Enhancing Digital Health Awareness and Mobile Health Competencies in Medical Education in Germany: Proof-of-Concept-Study and Sum-mative Process Evaluation of a Quality Improvement Project

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Fatma Sahan[1*] BSc; Lisa Guthardt[1*] MA; Karin Panitz[1] MSc; Anna Siegel-Kianer[1]; Isabel Eichhof[2] Dr rer nat; Björn D. Schmitt[2]; Jennifer Apolinario-Hagen[1] Dr rer medic

[1]Institute of Occupational, Social and Environmental Medicine Centre for Health and Society Heinrich-Heine-University Düsseldorf, Medical Faculty Düsseldorf DE
[2]Dean's Office of the Medical Faculty Startup4MED Heinrich-Heine-University Düsseldorf Düsseldorf DE
[*]these authors contributed equally

Corresponding Author:
Jennifer Apolinario-Hagen Dr rer medic
Institute of Occupational, Social and Environmental Medicine
Centre for Health and Society
Heinrich-Heine-University Düsseldorf, Medical Faculty
Moorenstr. 5
Düsseldorf
DE

Abstract

Background: In Germany, there is a need to optimize the knowledge on the digital transfor-mation in mental healthcare, including digital therapeutics (e.g., apps on prescription) in medical education. However, digital health has not yet been systematically integrated into medical cur-ricula, and is trained in relatively small number of electives. Challenges for lecturers may include the dynamic field as well as lacking guidance on how to apply innovative teaching formats for these new competencies in their routines. Quality improvement projects provide options to pilot new educational offers, as little is known about the acceptability of participatory approaches in conventional medical education.

Objective: This quality improvement study addresses this gap by introducing an elective scop-ing on app concepts designed to cultivate essential skills for future healthcare professionals.

Methods: This proof-of-concept study describes the development, optimization, implementation, and evaluation of a web-based elective on digital mental health competencies in medical education. Building on a previous face-to-face elective workshop, the content is based on a design thinking approach and focuses on the development of app concepts related to mental health. Implement-ed as part of a quality improvement project, the elective aimed to guide medical students in de-veloping app concepts using a design thinking approach at a German medical school from Janu-ary 2021 to January 2024. Topics included digital (mental) health, app selection based on quality criteria and user preferences, and critical reflection on digitization in medical practice. The elec-tive took place six times within 36 months, with continuous evaluation and iterative optimiza-tion using both process and outcome measures, such as verbal feedback and online question-naires. We present examples of app concepts designed by students and summarize the quantita-tive and qualitative evaluations reported by the students.

Results: Sixty students completed the elective and developed 25 health app concepts, most commonly including stress management and depression. In addition, disease management and prevention apps were designed for various somatic conditions, such as diabetes and chronic pain. The evalu-ation indicated a high overall satisfaction across the six courses (M = 1.70, SD = 0.68), with stu-dents valuing content, flexibility, support, and structure. While improvements in group work, submissions, and information transfer were suggested, the results underscore the effectiveness of the digital elective.

Conclusions: This quality improvement study provides insights into relevant features for the successful inte-gration of digital health education as an elective subject into a medical curriculum. Key factors for the satisfaction of students included the participatory mindset (empowerment, co-creation), focus on competencies, discussions with actual app providers, and flexibility. Future work should define learning objectives for digital health literacy and provide recommendations for integra-tion. Encouraging early engagement in digital health courses is critical, emphasizing effective implementation rather than debating the

need for digital health integration. Clinical Trial: NA

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Fatma Sahan[1*], Lisa Guthardt[1*], Karin Panitz[1], Anna Siegel-Kianer[1], Isabel Eichhof[2], Björn D. Schmitt[2], Jennifer Apolinário-Hagen[1**]

[1] Heinrich-Heine-University Düsseldorf, Medical Faculty, Institute of Occupational, Social and Environmental Medicine, Centre for Health and Society, Düsseldorf, Germany

[2] Heinrich-Heine-University Düsseldorf, Dean's Office of the Medical Faculty, Startup4MED, Düsseldorf, Germany

*Shared first-authorship
**corresponding author:

Correspondence:
Dr. Jennifer Apolinário-Hagen
E-mail: Jennifer.apolinario.hagen@uni-duesseldorf.de

Abstract

Background: In Germany, there is a need to optimize the knowledge on the digital transformation in mental healthcare, including digital therapeutics (e.g., apps on prescription) in medical education. However, digital health has not yet been systematically integrated into medical curricula, and is trained in relatively small number of electives. Challenges for lecturers may include the dynamic field as well as lacking guidance on how to apply innovative teaching formats for these new competencies in their routines. Quality improvement projects provide options to pilot new educational offers, as little is known about the acceptability of participatory approaches in conventional medical education.

Objective: This quality improvement study addresses this gap by introducing an elective scoping on app concepts designed to cultivate essential skills for future healthcare professionals.

Methods: This proof-of-concept study describes the development, optimization, implementation, and evaluation of a web-based elective on digital (mental) health competencies in medical education. Building on a previous on-site elective workshop, the content of the presented novel web-based elective is based on a design thinking approach and focuses on the development of health app concepts. Implemented as part of a quality improvement project, the elective aimed to guide medical students in developing app concepts using a design thinking approach at a German medical school from January 2021 to January 2024. Topics included digital (mental) health, app selection based on quality criteria and user

preferences, and critical reflection on digitization in medical practice. The elective took place six times within 36 months, with continuous evaluation and iterative optimization using both process and outcome measures, such as verbal feedback and online questionnaires. We present examples of app concepts designed by students and summarize the quantitative and qualitative evaluations reported by the students.

Results: Sixty students completed the elective and developed 25 health app concepts, most commonly including stress management and depression. In addition, disease management and prevention apps were designed for various somatic conditions, such as diabetes and chronic pain. The evaluation indicated a high overall satisfaction across the six courses (M = 1.70, SD = 0.68), with students valuing content, flexibility, support, and structure. While improvements in group work, submissions, and information transfer were suggested, the results underscore the effectiveness of the digital elective.

Conclusions: This quality improvement study provides insights into relevant features for the successful integration of digital health education as an elective subject into a medical curriculum. Key factors for the satisfaction of students included the participatory mindset (empowerment, co-creation), focus on competencies, discussions with actual app providers, and flexibility. Future work should define learning objectives for digital health literacy and provide recommendations for integration. Encouraging early engagement in digital health courses is critical, emphasizing effective implementation rather than debating the need for digital health integration.

Keywords: medical students, digital health, design thinking, digital health literacy, medical education, digital health competencies

Introduction

Initiated by the slow digital transformation of the German healthcare system, health policy passed the Digital Healthcare Act in December 2019, which made it possible to prescribe certain medical apps [1]. Since then, topics related to medical informatics, digital health and telemedicine have started to appear more and more in the curriculum of some German medical schools, mostly through few electives rather than compulsory subjects, though [2,3]. As digital health is a highly complex, dynamic field that constantly changes and advances, and that has rarely been implemented into medical curricula yet [4,5], it seems to be necessary to compile and establish designated novel teaching formats that focus on the different subtopics like digital mental health interventions (DMHIs), e.g., mobile health apps for dealing with depressive symptoms or managing study-related stress.

Digital mental health literacy, as well as competencies, becomes more and more important for (future) health professionals and medical education. It can be defined as “the degree to which individuals obtain, process, and understand basic mental health information and services needed to aid their recognition, management, or prevention of mental health issues” [6]. Even though younger generations are often supposed to be familiar with digitization and corresponding competencies, research showed that medical students did not feel adequately prepared for digitization in their course of study [2,3,7,8].

Prior studies found that medical students perceive a lack of digital literacy [9] and know little about available digital mental health interventions [10,11]. At the same time, mental disorders have relatively high prevalence rates among the general population (i.e., around 27.8 % of the general German population suffer from a mental disorder [12], around 20 % of the German

population are affected by depressive symptoms [13], a general decline of mental health in the last year [14]) and digital interventions could offer additional treatment and prevention options [15]. A systematic review and meta-analysis demonstrated that pooled depression prevalence among medical students worldwide was 37.9 % [16]. DMHIs are especially relevant for medical students because students are less likely to seek psychological help (due to barriers like fear of stigmatization or lack of awareness) on the one hand [17]. On the other hand, they themselves will eventually treat patients with (mental) health issues and may prescribe and use telemedicine, including digital health applications (German DiGA, "Digitale Gesundheitsanwendung"), as future physicians [18].

Since October 2020, physicians and psychotherapists can prescribe DiGA that are listed in the DiGA register by the German Federal Institute for Drugs and Medical Devices (Bundesinstitut für Arzneimittel und Medizinprodukte; BfArM), including different DMHIs for mental disorders, on the expense of statutory health insurance companies [1]. DiGA are certified medical products mainly based on digital technologies that can be used to detect, surveille, treat or mitigate diseases, injuries or disabilities [19]. Goals of DiGA include the monitoring and improvement of current treatments in patient care. In the face of aging societies and the rise of chronic diseases, developed industrial nations are confronted with rising health care costs. Digital healthcare and digital self-care practices are therefore linked to efforts to better prevent disease, calculate disease risks and life expectancy through algorithm-based personalized medicine, and at the same time delegate clinical treatment responsibilities to the affected individuals themselves [20]. The potential of digital therapeutics or DiGA in particular to improve the uptake of healthcare services is not fully exploited yet, and the uptake is relatively low compared to prevalence rates [21]. In preventive medicine and disease monitoring, digital interventions could improve patients' health and personal motivation [22]. In addition, digital data collection promises to optimize processes and increase the efficiency of the healthcare system on an institutional basis [20].

Studies have shown that physicians are open to the idea of DiGA [21], but the current prescription rates of DIGA are low with around 203,000 DiGA prescribed or granted by health insurances in Germany [23]. Physicians in a mixed-methods study described that they were skeptical, e.g., due to technical insecurities, and said they missed adequate information sources on how to prescribe DiGA and how to guide and advise patients concerning the usage [19]. From a patient perspective, there is a clear interest in digital health as well. A recent German study on health app acceptance found that 76 % of participants, including those without prior app experience, expressed willingness to use DiGA [18]. Information measures can effectively increase acceptance of quality-assured digital health services among health care providers and patients [24]. To address the knowledge gap and enhance digital health competencies, practicing physicians are considering continuing education opportunities [21].

However, digital health literacy, as well as competencies, or the acquisition of knowledge on DMHIs, including DiGA for the treatment of mental disorders and the management of chronic conditions, need to be part of the curriculum, which could be piloted in elective subjects in medical schools. To the best of our knowledge, there are only few studies concerning the teaching of digital health and digital competencies in German medical schools. Thus, little is known about strategies to implement such new teaching offers in medical education. In one

study, a total of 16 universities in Germany were identified that had included digital skills in their curricula (17 elective and 8 compulsory courses) [2]. For example, a study investigated the impact of an interdisciplinary and cross-faculty course concerning digital medicine with the help of an online questionnaire before the course and afterwards [3]. Aulenkamp et al. [2] found a positive impact of such courses on the students' digital competencies and concluded that more efforts to integrate them in the curriculum would be necessary. One comparative study examined the implementation of a module on digital health among undergraduate medical students at a German university, the knowledge gain of students, and their attitudes towards digital health, and suggested a firm implementation of digital competencies into medical education [25]. Another German study examined interdisciplinary teaching with the help of teaching teams of medical informatics professionals and physicians: In different academic years, new seminars on digital competencies were designed and implemented, and the usefulness of interdisciplinary teaching teams was shown [26]. Further studies covered the integration of an elective on digital health in diabetes for pharmacy students [27] or the design, implementation, and evaluation of a course with a focus on telemedical components [28].

Overall, it is essential to permanently integrate digital health education into the curricula of medical schools [29,30]. Practical, competence-oriented didactic concepts offer promising strategies to enhance knowledge transfer and enable students to proficiently handle DMHIs and health apps.

Goals of the Quality Improvement Project and the Case Study

The overarching objective of the quality improvement project was to develop and iteratively optimize an innovative learning and teaching offer for medical students based on their preferences and needs in a German medical school. The goals were targeted by an elective subject.

The elective subject in this present proof-of-concept study aimed to provide students with basic knowledge and practical skills and to promote a comprehensive understanding of designing concepts for digital health interventions in prevention and therapy with the potential user in mind. The focus of the elective was on digital health competencies in the field of mental health, the use of DMHIs in occupational and social medicine, especially in the area of primary prevention (e.g., stress management), and DiGA for somatic and mental diseases based on their choices.

Our proof-of-concept study on quality improvement in medical education is meant to provide insights into the piloting of an innovative digital elective subject concerning the development of theoretical prototypes for digital mental health interventions. We aimed to evaluate the implementation and realization of the elective subject using a design thinking process and to analyze students' feedback, ideas, and preferences concerning the competence-based education on mental health apps ("learning by doing" and co-creating).

Methods

Setting and background of teaching innovation

The focus of the innovative teaching offer at a German medical school was on digital mental

health in areas of application relevant to prevention and healthcare settings, quality criteria of mobile health apps, legal framework, including structural conditions for telemedicine (e.g., so-called Digital Healthcare Act, prescription of DiGA), and user-oriented app design (e.g., persuasive design [31]). The elective also aimed to promote knowledge of app development, self-competence, collaborative learning (co-development of an app concept in small student groups, according to the prominent design thinking approach by the Hasso-Plattner Institute [32]) as well as critical reflection on the opportunities and risks of digitalization for health professionals. The main target group were medical students, but due to the interdisciplinary nature of health app development, we allowed a small number of students from other disciplines to also participate.

