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The MINTFIT Computer Science Online Course

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***Abstract*—STEM degree programs in Germany suffer from high dropout rates. The project MINTFIT Hamburg, a joint project of the Hamburg University of Applied Sciences (HAW), HafenCity University Hamburg (HCU), Hamburg University of Technology (TUHH), Universität Hamburg (UHH) as well as the University Medical Center Hamburg-Eppendorf (UKE), funded by the Hamburg Authority for Science, Research, Equality and Districts (BWFGB), was founded in 2014 to tackle this problem. MINTFIT Hamburg offers online tests and courses for prospective students of STEM degree programs on the MINTFIT platform www.mintfit.hamburg. The subjects covered are mathematics, physics, chemistry and computer science. This paper describes the background for developing the computer science online course of MINTFIT Hamburg and explains how it was designed with respect to content and structure based on an online survey amongst lecturers of computer science at German universities. The content of the chapters of the computer science course (On Computer Science, Logic, Algorithms, Programming, Formal Language, Math in Computer Science and Panorama View) is shortly presented, as well as an analysis of the collected data of the user flow and a brief outlook to possible future developments of the course.**

I. Introduction

A primary goal of today's German education policy is the *strengthening of STEM* [1] – which stands for the academic disciplines "science, technology, engineering and mathematics" ("MINT" is the German equivalent of STEM). More young people should be motivated to enroll in a STEM degree program and should be supported to finish successfully their final degree. As a long-term result, the number of graduates should rise and the skilled labor shortage should decrease [1]. Against the background that in Germany about one third of all STEM students (45% in computer science) drop out of university or change their field of study before graduation (see [2], [3]), offering prospective students help to prepare themselves optimally for their STEM degree program with respect to required previous knowledge is estimated crucial, and support should start as early as possible guaranteeing a smooth start into the first academic year. For this purpose in 2014 the project "MINTFIT Hamburg" [4] started to give support with a free-of-charge online service for prospective students who are interested in independently reviewing their knowledge in mathematics, physics, chemistry and computer science. The MINTFIT platform, which runs on the learning management system Moodle, offers online tests in each of these areas that aim not to give a recommendation whether or not a user should start a STEM degree program respectively which one, but to give hints which knowledge should be brushed up or which knowledge gaps should be filled before entering university by using the corresponding MINTFIT online course. This paper describes the development of the MINTFIT computer science online course that corresponds to the MINTFIT computer science test, which launched in 2019.

The paper is structured as follows: Section II presents the development of the MINTFIT computer science online course, section III gives an analysis of user data and behavior, while section IV gives a brief outlook on future possible developments of the MINTFIT computer science course.

II. The MINFIT Computer Science Online Course

In mathematics, physics and chemistry, there was a content base for the MINTFIT online tests and courses, because they are compulsory school subjects in Germany - however, for computer science, this is not true [5]. Therefore, on the one hand, the MINTFIT offer (consisting of online test and course) in computer science should arouse interest and, on the other hand, test general skills related to computer science (like logic or abstract thinking) with the help of exciting examples.

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In order to understand the challenges in designing a computer science online course in Germany, it is helpful to get a rough overview of the German education system first. The sole jurisdiction over the education system rests with the federal states of Germany (the so-called "Bundesländer") and although a central organisation for coordination exists (the so-called *Kultusministerkonferenz* or *KMK* for short), all recommendations are non-binding for the federal states [6]. There are some recommendations for the content of teaching in computer science at German schools (e.g. [7]–[9]), but there is no standard all schools in Germany have to oblige to. Virtually every federal state has its own standard, and computer science is not a required subject in each federal state. This also means that there is no standard body of knowledge lecturers at universities can assume new students to have learned in school. To get at least a basic understanding of what university lecturers expect from student beginners, MINTFIT Hamburg conducted a survey asking university lecturers of computer science about their expectations of the previous knowledge and skills of freshmen [10].

A. The Computer Science Lecturer Survey

In the year 2019, an online survey amongst lecturers at German universities was conducted by the MINTFIT team. The aim was to elicit which skills and knowledge of freshmen in computer science at German universities is expected by lecturers. The survey was sent via link to about 7,000 lecturers of computer science at German universities. The addresses were collected at public web pages of the universities. The survey consisted of 14 questions, which included four questions with a Likert scale, four Fill in the Blank questions, and six single choice questions. For a statistical analysis, four attributes were prompted:

- Which kind of university is the participant of the survey working at (University, Technical University, German Fachhochschule/University of Applied Sciences)
- Position (University professor, scientific assistant, associate lecturer)
- Teaching activity with freshmen (yes/no)
- federal state of the university.

