 51% of students
- 1-3 times a week: 36% of students
- Less than once a week: 13% of students

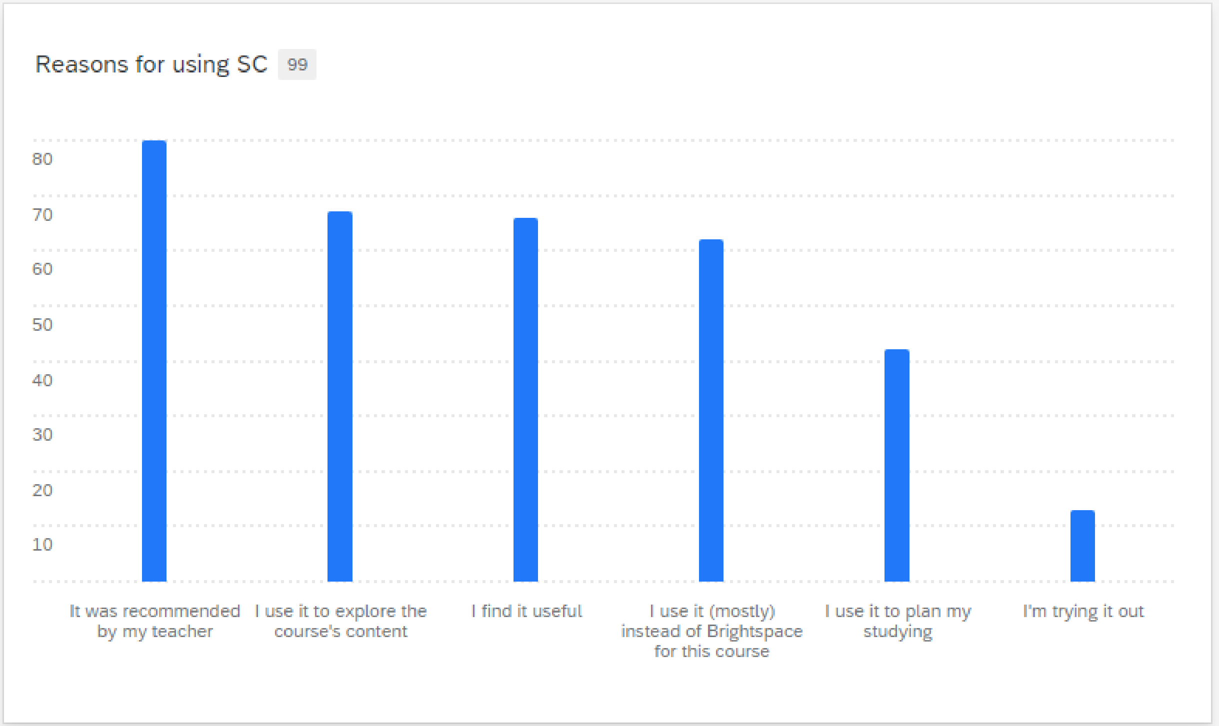


**Figure 7.1:** Reasons for using Skill Circuits

### 7.2.1. Cognitive load

Respondents were asked about the mental effort they experience when interacting with Skill Circuits as a tool. We want to have a base cognitive load with which to compare the playlist tool. Students were asked to answer the question *"How much mental effort do you actively put in when using Skills Circuit to learn?"* with 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. All respondents who used Skill Circuits at least once in the course filled in this question. The results can be seen in figure 7.2.

Students experience a "low mental effort" (score of 3) on average when interacting with Skill Circuits. Ideally, we would not want to exceed this amount of mental effort.

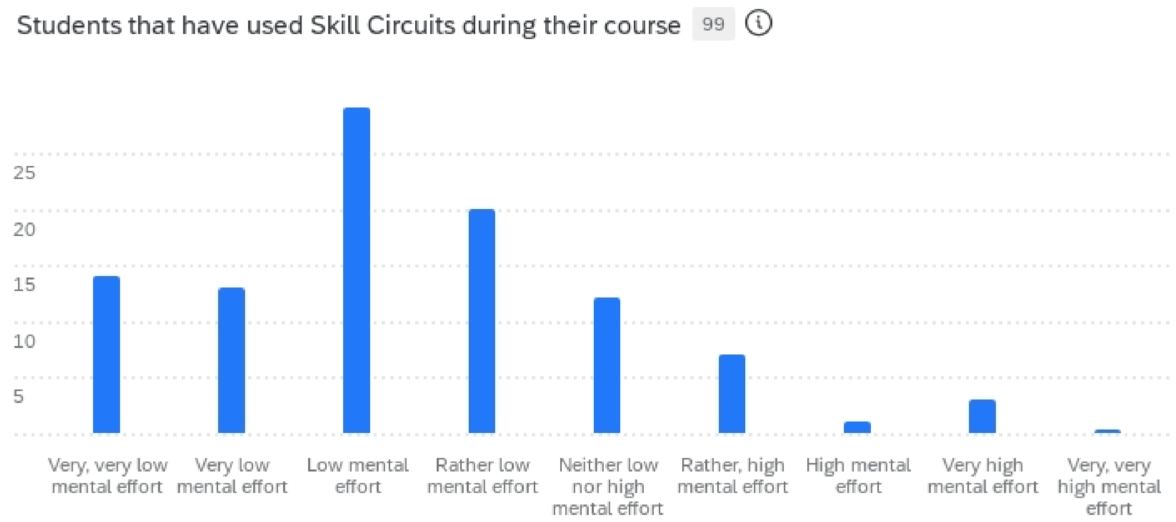


**Figure 7.2:** The self-reported mental effort of each respondent that used Skill Circuits at least once during their course.

### 7.2.2. AttrakDiff

Using the AttrakDiff word pairs, we can determine student's perspectives on Skill Circuits' usability and design, and how that may improve their overall experience in the learning environment. This will give us an idea of what the Playlist tool should aim for to not worsen the students' experience with an educational tool. 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

The value for each pair ranges from -3 to 3. The averaged score for each word pair can be seen in figure 7.4. The outliers are often the most interesting to look at.
Each word-pair is part of one of the AttrakDiff dimensions. Combining the average scores to each dimension then gives the complete Attrakdiff score for a tool, indicated with a 95% confidence rectangle. As can be seen in figure 7.3, Skill Circuits is seen as a neutral tool, meaning students, on average, answered each word pair with a zero. The tool's pragmatic quality isn't far off from the value of a task-oriented tool, and there seem to be no particular hedonic qualities.

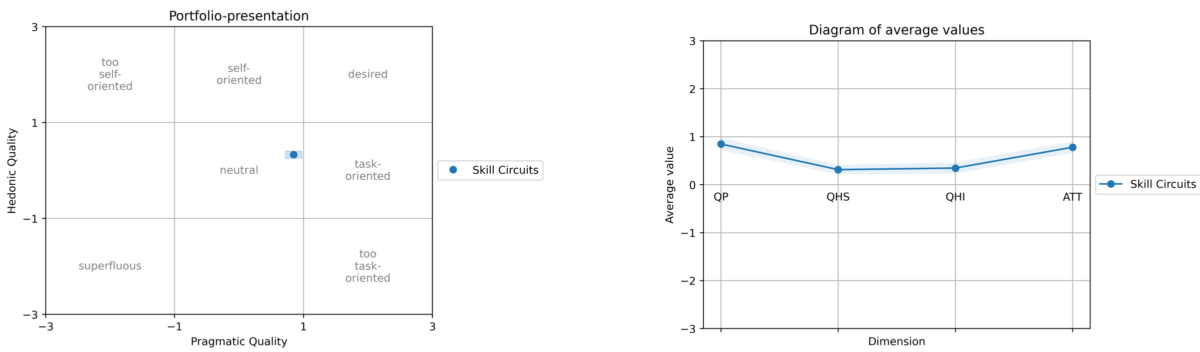


**Figure 7.3:** Left: the Attrakdiff score for Skill Circuits indicated by a blue dot within a 95% confidence rectangle. Right: the average values for each Attrakdiff dimension

In figure 7.4 we can see the average scores per word pair. There are no hedonic word pairs that reflect any aspects of Skill Circuits, as values are rarely more than one point from zero. There are 3-word pairs in the attractiveness dimension with a score higher than zero, showing that students would describe Skill Circuits as pleasant, attractive, and good.
The "attractiveness" dimension holds word-pairs that reflect a high-level evaluation of a tool based on many factors we can not (yet) determine. It is highly personal and relates the most to the QHI dimension but is a complex and personal evaluation on its own [22].

With the Playlist tool we would like to at least be perceived as neutral as well. Using the playlist analogy to support individual study sessions, it makes sense to aim for a task-oriented tool.

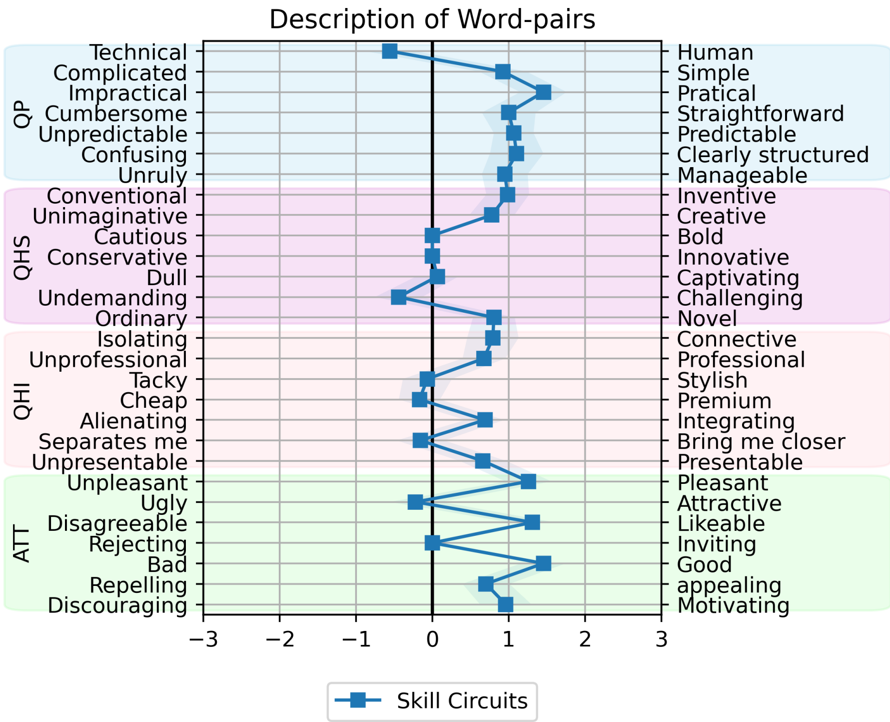


**Figure 7.4:** The average score for each word-pair of the AttrakDiff survey.

## 7.3. Data collection during tool usage

The playlist tool was implemented as a feature in Skill Circuits and available to bachelor students of the Computer Science course: Automata, Computability and Complexity. When students landed on the Skill Circuits page for the course, there was a button called Playlist. Before they can access the feature, they are made aware of this thesis project and that their usage data will be collected. If they agree with the terms, the feature is unlocked and accessible for the full length of the course. Opting out was always an option, including the removal of personal usage data.

### 7.3.1. Processing usage data

The 57 students that opted-in and used the Playlist feature, gave us access to the following data:

- Playlist usage: creation, usage, completion
- Tasks completed for the course

With this data we are able to see how students actually used the Playlist tool and find similarities between the input we retrieve during feedback moments.

### 7.3.2. Playlists created

A total of 153 playlists were created by the 57 students who used the playlist feature at least once. It was, however, discovered that only the data of 70 playlists, created by 29 students, were collected properly. Each playlist has an estimated completion time, the sum of the estimated time of all the learning activities it holds. Once the student "plays" the playlist, the actual time they spend working on the activities is the tracked time. In figure 7.5 the total amount of playlists created each week is plotted and how many of those playlists were actually played.