Quality improvement project

The project was divided in two parts: the quality improvement project including funding (24 months) and the implementation of the web-based elective into the curriculum after the pilot project (12 months). The quality improvement project took place for 24 months from January 1, 2021, to December 31, 2022, at the Medical Faculty of Heinrich-Heine-University Düsseldorf (HHU) in Germany. We offered the digital elective six times within three years. The concept was based on a predecessor elective subject in terms of a co-design workshop on digital mental health literacy in medical studies, which we conducted on-campus with n = 26 medical students in March 2020, as described in sufficient detail by Dederichs et al. [8]. Here, medical students developed theoretical prototypes of health apps in small groups, using appropriate background knowledge and the established 5-step design thinking principle [33]. The students gave us feedback and indicated that they would have liked more flexibility, online content, and additional guest lectures, which is why we developed the idea of a digital or hybrid implementation of the seminar (blended learning approach) [8]. The corresponding author conceived the project idea and acquired funding for an innovative educational project by the Quality Improvement Commission of the Dean' Office of the Faculty of Medicine in fall 2020. In January 2021, we prepared the digital elective "Fit for digitalization and 'apps on prescription'? – Understanding digital health applications and developing digital health offers such as health apps" for the summer semester 2021. Medical students were able to take the elective subject with two semester hours per week. Over time, we also extended the elective to students from other fields if there were enough available openings. This was achieved either in the framework of "studium universale" or as a psychology minor, including credit points for active participation. Finally, the following 12 months (01/2023-01/2024) were used to implement the project into medical education practice without additional staff, which required some adaptations, including providing a screen cast on mockup creating using the collaborative design tool Figma instead of personal assistance for each group.

Structure and composition of the elective

We varied the elective either as an intensive block course (5 consecutive days, full time during the lecture time, provided once) or as weekly seminars (7 times, part time during the lecture-free time, provided 5 times), equating a time effort of two semester hours for both concepts.

For more intensive support, we increased the proportion of synchronous live lectures after the first run in 2021. In addition, students were able to access the content (e.g., presentations) and additional material via the web-based Learning Management System ILIAS (ILIAS open-source e-Learning e. V., Cologne, Germany). Students could request feedback on their group work via ILIAS. We refined the ILIAS environment steadily to ensure its immediacy and to meet students´ preferences.

The focus was on competence-oriented learning and participatory design approaches: The acquired knowledge about health apps was directly transferred into a concrete app concept in the group work. In creating the group assignments, we were guided by the concept of design thinking and its phases for developing an app. Design thinking is an iterative, user-centered approach to innovation and problem solving. This framework emphasizes the comprehensive analysis and understanding of human needs to generate original approaches to solving complex problems [31–33]. The process, which typically involves multiple stages, includes understanding the problem, carefully eliciting user-specific requirements, generating ideas, creating prototypes, and testing solutions (see figure 1).

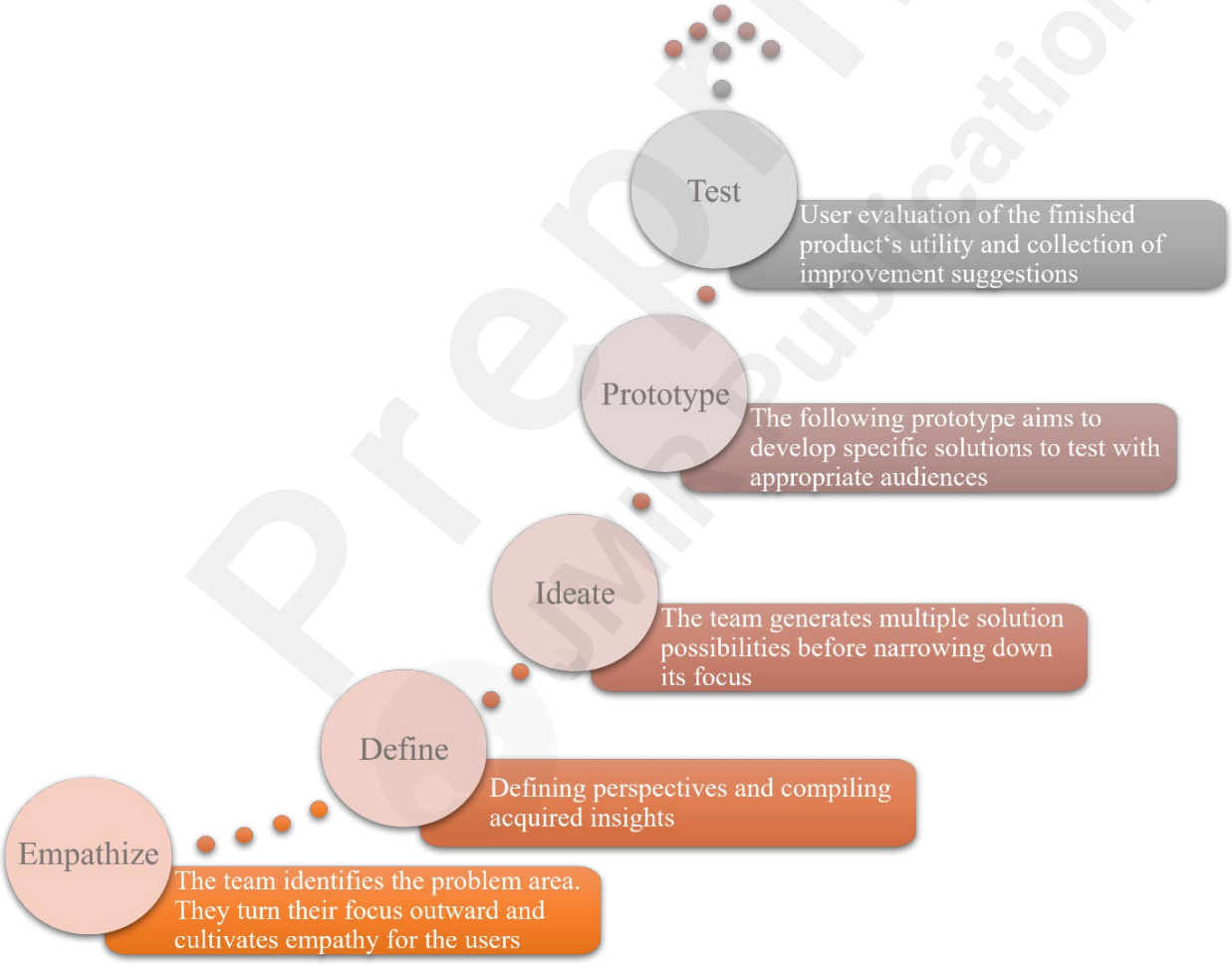


Figure 1. A simplified explanation of the five stages of design thinking (based on [31]).

The elective included an introductory session at the beginning of the semester, which introduced the procedure, contents, and objectives and brought students together in small groups with different app topics (e.g., insomnia). First content-related issues were also covered

(e.g., definitions, fields of application). In lessons 2-5, the students were given a group task aligned with the content of the lessons and a design thinking process, which systematically guided them in hypothetical app development.
The detailed description of the structure of the elective can be found in Table 1.

Table 1. Lessons and main contents of the elective.

Session	**Main Topic**	**Contents**
1	Organizational matters, Introduction	- Overview and examination - Presentation of group results (app concepts) from previous semesters - Introduction: working definition of digital mental health - Areas of application - Support with digital health interventions - Evidence of e-mental-health - Telemedicine and digital health in occupational medicine - Division into small groups for the development of own app concepts, introducing tools for group work - First introduction to design thinking - Option of test access to DiGA (GAIA AG)
2	Quality criteria of health apps	- Description of quality seals for health apps - Description of quality principles - Presentation of the DiGA register - Quality measurement using the "Mobile Application Rating Scala (MARS)" [34], German version [35] - Presentation of the search for quality-assessed health apps/e-mental health interventions - Presentation of an app (e.g., blood pressure app *Manoa*) - Group work
3	Digital health application (DiGA) – "apps on prescription"	- Regulation of the apps listed in the DiGA directory - Acceptance and use of DiGA - Various guest lectures on mental health DiGA (e.g., DiGA *somnio, deprexis, elona therapy depression*, *velibra*) - Guest lecture *ReHappy* (former stroke DiGA), including screencast - Group work
4	Design thinking and persuasive design (app development)	- Description of the phases of the design thinking process - Presentation of concept mapping - Teaching in persuasive design and persuasive design in mental health apps - Discussion on ideate/idea generation - Incentives for managing successful apps

		- Group work
5	Strategies to promote acceptance and adherence	- Measures to promote user adherence and motivation by communicating acceptance models such as the Unified Theory of Acceptance and Use of Technology (UTAUT) and UTAUT2, adapted to digital health [36,37]. - Presentation of usability in health apps, e.g., via "System Usability Scale (SUS)" [38] - Description of gamification approaches for health apps - Presentation on promoting acceptance through information - Description of the distinction between health and medical apps as well as trusted health apps - Group work
6	Finish for the final presentation	- Explaining peer feedback - Guest lecture Startup4MED, HHU (each semester) - Tips for the final presentations and peer feedback - Group work
7	Final presentation of the group work	- Lecture: Summary, plus current developments and perspectives - Presentation of the developed app concepts in small groups - Feedback, evaluation of the elective

Notes. Detailed description of the elective structure (session 1 to 7). The contents partly varied across the semesters based on expert availability (DiGA providers) and adaptations made following the evaluation results of the former semester. Abbreviations: DiGA = digital health applications, HHU = Heinrich-Heine-University Düsseldorf (Germany), MARS = Mobile Application Rating Scala; SUS = System Usability Scale; UTAUT = Unified Theory of Acceptance and Use of Technology, UTAUT2 = extension of the UTAUT to the consumer context.

Practical transfer through the integration of guest lectures and test access

We provided students with selected guest lectures by experts who created, provided, or presented DiGA to the professional community (e.g., somnio, velibra, elona therapy depression). Additionally, at the end of the course we hosted lectures from staff members of the medical specific start-up support unit "Startup4MED". "Startup4MED" is the internal start-up support unit of the University Medicine Düsseldorf and identifies, promotes, and supports the commercial exploitation of innovative medical projects from the Medical Faculty of the HHU and the University Hospital Düsseldorf. This allowed participants to connect with the start-up support team for extra guidance on their ideas and on how to implement their app concepts into practice.

Each semester, students had the opportunity to attend between one and three guest lectures, some of which were recorded as screencasts and uploaded online. Additionally, students were given the chance to try free demo versions of various DiGA through a trial program sponsored by a German company in 2021 and 2022 (GAIA AG, Hamburg).

Student support and competence-oriented performance recording

During their elective, students received comprehensive assistance through multiple media and communication channels that aligned with their individual preferences. These channels comprised Rocket Chat, an open-source team chat platform, as well as Microsoft Teams. To reinforce their learning process, the participants were assigned concise, structured tasks following every session, and the completion of these tasks was monitored by the project team. We also offered personalized feedback and guidance beyond the group feedback each week upon completion of tasks uploaded using ILIAS on demand. Throughout the design thinking process, students were gradually introduced to the app concept in a systematic manner. This approach aimed to promote collaboration, reduce inhibitions to reach out, and provide students with more flexibility. In the last session of the elective, student groups presented their developed app concepts to their instructors and peers and received feedback. Optionally, assessment could be completed as an exam. Finally, the students were instructed to evaluate the elective through an online survey provided by “evasys” (evasys GmbH, Lüneburg, Germany).

Evaluation

In addition to the oral feedback in the last session, we used an online evaluation questionnaire created with templates provided by the Dean’s Office (Department of Evaluation, Medical Faculty). The questionnaire, implemented with “evasys” (avasys GmbH, Lüneburg, Germany), included standardized questions for digital teaching offers and was completed by students online after finishing the course. Participation was voluntary, and thus we tried to increase it by sending reminders. In the first part of the questionnaire, we asked students to provide information about their gender and their field of study. In the second part of the questionnaire, we asked students to rate the module using 19 questions. The first 13 were answerable on a 6-point Likert scale ranging from 1 (“completely agree”) to 6 (“do not agree at all”). These questions concerned the content of the elective as well as the visualization and access to ILIAS, such as “The learning module was well structured”. Finally, we assessed the perceived difficulty level of the learning material, overall satisfaction with the elective (both in general and regarding digital implementation) and own estimated learning gains after completing the elective.

Three additional questions dealt with the difficulty of the learning content, the scope of learning and reading material, and the assessment of particularly helpful elements in the course (5 response options, e.g., text units, screencasts). The last three questions served as feedback and were asked in the form of open questions, e.g., what students liked most about the course, in which competence area they benefited most, and which suggestions for improvement they had. The evaluation was centralized and anonymized by the Dean’s Office. Results were accessible from a minimum of five surveys. Following the completion of the elective in the summer semester of 2021, the questionnaire was revised and employed in the subsequent courses (see Table 3). We further analyzed quantitative data from the elective descriptively (means, proportions, etc.) and summarized qualitative data (commentary fields) using Excel (Microsoft, Redmond, Washington, United States) and SPSS, version 27.0 (IBM Analytics, Armonk, New York, United States). Answers and commentaries to the open-ended

questions were analyzed using MAXQDA 2020 (VERBI Software, Berlin, Germany). We then formed categories both deductively based on our questionnaire and inductively from the material. The preliminary code system was discussed, revised and agreed on. To gather the anonymized feedback via the evaluation team of the Dean's Office, we did not require an ethical approval. In addition, we asked all participants for their consent to present the results of the elective subject as well as their feedback after completing the course in publications. Students gave their consent to present the described app concepts in this article.

Results

Sample Characteristics

A total of $N = 75$ students (women: 60 %, 45/75) from the University of Düsseldorf registered for the elective in six seminars over three years (2021-2024), i.e. five semesters (no elective in summer 2023 due to parental leave of the project lead). Of these, 72 % (54/75) were medical students (with a semester range from 3 to 11, Mdn = 5), 12 % (9/75) were psychology students (bachelor's program, semester range from 5 to 21, Mdn = 7), and 4 % (3/75) economics students (bachelor's program, semester range 7 to 16, Mdn = 9). Additionally, one person studied business administration (bachelor's program, semester 1), four were biology bachelor students (semester range 5 to 13, M = 9.50, SD = 2.96, one person each was a student of art history (semester 17), philosophy (semester 9), or medical physics (semester 7; bachelor's program each case), and one was a biology master student (semester 1). Overall, 15 students dropped out of the elective, mainly prior to its start, as they did not attend the first session. The remaining 60 students (80 %) successfully finished the elective (including course achievement). Of these $n = 60$ students (women: 60 %, 36/60), almost 77 % (46/60) were medical students (semester range from 3 to 11, Mdn = 5), 15 % (9/60) were psychology students (bachelor's program, statistical data as above), and slightly more than 8 % (5/60) studied one of the subjects above (2 economics, semester range 9 to 16, Mdn = 12.5; one each biology bachelor's program, semester 13; art history; biology master's program).

