

Leveraging Game-based and Blended Learning to Support Students with Heterogeneous Linguistic, Cultural, and Academic Backgrounds in a Lecture Series on Traffic Accident Biomechanics and Polytrauma Pathophysiology

R. Grau¹, A. Steiner², L. West², M. Mann¹, K. Bause¹, T. Düser¹

¹ IPEK – Institute of Product Engineering, Karlsruhe Institute of Technology (KIT)

² Center for Teaching and Learning in Higher Education, University of Tübingen

Introduction

Background

- New interfaculty **Master's program** in **Biomedical Engineering (M.Sc.)** at the Karlsruhe Institute of Technology (KIT) brings together **students** from **diverse linguistic, cultural, and academic backgrounds** with **varying prior knowledge and learning needs**.
- Lecturers of the interdisciplinary **lecture series "Trauma Science: Blood, Emergency Medicine, and Surgery"** come from **accident research** (DEKRA, a German technical inspection and expert organization), **prehospital Emergency Medical Service** (Workers' Samaritan Foundation Germany), and four chief **physicians** from Karlsruhe **Municipal Hospital** covering the fields of technologies for hemostasis, pathophysiology of blood, transfusion medicine, and minimally invasive surgery in infants and young children.
- To support students' entry into the **sensitive topics** of **biomechanics** and **pathophysiology** of injured patients, the **serious game Graveler** (based on [1]) was developed and implemented to enable self-paced learning aligned with individual interests and prior knowledge.

Didactic Scope & Goals

- Interdisciplinary contextualization** across engineering, medicine, biomechanics
- Immersive narrative learning** to enhance student **engagement** and **motivation** [2]
- Suitable for **heterogeneous international cohorts** with **varying prior knowledge**
- Supports **self-paced, competency-based, and exploratory learning** in **asynchronous** settings
- Scaffolded learning pathways** through narrative progression and multi-modal elements
- A **bridging tool** between various topics covered in the lecture series, as well as between theoretical lectures and applied clinical reasoning
- Promotes repetition & reinforcement** of core lecture content
- Serves as an **exchange** and **networking platform** for first-year students, fostering peer interaction, orientation, and community building
- Embedded in a **blended learning framework**, combining serious gaming, adaptive learning, and inclusive access for diverse learners

Research Questions

- Can a serious game serve as a thematic integrative element to address the challenges of a highly heterogeneous student cohort with diverse prior knowledge within an interdisciplinary lecture series in Trauma Science?
- How do students use the serious game Graveler, and what recommendations for improvement can be derived from this?

Methods

Game Development

- Graveler is a **web-based game engine** and **development platform** for **2D online multiplayer role-playing games** [1], enabling direct access without local installation and supporting real-time interaction between multiple users in a shared virtual environment. The platform integrates game mechanics with **learning management system functionalities** and **communication tools**, creating a digital learning and interaction space. The game design follows a narrative, linear structure with sequential stages that mirrored the real trauma care pathway.
- Avatar and perspective taking**: Players experience the game world from their customized avatar's perspective, which supports active, hands-on learning
- Free exploration**: Open maps with interaction points that reveal content step by step, including text, images, video, or quiz items.
- NPCs**: Non-player characters provide information and tasks
- Collectibles & achievements**: Items and achievements drive goals/ motivation
- Multiplayer & communication**: Concurrent players can chat and start video calls

Game Content

- The serious game guides students in the role of a paramedic intern through the complete chain of emergency care, from the ambulance station, to the prehospital incident scene, into the hospital shock room, and finally inside the human body:
- Ambulance/ EMS station** (Fig. 1): Introduction to emergency medical services, including structures, vehicles, equipment on the ambulance, workflows, and initial decision-making tasks.
- Prehospital accident scene** (Fig. 2): Following an emergency dispatch, students respond to a car-pedestrian collision, analyze accident biomechanics and injury mechanisms, Abbreviated Injury Scale (AIS)/ Injury Severity Score (ISS) assessment, fracture mechanisms, head injury criteria, and initial treatment of a polytraumatized patient according to the xABCDE approach.
- Hospital shock room** (Fig. 3): After transport, students perform a structured patient handover and engage in interdisciplinary clinical reasoning for trauma assessment and emergency management in the shock room.
- Inside the human body** (Fig. 4): Students are "teleported" into the human circulatory system, where they explore the physiological basis and pathophysiology of bleeding and hemostasis within the cardiovascular system, including blood function, clot formation, and coagulation processes as responses to severe injury.

