BRIDGING DISCIPLINES THROUGH MAKING: COMPETENCY DEVELOPMENT IN INTERDISCIPLINARY WEARABLE REHABILITATION TECHNOLOGY EDUCATION

Georgi V GEORGIEV[1], Sohail Ahmed SOOMRO[1], Emmanuel BALZAN[2], Maria Victoria GAUCI[2], Nathalie BUHAGIAR[2], Pierre VELLA[2], Francesco TAMBURRINO[3], Paolo NERI[3], Beatrice ARUANNO[3], Andrew WODEHOUSE[4], Ross MACLACHLAN[4], Onisiforos HADJIONISIFOROU[5], Ummi LATIF[1], Roshan FERNANDO[1], Heli KUIVILA[6], Noora KITKALA-MURTO[6], Kristina MIKKONEN[6], Edward ABELA[2] and Philip FARRUGIA[2]
[1]Centre for Applied Computing, University of Oulu, Finland
[2]University of Malta, Malta
[3]University of Pisa, Italy
[4]University of Strathclyde, United Kingdom
[5]Kinisiforo Ltd, Cyprus
[6]Research Unit of Health Sciences and Technology, University of Oulu, Finland

ABSTRACT
Interdisciplinary collaboration is essential in engineering and product design education, yet educators struggle to identify and develop the competencies it requires. This paper presents findings from an intensive workshop in which 21 students from engineering, design, and occupational therapy across four universities collaboratively developed wearable rehabilitation devices. A progressive four-session structure covered the full development cycle: 3D scanning, CAD modelling, electronics integration, and performance testing. Evaluation exposed critical gaps in traditional engineering education. Students flagged regulatory and clinical requirements as the most significant missing competency, followed by electronics and programming skills. Most consistently, participants lacked understanding of clinical rehabilitation contexts, such as patient needs, human anatomy, and real-world device usage, highlighting that contextual knowledge is as essential as technical skill in healthcare technology design. This research provides practical curricula frameworks for developing both technical and collaborative competencies. The findings confirm that hands-on, interdisciplinary learning bridges educational divides but requires deliberate integration of clinical context and cross-disciplinary exchange, further offering actionable guidance for educators in engineering and product design.

Keywords: Smart wearable devices, rehabilitation devices, interprofessional education, human-centred design, assistive technology

1 INTRODUCTION
The development of wearable rehabilitation devices requires technical expertise spanning multiple engineering and healthcare disciplines, along with a deep understanding of contexts and patient needs [1], [2]. However, traditional engineering and product design education typically operates within disciplinary limits, leaving graduates unprepared for the collaborative, context-related challenges of healthcare technology innovation [3]. While interdisciplinary collaboration is recognised as essential, educators lack clear approaches for identifying and developing the competencies needed for such cross-disciplinary teamwork in this domain [1], [3].
This study presents findings from an intensive hands-on workshop that brought together 21 students from engineering, design, and occupational therapy backgrounds across four European universities to collaboratively develop wearable rehabilitation devices. With a two-day four-session structure the workshop provided a complete device development cycle experience in an advanced makerspace environment (a collaborative workspace where people work together to create, invent, and build things using a set of tools and equipment). Part of a larger effort to develop an online course, this study

evaluates how this pedagogical approach promotes both technical competencies and collaborative teamwork while revealing gaps in students' preparedness for healthcare technology development. Grounded in constructivist and experiential learning theory, and building on existing competency frameworks for wearable technologies, this study moves beyond descriptive pedagogy to analytically examine why clinical knowledge represents the critical gap in interdisciplinary wearable education, positioning healthcare context integration, not technical skill alone, as the central and novel contribution of cross-disciplinary collaboration in this domain.