Insights into common themes and app development from the sessions and group discussions

According to individual preferences, students focused on both mental health promotion as well as dealing with mental and somatic diseases in the hypothetical app development, but for this case study we will only report some examples of health apps. After the first round of the elective, the scope was expanded beyond DMHIs in the course description for upcoming electives in order to better meet the preferences of more medical students. Overall, 25 projects were finished and presented, 10 of which covered somatic and 15 mental health conditions or indications. Table 2 shows an overview of all app concepts developed by the students in the different semesters.

Table 2. Overview of the different app concepts in each semester, partly translated into English.

No.	Topic/indication of the app	Target group/ population	Name of the App Concept	Course/ semester
1	Chronic conditions/diabetes	Patients (adults)	My Diabetes Pass	SS 21
2	Learning support/self-	Pupils, students	Studytime	SS 21

	management/stress management			
3	Resilience promotion	Young people in education	Mental Power	SS 21
4	Stress reduction	Students	MeTime	WS 21/22
5	Musculosceletal diseases/pain	Patients (rather adults)	legLos („getStarted“)	WS 21/22
6	Sleep disturbances/insomnia	Patients (children 3-12 years)	Morpheus goes to sleep	WS 21/22
7	Depression/depressive symptoms	Patients (13-25 years)	Dinotherapy	WS 21/22
8	Gastroesophageal reflux disease	Patients (+40 years)	StopGERD	WS 21/22
9	Breast cancer	Patients (adult Females)	BRUHNO	WS 21/22 intensive block
10	Stress reduction/exam anxiety	Students, trainees (15-30 years)	Companion	WS 21/22 intensive block
11	Glioblastoma	Patients (50-70 years)	GlioblAPP	WS 21/22 intensive block
12	Stress reduction/stress prevention	Company employees (i.e. finance sector)	Stress Cutter	WS 21/22 intensive block
13	Back problems/pain	Patients (18-60 years)	Backfit	SS 22
14	Eating disorders	Patients (i.e., anorexia nervosa)	Provida	SS 22
15	Hypertension/blood pressure problems	Patients (mainly adults +50 years)	Eutonia	SS 22
16	Stress management after rehabilitation	Patients (adults)	iGrow	WS 22/23
17	Blood pressure problems/arterial hypertension	Patients, risk groups (adults)	Tonus	WS 22/23
18	Sleep disturbance in Depression/burnout	Patients (adults, rather 35-45 years)	Happy Sleeper	WS 22/23
19	Exam anxiety	Students (18-25 years)	Exam Anxiety	WS 22/23
20	Skin diseases	Patients (children, adults)	DermaDiary	WS 23/24
21	PMS/PMDD/self-management	Patients (mainly Females 18-30 years)	ZenCycle	WS 23/24
22	Self-management/ (emotional) self-regulation	Primary school children (their quardians)	MaxiKids	WS 23/24

23	Stress management	Students	UniRelax	WS 23/24
24	Resilience promotion	Healthcare staff/nurses (16-64 years)	Pflege-Care	WS 23/24
25	Depression/depressive symptoms	Patients (adults)	Livetta	WS 23/24

Notes. Abbreviations: PMS = premenstrual syndrome, PMDD = premenstrual dysphoric disorder, SS = summer semester, WS = winter semester.

The following main topics occurred in the prototypes of the apps: exam anxiety in students, stress management, resilience, insomnia and sleep disturbances in children and adolescents, and depression in youths and young adults as themes for mental health apps, with some frequently chosen topics (esp. stress management). Furthermore, various disease management or prevention apps for somatic conditions were conceptualized (breast cancer, diabetes, stroke and arterial hypertonia, reflux disease, musculoskeletal diseases, glioblastoma, skin diseases, and premenstrual syndrome). Recurring app topics among different electives were stress, exam anxiety and stress-inducing learning behavior regarding procrastination as well as depression and anxiety.

In the context of app development, the students systematically applied the knowledge they had learned in the elective subject, considering various aspects, guided each week on different aspects by the elective's team (5 steps of design thinking [31,33]). The topics which students emphasized most often in their presentations of their app concepts included target group-specific information (e.g., prevalence rates, relevance of the app for healthcare), usability, features of persuasive design including gamification, accessibility, and the promotion of adherence (e.g., through reward systems, gamification, provision of human support, cost reimbursement), which we will illustrate with suitable case examples in the following paragraph. The featured functionalities varied depending on the selected app concept. For apps related to disease management, students often incorporated symptom diaries, reminders about medications or doctor's appointments, and educational resources about the respective illness. In contrast, apps aimed at stress management during learning focused mainly on structuring daily routines, relaxation, and avoiding procrastinating behaviors. An example of this would be the ability to lock smartphones for a set period of time. Most app prototypes included considerations for integrating professional guidance (e.g., via chat functions). These chat functions either established contact with professionals or facilitated communication among user groups.

Case examples: app development and concepts

In the following section, several app prototypes that were developed by student groups will be presented. All prototypes chosen for this paper serve as comprehensive and visually clear examples for app concepts. All design samples, images, and the creative theoretical work belong to the students and cannot be used without their permission.

- *Morpheus geht schlafen (Morpheus goes to sleep)* as an app for sleep disturbances in children; a group of two students (n = 2, 100 % female) created this app concept to improve sleep hygiene and facilitate falling asleep for children. In Textbox 1, the app, its

design, and implementation are described in detail. Figure 2 visualizes the app concept.

Textbox 1. App concept for „*Morpheus geht schlafen*“.

Figure 2. Mock-ups of the app *Morpheus geht schlafen* Top left*:* welcome screen. Top right/bottom left: choice of the customizable companion (animal or human). Bottom right: assessment of individual well-being.

- *Bruhno – Brustkrebs Helfer für Nebenwirkungen und Organisation (Breast cancer helper for side effects and organization)* as a companion app for female patients with breast

cancer; a group of two students (n = 2, 100 % female) created this app concept to support women in systemic therapy and aftercare. In Textbox 2, the app, its design, and implementation are described in detail. Figure 3 visualizes the app concept (additional prototypes, figures 3a-b, see Multimedia-Appendix).

Textbox 2. App concept for *Bruhno*.

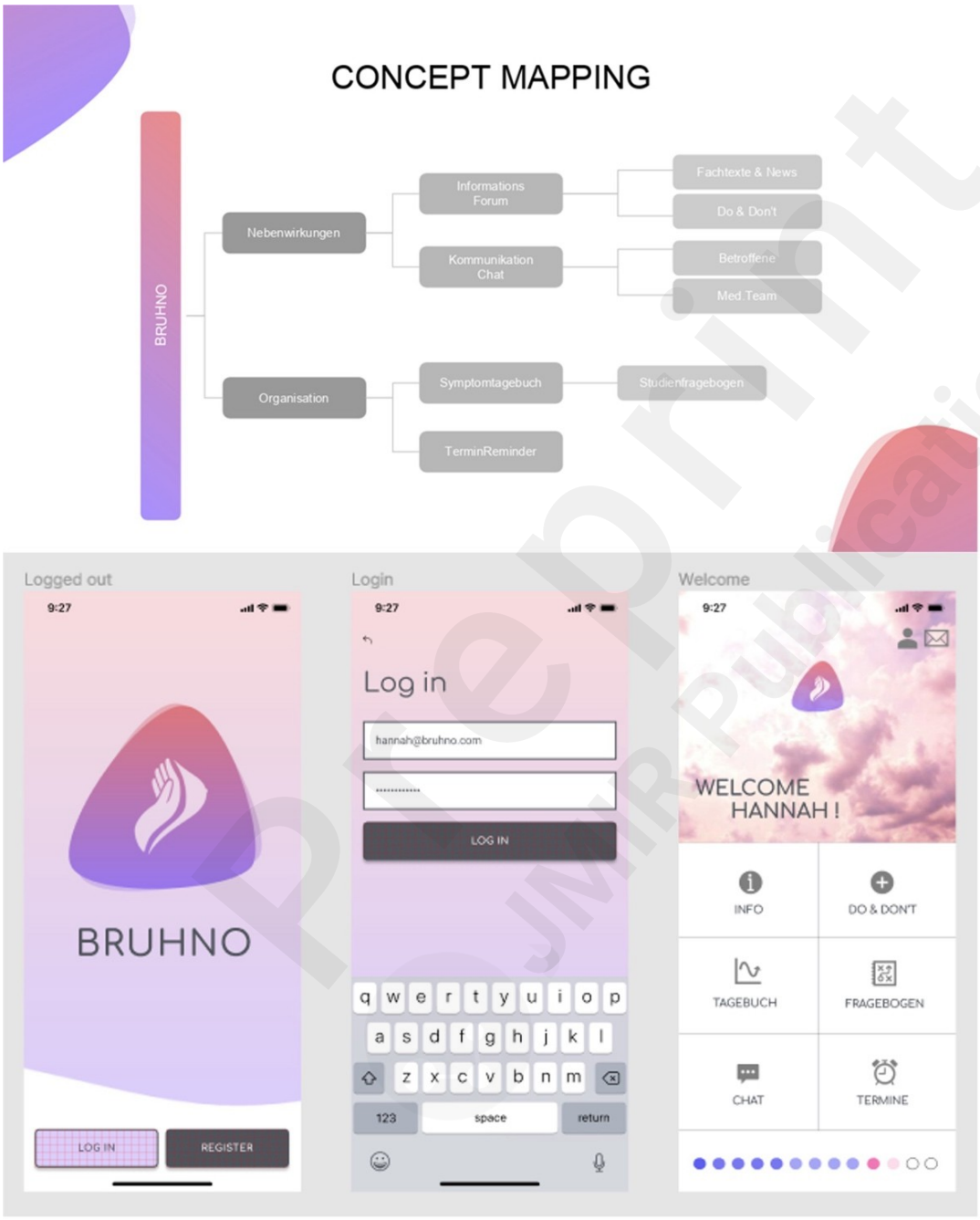
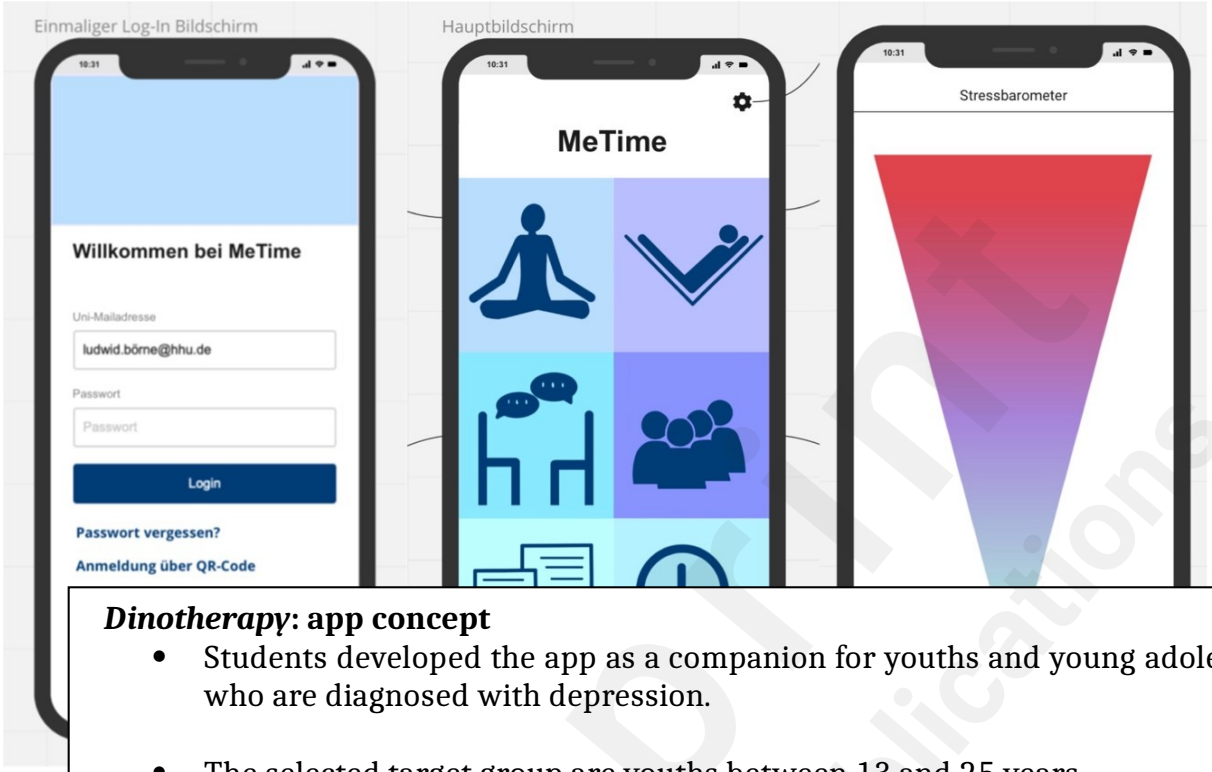


Figure 3. Above: Concept mapping for the mock-up app *Bruhno* as developed by the students. Below: Mock-up of the app *Bruhno*: Logo, logout, login, and welcome screen.

- *MeTime* as an app for stress reduction in students; a group of three students (n = 3, 67 % female) created this app concept to promote relaxation in students. In Textbox 3, the app, its design, and implementation are described in detail. Figure 4 visualizes the

app concept (additional prototypes, figures 4a-b, see Multimedia-Appendix).