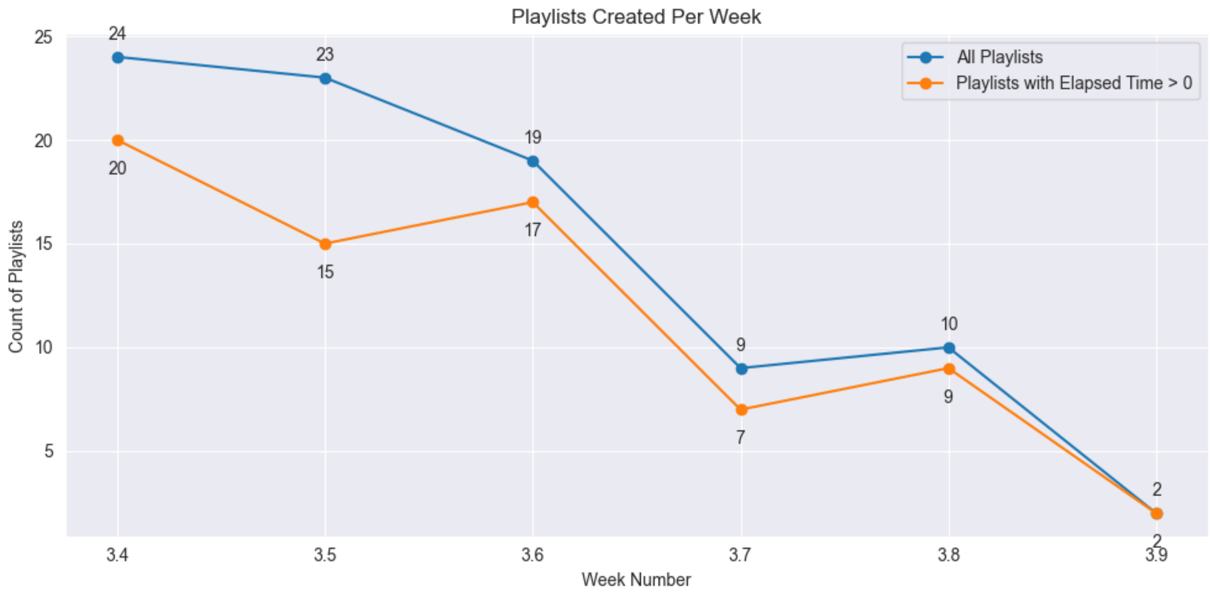


**Figure 7.5:** All playlists: The total amount of playlists created in each week the playlist feature was available. Played playlists: a subset of the total amount of playlists of which time studying has been tracked.

### 7.3.3. Playlist (estimated) lengths

As the feature is designed to support students in their study session, it is interesting to look at the length of the playlists students create.

- Average estimated length: 146 minutes
- Average tracked length: 75 minutes

According to figure 7.6, the majority of playlists have an estimated length of around 98 minutes. The average estimated length of 146 minutes can be explained by the outliers, with a few estimated playlist lengths exceeding 500 minutes.
The time students actually spent working on learning activities (and letting the feature track their time) was usually a little over an hour. The average and mean for tracked time are much closer to each other.

| **Consecutive playlist created** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Amount of participants** | 29 | 15 | 8 | 7 | 6 | 5 | 5 | 3 | 2 | 2 | 2 | 2 | 1 |

**Table 7.2:** The number of participants that created a first, second, third, etc., playlist

If we look at consecutive playlists made, the majority of students created up to 3 playlists. In table 7.2, we can see the most playlists a student created was 13. The average estimated and tracked lengths for consecutive playlists are seen in figure 7.7. If we look at the averages for the two students who created the most playlists (figure 7.8, it seems they are mostly responsible for outliers.

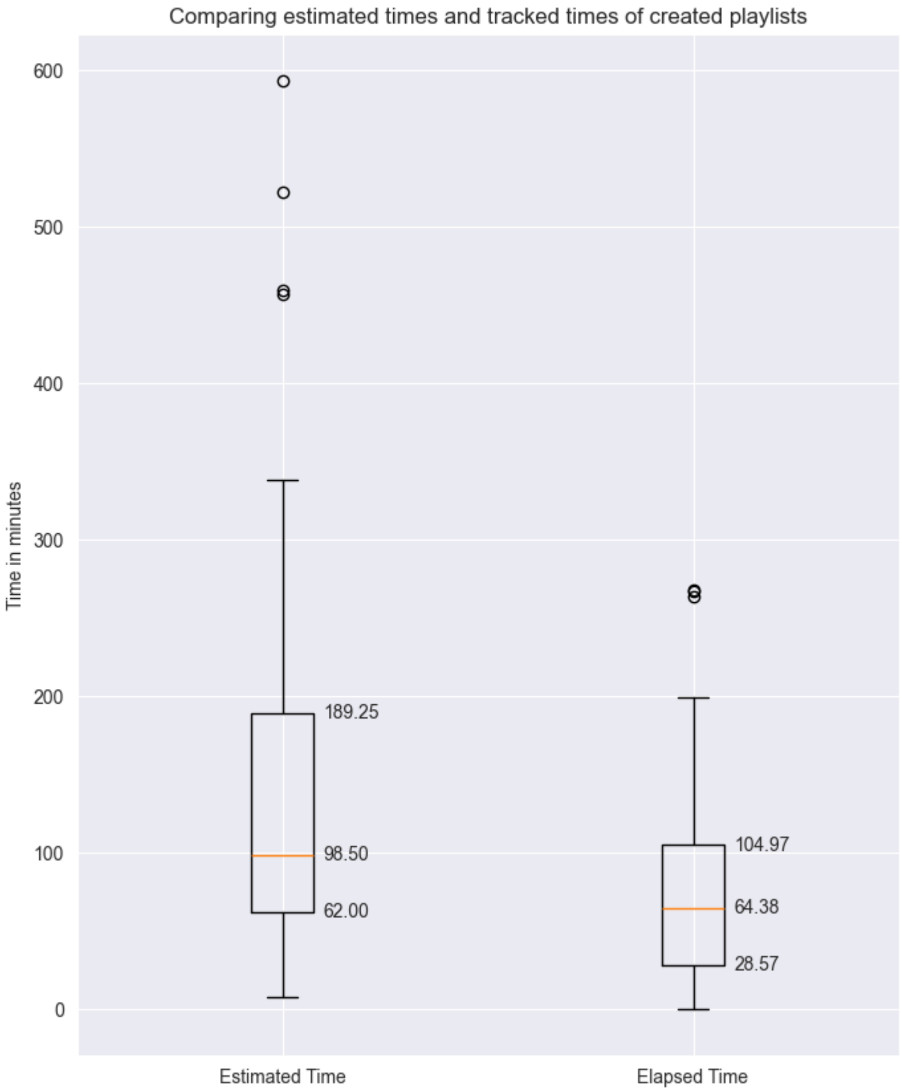


**Figure 7.6:** Boxplots showing the distribution of the estimated lengths and the tracked lengths (called elapsed time of created playlists

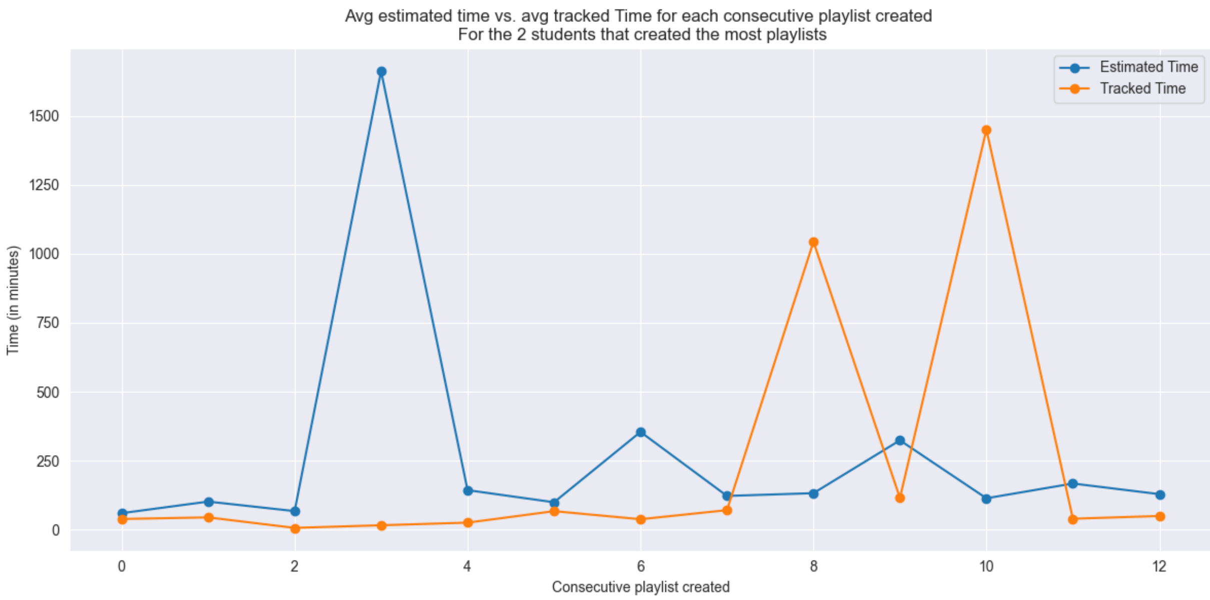


**Figure 7.8:** The average estimated and tracked time for each consecutive playlist made by the two students that made the most playlists. It seems they are mainly responsible for the outliers.

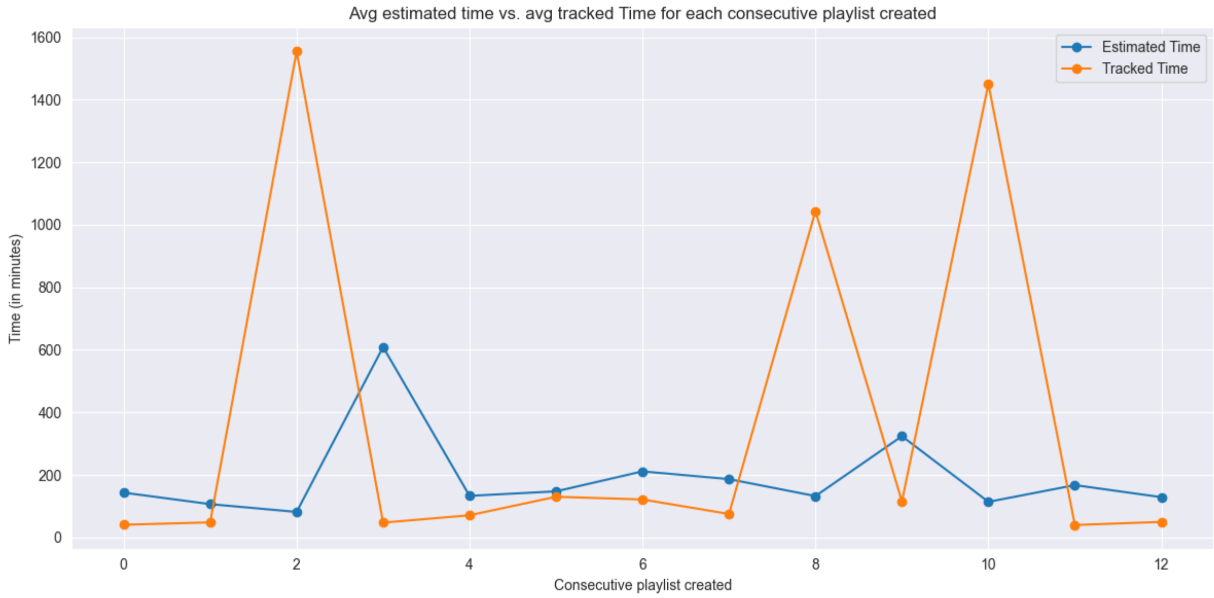


**Figure 7.7:** For each consecutive playlist, the average estimated length and average tracked length are shown.

### 7.3.4. Completion rates

Of the 70 created playlists, 11 playlists were completed; students completed all the learning activities in the playlist. The estimated and tracked completion times of these playlists, including the ratio (tracked time / estimated time), are shown in figure 7.9.

### 7.3.5. Correcting time estimates

Tracking students' time spent on learning activities is not only useful for them but can also help teachers gain insight into how much time their activities actually take to complete.
Over all the 70 playlists, 360 tasks that were added were actually worked on. These were 189 different tasks, with 1 to 5 different students working on them. For tasks at least 4 students worked on, I calculated the ratio for how much their tracked time differed from the estimated time set by the teacher. As these were still 24 different tasks, I grouped them based on type. In table 7.3, the biggest difference can be seen for tasks of type video. This was however due to an outlier as can be seen in figure 7.10; a student tracked 154 minutes for a video set to take 5 minutes. Still, a good portion of students tend to watch videos longer than estimated.
Exercises seemed to take student slightly less time than estimated, while reading takes them longer.

