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HybParc: Digitally supported, practice-oriented teaching and learning formats

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Abstract

The HybParc project develops digitally supported, practice-oriented teaching formats for medical education. Its aim is to provide flexible, safe, and repeatable training environments that foster clinical skills. Key didactic principles include blended learning, self-directed learn-ing, and immediate feedback. Implemented self-learning units include a sensor-based 12-channel ECG, Basic Life Support with CorPatch®, and surgical suturing with AI-supported analysis. In addition, virtual reality (VR) scenarios allow complex procedures to be practiced safely. Automated feedback summaries support reflection and self-regulated learning. Eval-uations show high acceptance, particularly for sensor-based feedback and VR. Learners value immediate feedback and independent practice. Limitations include technical instability, lack of haptic feedback, and high demands on didactic integration. Published as Open Education-al Resources (OER), the materials are sustainably reusable.

Das Projekt HybParc entwickelt digital gestützte, praxisnahe Lehrformate für die medizini-sche Ausbildung. Ziel sind flexible, sichere und wiederholbare Trainingsumgebungen zur Förderung klinischer Kompetenzen. Didaktische Schwerpunkte liegen auf Blended Learning, selbstgesteuertem Lernen und unmittelbarem Feedback. Umgesetzt wurden Selbstlernein-heiten wie ein sensorbasiertes 12-Kanal-EKG, Basic Life Support mit CorPatch® sowie chirur-gische Nahttechniken mit KI-gestützter Analyse. Ergänzend ermöglichen Virtual-Reality-(VR)-Szenarien das risikofreie Training komplexer Tätigkeiten. Automatisierte Feedbackzusam-menfassungen unterstützen Reflexion und Selbststeuerung. Evaluationen zeigen eine hohe Akzeptanz, insbesondere für sensorbasiertes Feedback und VR. Geschätzt werden unmittel-bare Rückmeldungen und eigenständiges Üben. Einschränkungen bestehen durch techni-sche Instabilität, fehlendes haptisches Feedback und hohen didaktischen Integrationsauf-wand. Als Open Educational Resources (OER) veröffentlicht, sind die Materialien nachhaltig nutzbar.

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1. Background

Heterogeneous student groups, which are particularly common in medical studies, require learning formats that take into account different levels of prior knowledge, learning styles, and learning requirements, and offer all students equal opportunities for competence development. Digital and hybrid formats create a flexible, personalized, and student-centered learning environment that enables independent knowledge acquisition and consolidation [1]. Self-directed learning describes an intentional learning process in which learners take responsibility for setting goals, planning, implementing, and evaluating their learning [2]. The integration of self-study phases and attendance training, as well as the use of digital tools for reflection and feedback, promotes needs-based learning and strengthens personal responsibility. In addition, digital learning opportunities contribute significantly to the development of digital skills, which are now considered a mandatory learning objective and a central prerequisite for future professional practice [3].

Self-directed learning is increasingly coming into focus and is understood as a complex cycle that encompasses psychological characteristics (e.g., self-efficacy, motivation), personal decisions (e.g., effort, learning strategies), assessments (e.g., self-assessment, attributions), and actions (e.g., goal setting, adjustments). Educational psychology recommendations emphasize the need for the systematic integration of such learning processes into curricula, accompanied by continuous support and feedback [4].

The German Council of Science and Humanities also highlights the central role of guided self-study as a sustainable teaching and learning format. This is closely linked to self-directed learning, which is described as a process in which learners take the initiative to identify their learning needs, formulate goals, tap into resources, select strategies, and evaluate their results [5]. Digital media offer a wide range of methodological options to support these steps. It is crucial that elements that enable and promote self-direction are specifically incorporated into the design of self-directed teaching units [2].

Feedback is a key element in this process: it enables continuous reflection on learning progress, the identification of learning gaps, and targeted improvements, which significantly increases the quality of the learning process. John Hattie emphasizes that learning is particularly effective when learners are supported in becoming "their own teachers" – by acting more independently, reflecting, finding their own learning paths, and critically evaluating their results [6].