588 persons completed the survey, which resulted in a return rate of 8.4 %. In the analysis of the survey results, a skill or knowledge was following [11] defined as explicitly required if more than 2/3 of the participants in general and more than 1/2 of the participants of each university type approved of the skill or knowledge. The survey asked for general skills and knowledge as well as for computer science specific skills and knowledge. For the general skills and knowledge, "Interest in computer science", "ability to reason", and "motivation" received the highest acceptance of lecturers, and nearly every general skill or knowledge got approval by more than half of the participants of the survey. Of the computer science specific skills and knowledge, none was explicitly required by the lecturers that completed the survey. The skills and knowledge that were required by more than half of the lecturers were "handling of standard software" and "set theory". For more detailed results, information about the theory behind the construction of the survey and the definition of the skills and knowledge asked for, see [10].

The lecturer survey revealed that no prior computer science knowledge is expected by lecturers of computer science. Instead, student beginners should have learned different soft skills (e.g. ability to reason, reading comprehension, basic math skills) in school. For the development of the MINTFIT computer science online course, this meant that there was no body of knowledge mandatory to be included into the computer science (test and) course. Instead, the focus should be on soft skills, generating motivation and offering an overview over computer science. Nonetheless, the survey revealed topics that lecturers estimated reasonable or appropriate for an online test and course in computer science for the target group.

As in the other fields that MINTFIT Hamburg is tackling - mathematics, physics and chemistry - the MINTFIT online course in computer science is subsequent to an introductory online test, the MINTFIT computer science test. After completing the MINTFIT computer science test, users get recommendations which sections of the computer science course they should pay attention to. The computer science test was (like the course) built upon the results of the lecturer survey and is accessible since the end of 2019. For more information on the MINTFIT computer science test, see [12].

B. Design Goals for the MINTFIT Computer Science Course

As discussed in the previous section, the contents of the course were not prescribed by requirements students have to meet when they start a degree program with elements of computer science. Thus, other aims dictated which content the course should cover. First of all, users of the course should be able to solve the MINTFIT computer science test (that is also based on the results of the lecturer survey and was mentioned in section II-A, see [12]) with the knowledge acquired in the course, since the course is highly recommended to users who only score a few points in the computer science test. Further, the course is intended to give users an impression of the kind of topics they would probably encounter during the first terms of their degree program. Especially users who are new to the subject "computer science" might not be aware that computer science incorporates many more aspects than just programming, mathematics and knowledge about hardware (see [13]). In order to counteract such wrong expectations, the course had to contain a broad range of topics.

Furthermore, a goal was to ease the users' start of their studies by lightly presenting content which they had to deal with in their first year at university. Mathematics takes a special role in this, as the importance of prior knowledge in mathematics was mentioned a lot by participants of the survey amongst lecturers. For that reason, the course had to emphasize the importance of mathematics in computer science. Since there existed already a MINTFIT test in mathematics (the first MINTFIT test) with supplementary online courses, there was no need to cover all areas of school mathematics in the MINTFIT computer science course. Nonetheless, there should

be hints to the importance of mathematics for the understanding of the content of first term computer science lectures plus some extra material covering issues in mathematics that are especially relevant for computer science.

Additional goals were related more to the way of presenting the topics than to the choice of contents. Since there was no strict requirement on the knowledge that users should gain by using the course, the design of the course could focus more on being engaging, in a way that users were motivated to work on the course for longer periods of time and such that interest was aroused. This goal - to design a course that arouses interest in the user - is linked with the big challenge that the users' previous knowledge might vary a lot. On the one hand, there might be users who have been taught computer science in school or who use their leisure time to engage in computer science, and on the other hand, there are users who are completely new to the subject (see section II-A). To compensate for this, the course should include interesting material for different levels of knowledge.

Since the MINTFIT tests and courses are mainly directed towards prospective students in Germany, the generic language of tests and courses is German, nonetheless they are already partially available in English.