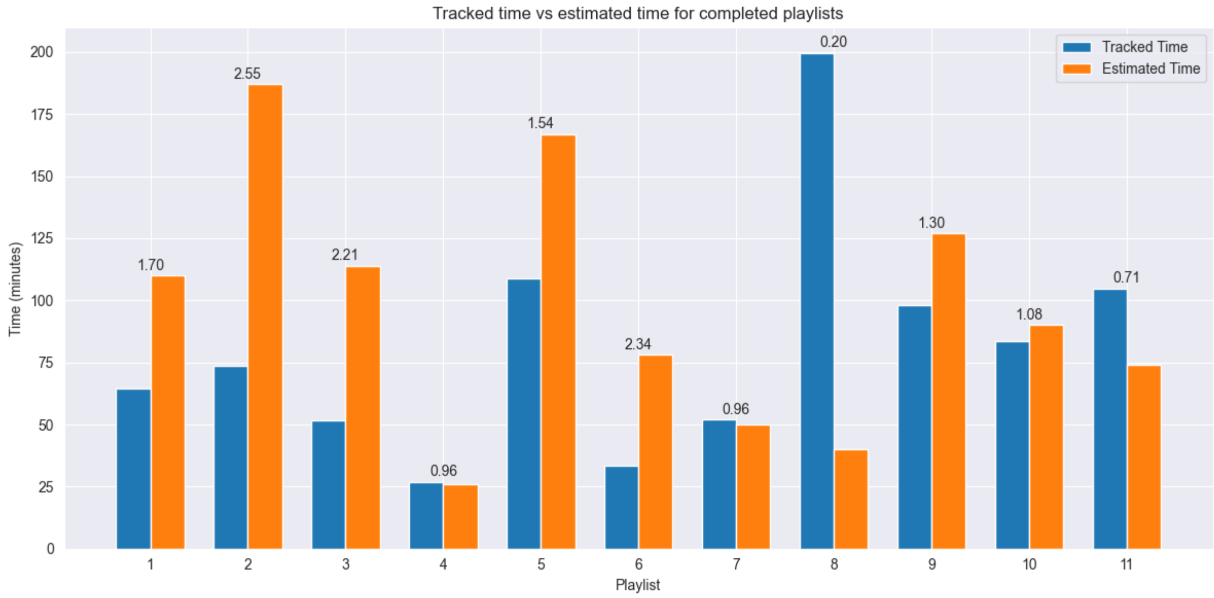


**Figure 7.9:** For the 11 playlists that were actually completed, the estimated and tracked time are shown. Ratios are included to indicate how much longer the playlists actually took the students to complete.

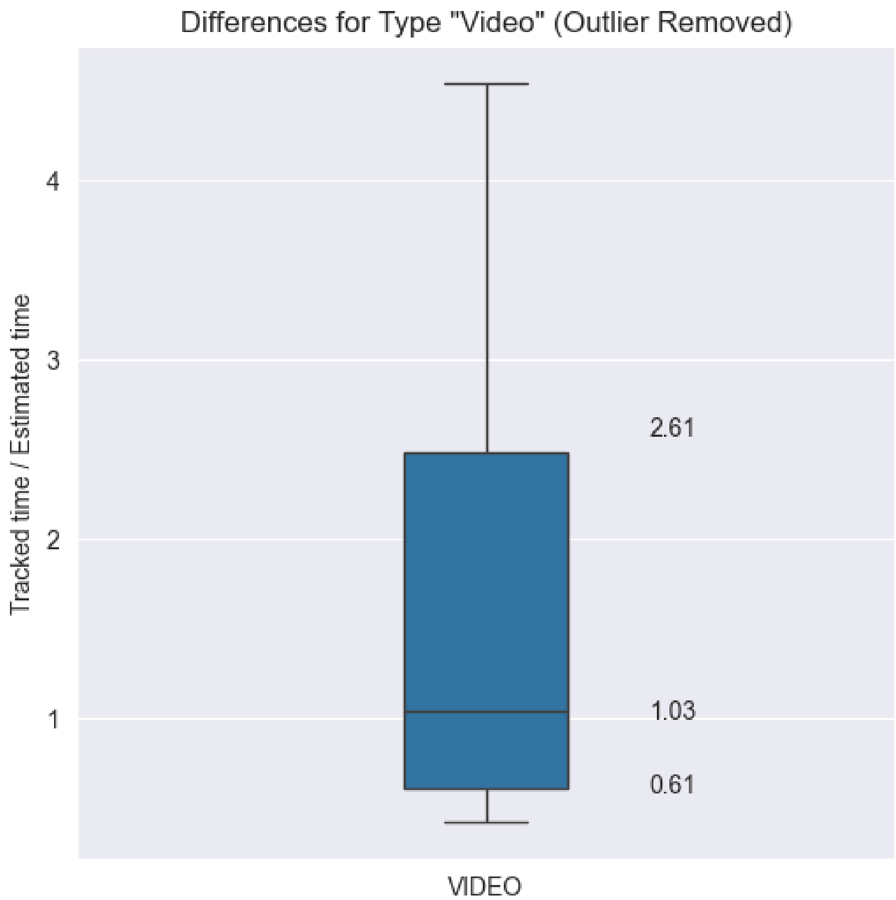


**Figure 7.10:** For 16 different learning activities that required students to watch a video, the distribution is shown for how much longer it took the students to complete the activity. The data is from learning activities that were done by at least 4 different students (5 students being the maximum amount).

| | Average tracked time difference | Amount of tasks |
|---|---|---|
| **Exercise** | 0.79 | 4 |
| **Reading** | 1.37 | 4 |
| **Video** | 3.48 | 16 |

**Table 7.3:** For tasks that were done by 4 or 5 students, the average ratio was calculated for how much the tracked time differed from the estimated time set by the teacher. These differences were then averaged per task type.

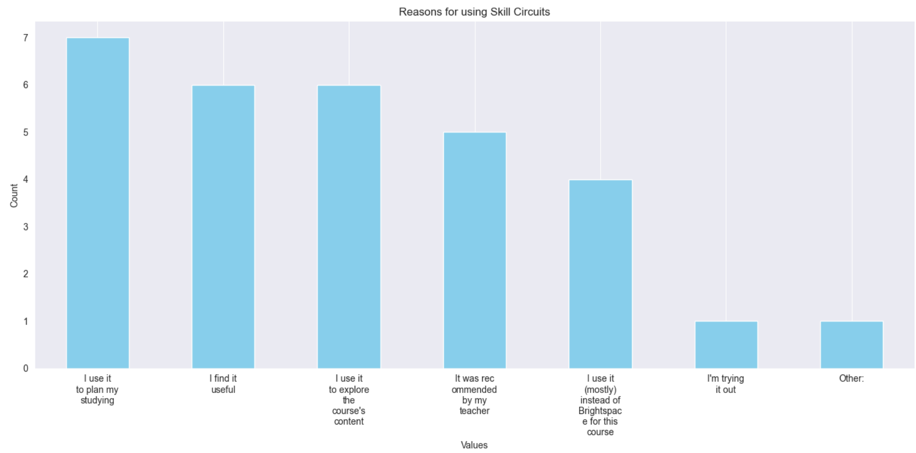


**Figure 7.11:** Reasons for using Skill Circuits, as chosen by the participants of the second survey

### 7.3.6. Processing feedback: initiated by students

During testing, students could also provide feedback on the tool. Five different students made use of this functionality, sending feedback a total of 14 times.
Half were bug reports that were presumably fixed afterwards, the other half were suggestions on how to improve the tool:

- make the interface less narrow in split screen
- add more info on the feature
- let the user return to the playlist after completing a task
- add tasks based on type
- let the playlist scroll along with you
- add module/skill title in created playlist
- clearer way of completing the playlist

As we will see in section 7.5, these are similar to the improvements given during the focus group sessions.

## 7.4. Data collection after tool usage: survey

At the end of the course, students were asked to fill in a survey to collect their feedback on the playlist feature. If they were interested, they could also sign up for a focus group session.
An adjusted version of the previous survey was used. User stories that were not related to the implemented features were removed. One user story was adjusted: *"I want to know how much time each module took me"* was rewritten to concern skills instead of modules. It now relates to the playlist feature grouping learning activities by skill. The survey was distributed during the last 3 weeks of the course. Even though the survey was accessible for a few weeks after the quarter had ended, only 9 valid responses were received. In addition to general questions about their usage of Skill Circuit and the newly added playlist feature, the survey held the following parts:

- The Achievement Goal Questionnaire [20]
- Mental effort rating scale [21] for both Skill Circuits and the playlist feature
- The AttrakDiff word pairs [22] to evaluate the Playlist feature instead of Skill Circuits
- The Playlist user stories, adjusted for the implemented functionalities

Like the first survey, students did not fill in every part of the survey. The amount of responses for each part can be seen in 7.4.

| | Skill Circuits usage | AGQ | Mental effort | Attrakdiff | User stories |
|---|---|---|---|---|---|
| **Amount of participants that filled in** | 9 | 9 | 9 | 6 | 6 |

**Table 7.4:** Data on students that filled in the second survey

### 7.4.1. General usage information

For the nine students that filled in the second survey, only one of them hadn't used Skill Circuits before. In figure 7.11 it can be seen that most of them indicated using Skill Circuits to plan their studying. Although we can not compare results, this is a different result than in the first survey.

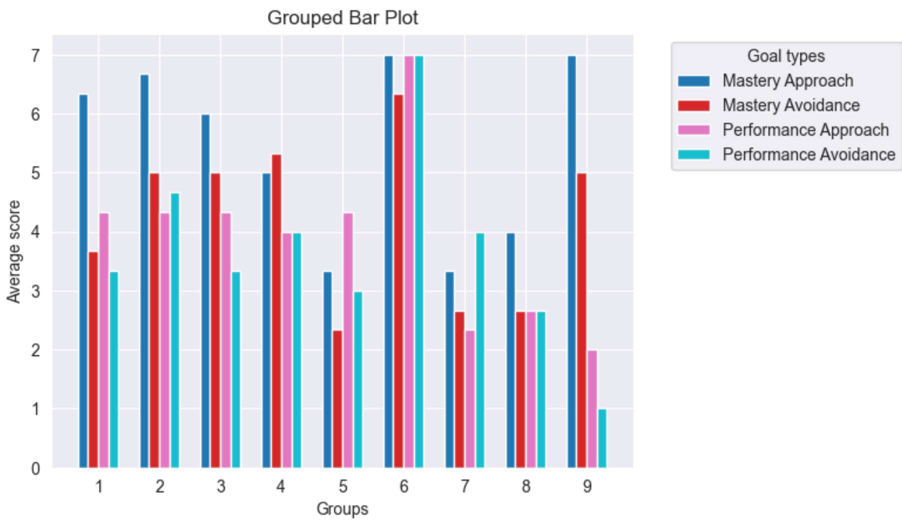


**Figure 7.12:** For each student, the average score for each goal type.

### 7.4.2. The achievement goal questionnaire

To uncover what type of goal students have for a course, we asked students 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.
In figure 7.12 we can see the highest scoring goal type is mastery approach. With mastery avoidance being the second highest. The students who filled out the questionnaire were either motivated to master the course's material as much as possible or wanted to avoid feeling incompetent.

The Attrakdiff score for both Skill CIrcutis and the Playlist Feature was neutral. As to be expected of a first iteration of the feature, it scored relatively worse on several word-pairs

### 7.4.3. Attrakdiff

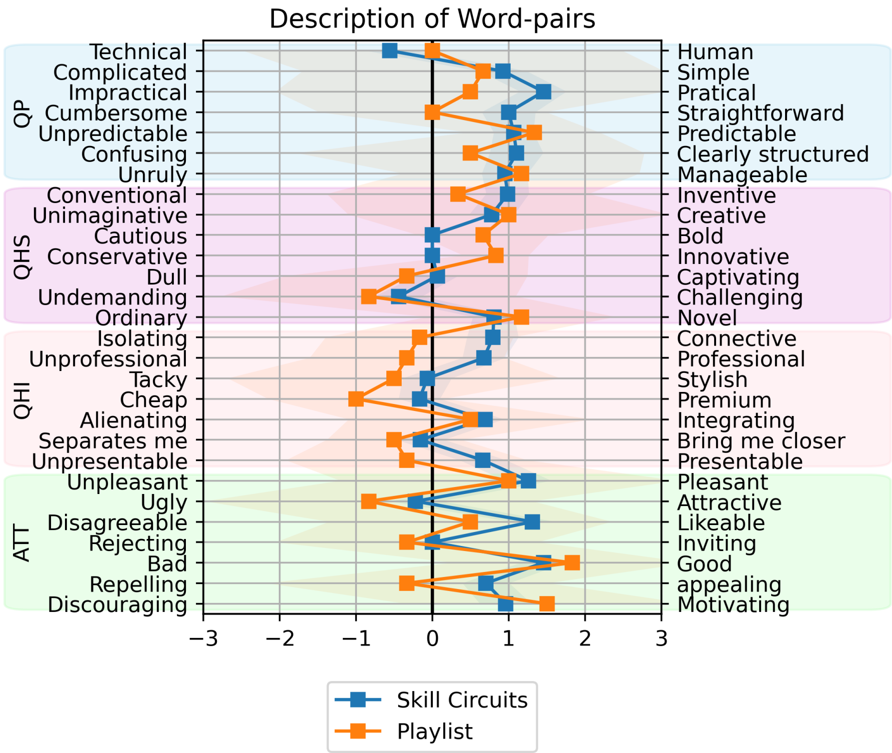


**Figure 7.13:** The AttrakDiff word pair averages for Skill Circuit (as seen in figure 7.4 and the Playlist feature)

### 7.4.4. Mental effort

Students were asked to report the experienced mental effort for both Skill Circuits and the Playlist feature. The averages were:

- Skill Circuits: 4.125
- Playlist feature: 5

Both are higher than the average mental effort reported in the survey. In figure 7.14 I present the self-reported mental efforts of these nine students in a parallel plot. There, we can see that when students indicated a higher mental effort for Skill Circuits, they indicated a lower mental effort for the Playlist feature and vice versa.

