Integrating Human Physiology and Industrial Robotics through Smart Textiles and Immersive VR Experiences

We propose the integration of Virtual Reality (VR), wearable technology, and gamification to offer students an immersive and interactive experience in exploring human physiology and human-robot interaction during the *2025 Boiler Gold Rush (BGR)* event. Using Purdue University's state-of-the-art VR CAVE in the Department of Industrial Engineering, along with portable *Meta Quest 3 VR* headsets, and smart textiles, the experience invites students into a dynamic exploration of interconnected physiological systems and industrial robotics. This project emphasizes hands-on engagement through real-time physiological feedback and interactive storytelling, ultimately enhancing students' understanding of technology's impact on both the human body and industry through two interconnected VR scenarios:

1. **Exploration of Human Body Systems:**

Objective: Provide an immersive tour of the human circulatory, respiratory, and nervous systems, where physiological data influences the experience.*Interactive Experience:* The real-time integration of students' physiological data, collected through smart vests developed by Prof. Martinez's research group, will dynamically influence the VR environment. For example, heart rate and breathing patterns will impact visualizations, such as blood flow and respiratory function. These smart textiles will enable students to explore their circulatory, respiratory, and nervous systems in a gamified VR experience, enhancing their understanding through interactive, personalized simulations.
Gamified Elements: Interactive challenges like "repairing" damaged cells or increasing oxygen flow will enhance understanding of physiological concepts and processes.
Educational Outcome: This immersive interaction not only reinforces concepts of human physiology but also highlights the capabilities of smart textiles to provide real-time health-status monitoring, demonstrating the potential of wearable technology in healthcare and biomedical engineering.

2. **Digital Twin Integration in Industrial Robotics Simulation:**

Objective: Provide a safe, virtual environment where students explore how wearable sensors and digital twin technology enhance human-machine communication in industrial robotics. This integration leads to safer and more efficient collaborations between humans and robots.
Interactive Experience: Students will take on roles in a virtual assembly line where they must collaborate with robotic arms to complete tasks such as assembling products or sorting items. The efficiency and accuracy of task completion are influenced by their physiological state, as detected by the smart vest. The smart vest monitors indicators like fatigue and stress levels. If a student shows signs of fatigue (e.g., elevated heart rate or irregular breathing patterns), the VR environment responds by simulating heavier components or slower robot response times, challenging the student to manage their physiological state to maintain performance.
Gamified Elements: Completing tasks efficiently and safely earns points, unlocks new tools or machinery in the simulation, and grants access to higher levels with more advanced robotics technology. Leaderboards can display top performers to encourage healthy competition.
Educational Outcome: The simulation bridges human physiology with industrial robotics through digital twin technology. It enhances student engagement and understanding of how wearable technology and VR can be applied to workforce development and training in safe human-robot interactions.

Safety and Privacy: Users will wear, on top of their cloths, a safe, non-invasive wireless smart vest with integrated pulse and breathing sensors. For privacy, no data is stored by the proposed systems.

Execution Plan and Student Involvement: Student teams from the LearnerX Lab (Team Lead: B. Castro) and the departments of IE and BME (PI: Prof. Martinez) will actively participate in content development, wearable technology integration, and user experience design. Planning and development will begin in the Spring semester, offering undergraduate research for credit through "*Smart Digital Twin*" (IE-490) to help with the initial prototype. The Summer phase will focus on installation preparation, testing, and refining the user experience.

Scalability and Short-term Expansion: Implementing a VR CAVE and developing a portable VR educational toolkit will support ongoing cross-departmental experiential learning, strengthen workforce development, and inspire innovative research. With additional funding to cover faculty overload compensation, undergraduate salaries for content development, and extra VR equipment to increase student capacity, we can broaden VR CAVE activities by incorporating them into a new honors course for Spring or Winter break. This course could later be scaled to engage more students across multiple colleges.

Budget Outline (TOTAL =$3,000):

- ***VR Equipment: $1100***
  - *Meta Quest 3 VR Headsets (2 units): $1,000*
    Estimated at $500 per unit, possibly utilizing educational discounts or bulk purchasing options.
  - *VR Accessories: $100*
    Protective cases, hygiene masks, and additional straps for comfort and sanitation during BGR events.
- ***Software Licenses and Development Tools: $200***
  - *Unity Pro Educational License: $200*
    For developing interactive VR content with advanced features.
  - *3D Modeling Software (e.g., Autodesk 3DS Max, Blender): $0*
    Blender is free and open-source, reducing costs.

- ***Plugin and Asset Store Purchases: $100***
  Specialized plugins or assets to enhance VR experiences.

- ***Wearable Integration Materials: $700***
  - *Smart Textile Components:*
    Heart rate sensors (e.g., Pulse Sensor Amped): $200
    Strain gauges for breathing patterns: $150
    Microcontrollers (e.g., Arduino Nano or Raspberry Pi Pico): $150
    Conductive thread and fabric materials: $100
    Miscellaneous electronics (wires, connectors, batteries): $100

- ***Student Developer Stipends: $900***
  - *Undergraduate Research Assistants (2 students): $768*
    30 hours ($12/hr) per student to support their involvement over the Spring and Summer phases.
  - *Undergraduate Student (LearnerX Lab)*: *$132*
    11 hours ($12/hr) to create a virtual story-telling, explaining the experience to the students, over the Summer.

Faculty Involved:

- Ramses V. Martinez. Hall Family Rising Star Associate Professor. Edwardson School of Industrial Engineering and Weldon School of Biomedical Engineering. Purdue University. (rmartinez@purdue.edu). Principal investigator of FlexiLab: https://engineering.purdue.edu/FlexiLab/
- Dr. Beatriz Castro, Department of Biological Sciences (bcastro@purdue.edu), instructor of Human Anatomy and Physiology I and II (BIOL203 & BIOL204). Team lead of LearnerX Lab: https://www.bio.purdue.edu/lab/learnerx-lab/