In the context of the Medical Interprofessional Training Center (MITZ), self-directed learning has so far been implemented through self-monitoring, checklists, peer feedback, and self-assessment of practical skills [7]. Recent studies show that hybrid self-learning training courses with digital feedback systems can provide targeted support to students in their individual learning processes [8]. Building on this, further training courses are being developed that integrate digital feedback systems even more intensively to ensure continuous individual support.

Digital technologies such as video recordings, sensors, and automated analysis methods open up additional opportunities to evaluate practical skills in a standardized and objective manner. Virtual reality (VR) can also create immersive learning environments for rare or sensitive scenarios and train both operational skills and non-technical skills such as communication and clinical decision-making [9, 10]. Automated and integrated feedback—whether through software, peer reflection, or self-reflection—provides targeted support for learning processes and makes progress transparent.

On this basis, the article outlines the approaches developed in the project for designing hybrid, interactive self-learning, training, and examination courses in a medical context. The focus was on the HybParc internship and assessment format, which aimed to teach clinical practical skills more efficiently. Video recordings, sensors, and (partially) automated analyses of action sequences were used for this purpose. Conversational agents provided automated feedback, while VR offered immersive learning environments as a complementary tool. HybParc was tested at the

Carus Teaching Center (CarL) in collaboration with the MITZ of the Carl Gustav Carus Faculty of Medicine (MFD) in order to integrate hybrid, interactive courses into practical studies and training and to enrich medical education and related disciplines in the long term.

2. Project development

As part of the overall project, various innovative teaching and learning methods were developed, tested, and partially evaluated. The aim was to provide medical students with practical, safe, and repeatable learning environments that promoted both practical skills and communication skills. The approaches ranged from sensor-based self-learning units and VR scenarios to automated feedback systems for communication-related exercises. All subprojects followed a didactic guiding principle that combined blended learning, self-directed learning, and immediate feedback to sustainably strengthen learners' practical skills.

Self-learning unit: Applying a 12-channel-ECG

One focus of the project was the development of a self-learning unit for applying a 12-channel electrocardiogram (ECG) with a sensor-based feedback system. The aim was to provide learners with a teaching-independent learning opportunity that combined theoretical basics with practical application and supported self-directed learning through immediate feedback [11].

The unit followed a blended learning approach: in the online phase via Moodle, participants were familiarized with the theoretical basics, worked on orientation tasks, and watched an instructional video demonstrating the correct electrode placement. In the attendance phase at MITZ, students practiced electrode placement on a simulation dummy and received feedback through the sensor-based feedback system. Structured checklists for peer feedback were also used, creating a flexible and practical learning format that combined digital innovation with classic teaching methods.

The technical setup included a training dummy with adhesive electrodes, a PC with a monitor, and two RGBD cameras that captured both the thorax area and the extremities. The cameras delivered image data to specially developed software that recorded the positions of the electrodes, compared them with target positions, and visualized the results on a user interface. Incorrect placements were displayed immediately, including brief notes on correct positioning, so that learners could directly recognize, reflect on, and correct their mistakes.

Fig. 1: Setup for applying a 12-channel ECG

Development took place iteratively in two rounds: First, an Artificial intelligence (AI)-based approach (YOLO) was implemented that recognized electrodes using annotated image data and compared them with target positions [12]. Despite multi-stage training, this approach was not sufficiently reliable, especially when it came to position and identity recognition of the electrodes. In addition, it was not always clear to users whether an electrode was incorrectly positioned or simply not recognized.

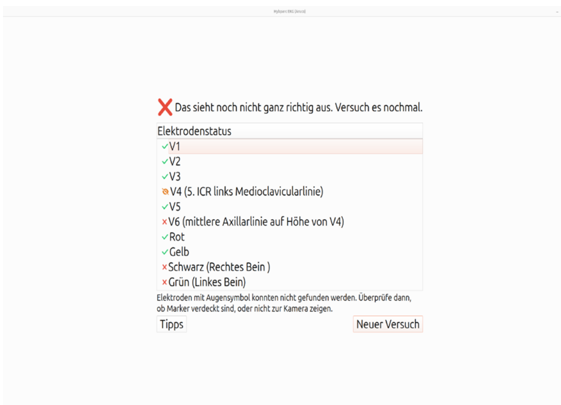

Fig. 2: Feedback on the placement of the 12-channel ECG on the user interface.