Implementation & Evaluation

- The lecture, which was limited to **35 master students**, reached full enrollment for its first implementation in the **winter semester 2025/2026**.
- Game was first introduced during a **synchronous** in-person session, where students received access credentials and a short introduction to login/ gameplay.
- Throughout the semester, students could play the content matching each lecture topic alongside the course in an **asynchronous** manner.
- To support **peer interaction**, an FAQ section and a chat room were implemented.
- Evaluation was conducted using the **User Experience Questionnaire** (UEQ) [3] as a standardized measure of user experience.
- Additional items from own **questionnaire** [1] were included, especially on perceived quality, successful elements, and aspects needing revision.
- Open-ended feedback** and **oral comments** from students were also collected to complement the quantitative results.
- Both game use and evaluation were **voluntary** and **anonymous**.

Results and Conclusions

Identified Strengths

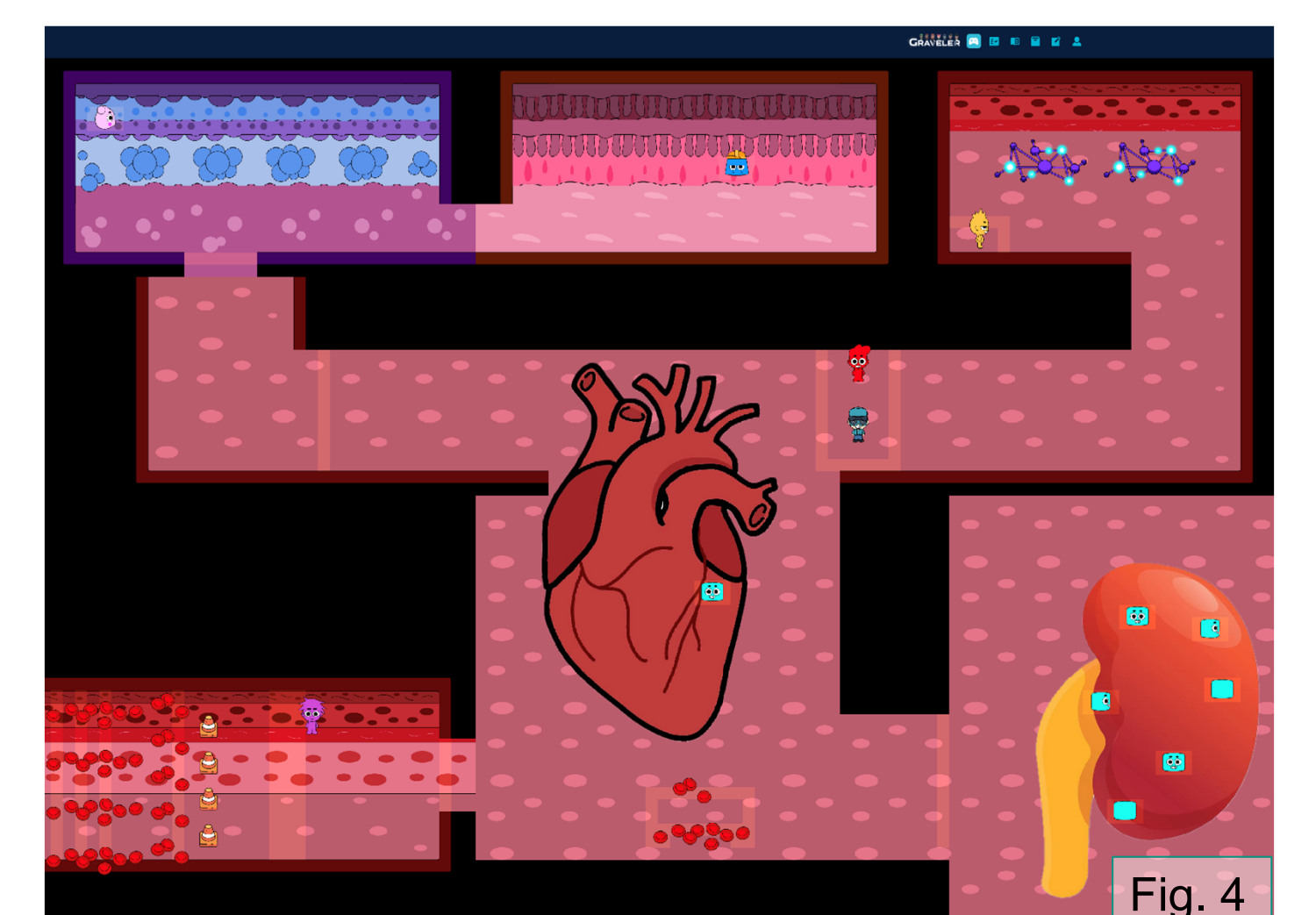
- The following aspects were most frequently highlighted positively in the UEQ (Fig. 5), in our own questionnaire, and in verbal feedback from students:
- Intuitive onboarding** during the synchronous in-person phase, reflected by the highest UEQ ratings for **perspicuity & dependability** (easy to understand, learn, and reliable)
 - Engaging course material** that fosters student motivation
 - Original abstract game elements** with a **positive aesthetic perception**
 - Support for self-paced, independent asynchronous learning**, reflected by completion times ranging from 15-90 min (mean: 40 min), indicating that students engaged with the serious game according to their individual learning pace and prior knowledge, while also offering the potential for students to expand the game within the course context.
 - Narrative framework** integrating multiple lectures, creating a coherent storyline ("common thread") across the **interdisciplinary lecture** series and supporting thematic continuity despite the involvement of different lecturers.
- Distribution of Answers per Item (UEQ)
- | Item | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|--|----|----|----|----|----|----|------|
| conservative/innovative | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| unfriendly/friendly | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| unattractive/attractive | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| cluttered/organized | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| impractical/practical | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| confusing/clear | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| inefficient/efficient | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| Doesn't meet expectations/does meet expectations | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| demotivating/motivating | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| not secure/secure | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| unpleasant/pleasant | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| usual/leading edge | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| unlikable/pleasing | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| complicated/easy | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| bad/good | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| obstructive/supportive | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| conventional/innovative | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| slow/fast | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| unpredictable/predictable | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| not interesting/interesting | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| boring/exciting | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| inferior/valuable | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| difficult to learn/easy to learn | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| dull/creative | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| not understandable/understandable | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| annoying/enjoyable | 0% | 0% | 0% | 0% | 0% | 0% | 100% |