C. Design Decisions for the MINTFIT Computer Science Course

In this section, it is discussed how the MINTFIT computer science course was designed to meet the design goals described in section II-B. The first few goals concern the topics and scope of the material which should be presented in the course. As the course is supposed to convey knowledge which can be used to solve the MINTFIT computer science test, the topics included in the test are explained in the course as well. These selected topics comprise "Logic", "Programming", "Algorithms", "Formal Language", and "Panorama View", which itself consists of "Computer Architecture", "Databases", and "Computer Networks". The topics were selected according to the results of the survey amongst lecturers of computer science (see [10]). In addition to these topics which were dictated by the MINTFIT computer science test, the course is supplemented by a short chapter "On Computer Science" as well as a chapter on mathematics. The first one is there to counteract common misconceptions about computer science as well as to show the diverse career options a computer science degree program offers. The chapter on mathematics emphasizes the importance of that subject for a degree program including elements of computer science and covers certain mathematical topics which are specifically relevant for computer science like discrete mathematics and numeral systems.

In addition to this, the section "Panorama View" is expanded by short sections on computer security and artificial intelligence. By doing this the course conveys a broader range of topics as required by the design goals.

Regarding the users' motivation to work on the course, the chapters are kept relatively short, such that they transport a brief overview of the topic instead of going into the details too much. Each chapter consists of around 10 to 20 pages (when saved in PDF). Until now, there is no recommendation given how much time users should plan for or spend on the course, but this would be an interesting future addition to the course when more reliable user data are available. Furthermore, the course contains many examples, pictures and animations to increase interest. The problem of the variation in the users' previous knowledge was solved by adding excursus. These are further information paragraphs which are hidden from the user, unless they want to see them. Thus, users with little or without previous knowledge (or without too much interest in the topic) can easily skip an excursus, while others are able to explore certain aspects of a topic in more detail with it.

D. Content of the MINTFIT Computer Science Course

In this section, the content of the chapters of the MINTFIT computer science course is briefly described.

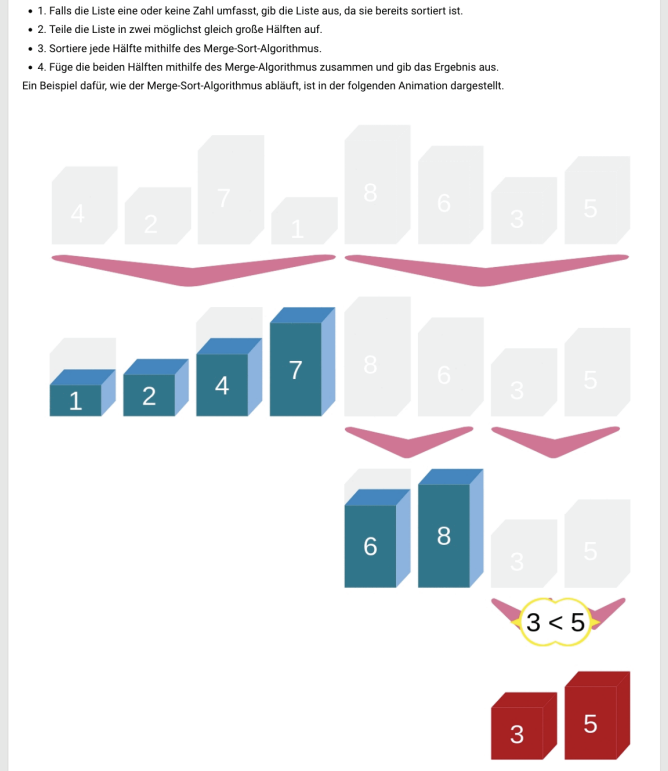

Fig. 1. Example of a GIF in the Algorithm chapter of the MINTFIT computer science course to illustrate the Merge Sort Algorithm.

1) **On Computer Science** In this short chapter, an attempt of a definition of computer science is discussed and its relevance is stressed by giving an overview of careers which involve computer science as well as considering the influence of computer science on society.
2) **Logic** This chapter incorporates different aspects of formal logic: formal notation of logical formulas is introduced, truth tables are described and simple rules how to simplify logical formulas are explained.