Based on these experiences, a marker-based algorithmic method was developed. Aruco markers on the manikin and electrodes enabled robust and precise detection. High-resolution cameras improved image quality, allowing the marker size to be reduced. A revised user interface visualized the results in a more transparent and understandable way, and an assistant checked the camera position at startup to avoid incorrect measurements. The "ArucoRoi" configuration tool allowed target ranges to be flexibly adjusted, which facilitated transfer to other setups.

This iterative development process resulted in a practical, robust, and transparent feedback system that combined theory, practical application, and immediate feedback, supporting learners in their professional competence.

Self-learning unit Basic Life Support

Another aspect of the project was the development of a self-learning unit on Basic Life Support (BLS). Unlike the ECG project, this unit made use of an existing device, the CorPatch®. This system enabled real-time analysis of resuscitation performance and provided audiovisual feedback, for example on the compression frequency and pressure depth of chest compressions, as well as a detailed evaluation after completion of the exercise.

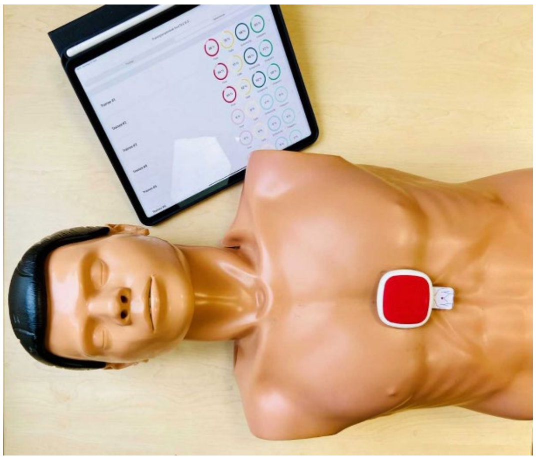

Fig. 3: CorPatch® system on the Basic Life Support dummy

The didactic structure was based on a blended learning approach: after an online phase in which theoretical basics were taught, participants practiced resuscitation skills independently in the attendance phase. The CorPatch® served as a central feedback tool, allowing learners to independently check and improve their performance.

Self-learning unit on surgical suturing techniques

Another aspect is the development of a self-learning unit on surgical suturing techniques in a blended learning format. At the end of the project, the technical setup was still in the development phase: an overhead GoPro camera continuously recorded the work area and transmitted the image data to specially developed software. The students practiced on a suture pad (vinyl/EVA) with a prepared incision using standardized suture material.

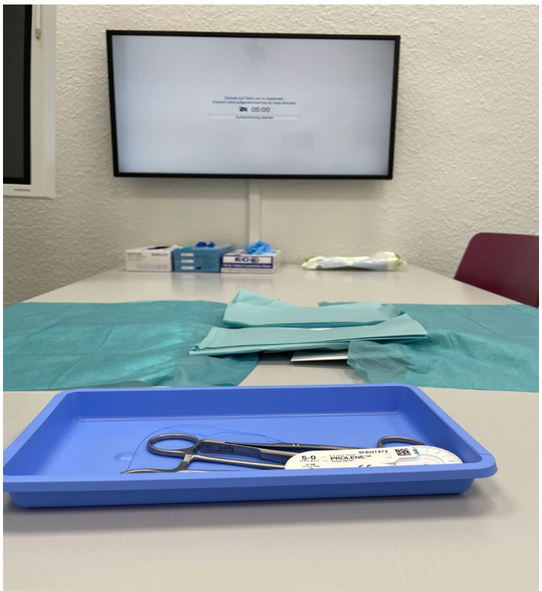

Fig. 4: Setup for surgical suturing techniques.

The software evaluated the suturing performance using AI based on image sequences that analyzed the entire suture as a video [13]. The result was reported back directly via the user interface in three assessment levels ("good," "average," "poor"). The interface also showed the current recording status and a countdown for the processing time, which reduced the mental load and increased clarity. In the future, this could lead to the creation of another self-learning unit that could be embedded in the overall didactic pattern of the project and use digital feedback systems for standardized, independent training.

VR post-mortem examination

In addition to sensor-based self-learning units, VR-based approaches were also developed. The aim was to depict complex clinical scenarios in a practical manner and offer students a safe, repeatable learning environment.

