E-LEARNING CONCEPT FOR STUDY PREPARATION IN STEM

Estella Francois[1], Ute Carina Müller[2]
[1] *University of Library Studies and Information Technologies*
[2] *Technische Universität Hamburg*

Abstract: The non-commercial, open access platform MINTFIT Hamburg (Germany) has the aim to support the preparation of prospective students for their studies in STEM (**S**cience, **T**echnology, **E**ngineering, **M**athematics) with the help of online tests and courses. The project aims to improve the knowledge level and by this to reduce the high dropout rates in STEM studies in Germany. This article presents the concept, content and use of the online tests and courses.

Keywords: E-learning, STEM subjects, shortage of skilled staff, digitalisation of teaching, study preparation

Introduction

The shortage of skilled staff with STEM degrees respectively in the STEM field is seen as a major disadvantage for technological and economic development and therefore competitiveness in Germany. This problem is tightened by the fact that a structural increase in demand for STEM specialists can be expected in the future. The reasons for this additional demand include the increasing use of complex technologies, the pressure for innovation in combination with global competition and digitalisation. Experts are needed who have both qualified technical knowledge and the ability to develop new technical systems or improve existing systems. The technological changes associated with the energy transition and climate protection also requires highly qualified STEM specialists. The demographic change is another aspect that is leading to a further increase in the structural gap in STEM graduates, as more and more technical and scientific specialists of the baby boomers are leaving the labour market for reasons of age and need to be replaced by STEM graduates [1].

Although the demand for academically trained STEM specialists is high and continues to rise, the study entry numbers of prospective students for STEM degree programmes is falling. According to the latest figures from the Federal Statistical Office, the number of first-year students in STEM subjects has been declining since 2018 [2]. It can therefore be assumed that the lack of people interested in studying STEM subjects will also contribute to an increase in the shortage of skilled staff.

Another challenge in the STEM field is that prospective students have deficits in basic STEM skills on the transition from school to university, which, in combination with the demanding requirements of a STEM degree

programme, are considered one of the main reasons for the comparatively high dropout rates of STEM students. The challenge of insufficient STEM skills among first-semester students is likely to increase further in the coming years. Current studies, such as the "STEM Spring Report 2024" (MINT-Frühjahrsreport) [3] or the "STEM Young Talent Barometer 2024" (MINT Nachwuchsbarometer) [4], confirm a significant decline in maths and science as an increasing decline in maths and science skills can be observed among school pupils in Germany, making it hardly possible for them to fulfil the demanding requirements of a STEM degree course. among schoolchildren and high dropout rates in STEM studies, which underlines the need for better preparation for university in order to counteract the shortage of skilled staff in STEM fields.

One suitable strategy could be the use of e-learning courses to compensate for the insufficient prior knowledge of prospective students before entering university and reduce drop-out rates by improving aptitude requirements. This is addressed by the online self-tests and online preparation courses from MINTFIT Hamburg.

Research methodology

This article is a case study that examines a project for preparing prospective students for a STEM degree programme. This concept is gradually adapted and optimised for practical use. It includes online tests for maths, physics, chemistry and informatics as well as supplementary e-learning units. The concept has also been iteratively adapted and optimised based on the findings from practical use and effectiveness studies.

Results

Project background

Digitalisation is progressing rapidly in the higher education sector. Innovative teaching and learning formats can be realised in STEM through the use of modern technologies. MINTFIT Hamburg is a non-commercial and open access platform that was created in a cooperative project between Hamburg's universities (as listed below) and is funded by the Hamburg's Ministry of Science and Research (Behörde für Wissenschaft, Forschung, Gleichstellung und Bezirke).

Project aims

MINTFIT aims to improve the entry requirements for a degree programme and thus the prospects of academic success through digital testing and learning opportunities [5]. The target groups are prospective students, pupils and first-year students. Up to 50 % of first-year students in STEM subjects drop out of their studies prematurely, often due to insufficient prior knowledge [6]. The

platform MINTFIT Hamburg aims to counteract these gaps in prior knowledge and the associated high drop-out rates.