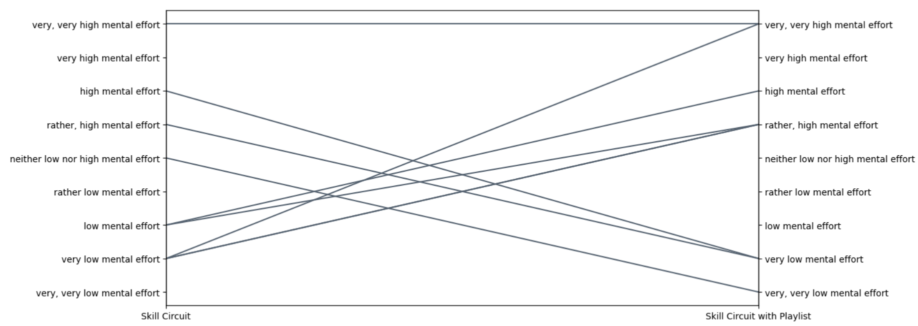


**Figure 7.14:** Comparing self-reported mental effort for Skill Circuits and the playlist feature for each participant

### 7.4.5. User stories

Students were also asked whether they would use the Playlist feature again. Of the six students who filled in this part of the survey, 3 chose **yes**, 2 chose **no**, and the remaining student chose **”Maybe, if certain changes were made”**.
The students that chose **yes** mentioned they enjoyed having an estimate of what they can do in certain time period and the time tracking.
One student that chose **no** explained they did not find the user interface intuitive.
The student who chose the maybe option indicated that their main concerns were having to scroll through a long list and the timer not always working.

The user stories used in the first survey were adjusted as the students now had actually used the Playlist feature. Also, instead of asking whether students would use the Playlist feature in certain situations, the question introducing the user stories was reframed to assess how well they reflected the students' intentions when they chose to use the Playlist feature. A 5-point Likert scale was used to rate each user story: '1 = Not accurately at all; 2 = Slightly accurately; 3 = Moderately accurately; 4 = Very accurately; 5 = Extremely accurately.
The score for each user story category can be seen in figure 7.15.

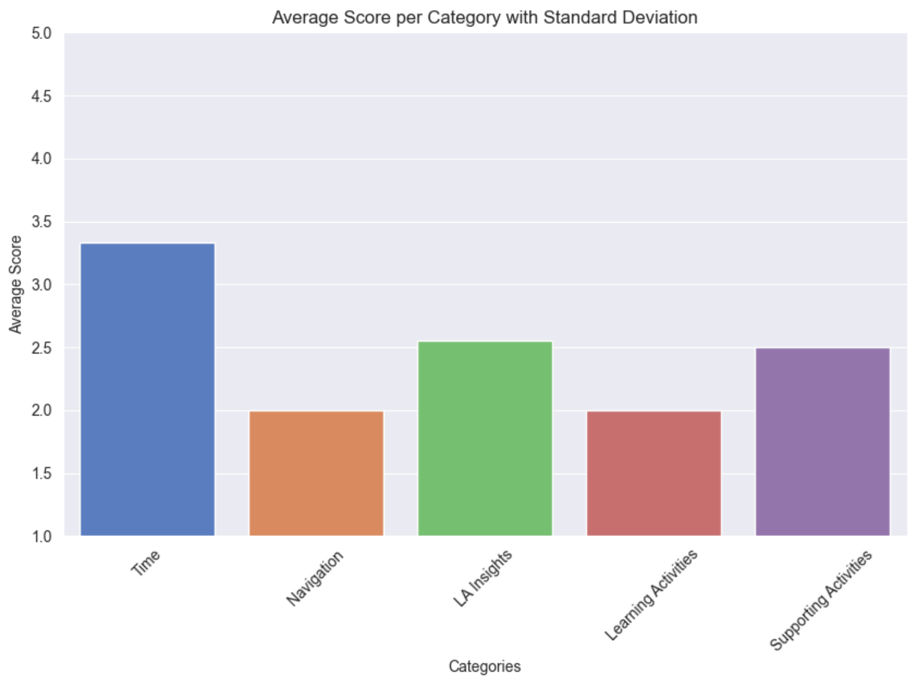


**Figure 7.15:** The average score for each category of the 13 user stories used in the second survey.

I then asked the students specifically to rate the three main functionalities of the Playlist feature:

- Selecting tasks to work on
- The main timer
- A timer per task

Using a 5-point Likert scale (1 = Not at all useful, 2 = Slightly useful, 3 = Moderately useful, 4 = Very useful, 5 = Extremely useful), students rated the functionalities as moderately useful on average. The scores can be seen in figure 7.16.

Students were also asked what their reasons were for using the Playlist feature. They could choose from four options, as can be seen in figure 7.17.

The final question regarded any feedback the students wanted to mention. Two students were interested in seeing the feature being developed further. One proposed maintaining a form of history and adjusting the estimated time in real-time when a student completes tasks faster.

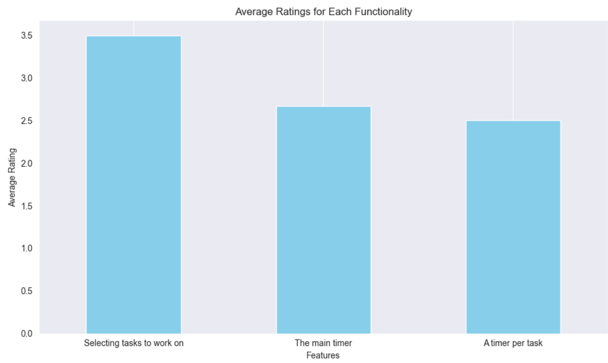


**Figure 7.16:** Participants of the second survey could indicate on a 5-point Likert scale how useful the main functionalities of the Playlist were to them

| Category | User story in survey 1 | Survey 2 |
|---|---|---|
| **Time** | I want to know what activity I can do in the coming 10 - 30 minutes | Included |
| | I want to work on a subject/course in a fixed timebox | Included |
| | I want to plan a study session of at least 1 hour | Included |
| | I want to know how far I can progress with X amount of studying time | Included |
| **Navigation** | I want help in determining where to start in the circuit | Included |
| | I want a study plan to be made for me | Removed |
| **LA Insights** | I want to know how much time each module took me | Adjusted: I want to know how much time each **skill** took me |
| | I want to know how much time I spend on different types of learning activities | Included |
| | I want to keep track of time spent on individual learning content | Included |
| **Learning Activities** | I want to transform learning content into a modality I prefer (i.e. text to audio) | Removed |
| | I only want to do activities of a certain type (i.e. reading material, watching videos, exercises) | Included |
| **Supporting Activities** | I want to switch between subjects/courses during my study session | Included |
| | I want to plan out regular breaks during studying | Included |
| | I want to plan to reflect more on what I have learned | Removed |
| | I want to plan to revisit past content more | Removed |

**Table 7.5:** This table shows which user stories from the first survey were reused in the second survey. One user story was adjusted.

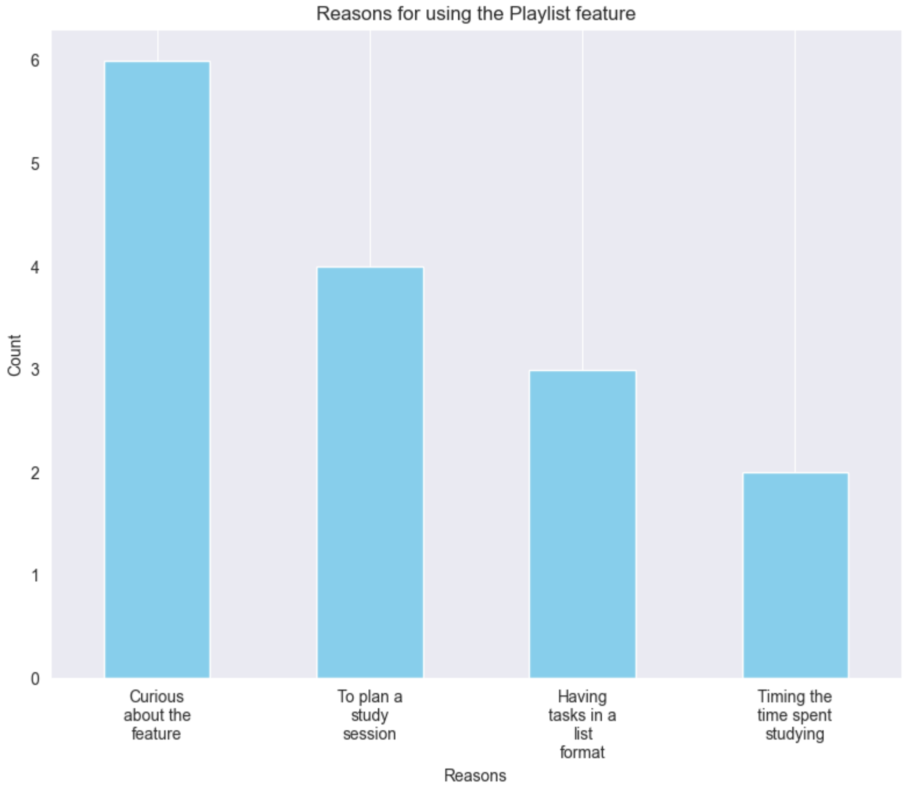


**Figure 7.17:** Participants of the second survey were asked to choose their reasons for using the Playlist feature

## 7.5. Data collection after usage: focus group

The focus groups were eventually opened up to all Computer Science students that had experience with Skill Circuits. This resulted in each focus group having one Computer Science bachelor student and the remaining participants being Computer Science master students. Two focus group sessions were held: one with five participants and one with four.
Following guidelines provided by the Data Innovation Project[1], I set up the following activities for the focus group sessions:

1. Filling in a ”Feedback Capture Grid” (FCG) based on the pilot version
2. Short discussing 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” (JTBD) template for chosen use cases and user stories

An explanation of the ”Feedback Capture Grid” and the ”Jobs To Be Done” method can be found in chapter 2. In the short discussion, students were asked two questions about their inclusion in this research project:

- Is this an appropriate time to ask for your feedback on the development of the Playlist feature?
- What are your main impressions about the current implementation of the Playlist feature?

Students were asked to provide their input in each activity through post-its. In table 7.6, the number of separate statements the students constructed can be found.

[1] https://datainnovationproject.org/tip-tools/

| | Focus group 1 | Focus group 2 | Total |
|---|---|---|---|
| **Feedback Capture Grid** | 38 | 13 | 51 |
| **JTBD:** | | | |
| **Participant chosen** | 5 | 7 | 13 |
| **User stories** | 6 | 5 | 11 |
| **Healthy learning habits** | 8 | 3 | 11 |

**Table 7.6:** The amount of statements the students of both focus group sessions produced for each activity.

### 7.5.1. Feedback capture Grid

For the first activity students were asked to test the Playlist feature. They could access the feature in the same way as the students of the "Automata, Computability and Complexity" course. While they were doing so, any feedback they had on the feature could be written down according to the four quadrants of the "Feedback Capture Grid".

For the analysis, I coded the statements in accordance with the functionality categories established in chapter 4. Some statements were, however, specific to how the feature was implemented and were categorized under "Playlist". Statements regarding functionalities in Skill Circuit were coded but will not be mentioned here. The categorized statements for each quadrant can be seen in figure 7.18

Within each category, it became clear that students addressed a certain aspect. For the playlist category, this resulted in 6 additional sub-categories. The categories and aspects used to analyze the statements in the "Feedback Capture Grid" are listed in table 7.7. In this section, I will summarize the student's statements to give an impression of their main feedback points.