Fig. 5: Processing the VR post-mortem examination scenario with VR glasses

Medical post-mortem examination required a combination of medical, legal, and organizational knowledge [14]. Since all medical personnel must master this skill and realistic simulations are very resource-intensive, VR training was transferred from the Dorothea Erxleben Learning Center in Halle to Dresden [15]. Halle provided the technical infrastructure, while the Dresden Faculty of Medicine took care of the didactic design, adaptation, and implementation.

The VR training followed the principle of the flipped classroom: students prepared online and then went through the scenario in small groups with tutors at the MITZ. They encountered a virtual deceased person, examined postmortem changes, integrated the apartment and personal belongings into the case study, determined the time of death, filled out the death certificate, and received individual feedback. The scenario was optimized during the project period: simplified user guidance, integration of input masks, two new cases, and a controller tutorial. In the future, the VR cases could also be offered as self-learning units.

The effectiveness of VR training was examined in a randomized teaching-learning study [16]. Students from the 5th semester onwards were first tested and then assigned to either the intervention group (VR) or the control group (simulation dummy), which used the previously established teaching methods [17]. The aim of the study was to evaluate the increase in knowledge and the effectiveness of the teaching methods used. Recruitment ran until the winter semester 2025/26; the results were then to be published.

VR operating theatre scenario

To expand the digital teaching offerings, a VR scenario based on 360° images was developed at MITZ [18] that depicts the operating theatre. The aim was to give students a practical introduction to the procedures and roles in the surgical team before teaching them complex surgical techniques. Students had repeatedly expressed the need for practice-oriented training in a safe environment.

Fig. 6: Excerpt from the VR application in the operating theatre scenario

In the VR operating theatre scenario, learners were able to explore the basics of the operating theatre on their own: roles in the team, the layout of the operating theatre, and key hygiene measures such as hand disinfection. The training was supported by short videos and explanatory texts demonstrating the correct procedure for hand hygiene [19]. In this way, the scenario taught the basic procedures in the operating theatre without delving into complex surgical techniques. Learners were able to familiarize themselves with the spatial and organizational structure of the operating theatre as often as they liked and understand the interaction between the roles [18]. The application could be used independently and did not require direct instruction from tutors. It could therefore be used as a self-learning unit to support attendance teaching.

The scenario was developed in Unity and could be played on Meta Quest VR hardware.

It was based on our own videos, photos, and 360° images produced with the Insta360 X3. In a requirements analysis, Unity was selected over 3DVista and PaneoVR based on its range of functions, documentation, development time, VR compatibility, and Open Educational Resource (OER) capability.

The didactic design took several key design decisions into account:

- 360° photographs enabled an immersive experience while also being efficient to implement and easily transferable to other scenarios [20, 21].
- Navigation via predefined views reduced motion sickness and increased user-friendliness [22].
- Physical presence at the location (only head and eye movement) facilitated participation even for people with limited mobility and reduced the risk of accidents.
- Screen-space panels ensured constant readability of information, regardless of the direction of gaze.
- Haptic and auditory feedback in button interactions enhanced the perception of virtual interfaces [23].

The scenario began with an introduction to controller operation. Then, , the students went through the induction process, interacted with informative hotspots, and then entered the virtual operating theatre. There, they were able to explore aspects such as the roles in the operating theatre, the correct way to dress, and the various devices in the operating theatre at their own pace. The task took about 30 minutes, making the scenario well suited as a stand-alone self-learning unit.

Automated feedback summaries

Another subproject was in the testing phase at the end of the project and was dedicated to the automated support of feedback rounds after curricular learning units with communicative learning objectives – for example, conducting conversations in a medical context with simulation persons. The aim was to automatically transcribe the feedback session and provide participants individually in the form of summaries. After evaluating existing tools in terms of usability, speech recognition accuracy, speaker tagging, AI compatibility, and data protection, a suitable system was selected. In a simulated feedback session with eight people, requirements for piloting and potential evaluation metrics were tested.

3. Evaluation results and outcome

At the end of the project, no direct evaluation results were available for some subprojects within HybParc, as these were currently in a development and testing phase. The evaluation items varied depending on the subproject, but always included key aspects such as didactic design, acceptance, technical implementation, usability, and the subjectively perceived learning effect.