Advantages of e-learning for the MINTFIT project

E-learning describes the use of digital technologies and materials for teaching and learning purposes, such as explanatory videos, podcasts, multimedia online courses or online tutorials in virtual classrooms. E-learning programmes can be used independently or as a supportive supplement to classroom teaching (blended learning). Knowledge is imparted either synchronously (simultaneously as a virtual or hybrid course) or asynchronously (time-shifted, e.g. through recorded lectures) [7]. An essential component of e-learning are online tests (summative or formative) that accompany and check the learning process or determine the entry level of learners, e.g. to provide individualised learning opportunities.

E-learning offerings create great spatial flexibility, enabling learners to participate in courses regardless of mobility or external constraints. Asynchronous formats also offer time flexibility so that learners can access their learning materials flexibly in terms of time and location. In addition, they can adapt their learning speed and the number of learning units to be completed to their individual needs and circumstances (self-directed learning) [8]. Taking individual learning needs into account breaks down barriers, counteracts under- or overload and improves learners' motivation and endurance. Hybrid formats can be a combination of face-to-face and digital offerings, but also a combination of synchronous and asynchronous components. They offer the opportunity to optimally utilise the advantages of digital learning opportunities and compensate for possible disadvantages.

In the preparatory phase, when prospective students are often not yet tied to a university or location, the advantages of the spatial (and temporal) flexibility of digital learning formats clearly outweigh those of face-to-face programmes [9]. For prospective students, this means avoidance of travelling, better compatibility with other engagements, dynamic adaptation of the learning pace to individual framework conditions and potential as well as the possibility of spontaneous participation, without fixed dates and binding registration. The MINTFIT tests and courses take advantage of the benefits of e-learning by using the asynchronous, digital format to help reduce the high drop-out rates in STEM degree programmes [10]. It enables prospective students to independently identify and compensate for any skills deficits before starting their studies.

Concept, objectives and implementation of the learning content

In order to make the transition to STEM degree programmes easier for prospective students and pupils, they are typically introduced via one of the orientation tests in mathematics, physics, chemistry and informatics in the form of an online self-assessment. This allows participants to assess their own STEM

skills. Once the test has been submitted, it is not only automatically evaluated and sample solutions are provided, but personalised learning recommendations are also generated directly, which refer to the corresponding chapters in the associated online courses. This means that gaps in knowledge can be closed by refreshing school knowledge on specific topics.

Access to the MINTFIT online offerings and the provision of information about the project takes place via websites created with Wordpress (https://www.mintfit.hamburg/). The actual e-learning programme uses the Moodle learning management system (www.moodle.org). In addition to spatial and temporal flexibility, it is important for the target group that the tests and courses can be completed anonymously, i.e. without registration, and that they are free of charge and freely available, i.e. not dependent on enrolment at a university. The contents of the tests and courses are presented below.

Subject-specific content and implementation

Mathematics was published as the first MINTFIT test already in 2015, as this subject is required as a basis for all STEM degree programmes [11]. The test comprises 54 active, randomised questions on lower and upper secondary school content as well as specific study requirements. The questions are divided into two test parts: Basic Knowledge I (lower secondary level) and Basic Knowledge II (upper secondary level). The questions are based on the catalogue of topics and the sample tasks from the so named Minimum Requirements Catalogue (Mindestanforderungskatolog) in Mathematics cosh [12]. For the learning opportunities, MINTFIT utilises offers from cooperation partners, OMB+ (https://www.ombplus.de) and viaMINT (https://viamint.de/). The tests and courses are available in German as well as in English.

The physics topics are mainly based on the Hamburg curricula for lower secondary level [13]; [14] and on the compilation of the educational plans of all federal states in the DPG study “Physics at school” [15]. 40 active, static questions were developed on the topics of mechanics, electricity, energy and optics.

The MINTFIT physics course includes content from the nationwide co-operation of the OBKP, the Hamburg education plan and follows the structure of the physics test [16]; [17]. The tests and courses are available in German as well as the offers for chemistry and computer science described in the following.