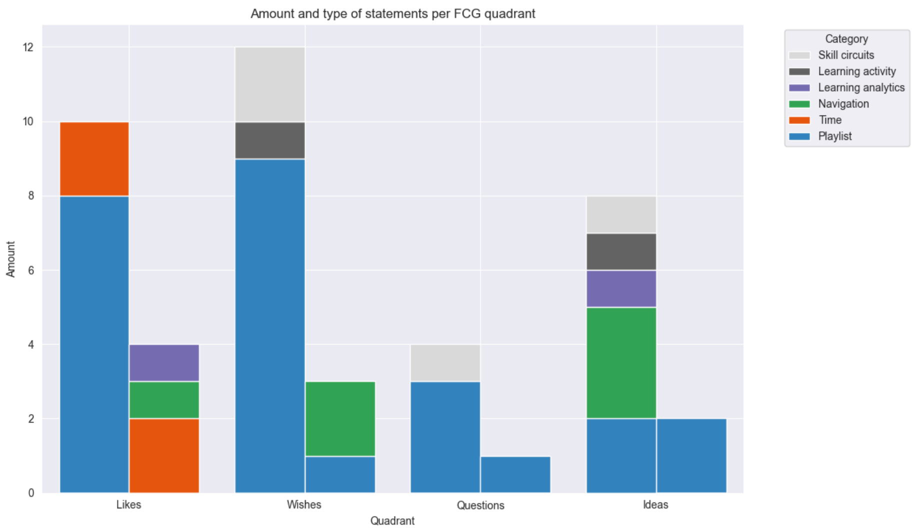


**Figure 7.18:** The amount and type of statements students put in the feedback capture grid when testing the Playlist feature. Each group of bars represents the statements for a quadrant. In each group, the left bar represents the statements from the first focus group session, the right bar represents the second focus group session.

| Category | Aspect | Amount |
|---|---|---|
| **Playlist** | Blending in Skill Circuits | 3 |
| | Information | 4 |
| | Feedback | 3 |
| | Functionality | 12 |
| | Size | 5 |
| | Automation | 2 |
| **Time** | Tracking | 4 |
| **Navigation** | Automation | 6 |
| **Learning analytics** | Progress | 2 |
| **Learning activity** | Reordering | 4 |
| **Supporting activity** | Revision, Breaks | 2 |
| **Skill Circuits (SC)** | | 4 |

**Table 7.7:** The categories used to code the statements students put in the feedback capture grid. Within each category, the statements are further categorized towards the different aspects students commented about.

**Likes**
Students liked that the playlist feature both blended in with the style of Skill Circuits and could easily be ignored if you wished not to interact with it. Time tracking was found to be useful and students hoped teachers would be able to use their data to update estimates. Choosing tasks to do and seeing them in a list was seen as motivating to keep working on them in the estimated time frame.

**Wishes**
The window for the playlist feature was too small, especially when choosing tasks. Students recommended a bigger window when creating (and editing) the playlist. When the playlist is being "played," the current size is appropriate.
Some buttons weren't as clear and would benefit from a central menu or at least a central place for information on functionalities.
Students would like to have filtering options when choosing tasks and the ability to reorder tasks after choosing them.
Finally, the ability to mark tasks as done in the playlist as well would improve the experience.

**Questions**
One student stated that the playlist analogy wasn't clear. Other questions related to what the possible functionalities of the feature are.

**Ideas**
Several wishes were repeated, such as wanting more ways of choosing and ordering tasks for their playlist, completing tasks in the playlist rather than only in the circuit, and having a bigger interface to interact with the feature. Examples of additional ways of task selection included an easy way of adding all the tasks for the current week or according to a certain task type.
Two types of supporting activities were suggested: automatically including breaks in the playlist and being able to choose completed tasks for revision.
Finally, a progress bar and being able to create multiple playlists (for multiple courses) were proposed.

**Take aways**
It seems the existing functionalities of the Playlist tool enabled students to think about how they would want to include the tool in their studying. My intended use case of the Playlist is (short) study sessions, but looking at student's proposals they would also like to create playlists for longer sessions. More as to keep track of what should be done for the next checkpoint and not necessarily what *can* be done in a given timeframe.
Being able to go through tasks in an ordered list was received positively, and there were many suggestions on how to improve it.

### 7.5.2. Short discussion

When students were briefly asked about the value of the focus session and the tool's concept in general, they indicated that even though a simpler prototype would have been enough to gain an impression, they liked that they could interact with the tool in a way that resembled how they would use it during a course. They also liked that it is integrated in an existing tool, as too many different tools are already present in their courses.

### 7.5.3. Jobs to be done

This activity consisted of three parts. In each part the "Jobs To Be Done" method was used to describe three different types of jobs. The first is any job the student would want to do with the Playlist feature, possibly something they mentioned in the wishes or ideas quadrant of the "Feedback Capture Grid".
For the second part, I asked them to choose one of the 13 user stories of the second survey that spoke to them the most.
The third and last part was about healthy learning habits. With some examples on the screen, I asked them to describe how they wished to be assisted in these habits. If, of course, this was a job to be done. Again, I used the categories in table 7.7 to analyze the different statements students wrote down. Below, I will summarize the statements for each part as a suggestion for further development in that category.

**Participant cases**
**Navigation, 3 statements:** Assistance in determining what is important to do *now* to be able to skip ahead. The playlist should support this by being able to add tasks directly from the circuit to the current or other playlists. When playing a playlist the focus should visually be on the current task(s).

**Time, 2 statements:** Students want the playlist's timer to start automatically after creation so they can get to work immediately. While working on tasks, the estimated time left is helpful when feeling the task is taking too long.

**Learning activity, 2 statements:** A created playlist should be editable to reflect students' change of environment or when they realize their priorities are different.

**Supporting activity, 2 statements:** Support in revising the advanced topics for an exam.

**Playlist, 3 statements:** I want the playlist to be clear on how it can support me. While working on tasks, I want to be able to proceed to the next task as smoothly as possible. At the end I want a clear way of indicating I am done with the playlist.

**User stories**

**Navigation, 2 statements:** When creating a playlist, I want to easily add tasks based on type and have help in determining which task to start.

**Time, 2 statements:** I want the playlist to create a recommended sequence of learning activities based on the allotted time I set. I want to be able to plan my activities better by gaining insight in how much time each activity usually takes me.

**Learning activity, 1 mention:** I want to edit the order of learning activities, including breaks, to be flexible during my study session.

**Supporting activity, 4 statements:** I want help in planning regular breaks during my studying and being reminded to actually take them. I would like to be reminded that I wanted to switch to another subject.

**Learning analytics, 1 statement:** I want an overview of the different blocks of a course to see how "fast" I am in each part of the course.

**Healthy learning habits**
**Breaks, 3 statements:** When reminded to take a break, I want a suggestion on how to be more mindful of them. I do not want breaks when I am in a flow.

**Asking for help, 3 statements:** I want to flag a task in the playlist to indicate I need help and I feel comfortable in parking this task. Adding in a new task to reflect the activity of asking help would also be nice.

**Reflection, 2 statements:** When I'm done with a playlist I want to see an overview of what I did and the time it took me to be able to reflect on the session. At the end I would like a short reflection question to let me think about the quality of my study session.

**Learning analytics, 2 statements:** I want to have easy access to how much I can accomplish in i.e. one hour. This will motivate me to stay engaged with the course if I know how much I can get done.

**Physical exercise, 1 statement:** I want a break reminder that tells me to stand-up and take a walk to be more healthy.

## 7.6. Summary

In this chapter, we provided the evaluation of the playlist feature implemented in Skill Circuits, focusing on its usage, student feedback and the effectiveness of its fit into the learning learning environment. This leads back to our RQ2 where we tried to define fitness by evaluating - 1) cognitive load 2) usability and 3) achievement of learning goals. These three aspects were compared with a baseline that consists of the Skill Circuit environment without the playlist feature and was compared with the playlist feature. We found that students experience low mental effort when using Skill Circuits in a course. When using both Skill Circuit and the Playlist feature the average self-reported mental effort is a point higher.
The AttrakDiff scores for Skill Circuits and the Playlist feature are similar, but can not be compared as the amount of responses for scoring the Playlist feature is much lower.

In terms of playlist usage, a fair number of students at least tried the playlist feature once. With 9 students having made at least 5 playlists.

Post-deployment feedback was collected through surveys that measured students' cognitive load, their perceptions of the playlist feature (AttrakDiff), and their general user experience. The results indicated a generally positive reception, with many students appreciating the feature's potential to aid in study planning, although some suggested improvements were necessary for better integration and usability.

Focus group sessions provided deeper insights into how students interacted with the playlist feature and what aspects they found most beneficial. The feedback emphasized the importance of navigation and personalization functionalities, with students expressing a desire for more control over their learning activities and the ability to tailor their study sessions to their specific needs.

# 8

# Discussion and reconjecturing

In this chapter, I use the student feedback collected on the playlist feature to determine future design decisions. I will begin by providing a more detailed discussion of the data presented in the previous chapter to better understand the contribution towards the research objective. Additionally, I will also take a look at how this data was collected and identify where these methods can be improved for future development iterations. To support future development of the Playlist feature, the chapter also presents a second version that incorporates the main points of feedback from students.
With this chapter, I aim to finalize the answers to both empirical research questions.

## 8.1. Discussion

In the conjecturing and iterating phase of this design-based research, student input was used to both inform and evaluate the process. The surveys had two main objectives: first, to be compared with each other to assess the impact of the Playlist feature on the existing learning environment; and second, to gather student impressions of the Playlist feature before and after using it. These objectives also address the two empirical research questions.

Since the Playlist's design is based on the literature review findings in the grounding phase, the survey results also help evaluate how well those findings hold up in an actual learning environment. Additionally, qualitative feedback from focus group sessions and usage data of the Playlist feature provide further insights.

Each evaluation moment involved participants from different courses and program levels, with their only common factor being experience with Skill Circuits. Therefore, the results provide a general perspective in each phase of the design-based research, rather than insights that can be directly treated as a whole.

Keeping the research questions in mind, I will review the results of each evaluation method and discuss how they contribute to answering them.

### 8.1.1. Using existing measures

**Mental effort**

We want to reserve cognitive capacity for learning as much as possible. Assuming the cognitive load caused by Skill Circuits is perceived as acceptable by students, we want the Playlist feature to not introduce a higher load.
In the first survey, 99 students self-reported an average mental effort of 3 (out of 9) when using Skill Circuits. The 6 students that responded to the second survey indicated a mental effort of 4 for Skill Circuits and 5 for the Playlist feature.
The first survey was distributed halfway through students' courses, the second at the end of a course. The higher average mental effort for Skill Circuits in the second survey can be explained by the timing and framing as discussed in [70]. Asking students to fill in the scale at the end of their usage often results in a higher self-reported mental effort, especially when asking them to fill it in for a series of tasks. If I were to ask them to fill in the scale after specific interactions within the tool, I might get a lower or at least more accurate representation.

Especially in regards to the Playlist feature, if students were asked to fill in the scale for specific interactions in the tool, we might gain a better understanding of which parts induce a higher mental effort.

These can already be hypothesised based on the qualitative feedback given on the tool: having to scroll through a large list of tasks to add them to a playlist, and the time tracker not always being accurate. Asking students' mental effort for these interactions once the tool has been adjusted, can be a simple and quick way of assessing if the adjustments are successful.

Finally, the parallel plot for the second survey, figure 7.14, is rather interesting. The lower mental effort students reported for Skill Circuits, the higher they reported for the playlist feature and vice versa. The sample size is not enough to call this observation significant, but this is an interesting connection to research further. Presenting learning activities in either the form of a circuit or in a sequence might be different enough to adhere to different preferences. A possible explanation could be Felder and Solomon's sequential vs global preference [50]

In its current state, the Playlist feature induces a higher mental effort than the tool surrounding it. This could explain why many students did not use the tool for a prolonged period of time as the benefits did not counterweight the mental effort needed.
Going back to the first survey, if we calculated the average mental load of students that (presumably) stopped using Skill Circuits halfway through the course, they had a higher average mental effort: 4. Was this part of the reasons they stopped using Skill Circuits for the course? And if so, is it worthwhile to address? Having minimal cognitive load when interacting with a tool may not always be a good thing as an intensive interaction with a learning environment or tool may contribute towards motivation to learn. To evaluate the Playlist feature in future iterations should therefore be done in combination with other evaluations.

**Attrakdiff**
*Before I discuss the AttrakDiff scores I must mention that an error was found in the surveys. Three word-pairs were not represented properly, resulting in me having to fill in the neutral rating for those word pairs. The affected word pairs are:*

- *Rejecting - Inviting (attractive dimension)*
- *Cautious - Bold (stimulation dimension)*
- *Conservative - Innovative (stimulation dimension)*

The Attrakdiff score for both Skill Circuits and the Playlist feature were neutral. The score for Skill Circuits being more accurate as the sample size was a lot bigger. Given that students in the focus groups mentioned they liked how the Playlist feature fit in Skill Circuits, it makes sense they fall in the same category.