2 BACKGROUNDS

2.1 The case of smart wearable technology

A **smart wearable** is an electronic device designed to be worn on the human body that collects, processes, and transmits data in real time, often connecting to other devices or cloud services. Such wearables can target rehabilitation context. For example, DigiClap is a smart wearable device designed to support rehabilitation in children with cerebral palsy (CP) through gamified occupational therapy [2]. Using a user-centred design approach, the device is worn on the hand and captures finger and hand movements to interact with a serious game on a tablet. The device is additively manufactured using a 3D printer, combining rigid material for structural housing and flexible material for the finger rings, ensuring comfort and a personalised fit. Its modular architecture allows finger modules to be added or removed based on each child's therapeutic goals. Onboard Inertial Measurement Units (IMUs) capture real-time motion data, processed via an algorithm and transmitted wirelessly to a cloud platform, enabling occupational therapists to monitor progress remotely. Clinical evaluations confirmed that the smart wearable motivated hand movement and was positively received by both caregivers and occupational therapists [2].

2.2 Learning and competency for designing, fabricating and testing smart wearables

Effective learning for smart wearables design requires multidisciplinary, hands-on approaches combining theoretical knowledge with practical fabrication and prototyping skills, supported by competency frameworks across novice to expert levels. Previous study describes an innovative syllabus covering theoretical knowledge (materials and design), practical "learning by doing" (coding and manufacturing), and industry-involved product design. Further reports [4] reveal successful multidisciplinary teaching, integrating jewellery design, programming, and electronics with user involvement and prototyping. On the framework side, a previous study proposes a three-level competency framework (novice/advanced beginner, competent/proficient, advanced/expert) for sensor and wearable technologies in clinical contexts [5]. Moreover, competency modelling was demonstrated through interactive learning environments with gamification feedback [6]. However, previous studies do not advance beyond example pedagogical approaches.

3 METHOD

The design brief targeted an adjustable motion-tracking ring for AR/VR-based upper-limb rehabilitation—specifically, a customisable wearable ring for phalangeal motion tracking. Background included clarification: Wearable devices that track finger joint movements can provide critical input for interactive VR/AR therapy sessions. However, commercial solutions are often rigid, bulky, or lack modularity. The design brief assigned to the group concerned the development of a simple, adjustable, and lightweight ring capable of tracking motion at individual phalanges, which can later integrate with sensor modules to support real-time data acquisition.

The activities spanned over two days and covered (i) 3D scan of the participant's fingers for average sizing, (ii) a parametric 3D CAD design of the adjustable ring, (iii) first iteration of 3D-printed prototype, (iv) sensor integration, (v) development of working principles of a typical test jig/test procedure/plan, (vi) ergonomic testing, (vii) short iteration cycle based on feedback, (viii) final prototype presentation at closure session with challenges encountered and lessons learnt. The participants worked in multidisciplinary teams of five, including mechanical engineering, design, computer science, and occupational therapy backgrounds. They were in their first or second year of master's studies or in doctoral studies in their respective majors. All participants provided informed consent prior to participation. Data was anonymised and handled in accordance with the EU General Data Protection Regulation (GDPR) and the ethical guidelines of the University of Oulu.

This study employed three complementary methods to evaluate competencies in wearable rehabilitation device development: (1) Hands-on and observation workshop (Figure 1a): Four progressive practical sessions covering the complete device development cycle (3D scanning (Figure 1b), CAD modelling and 3D printing, electronics and programming (Figure 1c), and testing, (2) Post-workshop survey (mixed-methods questionnaire administered to all participants to capture feedback, measure learning outcomes, and assess competency gaps), and (3) A qualitative feedback from educators. A total of 21 students participated. The majority (62%) were in the 20-24 age group, followed by 24% in the 25-29 range, while 14% were 35 or older. Participation was well-distributed across the four partner institutions. The University of Oulu was best represented, t (38%, n=8), followed by the University of Pisa (29%, n=6), the University of Malta (19%, n=4), and the University of Strathclyde (14%, n=3). Figure 1 shows the work in two workshop sessions.