For the subject of chemistry, 40 active, static questions on topics such as the structure of matter, chemical reactions and biomolecules were also compiled for the test on the basis of educational plans from secondary levels I and II that were reviewed throughout Germany [18]. MINTFIT also offers its own chemistry preparation course [19].

As informatics is not a compulsory school subject in many federal states, no specific school knowledge can be assumed here. Therefore, the selection of topics

was based on a Germany-wide survey of computer science lecturers [20], which was used to identify the important skills and abilities for a successful start to a computer science degree programme or a computer science lecture. The 22 questions relate to general informatics topics as well as logic and programming, divided into two tests: a short teaser with 4 questions and a more detailed test with 18 questions. The implementation is a further development of the originally developed informatics test [21]. The associated informatics preparation course, which is a MINTFIT in-house development, goes into more depth on the test topics [22].

Utilization of MINTFIT e-learning

Since the start of the MINTFIT e-learning programme, user numbers have been increasing continuously. The number of web accesses exceeded the 500,000 mark for the first time in 2023. This shows a strong interest in the tests and learning materials provided for study preparation. With around 40,000 test participations in 2023, MINTFIT is the largest non-commercial provider for this area in German-speaking countries. The evaluation results show that almost 20% of test takers come from Hamburg, around 78% from the other federal states and around 2% from other EU countries [23].

The following figure visualises the number of test participations per month in 2023 for the online offerings in mathematics, physics, chemistry and informatics. The number of test participations show typical fluctuations over the course of the year. This is also the case with the access numbers, which are not shown in the figure. The study preparation offers are used particularly intensively in the months of August to November, i.e. during the admission period and the introductory phase of studies.

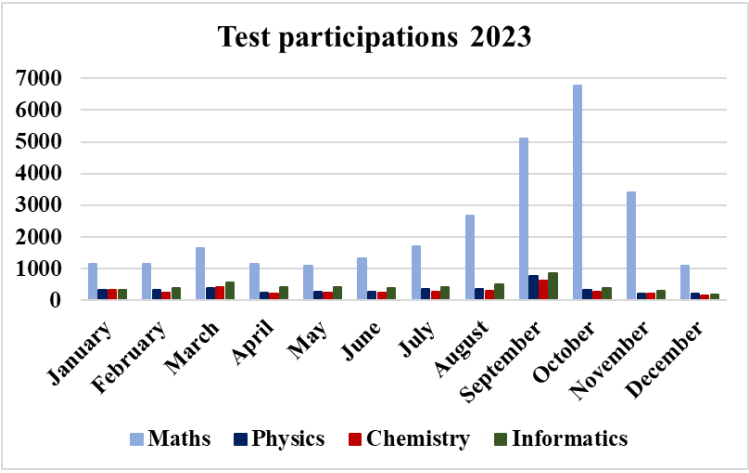

Fig. 1. Number of test participations per month in 2023 in maths, physics, chemistry and informatics (source: own figure)

The use of our own MINTFIT online courses shows a similar development since the publication of the first course in physics and a comparable annual trend. Evaluation results show that the majority of users rate the offer both positively and as appropriate in terms of level [24].

Conclusions/discussion

The previous chapters have described the successful implementation of e-learning as part of MINTFIT Hamburg. In the future, MINTFIT tests/courses could be expanded to include other subjects such as economics or biology, foreign languages, psychology, geography, etc. and their use in German-speaking countries could be further extended. It might also be useful to offer the online tests and e-learning units in English to attract international students. So far, only the math courses are available in English.

In addition, it could be helpful to offer more of the MINTFIT programmes or parts thereof to technical schools (e.g. vocational schools) in order to support preparation or teaching there.

A digital, AI-supported learning guide that is integrated into the system and creates a personalised learning plan for users could improve the user experience and strengthen loyalty to the offer, so that more intensive coursework could be achieved. In addition, a link between the existing subject areas could be achieved through appropriate automatic references, thereby increasing the depth of understanding. However, these measures require a corresponding development effort and funding.