Textbox 3. App concept for *MeTime*.



***Dinotherapy*: app concept**

- Students developed the app as a companion for youths and young adolescents who are diagnosed with depression.
- The selected target group are youths between 13 and 25 years.
- The app combines playful mediation of psychoeducation with practical tasks and uses dinos as protagonists, identification figures, and “virtual pets”.
- According to the students the app has different goals: 1.) development of knowledge and understanding of the disease – “depression as a disease”, 2.) continuous tracking of the course of the depression, 3.) establishing activities and fixed rituals that will have a beneficial effect on the course of the depression, 4.) social exchange with other persons affected via the app.
- Students said that a link between the accounts of the patient and doctor or psychotherapists responsible can be possible. This way, the attending person could set priorities, assign patients to each other as peers, and can specifically be informed if depression values fall below a critical threshold in case, for example, if there is a suicidal risk.
- To promote adherence students thought of self-monitoring (tracking with short, daily questions), a visual presentation of the course of depression, tailoring and personalization of tasks and contents, rehearsals/reminders, appraisal and points for each completed task that can be used for the dino, the “virtual pet” as well as peer interaction.
- The design of the dinos is also meant to promote adherence and should be appealing for the selected target group.
- The following functions were included by the students: 1.) surveys (TRACK), 2.) comics (EDUCATE), 3.) tasks (ACT), 4.) interaction (EXCHANGE), and 5.) INTERVENT.

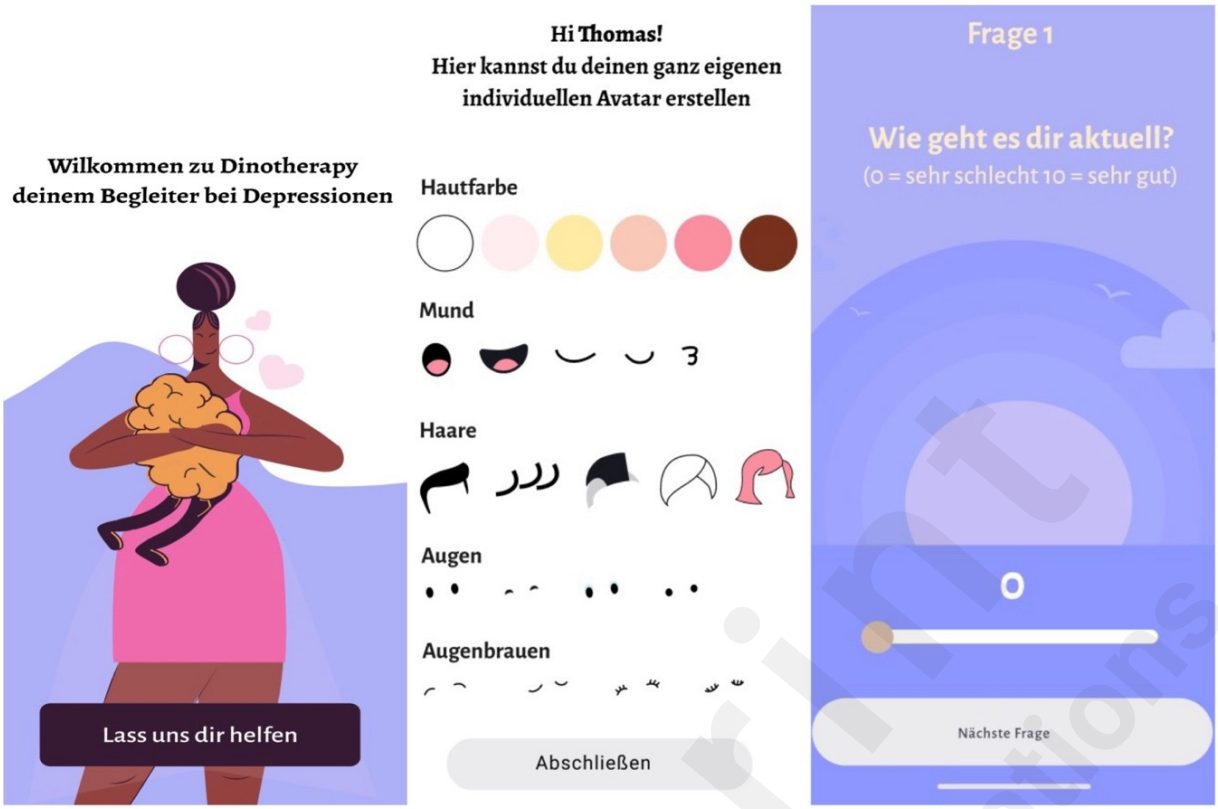


Figure 5. Mock-ups of the app *Dinotherapy*. Left: welcome screen (vivid user interface to create positive user experience). Middle: options for your individual, customizable avatar/companion. Right: questionnaire to assess the user's mood.

- *Companion* as an app to reduce stress and exam anxiety and enhance support for students and trainees; a group of two students (n = 2, 100 % female) created this app concept to accompany the target group in the course of the study and in vocational training. In Textbox 5, the app, its design, and implementation are described in detail. Figure 6 visualizes the app concept (additional prototypes, figures 6a-b, see Multimedia-Appendix).

Textbox 5. App concept for *Companion*.

Figure 6. Mock-ups of the app *Companion*. Left: welcome screen, current level, functions, and the customizable pet. Right: selection of tasks/activities for breaks.

The theoretical prototypes developed as part of the elective course were designed with a strong practical orientation and regard to applicable national requirements for medical devices. This opens up the possibility of using the products designed in the course in the inpatient or outpatient medical sector in the future.

Student groups of *Bruhno* and *Dinotherapy* approached "Startup4MED" with their ideas concerning the app concepts. Together with the start-up support unit, the students were given the opportunity to plan and work on the transfer of their theoretical prototypes into practice. For this purpose, next steps, analyses of marketability and customer needs as well as financial requirements were examined in individual consultation sessions. In order to address the financial requirements for further development of the concepts and their implementation into initial prototypes, suitable funding was identified, and the application process supported. Providing contact with founders of successful medical start-ups, additional team members, and mentors from the "Startup4MED" network further aimed to achieve translation of theory into practice.

The app concepts developed during the course showed valuable potential for founding their own start-ups and generating future-oriented innovations in the field of mental health. In addition, combining education and training in the field of digital health and the practical application of the designed products can thus make an important contribution to sustainable benefits in the field of innovation.

Evaluation and Suggestions for Improvement

Quantitative Results – Questionnaires

Students were asked to complete a questionnaire that had been designed by the research team in order to assess the elective and to receive suggestions for further improvement. To ensure comparability between the individual semesters, a basic average for each semester from all

questionnaires submitted per elective was calculated (a total of six seminars within five semesters). Overall, n = 44 of n = 60 students (73.3 %) completed the evaluation survey.
Table 3 shows the results of the different items of the questionnaires for each semester. Figures 7-8 display the perceived learning gain and the evaluation of the elective overall (additional results for the satisfaction with the module as well as the evaluation of the digitalization, figures 9-10, see Multimedia-Appendix).

Table 3. Items collected from the evaluation questionnaire, including means and standard deviations per course.

Items from the evaluation questionnaire	**Course**					
	SS 21	WS 21/22	WS 21/22 Block	SS 22	WS 22/23	WS 23/24
	n[a] = 5	n = 11	n = 9	n = 5	n = 5	n = 9
Overall assessment of the elective	M = 1.50, SD = 0.50	M = 1.70, SD = 0.80	M = 2.40, SD = 1.10	M = 1.30, SD = 0.40	M = 1.50, SD = 0.50	M = 1.80, SD = 0.80
Digital implementation	M = 1.70, SD = 0.80	M = 1.70, SD = 1.10	M = 1.80, SD = 0.70	M = 1.20, SD = 0.30	M = 1.40, SD = 0.60	M = 1.60, SD = 0.70
The learning module was well structured.	M = 1.60, SD = 0.50	M = 1.50, SD = 0.70	M = 1.60, SD = 0.70	M = 1.00, SD = 0.00	M = 1.00, SD = 0.00	M = 1.90, SD = 0.90
The content was made easy to understand.	M = 1.20, SD = 0.40	M = 1.60, SD = 0.90	M = 1.80, SD = 0.80	M = 1.00, SD = 0.00	M = 1.40 SD = 0.50	M = 1.30, SD = 0.50
The distinction between crucial information and insignificant particulars became evident.	M = 2.00, SD = 1.00	M = 2.10, SD = 1.00	M = 3.40, SD = 1.60	M = 1.50, SD = 0.90	M = 2.00, SD = 0.70	M = 2.10, SD = 1.10
The significance of the material instructed for the medical field has become evident.	M = 1.00, SD = 1.00	M = 1.50, SD = 1.00	M = 2.70, SD = 1.10	M = 1.40, SD = 0.50	M = 1.40, SD = 0.50	M = 1.70, SD = 0.70
The visuals (such as interactive images and video tutorials) made it easier to grasp the educational material.	M = 1.60, SD = 0.90	M = 1.40, SD = 0.50	M = 1.80, SD = 0.80	M = 1.60, SD = 0.50	M = 1.20, SD = 0.40	M = 1.80, SD = 0.80
The integrated tests (e.g., quizzes) were aligned with the learning content.	M = 2.40, SD = 0.80	-	-	-	-	-

The integrated tests (e.g., quizzes) helped me check my understanding of the learning content.	M = 2.40, SD = 1.30	-	-	-	-	-
Concrete tips were provided for following up on the learning material.	M = 1.20, SD = 0.40	M = 1.50, SD = 1.20	M = 1.60, SD = 0.70	M = 1.20, SD = 0.40	M = 1.50, SD = 0.50	M = 1.60, SD = 0.70
I found it easy to stay motivated throughout the module.	M = 2.20, SD = 1.30	M = 2.10, SD = 1.50	M = 2.90, SD = 1.20	M = 1.00, SD = 0.00	M = 1.60, SD = 0.90	M = 1.80, SD = 1.20
Access to the learning module was successful without any issues.	M = 1.20, SD = 0.40	M = 1.80, SD = 1.50	M = 1.30, SD = 0.50	M = 1.00, SD = 0.00	M = 1.00, SD = 1.00	M = 1.20, SD = 0.40
The learning module was easy to use.	M = 1.20, SD = 0.40	M = 1.50, SD = 0.70	M = 1.30, SD = 0.50	M = 1.00, SD = 0.00	M = 1.40, SD = 0.90	M = 1.40, SD = 0.50
All participants were engaged in the course.	-	M = 1.70, SD = 0.80	M = 1.80, SD = 1.00	M = 1.60, SD = 1.30	M = 1.20, SD = 0.40	M = 1.80, SD = 1.30
There were various opportunities available for inquiries and exchanges (e.g., through Rocket Chat, Webex, ILIAS, or email).	-	M = 1.20, SD = 0.60	M =1.40, SD = 0.50	M = 1.40, SD = 0.90	M = 1.00, SD = 1.00	M = 1.20, SD = 0.40

Note. With regard to the first two items listed in the table, students were requested to provide an assessment of the elective subject in terms of the German school grades. A 6-point Likert scale ranging from 1 (“completely agree”) to 6 (“do not agree at all”) was employed for the subsequent items. [a] Questionnaires submitted per course.

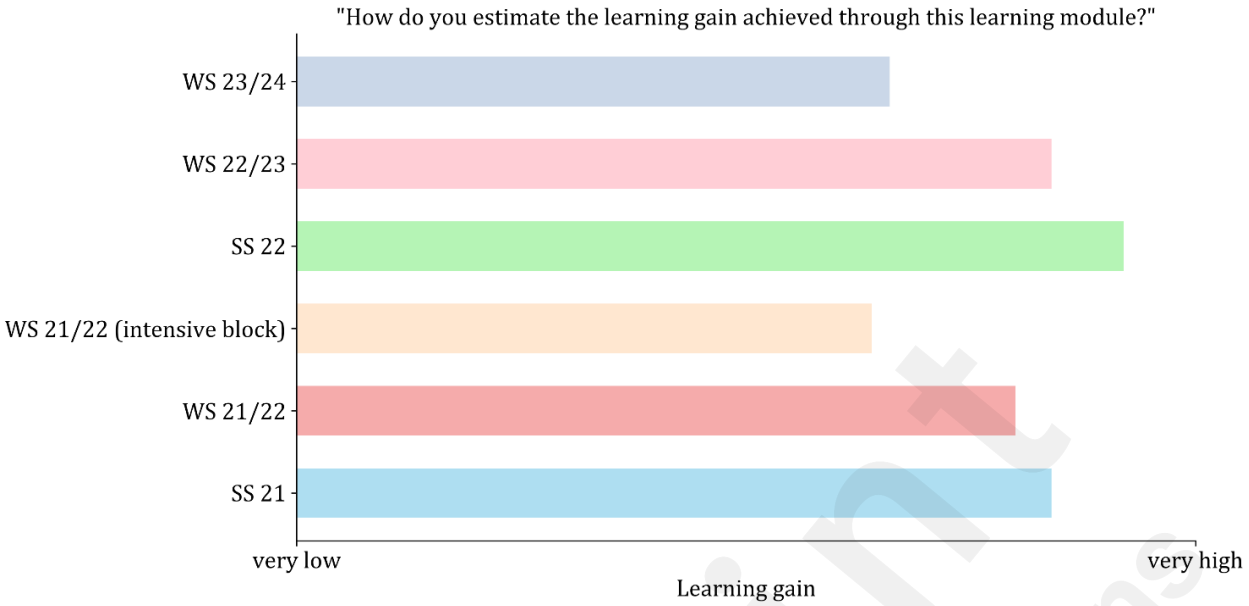


Figure 7. Assessment of students' perceived learning gain from the elective conducted at the end of each semester.