3) **Programming** In this chapter, the user can learn about basic programming constructs like variables, branches and loops. The chapter does not focus on a specific programming language but introduces a simple pseudo code which is supplemented by examples of different programming languages to show similarities between them. In the last chapter, the user can find a guide how they can start their own programming project - from selecting a programming language through completing a tutorial to debugging their own program.
4) **Algorithms** This chapter focuses on different sorting algorithms. Three different algorithms are explained and their running times are briefly analyzed (see Fig. 1).
5) **Formal Language** This chapter focusses on the motivation for theoretical computer science and on the reasoning of its importance. Additionally, some simple language models, for example regular expressions, are introduced.
6) **Math in Computer Science** This chapter includes information on set theory, powers, exponentials, and logarithms as well as numeral systems and discrete mathematics.
7) **Panorama View** This chapter consists of very brief introductions to different aspects of computer science. The topics included are computer architecture, databases, networks, artificial intelligence, and computer security.

E. Implementation of the MINTFIT Computer Science Course

The implementation of the course took about a year with four part-time employees working on it. The course runs on the MINTFIT Moodle platform like the other MINTFIT tests and courses. In order to make the course more accessible to the target audience - i.e. prospective students of STEM degree programs with elements of computer science - a number of features were implemented:

- A **navigation bar** is shown on the left-hand side at any time. This allows users to both get an overview of their current position in the course as well as to quickly navigate through the course.
- A **search engine** was integrated into the course. This is useful for many cases, e.g. if a user forgot the meaning of a term or if the reader is interested in specific subjects.
- Almost all chapters include small **tests** which give users the possibility to check whether they understood the content of the chapter correctly and which offer an important feedback to their learning progress.
- To improve both attention as well as understanding, a total of around **40 custom made graphics and animations** as well as six stock images were integrated.
- For the programming chapters, **source code examples** were provided in pseudo code and in the programming languages Python and C. This way, course users can get an idea where the programming languages are similar and where they differ from each other.
- Wherever possible, **examples** for the application of theory were given.

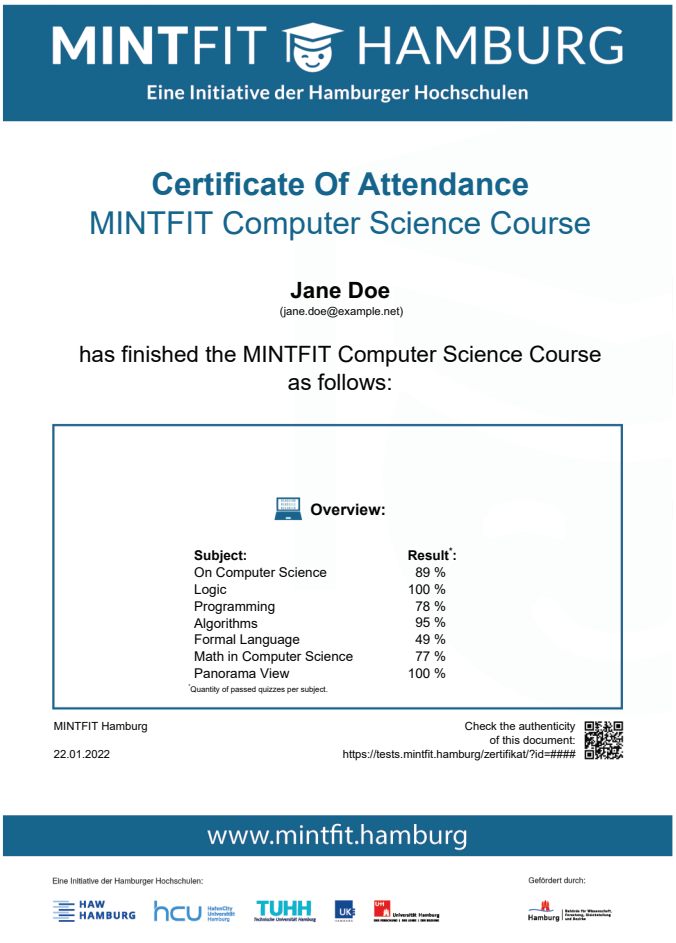

Fig. 2. Example of a certificate obtainable for users of the MINTFIT computer science course. The certificate is available in German and English.