The system could also be extended to include gamified learning elements (gamification in teaching) to further increase user motivation and engagement [25]. The MINTFIT-E learning offerings could also be extended to include other digital technologies such as virtual reality (VR) and augmented reality (AR). Virtual reality enables simulations in a virtual environment that are displayed realistically [26]. This could be used to simulate selected experiments, e.g. in physics and chemistry, or situations in professional life in which learners could practise working with complex machines, for example. Augmented reality can be used to supplement real environments with virtual information and materials [27]. AR can be used, for example, to train learners' practical skills in a real-life exercise using additional information displayed in AR glasses. Another possible addition to MINTFIT programmes would be the use of chatbots in the e-learning platform. Learners could receive technical explanations of their questions from the chatbot. Or they could ask the chatbot questions about the availability of the desired learning content in order to find it more quickly and effectively. In future, MINTFIT Hamburg will continue to work on continuously improving the online tests and e-learning units and adapting them to the needs of prospective students and potential other target groups.

Acknowledgement

MINTFIT Hamburg is a cooperative project of Hamburg's STEM universities – Hamburg University of Applied Sciences (HAW), HafenCity University Hamburg (HCU), Hamburg University of Technology (TUHH), University of Hamburg (UHH) – and the University Medical Centre Hamburg-Eppendorf (UKE) and is funded by the Hamburg Ministry of Science, Research, Equality and Districts.

References

1. **Anger**, C., **Betz**, J. & **Plünnecke**, A. (2024). MINT-Frühjahrsreport 2024: Herausforderungen der Transformation meistern, MINT-Bildung stärken. Gutachten für BDA, Gesamtmetall und MINT Zukunft schaffen. Köln: Institut der deutschen Wirtschaft Köln e. V. Available online at: https://www.iwkoeln.de/fileadmin/user_upload/Studien/Gutachten/PDF/2024/MINT-Fr%C3%BChjahrsreport_2024.pdf, last accessed: 30.05.2024.
2. **DESTATIS (2024).** Mehr als ein Drittel der Studienanfängerinnen und -anfänger im MINT-Bereich sind Frauen. Ed.: Statistisches Bundesamt, Wiesbaden, Pressemitteilung Nr. N003 vom 17. Januar 2024. Available online at: https://www.destatis.de/DE/Presse/Pressemitteilungen/2024/01/PD24_N003_213.html, last accessed: 30.05.2024.
3. **Anger**, C., **Betz**, J. & **Plünnecke**, A. (2024). MINT-Frühjahrsreport 2024: Herausforderungen der Transformation meistern, MINT-Bildung stärken. Gutachten für BDA, Gesamtmetall und MINT Zukunft schaffen. Köln: Institut der deutschen Wirtschaft Köln e. V. Available online at: https://www.iwkoeln.de/filead min/user_upload/Studien/Gutachten/PDF/2024/MINT-Fr%C3%BChjahrsreport_ 2024.pdf, last accessed: 30.05.2024.
4. **Köller**, O., **Stöcks**, P., **Fendl**, S., **Plath**, J. & **Tekhaus**, N. (2024). MINT Nachwuchsbarometer 2024. Ed.: acatech, München, und Joachim Herz Stiftung, Hamburg. Available online at: DOI https://doi.org/10.48669/aca_2024-8, last accessed: 30.05.2024.
5. **Sitzmann**, D. (2020). Fit ins Studium mit MINTFIT Hamburg – Unterstützungsangebote für ein erfolgreiches MINT-Studium und zur Senkung der Studienabbruchquote. In: Kahmann, S. & Ludwigs, S. (Ed.): So gelingt E-Learning – Reader zum Higher Education Summit 2019; Studienergebnisse und Praxisberichte zum Einsatz von E-Learning an deutschsprachigen Hochschulen. München: Pearson.
6. **Heublein**, U., **Ebert**, J., **Hutzsch**, C., **Isleib**, S., **König**, R., **Richter**, J. & **Woisch**, A. (2017). Zwischen Studienerwartungen und Studienwirklichkeit, Ursachen des Studienabbruchs, beruflicher Verbleib der Studienabbrecherinnen und Studienabbrecher und Entwicklung der Studienabbruchquote an deutschen Hochschulen, Forum Hochschule, 1|2017, DZHW, Hannover.
7. **Jensen**, C., (2022). Personalmanagement in Non-Profit-Organisationen. Besonderheiten, Rahmenbedingungen und Herausforderungen. Wiesbaden: Springer.