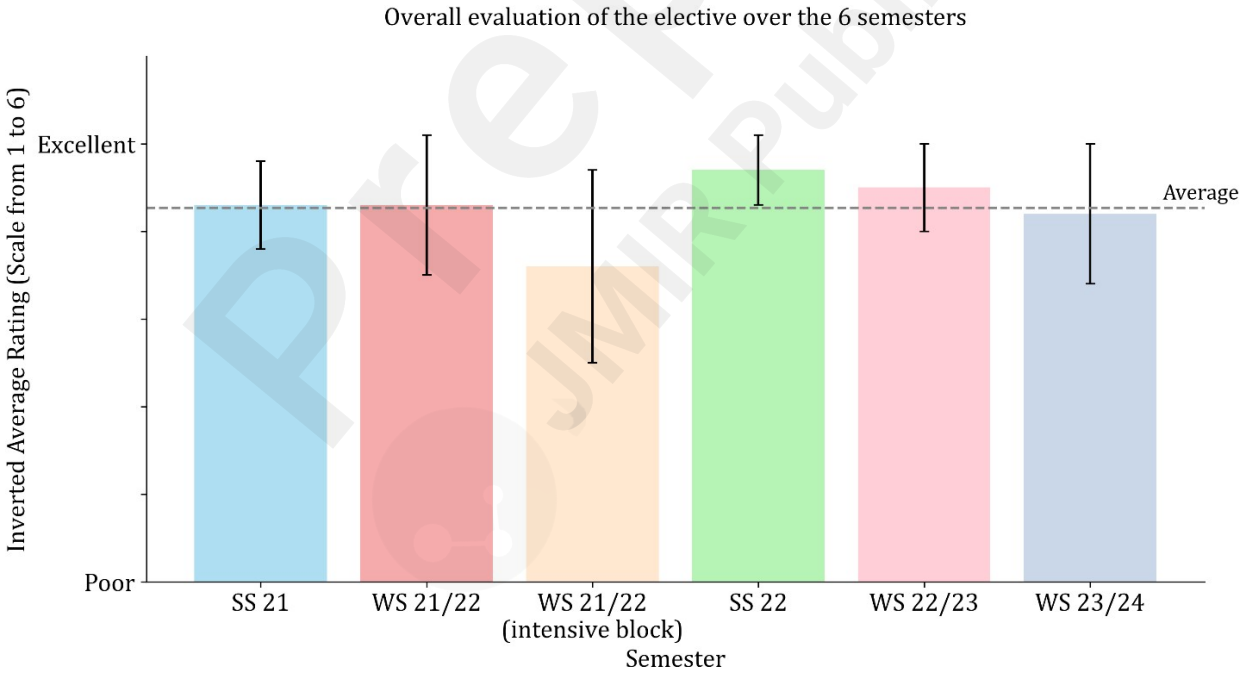


Figure 8. Overall evaluation of the elective course over 6 semesters. The ratings are based on student ratings in orientation to the German grading system (1 = completely agree, 6 = do not agree at all), with lower values indicating better ratings. The inversion is intended to improve readability, with higher bars now corresponding to higher satisfaction ratings. A dashed line indicates the average rating across all semesters.

The general feedback in the different semesters showed that the elective was well received by the students. Relevance of the various contents for their future work life was noticeable for many students, and there were enough opportunities to ask questions and discuss issues. It was also positively mentioned that contents were explained in a clear and comprehensible way, that the learning module could be accessed easily, and that the elective was well-structured. Room for improvement became apparent, e.g., with regard to self-motivation, the perceived helpfulness of integrated tests and quizzes, and the differentiation between important contents and less important detailed knowledge.

In winter semester 2021/2022, when the elective was presented as an intensive block seminar on 5 consecutive days, the overall rating and the rating concerning digital implementation were the lowest (see Table 3) compared to the other semesters. However, the mean score was good in terms of German school grades, even in the worst rated intensive course. Concerning the intensive block seminar, students were less satisfied with the block course, but still rating it as good. They reported having difficulties in motivating themselves to do the tasks and complete the module.

Qualitative Results – Open questions

In the open questions, students could give additional impulses in the form of free text. Overall, many of them seemed to appreciate contents concerning digital health and challenges in implementing digital health offerings and perceived a substantial knowledge gain after taking part in the elective. Students liked the following aspects best: autonomy, flexibility, support by teaching staff, contents, and structure:

> "Autonomy and free time management. Interesting content that is otherwise not covered in your studies! I learned a lot. Immediate feedback from the teaching staff, absolutely great!“ (SS 21)
>
> “The entire elective offered us the opportunity to freely shape our ideas, but it was all within a professional framework.” (WS 21/22)
>
> “Great support!” (SS 22)
>
> “Freedom of choice for the app concept.” (WS 23/24)

Additional factors that were perceived as positive were creativity, the fact that they could always ask questions, the guest lectures, fixed submission dates, and social exchange:

> “The freedom to design and be creative yourself.” (WS 21/22)
>
> “Plenty of room to ask questions.” (Block WS 21/22)
>
> “Permanent availability of the teaching staff.” (SS 21)
>
> “The guest lectures were very interesting.” (WS 23/24)

When being asked in which competence area students benefited most, several participants mentioned knowledge gain, self-sufficiency, and soft skills. It was also important to assess perceived deficits of the elective and aspects that could be improved. Students mentioned that submissions and arrangements within the work group seemed to be improvable (e.g., submission deadlines could have been communicated more clearly right at the beginning, communication between group members should be enhanced):

> “Addressing clearer deadlines at the beginning: For me, it was a bit difficult to understand the structure with the respective modules etc. right away.” (SS 21)

Some participants perceived group work as exhausting because of the structure of the groups (i.e., group members were determined based on thematic interests and it did not always seem to be clear enough who else was part of the group) and different work attitudes. It was also mentioned that some more face-to-face sessions would have been helpful (e.g., to address problems and issues and to get into contact with the others). More information on how to realize and implement app ideas and concepts was also desired:

> "I would have liked more guest lectures to learn more about their experiences in app development." (WS 22/23)
>
> "How do you actually turn a concept into an app? Who else do you need for this; how do you get the app into the app store when it's nearly finished?" (WS 21/22)

Some students from the block seminar in February 2022 (winter semester 2021/22) would have liked to have more time for the contents dealt with as it seemed to be a lot of input in a short period of time for them:

> "It's a lot of input for one week. Maybe you can try to skip or cut some parts if possible." (WS 22/23)

Furthermore, it was said that the elective would have been preferred as an in-class/face-to-face event to facilitate exchange and discussions:

> "For me, it would be easier to follow the content of the course in person. Unfortunately, I drifted off a lot of times." (WS 22/23)

Concerning missing contents or topics, the following suggestions were made: more economic contents (e.g., financial aspects, approaching sponsors, approaching programmers), more information on how to turn a concept into an actual app or how to publish the app in the app store, and more guest lectures.

In the winter semester 2023/24, the issue of artificial intelligence (AI) was also brought up:

> "The topic, or presentation on AI in the medical setting was something new, I would have liked more of that. In general, more variety would be good." (WS 23/24)

Discussion

The present study describes findings in the piloting and iterative optimization of a new, digitally mediated elective subject in the field of digital health at a German medical school. A central objective was to involve students actively and continuously in the optimization and design of the elective from the beginning onwards and to successfully convey relevant content.

Principal Findings

Through multiple iterations, a participatory optimized, innovative teaching offer was developed, tailored specifically to the needs and preferences of medical students. The overall implementation, digital execution, knowledge increase, content relevance, and supervision received (very) positive ratings by the students. The overarching goal of acquiring competencies and knowledge in the field of digital health (digital skills) was clearly achieved according to the surveyed participants.

Students considered several important aspects related to digital health (especially health apps, including DiGA) and implemented them accordingly in their app prototypes. As previous studies have shown, gamification [39], adherence promotion, and an appealing design are

important elements for creating a positive user experience [40,41]. These features were also considered by many student groups in our elective subject. Yet, it is important to emphasize that one should not only rely on elements of gamification in order to develop a useful, appealing, and persuasive app [41]. This was also considered by most of the students in their app concepts, as they often included background information, useful functions depending on the purpose of the app, and information on data security. Since data security concerns are one of the main barriers to the acceptance and broad implementation of mobile health apps, addressing these issues in the process of the app's development is essential [42].

According to the participants, the expansion of their knowledge in the area of mobile health apps was successfully realized as they reported having more information and an improved understanding of digital health after completing the seminar. In particular, the opportunities for independent and creative work seemed to convince the students of our approach to teaching digital health and digital competencies. Examining the mean scores for digital delivery reveals a slight positive trend. The comprehensive ratings of four courses ranged from "very good" to "good plus" in terms of overall implementation and digital delivery. Interestingly, the block course (on five consecutive days) in the winter semester 2021/2022 received substantially lower ratings compared to the other courses during the semester despite higher investment in the supervision. Potentially, the intensive course involved a workload perceived as too high with too little time between the sessions to develop the app concepts in a creative process that may benefit from a longer time to discuss the ideas within the group. Feedback regarding improvement suggestions indicated that the content and development of an app concept required more time for processing, which negatively affected student satisfaction with the elective in the form of a block seminar.

We were able to implement the proposed improvements, which proved successful as these suggestions were not mentioned again in subsequent course evaluations. It must be noted, however, that there might be other possible reasons for this (e.g., students with other needs in the following courses or students with generally lower expectations/previous knowledge). Some students emphasized in their feedback that the topics covered filled a gap in their previous education. This perceived gap aligns with the results of elective subjects in the field of digital health at other universities. Prior to participating in the digital health elective, a survey was conducted at another German medical school, the Charité University's Faculty of Medicine, where more than 85 % of participating students stated that digital medicine was not sufficiently integrated into the current curricula [25]. A further study examining medical students' perspectives indicated students' desire for a more robust integration of digital health into the curriculum [43]. While certain German medical faculties have initiated the provision of digital health electives [2], the integration of digital health topics into medical education in Germany and Europe is still not firmly established [9,26,44]. During our last elective course, the topic of AI was suggested for the first time. We had already anticipated this and included it as an excursus, which was well-received by the students during the seminar. Current research indicates that most physicians and medical students hold a favorable attitude towards the integration of AI into medical education. Many are already studying AI or intend to do so. The introduction of AI into the curriculum must be carefully planned to ensure that students' education remains up to date. The digitalization of the healthcare system, the use of digital

health apps, and AI in medicine are interconnected. Therefore, medical curricula should be adapted to the digital age as soon as possible [45].

Contrary to expectations, however, no substantial increase in the number of participants reflecting the demand for digital health education was observed. In all semesters, the total number of participants in the elective course remained below maximum capacity (five to seventeen students who successfully completed the elective). One exception was the winter semester 2021/2022, in which the course was offered both weekly and as a block course during the lecture-free period with 30 course places, which was the upper limit of participants. This could be attributed to the wide range of parallel electives offered at the Faculty of Medicine at the HHU (around 150 different electives each semester [46]), as well as the lack of integration of digital health into the National Competence-Based Learning Objectives for undergraduate medical education. Higher registration numbers for other electives indicate that students' interest and focus rather seems to lie on clinical diseases or imaging procedures, possibly due to a supposedly clearer and more tangible practical relevance. Feedback of the students in the final discussions after their app concept presentations also revealed that the content of the elective was considered very important, but that there were other decisive factors in the course selection like the integrability into the rest of the schedule and the expected workload. The number of participants should be further improved in possible consecutive courses after the intended integration of digital competencies in the medical curriculum. It might be beneficial to organize more large-scale courses and interdisciplinary sessions, maybe also in collaboration with other departments in the medical school and beyond (e.g., medical informatics) to increase the range and to achieve higher participation numbers. In doing so, the relevance of digital health for students' future daily work as physicians could also be highlighted. It is also worth discussing in how far students' needs regarding organization, amount of work and implementation could be combined (e.g., preferences regarding block seminars in the semester break, face-to-face sessions, or blended learning formats).

The provision of digital health education represents an important step in supporting future practicing physicians who need to be able to utilize and prescribe digital health interventions. By integrating the elective into medical curricula, the willingness of physicians and psychotherapists to prescribe DiGA could be increased. In a previous study, 63 % of surveyed general practitioners indicated a relatively low willingness to prescribe DiGA [47]. This could be attributed to concerns about safety, reliability, additional workload [48], personal uncertainty [21], lack of knowledge, lack of reliable information sources [49], and a lack of evidence of effectiveness [19]. The inclusion of digital health education in medical studies could address these concerns and positively influence the already established infrastructure of DiGA through well-designed and trusted information based on academic training.

Limitations

Limitations of this case study are the small sample sizes and the conduction at only one medical school in Germany, which may restrict the representativeness of the findings of the evaluation to a broader or more diverse population of medical students (e.g., students with different preferences and experiences, students in higher semesters, etc.). We did also open the elective to further study subjects beyond medicine in order to broaden the perspectives and capture the interdisciplinary nature of digital health. The integration of a certain proportion of other

subjects was also beneficial due to the fact that there are about 200 electives per semester at our medical school that the students can freely choose and we could only conduct the elective with at least 5 students. Nonetheless, we adhered to the requirement that the vast majority of the web-based seminars had to consist of medical students (usually at least 2/3 of the participants).

Furthermore, we did not statistically compare the evaluation outcomes (mean scores) across the semesters as the sample sizes were small and unequal. Instead, first individual insights can serve as starting points for a broader implementation of digital health into the German curricula of medical students. Additionally, there could be a potential bias due to participant self-selection: Students chose the elective course themselves. Therefore, it might be possible that they already had a greater interest in the topic or were more familiar with digital health in general, which might have led to more positive evaluations.

Furthermore, the prescription of DiGA, which was a key topic of the elective, is still unique for the German healthcare system, making several contents of the lectures and ILIAS modules for self-guided learning hardly generalizable to medical education in other countries. However, other aspects are general important for education on digital health and app development (e.g., gamification). In addition, the design thinking approach to develop app concepts is universally adaptable to electives that aim at fostering digital competencies in medical education outside of the context of Germany.