- At many locations in the course, **excursus** containing both further topics as well as interesting side facts are given. This way, advanced users can get additional content while users new to the topic do not get overwhelmed.
- After participating in the course, users can generate a **certificate** showing their progress in the different areas of computer science that the MINTFIT computer science course covers. With this, we hope that users have more motivation to complete the course. An example of such a certificate can be seen in Fig. 2.

The beta version of the MINTFIT computer science course is accessible via www.mintfit.hamburg.

III. Analysis

Since the launch of the MINTFIT computer science course in November 2020, user data were collected with respect to data privacy and are now being analyzed by the MINTFIT team in the scope of learning analytics. Thus, the structure of the computer science course or recommendations and highlighting of chapters could be optimized with respect to the user flow or advertising for the course could be matched to known user groups.

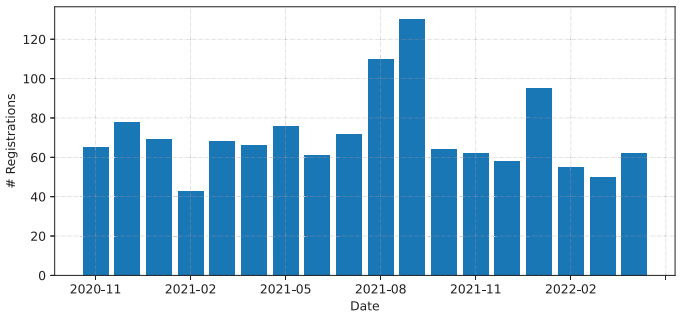

Fig. 3. Number of first-time user registrations for the MINTFIT computer science online course per month

Fig. 3 shows the distribution of first-time user registrations for the computer science course on the MINTFIT platform. Over the first 18 months, the course received an average of 71 first-time registrations per month, and a total of unique 1284 users registered for the course. Registrations for the course peak in August and September 2021. At the Hamburg universities with STEM degree programs, summer term starts around April and winter term around October. In the time period when universities accept applicants for their STEM degree programs starting in winter term, the Hamburg universities involved in the MINTFIT project sent out emails to their successful applicants promoting the MINTFIT test and course system with a special mentioning of the computer science course. This explains the peak in user registrations around August. This leads to the legitimate assumption that, although the MINTFIT test and course system is open to everybody and though there are other advertising efforts at MINTFIT Hamburg, the target group "prospective STEM students" is indeed a group with high interest in the computer science course and the period when the computer science course is mostly made use of is the period right before the start of the winter term. A second peak in January could be explained with a group (like students of high school classes) using the course as additional material, as it is not known that a specific advertisement measure had taken place at this time. We also examined which sections of our course were most frequently completed by participants (see Fig. 4). Blue bars indicate the usual course sections consisting of learning material. The green bars represent test sections in which participants are asked questions about the previous learning material. For example, 325 unique participants attend to section 1.1. whereas 238 participants attend to section 2.1. Fig. 4 illustrates that most participants work on the first sections of the course, whereas the later sections are less frequently attended. Although participants can navigate and start with sections of their interest, the course is mostly started from the top. Main sections (e.g. 1.1, 2.1, ...) are visited more frequently than subsections (e.g. 1.2, 1.3, ...), since main sections can be directly accessed via the navigation menu. Sections 4-7 have less than half of the user numbers that sections 1-3 have. After finishing the first three sections (On Computer Science, Logic and Programming), almost every participant would complete the entire course. Nearly every