8. **Arnold**, P., **Kilian**, L., **Thillosen**, A. M. & **Zimmer**, G. M. (2018). Handbuch E-Learning: Lehren und Lernen mit digitalen Medien, 5th edition. Bielefeld: Bertelsmann Verlag.
9. **Arnold**, P., **Kilian**, L., **Thillosen**, A. M. & **Zimmer**, G. M. (2018). Handbuch E-Learning: Lehren und Lernen mit digitalen Medien, 5th edition. Bielefeld: Bertelsmann Verlag.
10. **Sitzmann**, D. (2020). Fit ins Studium mit MINTFIT Hamburg – Unterstützungsangebote für ein erfolgreiches MINT-Studium und zur Senkung der Studienabbruchquote. In: Kahmann, S. & Ludwigs, S. (Ed.): So gelingt E-Learning – Reader zum Higher Education Summit 2019; Studienergebnisse und Praxisberichte zum Einsatz von E-Learning an deutschsprachigen Hochschulen. München: Pearson.
11. **Barbas**, H. & **Schramm**, T. (2018). The Hamburg Online Math Test MINTFIT for Prospective Students of STEM Degree Programs. MSOR Connections, Vol 16 (3), pp. 43 – 51.
12. **cosh (Arbeitsgruppe)** (2021). Mindestanforderungskatalog Mathematik (Version 3.0). Available online at: makV3.0.pdf (cosh-mathe.de), last accessed: 30.05.2024.
13. **Freie und Hansestadt Hamburg, BSB (Ed.)** (2011). Bildungsplan, Gymnasium, Sekundarstufe I, Physik. Available online at: https://www.hamburg.de/contentblob/2373266/8c3d4d03adf8ddad189172bef45ab665/data/physik-gym-seki.pdf, last accessed: 30.05.2024.
14. **Freie und Hansestadt Hamburg, BSB (Ed.)** (2014). Bildungsplan, Stadtteilschule, Jahrgangsstufen 7-11, Physik. Available online at: https://www.hamburg.de/contentblob/4327802/aa65dc06546753a7fa47ad938a3b0192/data/physik-sts.pdf, last accessed: 30.05.2024.
15. **DPG, Eine Studie der Deutschen Physikalischen Gesellschaft e.V. (2016).** Physik in der Schule (Anhänge). Schulstudie DPG. Available online at: dpg-physik.de, last accessed: 30.05.2024.
16. **Müller**, U. C. & **Sitzmann**, D. (2019a). MINTFIT Physik: Onlineangebot zur Vorbereitung auf ein MINT-Studium. PhyDid B – Didaktik Der Physik – Beiträge Zur DPG-Frühjahrstagung. Available online at: https://ojs.dpg-physik.de/index.php/phydid-b/article/view/979, last accessed: 30.05.2024.
17. **Müller**, U.C. & **Sitzmann**, D. (2019b). MINTFIT Physics Online Diagnostic Test and E-Learning Course for Preparation of Freshmen in STEM. The 10th International Conference on Physics Teaching in Engineering Education, PTEE2019, Delft, Mai 2019. Available online at: http://sefiphysics.be/mirror_PTEE2019/proceedings/PTEE_2019_article-O11.pdf, last accessed: 30.05.2024.
18. **Meiling**, S., **Kubick**, N., **Eggers**, R. & **Sitzmann**, D. (2019). MINTFIT: Chemie-Onlinetest und -Kurs zur MINT-Studienvorbereitung am Übergang Schule-Hochschule. 4. Symposium zur Hochschullehre in den MINT-Fächern, TH Nürnberg, September 2019.
19. **Meiling**, S. (2023). Der MINTFIT-Chemiekurs: Entwicklung und Nutzung. 5. Symposium zur Hochschullehre in den MINT-Fächern, Nürnberg, 09/2023. Tagungsband zum 5. Symposium zur Hochschullehre in den MINT-Fächern (ISSN 1612-4537), pp. 82 – 89.

