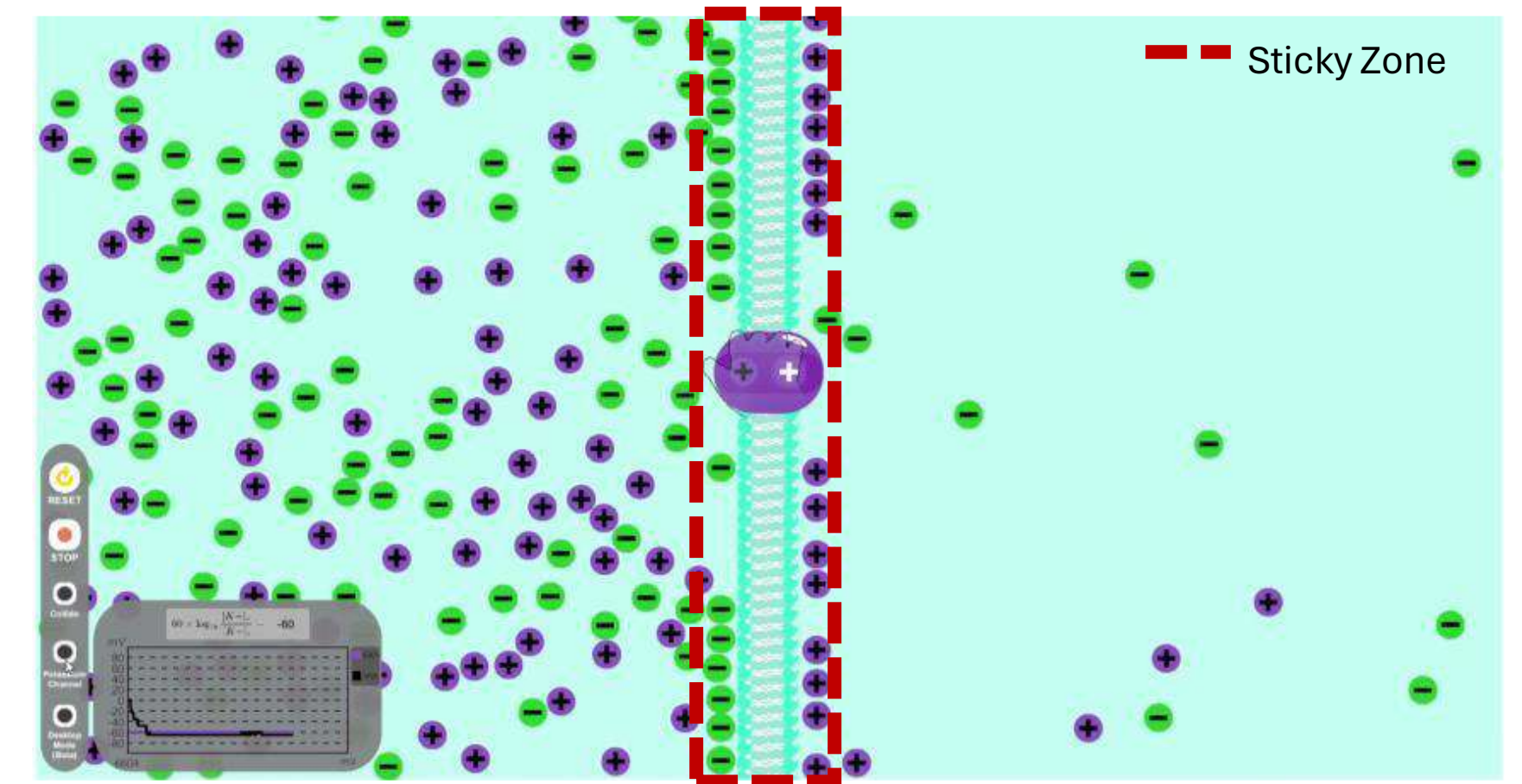


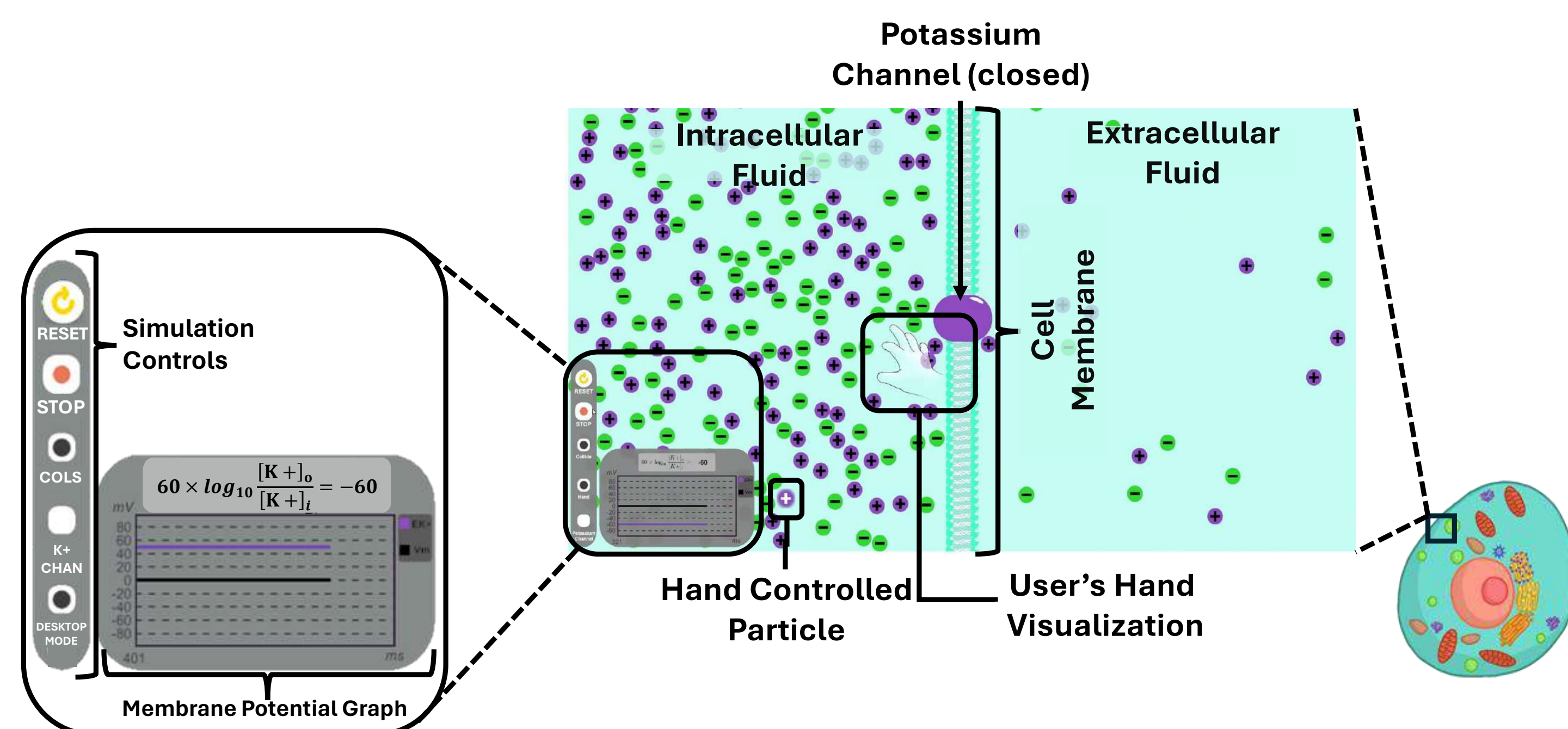
Beyond the Screen: Gestural Perspective-Taking with a Biochemistry Simulation



Significant research has been conducted on how students' gestures aid in learning scientific concepts, yet there remains a gap in understanding the impact of gesture-based interactions between students and simulations on their interpretation of visualized scientific phenomena. Addressing this, our paper presents a usability test conducted on a dynamic equilibrium visualization simulation developed for introductory college courses. Through a user study involving 40 participants, we conducted a qualitative evaluation to determine how students interpret gesture-controlled simulations. The findings confirm that students generally interpret visualized scientific concepts effectively and that interacting through gestures enhances their interpretation of the simulations. Additionally, this paper discusses the limitations of the current study and suggests directions for future research.