Another limitation is the fact that the input of lecturers and experts might have had a strong influence on the students' focus on the development of app concepts. This could have led to a potential bias on behalf of the students in terms of topics and priorities in the implementation process. Yet, it was essential to provide sufficient knowledge beforehand due to the lack of knowledge, and this enabled students to put special emphasis on factors that were relevant for them (like gamification, adherence promotion, or data security). Furthermore, the evaluation was based primarily on students' feedback. Thus, the possible gain of knowledge and usefulness for the students cannot really be assessed. In future electives, it could be helpful to assess pre- and post-knowledge on digital health topics addressed in the elective in a standardized manner. In this project, we only gathered this information via verbal feedback in the first and last session as well as via one item in the anonymized survey (perceived knowledge gains). However, students' presentations and feedback indicated that they seemed to have learned relevant aspects concerning digital health. Finally, there is no feedback from students who started the elective but chose to terminate participation or from students who did not choose the elective in the first place. These insights could have been useful in order to further improve the course and find out more about the generally rather low participation rate (e.g., if this was related to the course content or to organizational and time aspects).

Implications

For medical schools: Currently, there is a discrepancy between the demand for and the benefits of DMHIs and their integration in medical education. Although medical students acknowledge the importance of digital health in enhancing core skills [50], participation in our elective was rather low. Existing research literature highlights that students and healthcare providers have a discernible knowledge gap in the domain of digital health. To address this, providing clear information about the benefits of such electives is crucial. A general lack of awareness,

compounded by insufficient information from academic faculties, may hinder progress. In Germany, digital health courses are limited, mainly offered in electives [2]. While surveyed medical schools increase, the percentage of schools offering digital health courses stagnates [51]. Integrating digital health into curricula has the potential to enhance future doctors' capabilities, but specialized training is vital for navigating the digital age. Introducing digital health competencies equips aspiring clinicians with essential skills. These include fostering positive patient-physician relationships and explaining the risks and benefits. Foundational knowledge can be integrated into standard medical curricula, with electives focusing on specific in-depth knowledge and specializations [30].

For teaching staff: To successfully implement and execute courses that focus on digital health and app development, it is useful to provide enough time for the students to take in relevant aspects and knowledge (e.g., regular weekly courses instead of block seminars). Regular exchange among students and between students and teaching staff also seems to be important. The use of interactive digital learning platforms and chat programs can also improve the course (e.g., ILIAS, Rocket Chat). Involving different occupational groups and experts (e.g., start-up developers, economists) facilitates networking and allows for different perspectives and in-depth knowledge for the students. The concept itself is scalable on a larger level, even though it needs staff deployment, and the focus or topics of the elective are interchangeable. Finally, it could be beneficial to collaborate with other institutes or departments in order to increase the range of courses related to digital health.

For researchers: Further quantitative and qualitative research methods could be useful in order to gain more insights into preferences and needs of medical students with regard to digital health. It might also be beneficial to conduct research concerning outcomes of learning success that goes beyond individual feedback in the form of questionnaires and open questions. Research among the general population of medical students in Germany is needed to deepen existing knowledge, to further adapt elective courses, and to prepare the integration of digital health into the medical curricula.

Conclusions and Outlook

A current challenge in healthcare and prevention is a lack of knowledge and competencies in the field of digital health among healthcare providers. To increase the prescription readiness and establish digital health in everyday lives of patients and physicians, it needs to be implemented in medical education. Further research is needed to define specific learning objectives for digital health competencies and develop detailed recommendations for their integration into medical curricula.

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Conflicts of Interest

None declared. DiGA providers held their lectures for free and we did not receive any kind of compensation from them. We received funding from the Deans' Office/commission for quality improvement of the Medical Faculty of the Heinrich-Heine-University Düsseldorf for the first two years of the project for student assistants (quality improvement funds, financed by means of the state North Rhine Westphalia in Germany).

References

1. Lauer W, Löbker W, Höfgen B. Digitale Gesundheitsanwendungen (DiGA): Bewertung der Erstattungsfähigkeit mittels DiGA-Fast-Track-Verfahrens im Bundesinstitut für Arzneimittel und Medizinprodukte (BfArM). [Digital health applications (DiGA): assessment of reimbursability by means of the "DiGA Fast Track" procedure at the Federal Institute for Drugs and Medical Devices (BfArM)]. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 2021;64(10):1232-1240. PMID:34529095
2. Aulenkamp J, Mikuteit M, Löffler T, Schmidt J. Overview of digital health teaching courses in medical education in Germany in 2020. GMS Journal for Medical Education 2021;38(4):Doc80. PMID:34056069
3. Nitsche J, Busse TS, Ehlers JP. Teaching Digital Medicine in a Virtual Classroom: Impacts on Student Mindset and Competencies. International Journal of Environmental Research and Public Health 2023;20(3):2029. PMID:36767393
4. Waibel A-M, Bischoff M. Digitale Kompetenzen im Medizinstudium: Ergebnisse einer interdisziplinären Lehrveranstaltung. [Digital competencies in medical studies: results of an interdisciplinary course]. HNO 2024;72(3):161-165. PMID:38265753
5. Särchen F, Springborn S, Mortsiefer A, Ehlers J. Digital learning about patients: An online survey of German medical students investigating learning strategies for family medical video consultations. Digital health 2024;10:20552076241230070. PMID:38323240
6. Root E, Caskie G. eMental Health Literacy and the Relationship to Barriers to Mental Health Care. Innovation in Aging 2020;4(Supplement_1):305. doi:10.1093/geroni/igaa057.978
7. Policy-2019-04-Digital-Health-in-the-Medical-Curriculum_-Addressing-the-Needs-of-the-

Future-Health-Workforce.
8. Dederichs M, Nitsch FJ, Apolinário-Hagen J. Piloting an Innovative Concept of e-Mental Health and mHealth Workshops With Medical Students Using a Participatory Co-design Approach and App Prototyping: Case Study. JMIR Med Educ 2022;8(1):e32017. PMID:35006085
9. Poncette A-S, Glauert DL, Mosch L, Braune K, Balzer F, Back DA. Undergraduate Medical Competencies in Digital Health and Curricular Module Development: Mixed Methods Study. Journal of Medical Internet Research 2020;22(10):e22161. PMID:33118935
10. Mayer G, Gronewold N, Alvarez S, Bruns B, Hilbel T, Schultz J-H. Acceptance and Expectations of Medical Experts, Students, and Patients Toward Electronic Mental Health Apps: Cross-Sectional Quantitative and Qualitative Survey Study. JMIR Mental Health 2019;6(11):e14018. PMID:31763990
11. Dederichs M, Weber J, Pischke CR, Angerer P, Apolinário-Hagen J. Exploring medical students' views on digital mental health interventions: A qualitative study. Internet Interventions 2021;25:100398. PMID:34026567
12. DGPPN. Zahlen und Fakten 2023 URL: https://www.dgppn.de/schwerpunkte/zahlenundfakten.html [accessed 2023-12-20].
13. Arbeitsmappe: hf-MHS_Dashboard 2023 URL: https://public.data.rki.de/t/public/views/hf-MHS_Dashboard/Dashboard?%3Aembed=y&%3AisGuestRedirectFromVizportal=y [accessed 2023-12-20].
14. Mauz E, Walther L, Junker S, Kersjes C, Damerow S, Eicher S, Hölling H, Müters S, Peitz D, Schnitzer S, Thom J. Time trends in mental health indicators in Germany's adult population before and during the COVID-19 pandemic. Front. Public Health 2023;11:1065938. PMID:36908429
15. Phillips EA, Himmler SF, Schreyögg J. Preferences for e-Mental Health Interventions in Germany: A Discrete Choice Experiment. Value in Health 2021;24(3):421-430. PMID:33641777
16. Jia Q, Qu Y, Sun H, Huo H, Yin H, You D. Mental Health Among Medical Students During COVID-19: A Systematic Review and Meta-Analysis. Frontiers in Psychology 2022;13:846789. PMID:35619776
17. Wada M, Suto MJ, Lee M, Sanders D, Sun C, Le TN, Goldman-Hasbun J, Chauhan S. University students' perspectives on mental illness stigma. Mental Health & Prevention 2019;14:200159. doi:10.1016/j.mph.2019.200159
18. Uncovska M, Freitag B, Meister S, Fehring L. Patient Acceptance of Prescribed and Fully Reimbursed mHealth Apps in Germany: An UTAUT2-based Online Survey Study. J Med Syst 2023;47(1):14. PMID:36705853
19. Dahlhausen F, Zinner M, Bieske L, Ehlers JP, Boehme P, Fehring L. Physicians' Attitudes Toward Prescribable mHealth Apps and Implications for Adoption in Germany: Mixed Methods Study. JMIR Mhealth Uhealth 2021;9(11):e33012. PMID:34817385
20. Hoch P, Arets J. Die Videosprechstunde als Modell der Akzeptanz digitaler Leistungen im Gesundheitswesen. B&G Bewegungstherapie und Gesundheitssport 2021;37(04):151-156. doi:10.1055/a-1528-3793
21. Wangler J, Jansky M. Welche Potenziale und Mehrwerte bieten DiGA für die hausärztliche Versorgung? – Ergebnisse einer Befragung von Hausärzt*innen in Deutschland. [What potential and added value do DiGA offer for primary care?-Results of a survey of general practitioners in Germany]. Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz 2022;65(12):1334-1343. PMID:36269336
22. Heidel A, Hagist C. Potential Benefits and Risks Resulting From the Introduction of Health Apps and Wearables Into the German Statutory Health Care System: Scoping Review. JMIR Mhealth Uhealth 2020;8(9):e16444. PMID:32965231
23. GKV-Spitzenverband. 2022_DiGA-Bericht_BMG [accessed 2024-02-25].
24. Byambasuren O, Beller E, Hoffmann T, Glasziou P. mHealth App Prescription in Australian

General Practice: Pre-Post Study. JMIR Mhealth Uhealth 2020;8(6):e16497. PMID:32478660
25. Seemann RJ, Mielke AM, Glauert DL, Gehlen T, Poncette AS, Mosch LK, Back DA. Implementation of a digital health module for undergraduate medical students: A comparative study on knowledge and attitudes. Technol Health Care 2023;31(1):157-164. PMID:35754241
26. Behrends M, Paulmann V, Koop C, Foadi N, Mikuteit M, Steffens S. Interdisciplinary Teaching of Digital Competencies for Undergraduate Medical Students - Experiences of a Teaching Project by Medical Informatics and Medicine. Studies in health technology and informatics 2021;281:891-895. PMID:34042802
27. Emina Obarcanin, Bushra Ali-Sherazi, Armin Dabidian, Sabina Schlottau, Maira Anna Deters, Stephanie Läer. Introducing m-Health and Digital Diabetes Apps in Clinical Pharmacy Education in Germany. J Diabetes Clin Res 2022;4(1):17-19. doi:10.33696/diabetes.4.051
28. Vogt L, Schmidt M, Follmann A, Lenes A, Klasen M, Sopka S. Telemedicine in medical education: An example of a digital preparatory course for the clinical traineeship - a pre-post comparison. GMS Journal for Medical Education 2022;39(4):Doc46. PMID:36310883
29. Khurana MP, Raaschou-Pedersen DE, Kurtzhals J, Bardram JE, Ostrowski SR, Bundgaard JS. Digital health competencies in medical school education: a scoping review and Delphi method study. BMC Med Educ 2022;22(1):129. PMID:35216611
30. Zainal H, Xin X, Thumboo J, Fong KY. Medical school curriculum in the digital age: perspectives of clinical educators and teachers. BMC Med Educ 2022;22(1):428. PMID:35659212
31. Meinel C, Leifer L, Plattner H. Design Thinking. Berlin, Heidelberg: Springer Berlin Heidelberg; 2011. ISBN:978-3-642-13756-3.
32. Hasso-Plattner-Institut 2024 URL: https://hpi.de/ [accessed 2024-02-02].
33. Sandars J, Goh P-S. Design Thinking in Medical Education: The Key Features and Practical Application. J Med Educ Curric Dev 2020;7:2382120520926518. PMID:32548307
34. Stoyanov SR, Hides L, Kavanagh DJ, Zelenko O, Tjondronegoro D, Mani M. Mobile app rating scale. JMIR Mhealth Uhealth 2015;3(1):e27. PMID:25760773
35. Terhorst Y, Philippi P, Sander LB, Schultchen D, Paganini S, Bardus M, Santo K, Knitza J, Machado GC, Schoeppe S, Bauereiß N, Portenhauser A, Domhardt M, Walter B, Krusche M, Baumeister H, Messner E-M. Validation of the Mobile Application Rating Scale (MARS). PloS one 2020;15(11):e0241480. PMID:33137123
36. Philippi P, Baumeister H, Apolinário-Hagen J, Ebert DD, Hennemann S, Kott L, Lin J, Messner E-M, Terhorst Y. Acceptance towards digital health interventions - Model validation and further development of the Unified Theory of Acceptance and Use of Technology. Internet Interventions 2021;26:100459. PMID:34603973
37. Azad-Khaneghah P, Neubauer N, Miguel Cruz A, Liu L. Mobile health app usability and quality rating scales: a systematic review. Disability and rehabilitation. Assistive technology 2021;16(7):712-721. PMID:31910687
38. Inal Y, Wake JD, Guribye F, Nordgreen T. Usability Evaluations of Mobile Mental Health Technologies: Systematic Review. Journal of Medical Internet Research 2020;22(1):e15337. PMID:31904579
39. Pei-Shan Wei, Szu-Ying Lee, Hsi-Peng Lu, Jen-Chuen Tzou, Chien-I Weng. Why Do People Abandon Mobile Social Games? Using Candy Crush Saga as an Example. World Academy of Science, Engineering and Technology, International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering 2015 URL: https://www.semanticscholar.org/paper/Why-Do-People-Abandon-Mobile-Social-Games-Using-as-Wei-Lee/0a8affdc4ea4b65b9dc6dcf19e7dd7472398a905.
40. Al-Shamaileh O, Sutcliffe A. Why people choose Apps: An evaluation of the ecology and user experience of mobile applications. International Journal of Human-Computer Studies 2023;170:102965. doi:10.1016/j.ijhcs.2022.102965