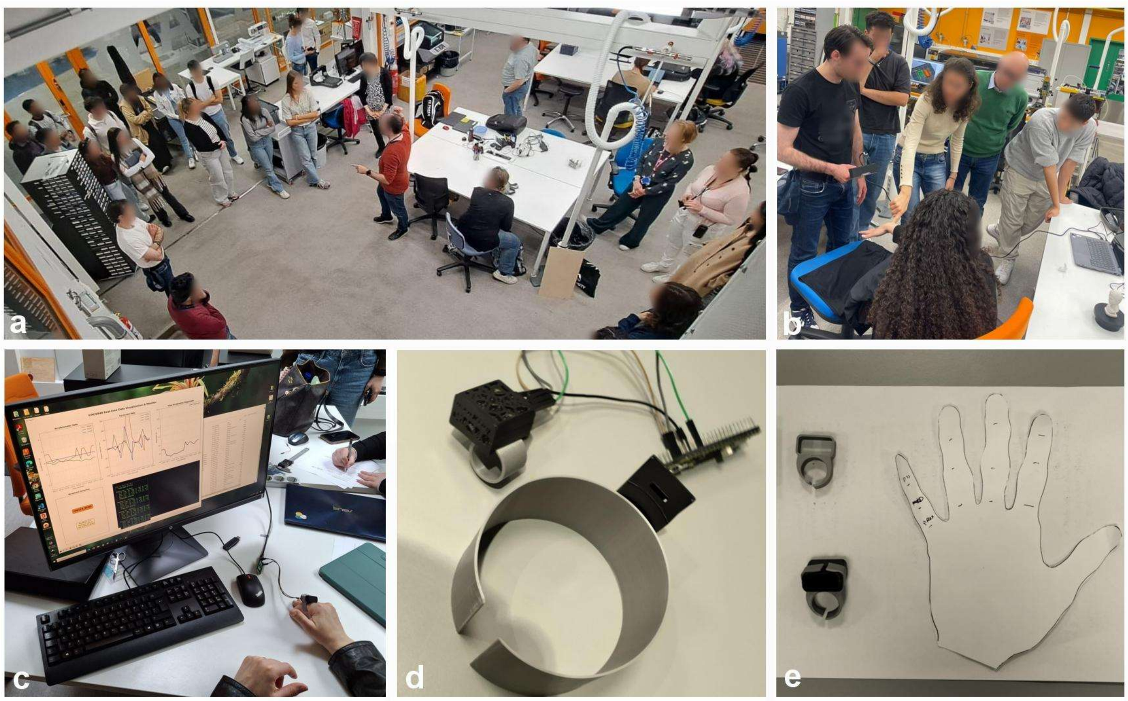

Figure 1. Super Fab Lab Oulu environment during the introductory (a), 3D scanning (b), electronics and programming (c) sessions, and example developed solutions (d, e)

3.1 Workshop

The workshop sessions are outlined in Figure 1a-e: **3D Scanning:** Students were introduced to 3D scanning technology and practiced capturing objects as digital 3D models. While few had prior experience, the activity sparked strong interest and highlighted both potential applications and challenges in handling complex anatomies. **CAD Modelling and 3D Printing:** Engineering and occupational therapy (OT) students collaborated to design a finger module for a wearable rehabilitation device (see example in section 2.1). Using CAD tools, clinical insights were translated into prototypes, which were then fabricated with 3D printing for further testing. **Electronics and Programming:** Participants integrated Raspberry Pi Pico boards and IMU sensors into the 3D-printed devices. After a brief introduction to circuitry and real-time monitoring, they assembled and programmed the system to capture and visualise motion data. **Testing Wearable Devices:** The workshop concluded with assembly and testing of the devices. Students evaluated performance, sensor outputs, and discussed feedback with OTs, reflecting on limitations and improvement opportunities.