Looking at the scores for each word pair in figure 7.13, the Playlist feature might grow closer towards Skill Circuits' scores after adjustments have been made according to students' feedback.
Both Skill Circuit and the Playlist feature will then benefit from focusing improvements on getting into the task-oriented category. This means working on the tool's usability or pragmatic quality. Feedback from students regarding information on how to use the Playlist feature and having more support for adding tasks are indicative on how to achieve that score.

Once that score is achieved, the question may arise if and how we might want to increase the hedonic qualities. As mentioned before, the hedonic dimension "stimulation" is not representative of students' perception as two word pairs in this dimension were set to neutral. Asking students to fill in the AttrakDiff questionnaire after adjustments have been made, will give a more accurate evaluation of this dimension. Increasing a student's subjective experience with educational tools is said to have a positive impact on their learning experience [71]. The inclusion of learning analytics in a next iteration might seem as a pragmatic improvement to the Playlist feature but finding a way of incorporating them in personal way may target the hedonic dimensions as well.
Further development of the feature would definitely benefit from asking students what could make the feature more visually appealing to them, especially when showing personally relevant information.

The AttrakDiff questionnaire is a simple, and slightly time-consuming way, of asking student's complete evaluation of a tool. It can serve as a starting point in determining how to introduce improvements in a holistic manner. I would therefore encourage the utilization of AttrakDiff to assess the impact of the Playlist feature, and any other educational tool, throughout its development.

**The revised achievement goal questionnaire (AGQ)**
*This survey was distributed in a different way than intended by its creators [20]. A 7-point Likert scale was used instead of a 5-point, using the labels ”not true - very true” instead of ”strongly disagree - strongly agree”.*
This questionnaire was only included in the second survey. The *goal* of this questionnaire was to discover the type of achievements students aim for in the learning environment of the Playlist feature. This not only provides additional context to their responses in other parts of the survey but can also guide future developments of the feature to better cater to students’ needs.

The 6 students that filled in the questionnaire had mastery-approach as their main goal type for the course ”Automata, Computability and Complexity”. This self-oriented goal, combined with their indication of using Skill Circuits and the Playlist feature to plan their studying, suggests that these students might be open to tools that support at least the goal-setting and planning phase of self-directed learning.

Although the responses are few, the AGQ scores can be seen as an indication that the current state of the tool may be less accessible to students that are less proficient in self-directed learning. This observation is also supported by students mentioning that they appreciated the ability to construct a playlist for a study session but desired more guidance in curating that playlist. They expressed a need for assistance in finding the types of learning activities they are interested in or receiving more pointers on which tasks are best to select for a study session.

For future iterations, I suggest asking students to fill in the AGQ scores to be able to compare it to their usage of the Playlist feature. This approach may help identify which goal types are (still) less supported and determine how to best assist those students while improving their self-directed learning skills. Once the feature is more advanced in providing personalized suggestions for students,the AGQ could be integrated as a way of determining a baseline of personalizing learning sequences.

**Skill circuits with playlists**
For further development of the playlist idea it would seem keeping it as a feature of Skill Circuits has more benefits than making it a standalone tool. Skill Circuits provides access to a course’s sequence of learning activities, and students’ interactions with the Playlist feature give developers valuable insights into what students need and expect from their courses.
Although Skill Circuits and the Playlist feature have different objectives, keeping them in the same virtual environment is beneficial to both students and tool developers. This setup improves functionalities, enhances the student experience, and provides useful data to help optimize both Skill Circuits and the Playlist feature.

### 8.1.2. The Playlist feature
In this section I will use the collected usage data and the qualitative feedback students provided to evaluate the Playlist feature’s current design. The aim is to determine whether the intended use of the feature is clear and if the students see any potential in its usage. We will use these findings to evaluate the conjectures guiding the design for future iterations, adjusting them to better fit the tool within the TU Delft environment.

**The playlist analogy**
Using the playlist analogy provided a clear design for a tool that aims to support self-directed learning. For some students, however, the link with a conventional playlist did not have an added value and may even be confusing.
The different views made the steps in creating the playlist clear, but students would still like additional information on how the tool is best used.

**Tool accessibility**
Students indicated that integrating the playlist tool in Skill Circuits increased the chances of using the tool. Not only is it readily available in an existing environment, not having to switch to another platform incentivized the students to keep trying it.
The playlist overlay was often a bit too small for students, especially when creating the playlist. They advised enlarging the window when creating and editing the playlist, and keeping the smaller size window for when the created playlist is in use.

**User stories**

- Navigation-based functionalities were the most wanted, in line with the expectation of students wanting tools to find preferred learning materials
- When studying, expected time to spend on different learning activities is important to be able to plan. While estimates given by the teacher are a good start, students would prefer time estimates based on their own experiences.
- Learning analytics were interesting in general, as students would like to see their academic progress in numbers to evaluate themselves.
- Students were more interested in learning activities that would help them incorporate healthy learning habits, than learning activities to enhance their learning. Students would like the most help with scheduling breaks and asking help when stuck.

### 8.1.3. Feedback collection

Given that Skill Circuits serves as both the entry point and proxy for a learning environment, it was logical to collect feedback from students actively using Skill Circuits in their courses. During the design and development of the Playlist feature, several design decisions were discussed with the developer team of Skill Circuits. Collaborating with the teachers in this team, it was determined which courses could be included for feedback collection. One challenge encountered was the timing of feedback collection, as asking for student input during exam weeks significantly limited the number of participants willing to engage. Organizing focus group sessions during lunch hours increased participation but also restricted the available time for in-depth discussions, necessitating a tightly scheduled set of activities with minimal room for free discussion. Although the response rate for the second survey was low, the data collected provided valuable insights into the comparison between Skill Circuits and the Playlist feature. The results indicate that these two can complement each other and cater to different student needs.

Integrating questionnaires within the learning environment and asking students to complete them at various points during a course could enhance the data collection process in future iterations. Overall, the feedback collected highlighted the potential benefits of combining Skill Circuits and Playlist features to create a more supportive learning environment.

### 8.1.4. Skill circuit as a learning environment

Building upon an existing tool, rather than creating a new one, is important for improving centralization in the complex learning environments of students while providing them with the tools to shape that environment according to their needs. Skill Circuits, an open-source platform, is particularly well-suited for this purpose. It allows students to visualize their course structure and supports the inclusion of diverse learning activities. Students can also apply for its development team, making it a perfect co-design environment for educational tools.

Skill Circuits is developed by the Computer Science & Engineering Teaching Team (CSE-TT) at TU Delft, comprising lecturers, developers, and PhD candidates dedicated to enhancing the Computer Science Bachelor's program through high-quality educational content and in-house educational tools. However, to properly include stakeholders in the development and effective use of Skill Circuits, more comprehensive documentation on the ideas and science behind the tool is needed. This will help teachers create better circuits and understand how these circuits benefit their students [18]. For students, understanding the intention behind the tool can help them articulate their experiences and suggest improvements.

Asking students for feedback on the Playlist feature and utilizing for the next iteration hopefully demonstrates that their input is crucial for the ongoing development and improvement of educational tools.

## 8.2. Reconjecturing

The Playlist tool has shown potential in supporting students' learning processes by allowing them to organize their study sessions more effectively. However, there are several areas where further development is needed to enhance its functionality and user experience.

First, integrating more navigation features is crucial. Students have expressed a desire for better tools to help them find and organize learning activities based on their goals and preferences. Enhancing these navigation functionalities, rather than implementing an automated recommender system, promotes agency and helps them actively plan their study sessions. Encouraging students to engage more with their learning activities and to take control of their educational journey.

Second, improving the Playlist tool's ability to incorporate learning analytics can provide valuable insights for both students and educators. By collecting and displaying data on the time spent on various tasks, the tool can help students better understand their learning habits and identify areas for improvement. Additionally, educators can use this data to tailor their instructional strategies and provide more targeted support to students.
Third, expanding the types of learning activities that can be included in playlists. Students have expressed interest in incorporating activities that promote healthy learning habits, such as regular breaks and help-seeking behaviors. By integrating these types of activities, the Playlist tool can support a more holistic approach to learning that considers students' overall well-being.
Lastly, the user interface and overall usability of the Playlist tool should be continuously refined based on user feedback. Ensuring that the tool is intuitive and easy to use is essential for its widespread adoption and effectiveness. This includes making the playlist creation and editing processes more streamlined and visually appealing.
In conclusion, the further development of the Playlist tool should focus on enhancing navigation features, incorporating learning analytics, expanding the types of learning activities included, and refining the user interface. These improvements will help create a more effective and supportive learning environment for students, ultimately contributing to their academic success and personal growth.

### 8.2.1. Incorporating student feedback in Skill Circuits

Promoting student involvement in innovation projects like Skill Circuits is essential for fostering continuous improvement of and innovation in education. While creating clear feedback channels allows students to share their input, maintaining active student engagement in the development process is equally important.

To address this, introducing learning activities that encourage students to contribute to course improvements while simultaneously learning the subject matter can be beneficial. These activities could include projects where students identify potential enhancements to existing tools or suggest new features based on their learning experiences. Such involvement not only enriches the students' educational journey but also provides valuable insights that can drive innovation.

Furthermore, to keep students engaged, it is crucial to establish clear and accessible channels for ongoing feedback and dialogue. Regular updates on how student feedback is being implemented can help sustain their interest and demonstrate the tangible impact of their contributions. Encouraging a culture of co-creation where students feel their voices are heard and valued.

Incorporating these strategies into the development of educational tools like Skill Circuits can lead to a more inclusive and effective innovation process. By actively involving students, we can ensure that the tools developed meet their needs and preferences, ultimately enhancing the overall learning experience at TU Delft.

### 8.2.2. Balancing design choices

During this project, many envisioned functionalities were not tested by students as developing them would have compromised the feature's visual representation. Simpler functionalities were prioritized to allow time to blend the feature visually into Skill Circuits. During focus group sessions, students indicated that the seamless integration with Skill Circuits made them more inclined to try the feature.

However, the downside of not solely focusing on functionalities is that several feedback points were anticipated. These were identified through surveys, feedback during tool usage, and focus group sessions. Although these suggested improvements were part of the original user stories, their absence in the implemented tool led students to naturally request them. This indicates that the envisioned tool aligns well with student interests.

An important area of future development is learning analytics, a feature that students currently have limited access to but which would significantly enhance their learning experience. As there is a vast amount of data to collect and many ways to present it to students, this offers a valuable co-design opportunity for both the Playlist feature and Skill Circuits. Learning analytics must be presented thoughtfully, ensuring that students are educated on how to use their data beneficially. The goal is to help students improve without overwhelming them or setting unrealistic performance-based goals.

Another aspect to consider is supporting learning activities. Future work should explore the categories of activities included and allow students to decide where these activities fit into their playlists versus recommending an order. Additionally, providing students with knowledge on the importance of these activities, rather than simply nudging them to try them out, is crucial.

In conclusion, balancing design choices involves a trade-off between visual integration and functional development. While the initial focus was on creating a cohesive visual experience, the next steps should prioritize expanding functionalities, especially in areas like learning analytics and supporting learning activities. This approach will ensure that the tool not only looks integrated but also meets the comprehensive needs of students, thereby enhancing their overall learning experience.

**Learning analytics**
Something students do not yet have much access too and would be a clear improvement to their learning experience. As there is lots of data to be collected and many ways of mirroring that students, this might be a nice co-design opportunity for both the playlist feature and Skill Circuits. As with any visualization of data, learning analytics must be presented with care, and students must be properly educated on how to use their data to their benefit. Learning analytics should help them improve and not overwhelm them or impose an unrealistic performance-based goal.

### 8.2.3. Navigation to other learning environments

Skill Circuits is an optional tool that teachers can use to help their students understand the structure of their courses. Since it does not contain actual learning content, it is always used in conjunction with BrightSpace. Depending on the course, Skill Circuits may also include connections to other platforms such as WebLab (for coding exercises) or video hosting platforms like YouTube or Collegerama. Occasionally, it does not directly link to educational content but instead instructs students on what to do (e.g., read a chapter from the course book), assuming they know where to find the necessary educational content for the learning activity.

During the focus group sessions, students expressed frustration with having to switch between multiple platforms. This was particularly problematic when engaging in knowledge absorption activities (reading, watching, or listening to educational content). They felt that such content could be hosted directly on Skill Circuits. However, design decisions have been made not to host educational content on Skill Circuits, as it does not align with its primary goal. Nonetheless, if Skill Circuits becomes more widely used, thus adding another platform to the students' learning environment, this concern needs to be addressed.

In line with this thesis's objective of helping students better navigate their learning activities, assisting them in managing the various platforms where these activities are hosted is a logical next step. To increase the adoption of any tool, including our playlist idea, it is crucial to understand how students experience its usage in conjunction with other tools in their learning environment. Even if a tool perfectly meets a student's needs, if it does not integrate comfortably into the overall learning environment, they may discontinue its use altogether.