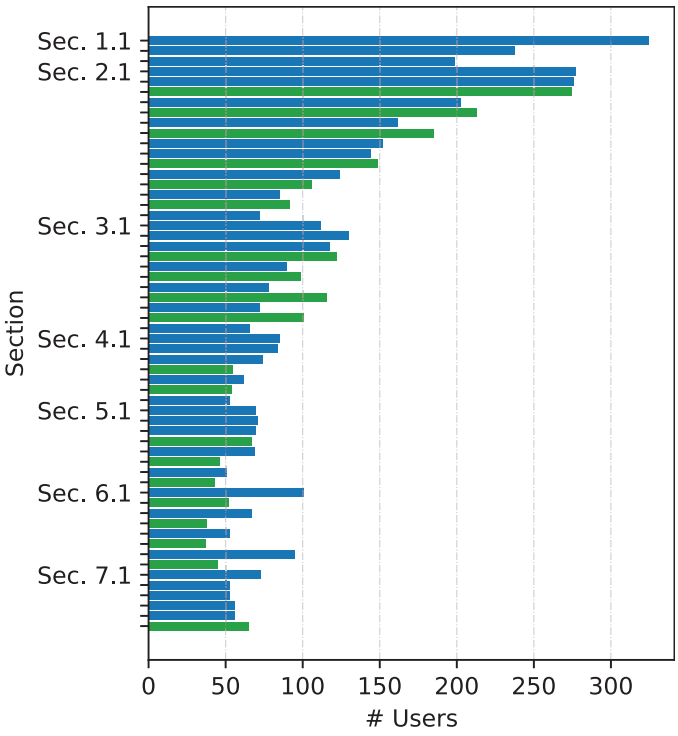

Fig. 4. Number of unique users who entered a section of the course. Information and test sections are highlighted blue and green respectively. The sections of the course are listed from above along the y-axis, each line representing one section.

user starts the course with the first two sections, so dropout rates after the other sections can be estimated using Fig. 4. It is not noticeable that there are topics that lead to an increased dropout of participants. It seems plausible that the dropouts are due to the arrangement of the topics and that many participants lack time or motivation to work through the course for longer or through the full course, but we do not know with certainty that they are not related to the topics themselves.

IV. Outlook

The MINTFIT computer science course was launched as a beta version in November 2020. Data of about 1,300 users have since then been collected and can serve as a basis for future developments, together with continuously added data of newly registered users. As described in section III, there is a quite high number of dropouts in the early chapters. One goal of future improvements of the course is to reduce the number of dropouts and to support a longer engagement of the participants. To achieve this goal, there are three key points:

- the course could be adapted to increase the motivation of participants to continue,
- participants should be discouraged from dropping out in between and
- participants who paused using the course should be motivated to resume the course.

As a dropout occurs very often at the end of a page or topic, it might be helpful to integrate elements which increase the

curiosity of the user to take a look at the next page. This could be achieved through meaningful transitions between topics or outlooks with convincing explanations of the significance of the following content. With reminder emails, users could be motivated to revisit the course if they did not visit it for a certain time. Changing the order of the chapters could be considered if further analysis shows that specific topics are better or worse received than others, thus optimizing the order of the topics with respect to the user motivation. An interesting object of future investigations would be to see if there is a positive correlation between a person using the MINTFIT computer science course and starting a STEM degree program or even studying successfully such a degree program. Such a statistical analysis study would be possible when there is a sufficient number of users. Last, the evaluation of the number of registrations can help to assess advertising measures in order to be able to place more targeted advertising in the future and to increase thus the number of user registrations.

The MINTFIT computer science course is closely linked to the MINTFIT computer science test, which prospective students can use to assess their knowledge in computer science. All topics that appear in the test are also covered in the course while the course additionally includes the chapters "On Computer Science" and "Math in Computer Science" which are not covered by the test. Many users of the MINTFIT computer science course did previously take the MINTFIT computer science test. It is noticeable that the results in the MINTFIT computer science test for the later topics are worse than for the first two topics ("Logic" and "Programming"). Nevertheless, the access numbers in the course are higher for the early topics, including "Logic" and "Programming". Here, a possible improvement of the course could be to motivate participants to deal with the later content through more specific recommendations based on the results of the MINTFIT computer science test. Additionally, the MINTFIT computer science test and course will be revised by adding the topics "Modeling" and "Formal Writing".

V. SUMMARY

The project MINTFIT tackles the problem of high dropout rates in STEM degree programs at German universities by offering free of charge online tests and courses in mathematics, physics, chemistry and computer science since 2014. Prospective students of STEM degree programs can use the tests on the platform www.mintfit.hamburg to diagnose gaps in their knowledge and fill those gaps by studying with the MINTFIT online courses. To identify the expectations of the skills and knowledge that lecturers of computer science at German universities have of freshmen, a survey amongst those lecturers was conducted. Based on the results and on other considerations, the content of the MINTFIT computer science online course was defined. With the MINTFIT computer science online course, future students of STEM degree programs can prepare themselves for the computer science courses of the first year. The paper describes design decisions of the computer science course, gives a first analysis of user behavior and presents a short outlook on possible further developments of the MINTFIT computer science online course.

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