Improvement Opportunities

Optimization Potentials	Possible Solutions & planned Improvement Measures
Navigation on the Game Map	- Integration into the tutorial - In-person onboarding includes the tutorial (immediate lecturer assistance) - Optional hints
Stimulation and difficulty level	- Diversification of task types - Tasks at higher taxonomic levels (e.g. with decision paths)
Perceived learning efficiency	Establishment of a transparent constructive alignment
Didactic integration	- Optimization of orchestration - In-person onboarding enables independent use of game - Use of asynchronous gameplay time

Discussion & Conclusions

- UEQ results show a high standard deviation due to the low response rate (<10 students). A more comprehensive evaluation with a larger cohort is planned for the next semester.
- Graveler demonstrates strong potential as a motivating serious game for **supporting asynchronous learning** in higher education.
- The game supports the reinforcement of trauma science content through interactive learning while **strengthening connections between different lecture topics**.
- To maximize its **educational effectiveness**, further improvements are needed in navigation, task variety, difficulty balancing, and feedback mechanisms.
- The initial implementation suggests that Graveler can help **address the challenges of heterogeneous student cohorts** by serving as a thematic bridge across interdisciplinary trauma science topics. **Ongoing iterative development** and **evaluation** will further strengthen its educational impact.



References:

- [1] Körner, K., Fink, E., Steiner, A.K., Chupakhin, J., da Silva, G.P. (2025). Graveler - Global Awareness Education Through Virtual Voyages. In: Schönbohm, A., et al. Games and Learning Alliance. GALA 2024. Lecture Notes in Computer Science, vol 15348. Springer, Cham. https://doi.org/10.1007/978-3-031-78269-5_15
- [2] Grau, R. M., Bastian, A., Frank, N., Volpp, T., & Düser, T. (2024). Immersive Paths for Digital Product Engineering: Evaluation of a Game-Based Virtual Gearbox Workshops in Mechanical Design Education. In: Malmqvist, J., Candi, M., Saemundsson, R. J., Bystrom, F., & Isaksson, O. (Eds.), DS 130: Proceedings of NordDesign 2024, Reykjavik, Iceland, 12th–14th August 2024, pp. 831–840. Institute of Product Engineering, Karlsruhe Institute of Technology, Germany. <https://doi.org/10.35199/NORDDESIGN2024.88>
- [3] Laugwitz, B., Held, T., Schrepp, M. (2008). Construction and Evaluation of a User Experience Questionnaire. In: Holzinger, A. (eds) HCI and Usability for Education and Work. USAB 2008. Lecture Notes in Computer Science, vol 5298. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-540-89350-9_6

Contact: **Raphael Grau, M. Ed.**
Research Group Medical & Health
Technology, Doctoral Researcher
✉ raphael.grau@kit.edu

IPEK – Institute of Product Engineering
Karlsruhe Institute of Technology (KIT)
✉ www.ipek.kit.edu