## 8.3. Preparing the tool for the next iteration

### 8.3.1. Front end

Goal setting is supported more clearly by giving student the ability to choose a pre-set goal. Depending on the chosen goal, the total estimate is adjusted to account for additional learning activities that will be added in the next view. Any added activities can always be removed.
Navigation is improved by:

- Finding a learning activity based on its type
- Choosing all learning activities belonging to a checkpoint

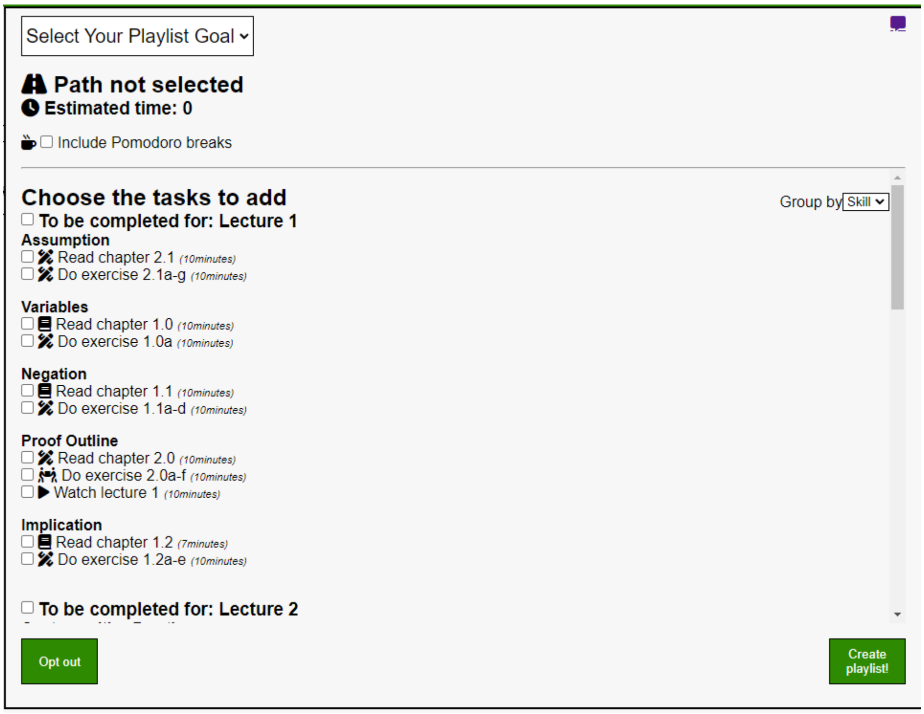


**Figure 8.1:** The new create view which is wider and has new functionalities

A new view is added after learning activities have been selected to reorder learning activities:

- A student may rearrange the activities in a preferred order
- Based on the selected goal in the previous view, an ordering is recommended
- In this view students can adjust the added breaks and reflection prompts

### 8.3.2. Back end

To include learning activities that are not originally part of the Skill Circuit, a new entity is introduced to represent the different kinds of learning activities: learning activities originating from the course's circuit, learning activities to support learning, and learning activities to support healthy learning habits.
Model and controller are updated to compute basic learning analytics of a student:

- average time spent on a learning activity
- percentage of created playlists completed

A service is added to handle different types of ordering from which students can choose. This service can later be expanded with other evidence-based ordering or sequencing methods.

All code associated with the playlist feature is done in a way that it can be easily removed from Skill Circuits. A basic description of the playlist feature and how to further develop the code is included in the code's documentation.

## 8.4. Roadmap

This section outlines the roadmap for the further development of the Playlist feature, focusing on enhancing its integration, functionality, and user experience based on feedback received from students.

#### Short-Term Goals

- **Integration with Existing Systems:** Improve integration with Skill Circuits, ensuring that the Playlist feature can be easily adopted without disrupting existing workflows.
- **Enhanced User Interface:** Refine the user interface to make the Playlist feature more intuitive and visually appealing. This includes implementing user feedback to improve playlist creation and editing.

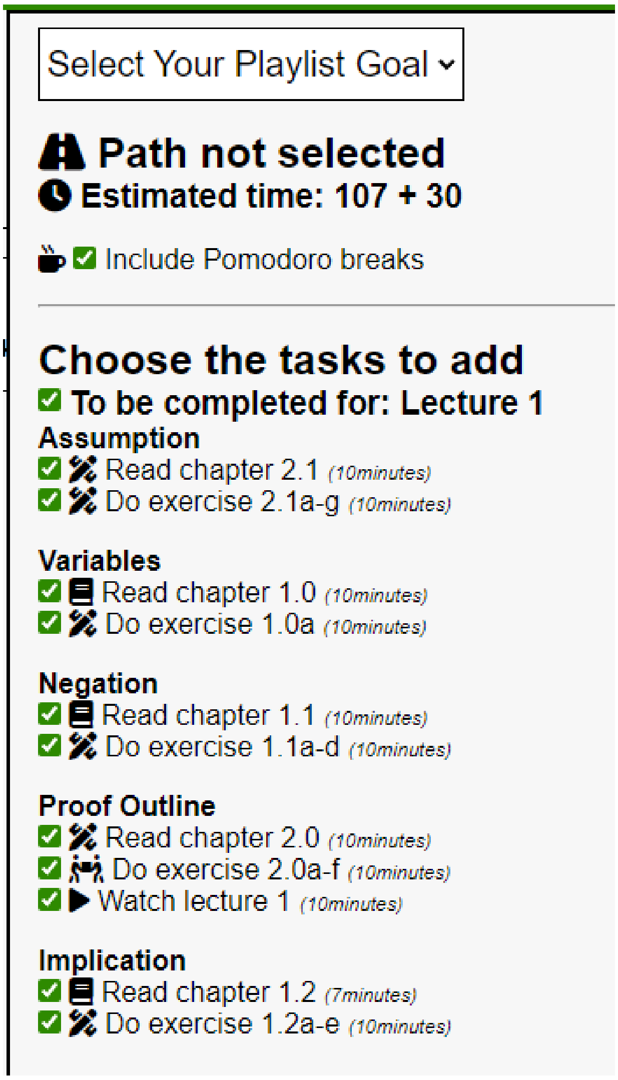


**Figure 8.2:** The time estimate is updated as the option for adding breaks is checked

- **Learning Analytics:** Begin incorporating basic learning analytics to help students track their progress and identify areas for improvement. This will include features like time tracking for types of learning activities
- **Beta Testing:** Conduct more tests in courses to gather more user feedback to make iterative improvements to the feature.

**Medium-Term Goals**

- **Learning Analytics:** Develop more sophisticated learning analytics features, including personalized recommendations based on student performance and engagement data.
- **Learning activities:** Include the recommendation of domain-agnostic learning activities, such as revising materials or utilizing different learning strategies.
- **Mobile Accessibility:** Ensure that the Playlist feature is fully accessible on mobile devices, allowing students to manage their learning activities on the go.
- **User Training and Support:** Develop supporting resources to help students and educators effectively use the Playlist feature.

**Long-Term Goals**

- **Scalability and Customization:** Enhance the feature's scalability to support a larger number of users and allow for customization to meet the specific needs of different courses

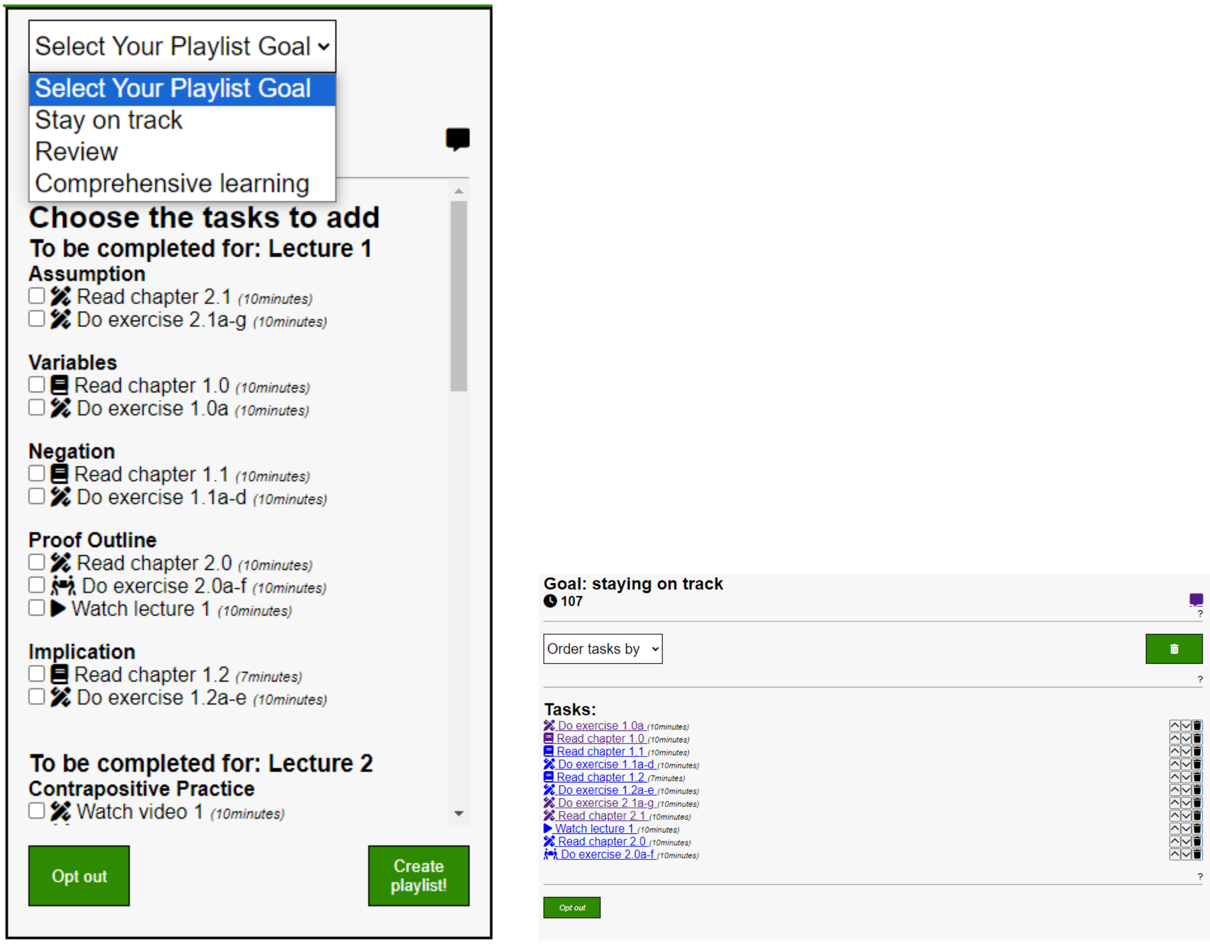


**Figure 8.3:** **Left**: Selecting one of 3 pre-set goals for the next view **Right**: the next view where students can edit the ordering of the added tasks

- **Ongoing Research and Development:** Foster an iterative cycle of research and development to keep the Playlist feature up to date with the TU Delft's learning environment.

# 9 Conclusion and reflecting

In this thesis project, I embarked on a design-based research to develop an educational tool that helps higher-education students personalize the learning sequences provided by their teachers. My goal was to give students more agency in their learning and demonstrate that current technology provides numerous opportunities for personalizing your learning. Both the internet and the campus of an institution like the TU Delft offer numerous ways to tailor learning experiences. I aimed to create a tool that would assist students in finding suitable learning activities to create a personalized sequence.
It is of course an incredible feat to design a tool that can accurately personalize a students' learning while also maintaining a certain educational quality. Instead of exploring the vast possibilities available for personalizing a teacher-set learning sequence, I focused on understanding the elements of a learning sequence and the small opportunities it may hold for personalizing. With this project I hope to set the foundation for personalizing learning sequences for students at the TU Delft. Starting with the learning sequences in the courses of Computer Science & Engineering bachelor.

In this closing chapter, I will recap the design-based research journey by revisiting the research questions one final time. I will reflect on the progress made towards the research objective and provide recommendations for the future development of the Playlist feature and the personalization of sequences of learning activities.

## 9.1. Answering the research questions

The Computer Science & Engineering Teaching Team turned out to be an appropriate space for this research. This team of experts in both education and tool development, focuses their efforts on improving education for both teachers and students. One of their products, Skill Circuits, seemed to be a good fit to test whether a personalization of learning sequences could be realized for the students at the TU Delft. Before I could attempt to design such an intervention, I had to understand what these sequences are and how personalizing them can be beneficial to students.