3.2 Survey

To complement observations during the workshop, independent educators took notes, and the post-workshop survey was administered. The survey was completed by all 21 participants, representing engineering, design, and occupational therapy students. The survey design combined Likert-scale ratings, multiple-choice items, and open-ended questions. This allowed for both quantitative assessment of key aspects and qualitative feedback, providing deeper insights into the student experience. The survey covered five main areas: (1) student profile – age and university affiliation, (2) organisation of activities – perceptions of the schedule, balance between theory and practice, and pacing of sessions, (3) logistics – availability and suitability of machines, facilities, and other resources, (4) sessions – ratings of whether each session was complete, enjoyable, useful, and relevant to learning goals, and (5) session-specific comments – space for participants to provide positive observations, highlight challenges, and suggest improvements for each session.

4 RESULTS AND DISCUSSION

4.1 Quantitative results

Participants expressed high satisfaction with workshop organisation, with over three-quarters providing positive ratings (57.1% rating it as excellent and 19% as good). Only 23.8% rated it as satisfactory, with no negative ratings, indicating effective planning and execution. The high satisfaction possibly meant that the results around content balance and gaps were more valuable. Specifically, the **balance between theoretical content and hands-on practice** received mixed but generally positive feedback. Equal proportions of participants (33.3% each) rated this aspect as good or excellent, while 23.8% found it satisfactory and 9.5% provided lower ratings, suggesting room for improvement in content balance. All four workshop sessions (3D Scanning, CAD Modelling and 3D Printing, Electronics and Programming, and Testing Wearables) were rated highly for being both engaging and comprehensive (Figure 2a). Participants found all sessions highly applicable to their learning objectives, with predominantly high ratings for usefulness and relevance (Figure 2b). Furthermore, the workshop successfully met or partially met expectations for all participants, with 90% fully satisfied and 10% partially satisfied. Figure 2c shows what students identified as areas of further development. Students identified regulatory and clinical requirements as the primary area needing development (n=15), followed equally by electronics/embedded systems and programming/software integration (n=14 each).

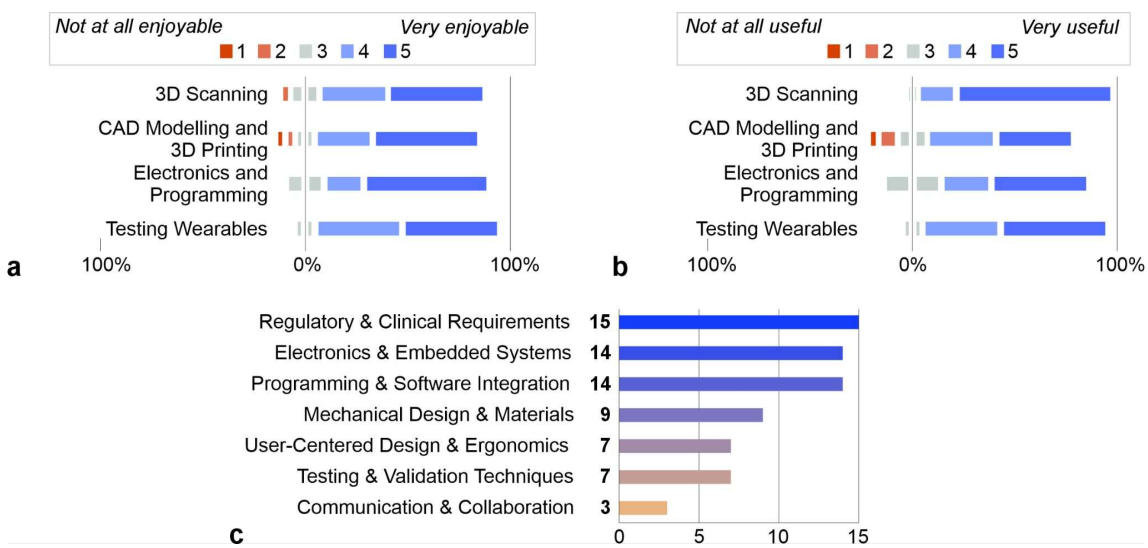

Figure 2. Enjoyability (a) and usefulness (b) of the workshop sessions; (c) areas of further development identified by the students