41. Jessen S, Mirkovic J, Ruland CM. Creating Gameful Design in mHealth: A Participatory Co-Design Approach. JMIR Mhealth Uhealth 2018;6(12):e11579. PMID:30552080
42. Schreiweis B, Pobiruchin M, Strotbaum V, Suleder J, Wiesner M, Bergh B. Barriers and Facilitators to the Implementation of eHealth Services: Systematic Literature Analysis. Journal of Medical Internet Research 2019;21(11):e14197. PMID:31755869
43. Machleid F, Kaczmarczyk R, Johann D, Balčiūnas J, Atienza-Carbonell B, Maltzahn F von, Mosch L. Perceptions of Digital Health Education Among European Medical Students: Mixed Methods Survey. Journal of Medical Internet Research 2020;22(8):e19827. PMID:32667899
44. Tudor Car L, Kyaw BM, Nannan Panday RS, van der Kleij R, Chavannes N, Majeed A, Car J. Digital Health Training Programs for Medical Students: Scoping Review. JMIR Med Educ 2021;7(3):e28275. PMID:34287206
45. Sun L, Yin C, Xu Q, Zhao W. Artificial intelligence for healthcare and medical education: a systematic review. American Journal of Translational Research 2023;15(7):4820-4828. PMID:37560249 URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10408516/.
46. Universität Düsseldorf: Wahlcurriculum 2024 URL: https://www.medizinstudium.hhu.de/duesseldorfer-curriculum-medizin/wahlcurriculum [accessed 2024-02-02].
47. Deutscher Ärzteverlag GmbH, Redaktion Deutsches Ärzteblatt. Digitale Gesundheitsanwendungen: Die Akzeptanz steigern 2021 URL: https://www.aerzteblatt.de/archiv/217790/Digitale-Gesundheitsanwendungen-Die-Akzeptanz-steigern [accessed 2023-12-20].
48. Wangler J, Jansky M. Gesundheits-Apps als Instrumente der Prävention? – Eine Interviewstudie zu Potenzialen für das hausärztliche Setting. Präv Gesundheitsf 2020;15(4):340-346. doi:10.1007/s11553-020-00769-x
49. Byambasuren O, Beller E, Hoffmann T, Glasziou P. Barriers to and Facilitators of the Prescription of mHealth Apps in Australian General Practice: Qualitative Study. JMIR Mhealth Uhealth 2020;8(7):e17447. PMID:32729839
50. Boyers LN, Schultz A, Baceviciene R, Blaney S, Marvi N, Dellavalle RP, Dunnick CA. Teledermatology as an educational tool for teaching dermatology to residents and medical students. Telemedicine journal and e-health : the official journal of the American Telemedicine Association 2015;21(4):312-314. PMID:25635528
51. Pourmand A, Ghassemi M, Sumon K, Amini SB, Hood C, Sikka N. Lack of Telemedicine Training in Academic Medicine: Are We Preparing the Next Generation? Telemedicine journal and e-health : the official journal of the American Telemedicine Association 2021;27(1):62-67. PMID:32294025

Abbreviations

AI: artificial intelligence
BfArM: Bundesinstitut für Arzneimittel und Medizinprodukte (German Federal Institute for Drugs and Medical Devices)
DiGA: Digitale Gesundheitsanwendungen (digital health applications)
DMHIs: digital mental health interventions
HHU: Heinrich-Heine-University Düsseldorf, Germany
PMDD: premenstrual dysphoric disorder
PMS: premenstrual syndrome
SS: summer semester
WS: winter semester

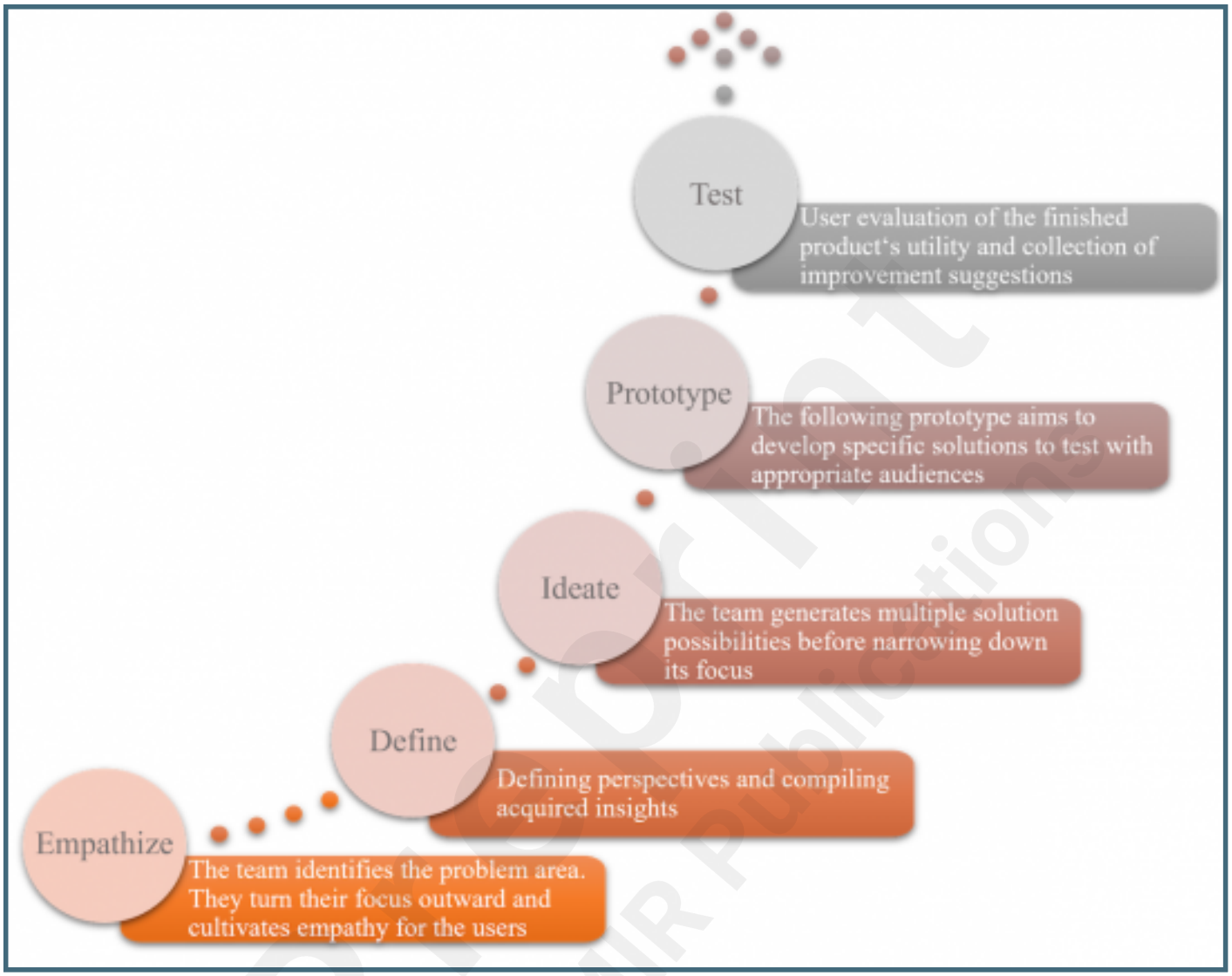
Multimedia Appendix 1
Additional Prototype-Visualization
Multimedia Appendix 2
Additional Results

Author contributions
FS: Methodology, Conceptualization, Formal analysis, Software, Visualization, Data Curation, Investigation, Writing – original draft
LG: Methodology, Conceptualization, Formal analysis, Data Curation, Visualization, Writing – original draft
KP: Conceptualizing, Investigation, Visualization, Writing – review & editing
ASK: Software, Investigation, Visualization, Writing – review & editing
IE: Conceptualizing, Writing – review & editing
BS: Conceptualizing, Writing – review & editing
JAH: Conceptualization, Funding acquisition, Project administration, Methodology, Investigation, Data Curation, Supervision, Writing – review & editing

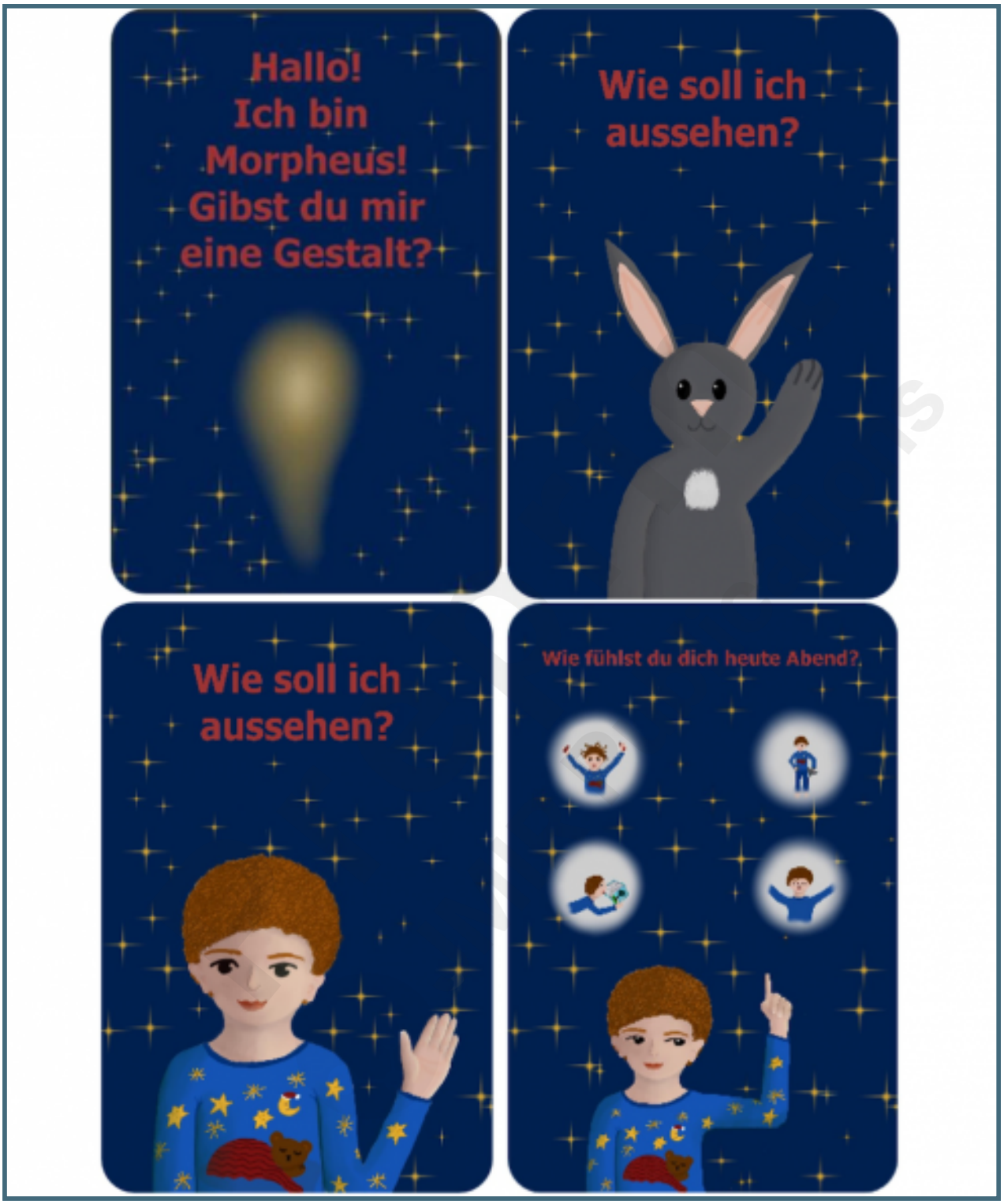
Supplementary Files

Figures

Design thinking process.