20. **Bender**, E., **Barbas**, H., **Hamann**, F., **Soll**, M. & **Sitzmann**, D. (2021). Fähigkeiten und Kenntnisse bei Studienanfängerinnen in der Informatik: Was erwarten die Dozentinnen? Ergebnisse einer deutschlandweiten Umfrage unter Informatik-Hochschuldozent*innen. 9. Fachtagung Hochschuldidaktik Informatik (HDI) 2021, Tagungsband, Reihe Commentarii informaticae didacticae (CID) I 13, p. 279.
21. **Sitzmann**, D., **Barbas**, H., **Soll**, M., **Hamann**, F. & **Bender**, E. (2019). Entwicklung eines Informatik-Onlinetests zur Studienvorbereitung im Projekt MINTFIT Hamburg. 4. Symposium zur Hochschullehre in den MINT-Fächern, TH Nürnberg, September 2019.
22. **Barbas**, H., **Soll**, M., **Andersen**, J., **Bender**, E., **Hamann**, F., **Haustermann**, M. & **Sitzmann**, D. (2022). The MINTFIT Computer Science Online Course. Erschienen in: IEEE German Education Conference 2022 (GeCon).
23. **Barbas**, H., **Großmann**, J., **Huelmann**, T. & **Müller**, U. (2023). Was können wir aus den Daten eines Mathematik-Onlinetests über die Nutzenden lernen? Learning Analytics im Projekt MINTFIT Hamburg. In Katharina Hombach & Heike Rundnagel (Ed.), Kompetenzen im digitalen Lehr- und Lernraum an Hochschulen (pp. 141 – 151). Bielefeld: wbv Publikation.
24. **Barbas**, H. & **Müller**, U. C. (2024). Nutzung und Nutzen des MINTFIT-Angebots: Ergebnisse einer Fragebogen- und Interviewstudie. In: Online-Self-Assessments zur Studienorientierung: Quo vadis? Aktuelle Entwicklungstrends bei ihrer Gestaltung und Nutzung, OSA-Symposium 2024.
25. **Kettler**, C. & **Kauffeld**, S. (2019). Game-based Learning. In: Kauffeld, S. & Othmer, J. (Ed.) (2019). Handbuch Innovative Lehre, pp. 249 – 253. Wiesbaden: Springer Fachmedien.
26. **Falk**, S. & **Riemensperger**, F. (2022). Digitaler Doppelpass: Wie Konkurrenz und Kooperation gemeinsam zu Wirtschaftswachstum führen. München: Redline.
27. **Croome**, C. & **Gleich**, C. (2023). Praxisbuch Metaverse: Nutzen Sie die Internet-Revolution für Ihr Unternehmen, 1st edition. Offenbach: GABAL.

About the Authors

Estella Francois graduated a master's degree in human resources management after graduating in Business Administration. During her PhD studies at ULSIT, Prof. D.Sc. Gosho Kirilov Petkov is her supervisor. She has experience in various professions for example as an entrepreneur, an onboarding manager, a research assistant. She currently works as a project manager for the digitalisation of government processes in the federal state of Hamburg. In addition to her project management tasks, she organises and holds training courses and workshops on various software systems. Prior to this, she was a research assistant at the Technical University of Hamburg in E-Assessment. Her main tasks there were to consult academic staff and provide technical support regarding the implementation of electronic examinations.

To contact the Author: Estella.Francois@gmail.com

After studying physics, **Dr Ute Carina Müller** initially conducted research in high-energy and accelerator physics at CERN (Geneva) and DESY (Hamburg) until the focus of her work shifted to the field of e-learning over 10 years ago. Her current focus is on the development and support of digital learning programmes in the STEM field at the transition from school to university as well as the use and testing of Computer Adaptive Test Systems (CAT) and other test procedures. Since completing her M.A. in Higher Education, she has also been investigating digital learning programmes in the context of learning analytics.

To contact the Author: ute.mueller@tuhh.de