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

A personalized sequence of learning activities is tailored towards the preferences and needs of each student. As higher-education institutions face increasing student numbers, they have to create educational content appropriate for the masses rather than individuals. Introducing personalization becomes crucial to ensure that every student meets their educational needs.
When learning activities are chosen according to students' preferences, it increases their motivation to engage with the content. Activities that align with their goals improve their learning experience. Additionally, tailoring activities to students' knowledge levels helps them manage their cognitive load and enhances their learning.
While a tool that automatically personalizes an existing sequence for students might seem ideal, we found that involving students actively in the personalization process is important as well. This active participation helps students develop an much needed skill in future professionals: self-directed learning. Self-directed learning is a complex skill that students will need in their future careers, as professionals are required to adapt to ever-changing demands in our highly connected and complex society. Practicing this skill within a managed learning environment, such as a course, prepares students for real-world scenarios.

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

A sequence of learning activities becomes personal when a student is capable of adjusting that sequence to better fit their goals and needs. To do so they need appropriate strategies and the opportunity to adjust the learning activities. Until a student is proficient in self-directed learning and knows how to apply strategies, they need the support of an external party. This can be a teacher or a tool that knows how to infer a student's goals or learning preferences. To infer the preferences of students, we can ask them to fill in questionnaires or collect their learning analytics. In both cases we want to mirror our findings back to students to help them improve in personalizing their learning on their own. Ideally, we would like to guide them through the steps the tool or teacher takes to personalize a sequence for them. Which relates back to self-directed learning. We therefore look for methods to support students in personalizing their learning sequence.

The phases of self-directed learning are used to identify what kind of methods are needed.
The task-definition phase asks for personalization based on finding fitting learning activities. Being able to properly **navigate** the learning environment is therefore important.
The goal setting and planning phase requires students to be aware of what they want to achieve when completing learning activities. Additionally, they need access to information about how **learning activities** can be carried out to be able to plan accordingly. When creating a personal sequence for a study session, students need to at least know how much **time** they should allocate for the learning activities they choose to do.
The strategy enactment phase is where students actually engage with the learning activities. Support in this phase is provided by giving students methods to stay engaged with the learning content. This is were making students aware of **supporting learning activities** comes in and the learning environment should enable them to incorporate these in their sequences. The last phase, monitoring and reflecting, can be supported by providing a student with methods to assess and reflect on their learning. Both supporting learning activities and **learning analytics** can benefit students in this phase. Proper interpretation of these analytics to actually help students improve in personalizing their learning sequences requires guidance from a teacher.

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

Learning is not only about engaging with learning activities; it also involves effectively integrating learning into 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 [11].
Showing students that activities concerning self-directed learning and healthy learning habits are just as important as activities that are directly related to learning content, can make learning a more holistic experience.

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

Students were most interested in sequences that aligned with their preference for certain learning activities. Having the ability to choose and find certain types of learning activities were asked for the most.
Time management and personal learning analytics were the next strong contenders. Students might already have certain ideas on how they wish to structure their study session and mostly need help in knowing what to do and how far they have progressed.
Students are not always aware of how they asses themselves, so giving them analytics might help them understand what type of progression they find important. Which analytics to show students is something that must be very carefully considered. Not only can it be overwhelming, but often, they do more harm than good. Negative effects can be mitigated by not only thinking about what analytics are useful but also educating students on what the numbers mean. Analytics are just one way of describing one's progress and should be viewed in tandem with other aspects of learning.
Students were asked about reflection prompts and integrating breaks in a personal sequence. These were learning activities that would require the least amount of explanation on how to execute them and are domain-agnostic. Being able to add breaks to a sequence of learning activities was very well received.

Students indicated they often forget to take (regular) breaks or see it as a waste of time during their study sessions. Seeing breaks being incorporated in their study session beforehand helps them reserve time for it.

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

Asking students for direct feedback on a designed tool was the most valuable method for uncovering how the tool can best address their needs. However, this approach is time-consuming and can be difficult to schedule with students. Using existing questionnaires to assess different aspects of learning proved to be an easier way to gather quantitative data on students' perceptions. These questionnaires can also be integrated in the tool to ask for regular feedback from students and evaluate the tool throughout the full development process.

Teachers play a crucial role in introducing students to new technologies within a course. This was reflected in the first survey as almost all students indicated using Skill Circuits was due to the recommendation of their teacher. And since the teacher put effort in utilizing the tool as much as possible, students are more inclined to use it.
Several initiatives exist at the TU Delft to help teachers improve their teaching and keep up to date with any possibilities new technologies bring. However, integrating this new knowledge into their courses requires significant effort and time. Consequently, it might take a while before students can benefit from the many collaborations teachers engage in to improve learning.
Therefore, it was important to find a way to introduce an intervention that enhanced an existing technology rather than trying to find and convince teachers to adopt a new technology that may potentially help their students. Fortunately, this approach aligns with the goals of the CSE-TT, which aims to improve education by making their platforms open source and welcoming collaborations to enhance the learning experience of their bachelor students.

Students also have opportunities to develop their learning skills and enhance their studying experience with non-academic activities. The TU Delft campus offers a variety of activities, courses, and workshops to help students develop all sorts of skills. It then depends on the student's proficiency in self-directed learning to integrate activities supporting their learning properly during study sessions. Therefore, I saw an opportunity to design a tool that acknowledges the place such activities can have in a learning sequence.

## 9.2. Further development of Playlist

### 9.2.1. Navigation

Adding functionalities to navigate learning activities in accordance with learning goals and preferences. Enhancing navigation functionalities instead of implementing a recommender system to do this for them promotes student autonomy and active study planning.
Exploring ways of improving navigation outside *Skill Circuits with Playlists* will not only improve the student's experience but also make the tool's position in the learning environment more clear.

### 9.2.2. Learning analytics

Not only can data on students' learning help improve the tool and the education it supports, students are also very much interested in seeing more numbers on their academic progress. Co-designing the implementation of this component is highly recommended. Not only does that ensure that the implementation fits the needs of both students and teachers, but it also ensures the discussion on both the advantages and disadvantages of learning analytics is held.

To learn more about how to present Learning Analytics to students, we can take a look at Learning Analytics Dashboards, a visual interface designed to present learning analytics in a human-friendly way. Most LADs have a descriptive goal as that is the most simple way to utilize LA. Comparing it to the other two approaches, its possibilities are also the most limited, but an important benefit is that this approach is much more comprehensible. Prediction and prescription require machine learning or other Artificial Intelligence (AI) methods to gain good results. AI systems are known for being a black box; it is unclear how results are produced from the data given to them. This can be challenging when using AI to tell learners what to do as they might not trust what the system tells them as they do not understand the

reasoning behind it.[53]
LADs do not have a fixed look and feel, as they are created with different goals and stakeholders in mind. Still, there is overlap, especially in the challenges they face. When designing a LAD, [53] explain there are several things to consider for your users:

- you do not want to overload users with information
- the dashboard should be clear in its intentions
- you want to be aware of the possible effects it may have

Susnjak, Ramaswami, and Mathrani argue that there is not much evidence for improvement in learning when using learning analytics or dashboards. It would, therefore, help the field if we can find a logical way to incorporate learning analytics in our tool.[53]

### 9.2.3. Incorporating student feedback in skill circuits

Creating a feedback system is essential for better aligning Skill Circuits with student needs. Currently, developments seem to be centered around teacher preferences or their ideas of what might benefit students, with students lacking a clear channel to provide feedback.

One proposed functionality for Skill Circuits is enabling interaction with other students or, at the very least, allowing students to view learning analytics regarding their peers' progress in the course. Addressing the readiness gap mentioned in [5], sharing both student progress and the ways they personalized their learning sequences could be a step towards recommending learning activities in a context-aware manner. This idea aligns with a request from one of the focus group sessions, where a student expressed a desire to filter learning activities based on type. Specifically, they mentioned that while traveling, they would prefer to have only reading activities in their playlist, as other types often require a stable internet connection.

## 9.3. Reflecting

This thesis makes a small but valuable contribution to the design of an educational tool aimed at fostering self-directed learning—a crucial skill in our technology-driven society where knowledge acquisition is increasingly important. The tool adopts a learner-centered approach in its design decisions, adding to studies that focus on more than just advancing learning technology [5]. It is intended not only to aid students during their learning but also to serve as a stepping stone for tools that promote self-directed learning. Additionally, it contributes to the relatively understudied field of supporting the sequencing of learning materials [5].

The curriculum and learning activities in Computer Science are well-suited for sequencing and creating individual study sessions. However, the applicability of this approach to less structured courses remains uncertain.

### 9.3.1. Involving students in innovation spaces for education

Students are increasingly included in efforts to improve their education. When teachers work on innovations for their learning environment, they carefully consider how and when to involve students. These experiences, from a teacher's perspective, are shared and documented, while students' experiences are less recorded.

The learning outcomes I focused on can be described as affection [5], as I examined students' evaluations of the technology (AttrakDiff [22]), their engagement with the provided content, and the self-reported effects on their cognitive load [21]. An advantage of Skill Circuits is that it requires teachers to present their course contents in a standardized way, which can enhance clarity for students. However, this standardization demands significant effort from teachers to properly represent their courses as circuits. In contrast, BrightSpace provides teachers with more freedom in how they present their course materials, but leads to inconsistencies in student interactions with the platform.

By further developing Skill Circuits with Playlists and showcasing how addressing students' learning needs can improve their learning experiences, we may encourage teachers to adopt technologies that students prefer to interact with. Alternatively, teachers might use existing technologies in ways that align more closely with student preferences. Achieving this requires proper guidelines for teachers, user-friendly technologies, and clear feedback channel for students to share their needs. This can be accomplished by utilizing learning analytics to track student tool usage, asking frequent student feedback on technologies and educational content, and providing opportunities for students to discuss potential improvements.

This thesis project can also serve as a catalyst for educational innovation at TU Delft. By using existing tools to identify and address students' needs, and iteratively improve Skill Circuits with input from both students and teachers, we can create tools that are truly needed. This approach not only results in useful tools but also demonstrates how the existing learning environment can be a space for innovation, ultimately leading to improved learning outcomes.

### 9.3.2. Limitations of this research

Like many other systems designed for personalized learning, the Playlist feature was tested with engineering and computer-related educational content [5]. It is unclear how the Playlist feature could be adapted for courses that are less structured and consist of domain-specific learning activities. While self-directed learning is important in all contexts, synthesizing a sequence to be enhanced in less structured courses might become challenging. The Playlist feature might then primarily assist in planning supporting learning activities.

There is also a volunteer bias in the collection of feedback from students, as the feedback primarily comes from those who were more willing or available to participate. This volunteer bias, together with the author's basic proficiency and experience in the field of educational technologies, limited the opportunities to be explored for the design of the Playlist feature

**The author's knowledge base**

Before this thesis, I had no knowledge of educational technologies and the learning sciences but was motivated by a personal interest in developing tools to support learning. Throughout the project, I had to explore many new fields, theories, and concepts with little time to fully grasp them. This made it difficult to properly outline them in this report and synthesize them into one complete intervention.

As a result, my understanding of educational technologies and the learning theories that support them is basic and sometimes superficial. With literature not always being clear on the meaning of certain terms (adaptive vs. personalized, self-regulated vs. self-directed) and the many approaches that exist toward improving learning, I undoubtedly missed important aspects to consider in the Playlist feature's design. Nonetheless, I hope that my conjectures are clear and that the project's outcome can serve as a stepping stone for further development of evidence-based educational tools at TU Delft.

The terminology used throughout the project is more or less consistent in this report, but the data collection tools in the appendix show how my understanding of different concepts evolved and which concepts I wanted to include in my research.

Foundational learning theories were only mentioned in relation to proven methods or systems. Existing work was used as a gateway to learn more about educational sciences and build upon evidence-based research. This resulted in a tool design that is not directly grounded in the learning sciences but is somewhat influenced by them. By using official terms to describe the different concepts in the tool's design (mostly backend), further iterations of the tool will hopefully be incentivized to dive deeper into the theories that inspired various referenced systems, such as constructivism in the 4C/ID model.

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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[72]. 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 contact me at r.n.glans@student.tudelft.nl .

Thanks in advance,
Rebecca Glans

## 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 |

## C.2. Second survey results

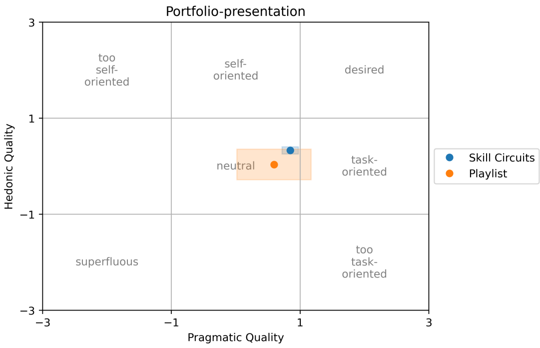


**Figure C.1:** Second survey: AttrakDiff scores for both Skill Circuits and the Playlist feature.