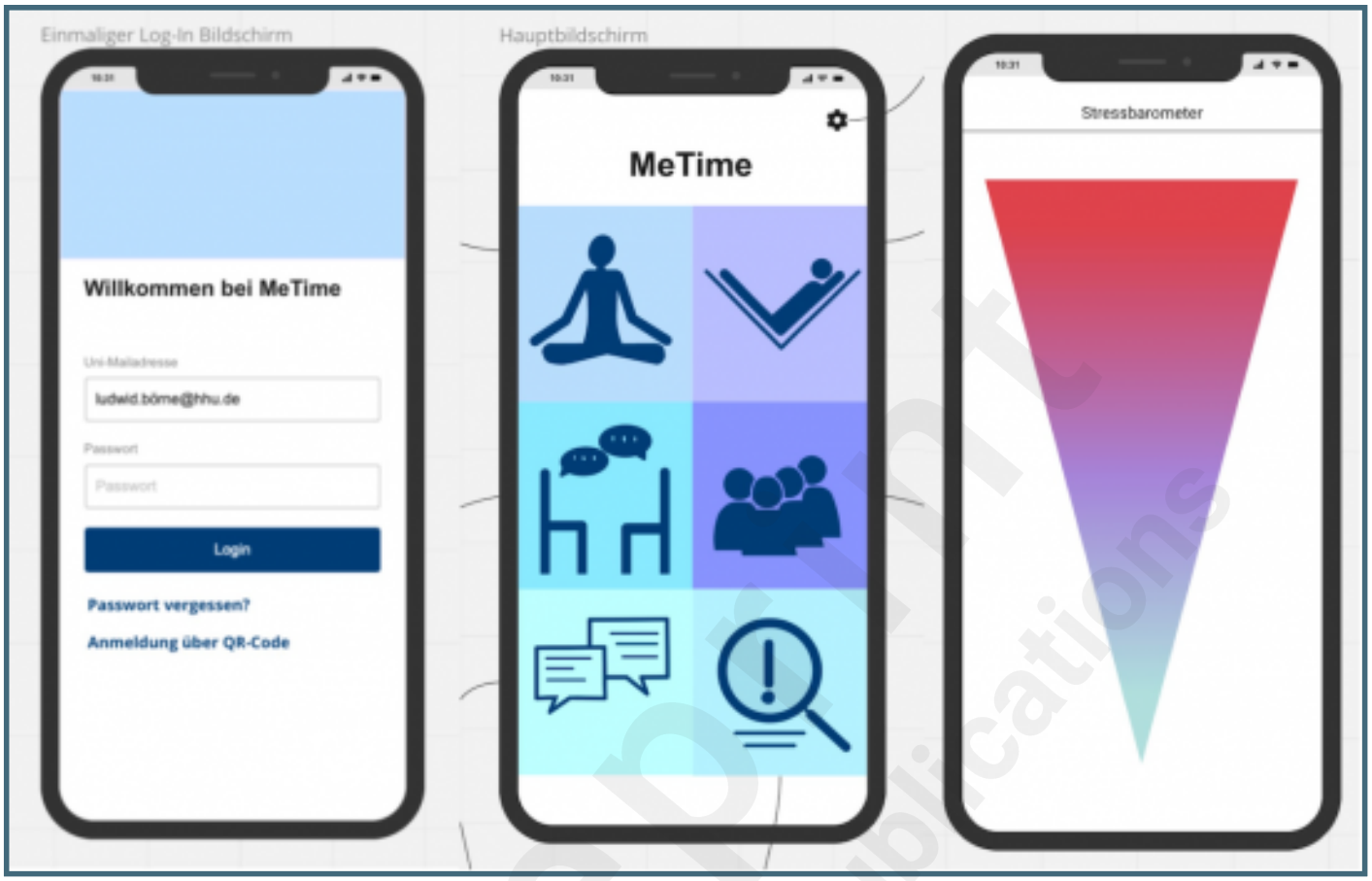
Morpheus app.



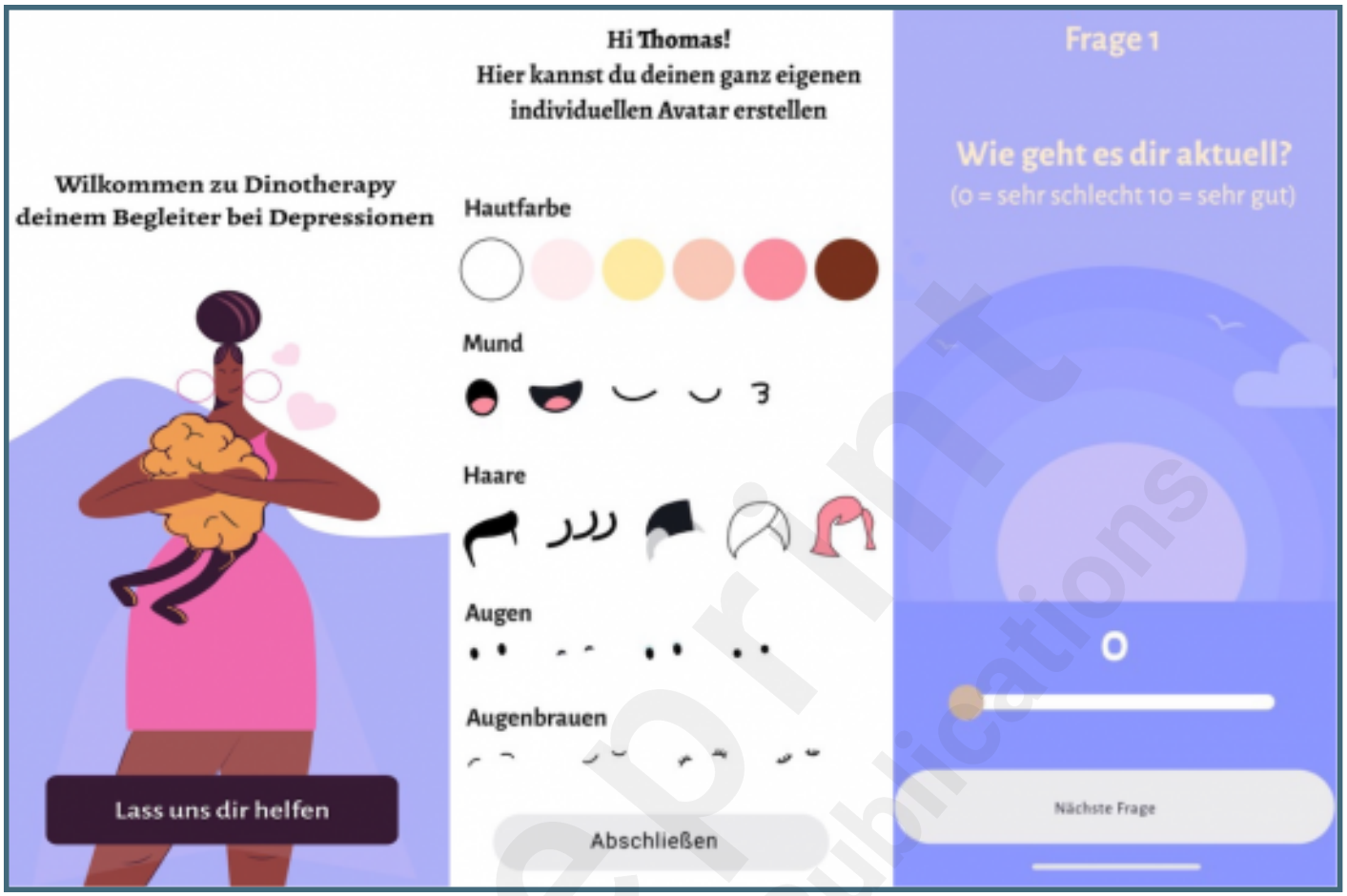
Bruhno app.


CONCEPT MAPPING
BRUHNO
Nebenwirkungen
Informations Forum
Kommunikation Chat
Organisation
Symptomtagebuch
TerminReminder
Logged out
Login
Welcome
BRUHNO
LOG IN
REGISTER
Log in
LOG IN
WELCOME HANNAH !
INFO
DO & DON'T
TAGEBUCH
FRAGEBOGEN
CHAT
TERMINE

MeTime app.

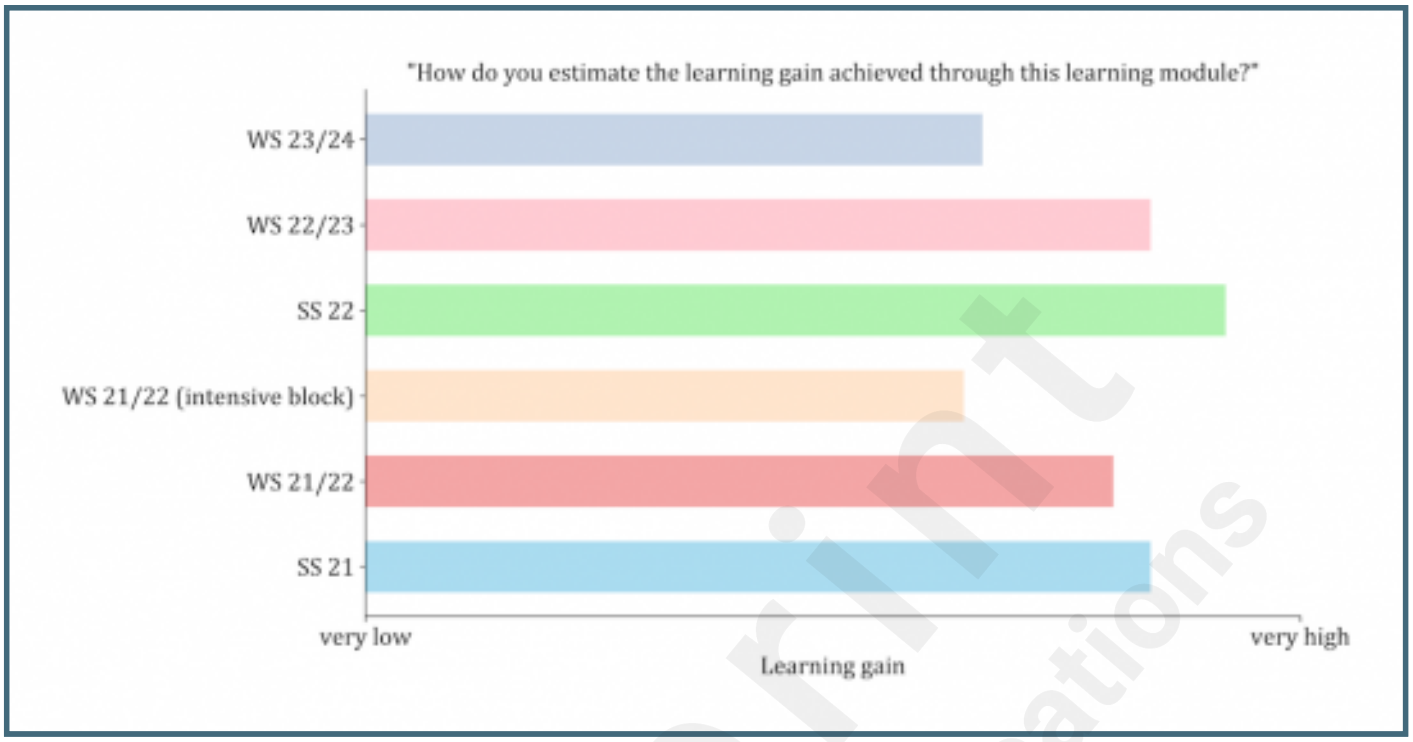


Dinotherapy app.

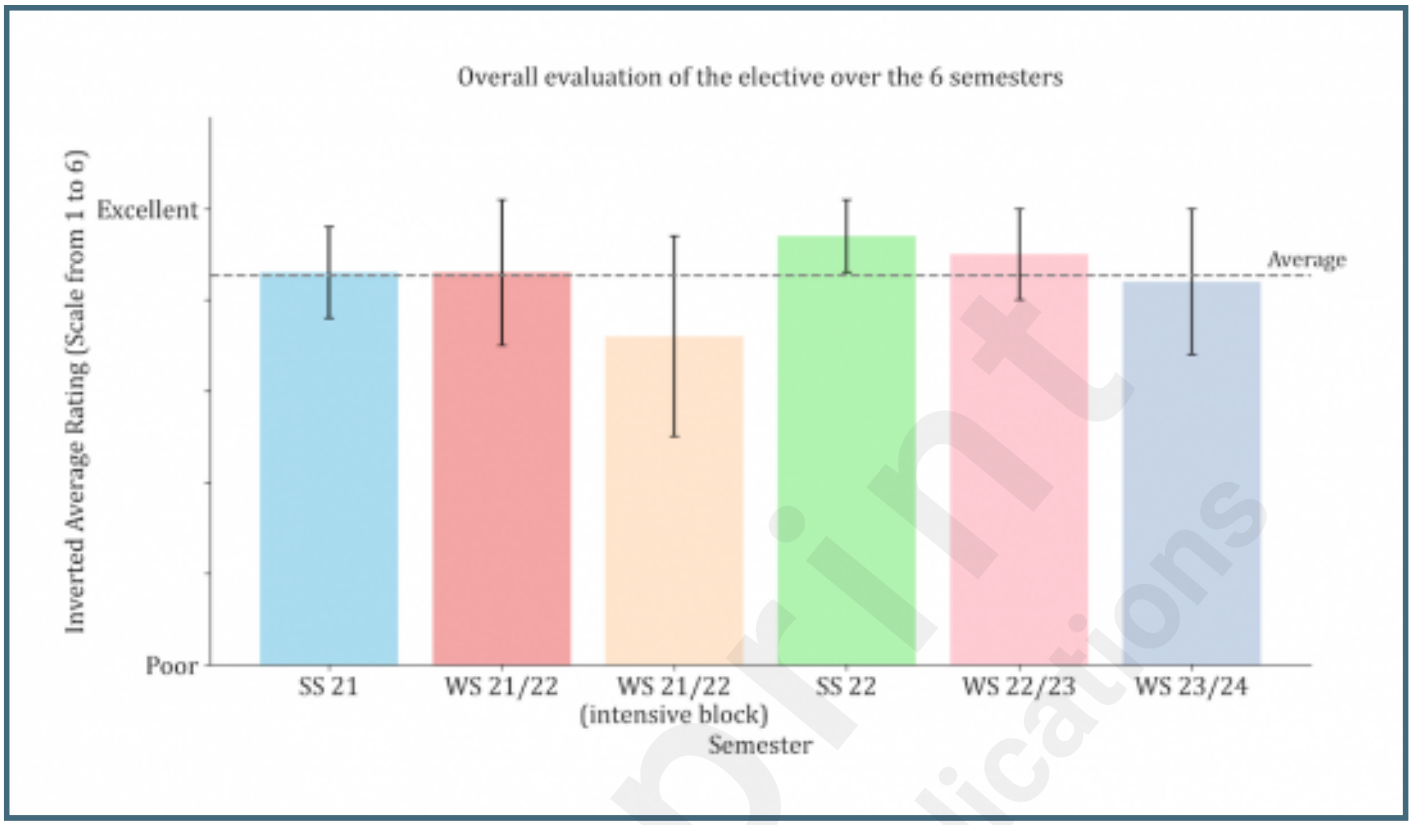


Companion app.

Reported knowledge increase.



Overall satisfaction with the elective.



Multimedia Appendixes

Additional app prototypes.
URL: http://asset.jmir.pub/assets/6806873e8d731878d376a2146ce964a7.pdf

Additional results.
URL: http://asset.jmir.pub/assets/3552a0e0defd4a06bd93aa5de0a7a010.pdf