4.2 Qualitative results from student observations

To capture detailed feedback, students were asked to reflect on each of the four sessions in terms of what they found positive, useful, challenging, and what could be improved. Students found the workshop engaging and highly valuable, particularly praising the hands-on learning approach that allowed them to apply all sessions directly. Interdisciplinary collaboration emerged as a key strength, with participants noting that working across different backgrounds helped bridge knowledge gaps and enriched the learning process. However, a number of challenges surfaced consistently. Time constraints limited opportunities for iteration and refinement, while steep learning curves in electronics and CAD sessions created disparities between beginners and experienced students. Technical difficulties, from scanner stability and CAD precision to sensor calibration and data consistency, also hindered progress. Overall, students appreciated the balance between theory and practice, expressing interest in broader applications to healthcare contexts. They recommended clearer clinical integration, more structured interdisciplinary exchange time, and extended practice opportunities to strengthen future implementations.

4.3 Qualitative results from educator observations

Educators provided complementary perspectives on the workshop. Their observations focused on both the potential of the technology and the practical challenges encountered during its use. Key points noted by educators included: Challenges in identifying suitable procedures for 3D scanning in context; Limited participation from OT students/teachers in some cases; Recognised the relevance and potential of 3D scanning technology; Strong interest in exploring and testing new methods for scanning; Emphasised the need for more hands-on practice to develop problem-solving skills, particularly when scanning complex anatomies; Despite enthusiasm, the integration of scanning results into subsequent phases (CAD design, electronics integration) was limited or partial.

4.4 Differences and missing topics

While several similarities were observed across the sessions, the survey also highlighted notable differences in how students experienced each activity. These differences related to the perceived strengths of the sessions, the main challenges encountered, unique aspects that stood out, and the diversity of prior experience among participants (Table 1).

In addition to evaluating the sessions, students were asked to reflect on areas where they felt further knowledge or skills would have enhanced their learning experience. Their responses pointed to gaps in both technical and contextual competencies, ranging from a stronger rehabilitative and biopsychosocial perspective to more practical knowledge about materials and fabrication (Table 2).

Table 1. Major differences in sessions

Aspect	3D Scanning	3D Modelling	Electronics	Testing
Biggest positive	The theory was clear and made the hands-on activities easier.	Creative process of turning ideas into objects	Seeing complex electronics explained clearly	Real-world insight: spotting design flaws and iterating
Biggest challenge	Multitasking: keeping the scanner steady, covering all angles	Learning a new CAD tool vs known tools; tolerances	Beginners struggled with coding & sensor calibration	Short time made re-testing and fixes tough
Unique aspect	Opened students' eyes to new applications in various sectors	Highlighted the link between design choices & real printing outcomes	Students enjoyed seeing how changing code affected sensor data in real time	Introduced structured frameworks like VVT for testing methodology
Learner diversity	Many total beginners	Mixed: some with strong CAD experience	Divide: some with coding experience, others none	Some already knew basic testing concepts

Table 2. Missing topics and skills from the *student perspective*

Missing competence	Description
Clinical / Rehabilitation Context	Many students felt they lacked a solid understanding of how the device would be realistically used by patients and therapists. They wanted more insight into human anatomy, clinical needs, and usability in real scenarios.
Creative Process & Concept Ideation	Several students felt the ideation phase was too rushed, which limited their ability to generate and refine creative concepts. They suggested including techniques for concept development and exploration before jumping into the design.
Technical Skills	Some students identified technical gaps, mainly related to using unfamiliar CAD software or lacking experience in modelling and scanning the body accurately.
Cross-Disciplinary Awareness	Students highlighted the importance of bridging the gap between different academic backgrounds. They felt more basic cross-field knowledge would help engineers, designers, and health science understand each other's perspectives.
Time & Group Dynamics	Many didn't think topics were missing but pointed out that time was a major issue. More time would have allowed them to refine designs, test more iterations, and better connect within their groups.