Self-learning unit: Applying a 12-channel-ECG

Within the framework of the project, all fully developed self-learning units and VR scenarios were successfully piloted and evaluated. The self-learning unit on applying a 12-channel ECG was initially tested in the summer semester of 2023 with twelve participants, consisting of medical students and trainees studying to become medical assistants. The evaluation showed a high level of acceptance of the concept, while technical weaknesses, particularly in the stability of electrode detection and color recognition, made error-free feedback difficult. The theoretical preparation was rated with an average of 1.5 (s=0.7), the content implementation with 1.6 (s=0.5), the technical implementation with 1.9 (s=0.5), and the overall grade was 1.3 (s=0.5).

The unit was offered again in the summer semester of 2024 and in the period from April to July 2025. The revised prototype showed progress but was not stable in all cases. Supplementary feedback methods such as structured checklists and peer feedback ensured that, despite technical limitations, a didactically effective learning effect was achieved. The evaluation of 16 participants resulted in an overall grade of 1.9 (s=0.9). After the unit, all participants felt able to write a 12-channel ECG independently, and 81% would recommend the unit to others. Suggestions for improvement included pathological ECG and extended detection limits.

Self-learning unit Basic Life Support

The self-learning unit on BLS was piloted in February and March 2025 with eleven participants. The CorPatch® system was used, which provided real-time feedback on frequency and pressure depth during chest compressions and then provided a detailed evaluation. All participants got along well with the system, rated the instructions as helpful, and appreciated the real-time feedback as valuable support for improving their technique.

The implementation showed that the model developed for self-learning units could be flexibly applied to different content: While the ECG project involved a technically complex inhouse development project, with BLS an existing system can be meaningfully embedded in a didactic structure.

VR post-mortem examination

The VR post-mortem examination was tested at MITZ with 73 students, 63 of whom completed a full evaluation (15). 93.1% of students reported that their confidence in performing medical post-mortem examinations had increased, and 96.8% felt more confident in completing death certificates. At the same time, 91.6% emphasized that VR training could not replace the necessary tactile feedback of real corpses. The scenario was expanded to include a self-directed learning unit that allows students to perform the individual steps independently, determine their own learning pace, and repeat content as often as they like. In the comparative study on VR post-mortem examination, which has been running since 2023 and examines the learning effect of the VR method compared to the established simulation dummy, interim results showed an increase in knowledge in both teaching formats. The advantages of the VR method lay in its interactive design and realistic perception, while limitations arose from a lack of haptic feedback and occasional technical operating problems. Self-assessments of practical skills showed that after the course, students were significantly more confident in the practical performance of post-mortem examinations and in filling out death certificates. Recruitment ran until the winter semester 25/26 and was not yet complete at the time of writing. Subsequently, statements could be made about its effectiveness compared to the traditional method.

VR operating theatre scenario

The VR-OP scenario was piloted as part of the PJ warm-up course with twelve students in their 10th–11th semester, of whom eleven provided complete feedback. The overall impression was consistently positive: seven students rated the scenario as "very good" and four as "good." The usefulness and acceptance of VR in their studies was rated as very high by the majority, and the participants reported that it was a lot of fun. Side effects occurred only in isolated cases. The feedback particularly highlighted the realistic representation of the operating theatre and the attention to detail. The technical design allowed for easy transfer to other departments, and the scenario could be used for both medical students and trainees to become surgical and anesthesia technicians. All materials, including how-to instructions, are available as OER on Twillo.

Handouts and OER

As part of the project development, instructions for using the systems were created for students and teachers. These include step-by-step instructions for preparing, setting up, operating, and maintaining the systems, including information on technical configuration and the use of mobile connections. The materials are designed to be practical in order to support teachers and students in using them independently. All instructions are available on the OER platform Twillo and can be freely accessed, downloaded, and adapted for your own teaching.

Fig. 7: QR code for the Twillo collection HybParc (https://www.twillo.de/edu-sharing/components/collections?id=b958881c-5d8a-4d38-beb4-4b237daa58f4&scope=EDU_ALL)

Conference contributions and publications

The use of sensor-based feedback was first presented at the 2024 annual conference of the Society for Medical Education (GMA) in Fribourg, where initial results were presented on the use of video recordings and sensor data in learning of applying a 12-channel ECG [24]. This was followed in 2025 by the presentation of the CorPatch® system for supporting resuscitation training at the 19th International SkillsLab Symposium in Munich [25].

At the same time, the use of VR in medical education was intensified. As early as March 2022, the VR Working Group was founded within the GMA Committee on "Digitization – Technology-Supported Learning and Teaching." Initial results were presented in 2023 at the 17th International SkillsLab Symposium in Cologne [26] and published in the same year [15].

At the 2023 GMA Annual Conference in Osnabrück, the focus was on immersive VR projects and didactic application scenarios [27, 28] , while in 2024 in Fribourg, issues of cross-location evaluation were discussed [29].

Networking within the VR Working Group proved to be an important driver for technical and didactic developments. Through exchanges between different locations, technical solutions and didactic concepts could be jointly tested, reflected upon, and further developed. In addition to questions concerning the immediate use of VR, aspects of implementation, evaluation, and sustainability also came into focus. This resulted in practical recommendations that can be applied not only to VR, but also to other digital teaching and examination formats. In addition, the work led to broad dissemination via conferences, publications, and specialist networks, making the results visible and usable for medical education in various specialist areas.

4. Discussion

The evaluations had some limitations: there were several evaluations on different topics, which were sometimes heterogeneous within the topics and did not always contain the same questions, making direct comparison difficult. The samples were limited, participation was voluntary, and the feedback could have been influenced by positive expectations of the innovative teaching methods.

Proven and less proven

The introduction of sensor-based feedback systems has proven to be particularly effective. Learners benefit from immediate, objective feedback that supports reflection and error correction and strengthens personal responsibility in the learning process. This is in line with current best practices, which emphasize the active involvement of learners and the promotion of self-directed learning as key success factors for digital teaching formats. However, the project results show that the successful use of complex technologies—such as sensor-based feedback or VR—requires a well-thought-out didactic concept, extensive testing phases, and specific personnel expertise. Only the interplay of concept, technology, and didactic expertise makes digital tools a valuable building block in teaching [30]. This finding is consistent with the experiences from cross-faculty cooperation projects, in which integration into curricula and collaboration between different disciplines are considered key factors [31].

The publication of the self-study units as open OER has enabled connectivity beyond the local context. This promotes the sustainable digitization of practice-oriented teaching and learning formats and facilitates implementation or further development by other institutions. The transfer of the VR post-mortem examination scenario to other locations demonstrates the potential for interdisciplinary dissemination and sustainable use [15].

The project results show that the threshold for the integration of digital teaching formats by other institutions should be kept as low as possible in order to enable broad dissemination and sustainable use. This is in line with the recommendations for sustainable OER strategies [32].

The VR post-mortem examination and VR operating theatre scenarios were perceived by students as offering clear added value. They enable risk-free, structured training in complex medical activities and offer the opportunity to learn about procedures and roles in the operating theatre without burdening patients or resources. Despite this, VR scenarios cannot completely replace practical experience with real corpse or in the operating theatre. In particular, the lack of tactile and olfactory feedback remains a key limitation that must be compensated for by accompanying practical exercises.

Furthermore, the use of existing structures and the combination of automated setup, AI-based evaluation, and a user-friendly interface significantly reduced the amount of work required for surgical suturing techniques. This offers an efficient solution for medical training and is transferable to other contexts. The possible applications of AI in medical education are currently still limited, as high quality standards and regulatory requirements (e.g., data protection, exam formats) must be met. The development of reliable, fair, and legally compliant AI systems remains a challenge [33].

5. Conclusion

Overall, the subprojects show that digital and AI-supported teaching formats and VR scenarios have the potential to make medical education more practical, flexible, and sustainable. In particular, immediate feedback from sensor-based systems, the use of OER for sustainable dissemination, and the practical simulation of complex activities through VR have proven successful. The greatest challenges are the didactic and technical complexity of integration and the associated close interdisciplinary cooperation, as well as the limited transferability of virtual experiences to reality. The project results provide valuable impetus for the further development of digital teaching formats and their sustainable anchoring in medical education.

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