The workshop findings recommend five key improvements for interdisciplinary wearable rehabilitation education. First, extend practical sessions across multiple days with open lab hours and buffer time for iteration. Second, integrate clinical context through therapist-led presentations, patient case studies, and rehabilitation setting observations at the start of each session. Third, structure interdisciplinary exchange through mixed engineering-health teams, knowledge translation exercises, and reflection sessions. Fourth, strengthen materials understanding via property libraries, hands-on testing, and manufacturing demonstrations. Fifth, implement progressive skill building across four sessions assessed on technical competency, clinical integration, collaboration quality, and regulatory awareness.

5 CONCLUSION, IMPLICATIONS AND FUTURE WORK

The study illuminates how diversity in educational backgrounds (spanning engineering, design, and health sciences) enriches the learning process while simultaneously creating pedagogical challenges in wearable rehabilitation technology education. Drawing on students' experiences, they particularly value interdisciplinary collaboration for bridging knowledge gaps, yet steep learning curves create disparities between participants with different prior experiences. These findings directly inform strategies for accommodating diversity in multidisciplinary student projects in design education. Based on comprehensive feedback from student participants, the study proposes evidence-based recommendations for interdisciplinary design education. The five evidence-based recommendations proposed address practical, clinical, and collaborative dimensions of future course design. A follow-up clinical study is planned, in which students will complete a design brief drawing on knowledge from the e-learning course, with outputs evaluated by an expert panel. The modular session structure of the workshop is designed to be adaptable for distributed or online delivery but also can be scaled up to traditional course structure. This structure is forming the foundation of a forthcoming e-learning course that will allow broader cohorts across institutions and disciplines to engage with the same interdisciplinary competency development framework.

ACKNOWLEDGEMENTS

This research has been funded through the Erasmus+ Key Action II project titled "Engineering Educational Competence Development on Customisable Wearable Rehabilitation Devices (EDUWEAR), project reference number 2024-1-MT01-KA220-HED-000244341. Special thanks also go to all the participants (students and educators) who volunteered in this study.

REFERENCES

[1] Georgiev G. V. et al. A Comprehensive Methodology to Identify Competence Gaps in Product and Design Engineering Curricula. In *DS 137: Proceedings of the International Conference on Engineering and Product Design Education (E&PDE 2025)*, 2025, pp. 7–12. doi: 10.35199/EPDE.2025.2.

[2] Bonello M., Buhagiar N., Farrugia P. and Mercieca J. Unveiling the impact of the SMARTCLAP project on rehabilitation. *Comput. Struct. Biotechnol. J.*, vol. 24, pp. 451–463, Dec. 2024, doi: 10.1016/j.csbj.2024.06.001.

[3] Hall A., Leff D., Wojdecka A., Kinross J., Thompson P. and Darzi A. Beyond the Healthcare Paradigm: Co-Creating a New Model for Collaborative Transdisciplinary Healthcare Design Education. In *DS 95: Proceedings of the 21st International Conference on Engineering and Product Design Education (E&PDE 2019)*, 2019. doi: 10.35199/epde2019.16.

[4] Ahde-Deal P., Henriksen M. and Andersen R. Teaching Wearables. In *Learn X Design Conference Series*, Jul. 2019. [Online]. Available: https://dl.designresearchsociety.org/learnxdesign/learnxdesign2019/researchpapers/72

[5] Hilty D. M., Armstrong C. M., Edwards-Stewart A., Gentry M. T., Luxton D. D. and Krupinski E. A. Sensor, Wearable, and Remote Patient Monitoring Competencies for Clinical Care and Training: Scoping Review. *Journal of Technology in Behavioural Science*, vol. 6, no. 2, pp. 252–277, Jun. 2021, doi: 10.1007/s41347-020-00190-3.

[6] Zinnen A. and Godehardt E. SmartEducation: Prototyping a Configurable Learning App Using Gamification. In *2018 22nd International Conference Information Visualisation (IV)*, Jul. 2018, pp. 518–523. doi: 10.1109/iV.2018.00096.