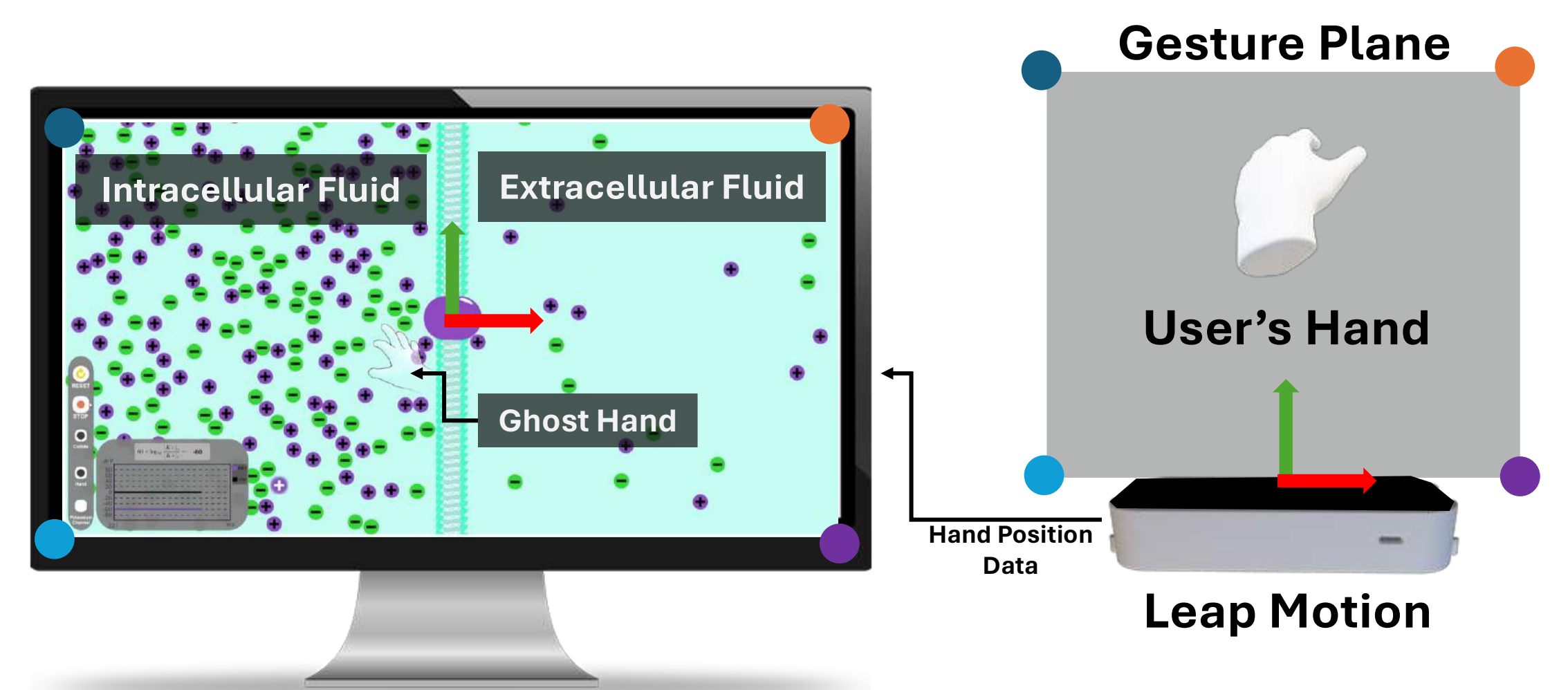
Simulation Development



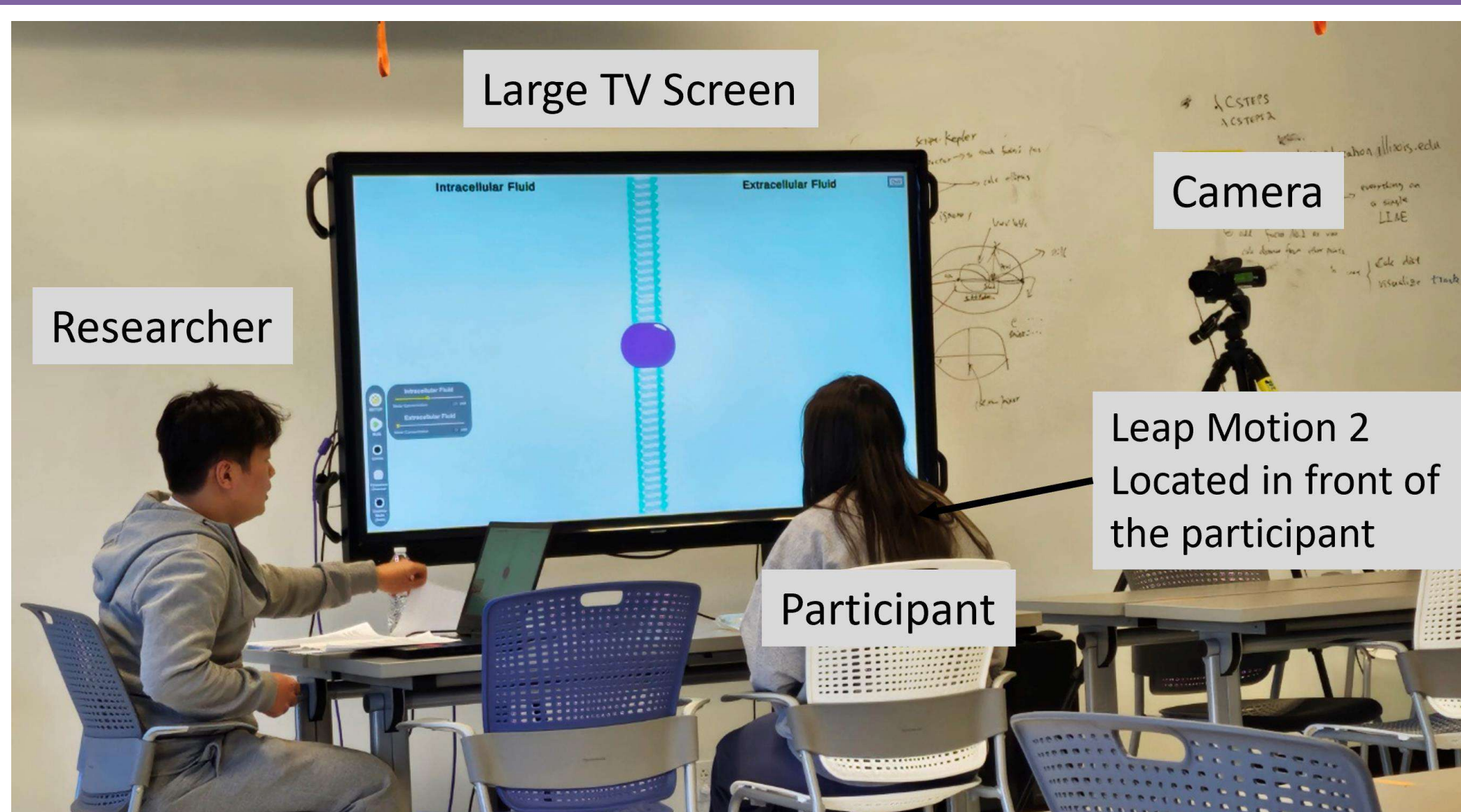
- The simulation visualizes a zoomed in section of a cell membrane
- There are small green and purple dots representing negatively charged chloride (Cl^-) and positively charged potassium (K^+) ions.
- A purple (K^+) channel is embedded in the cell membrane
- The movement of K^+ across the channels is dictated by two factors:
 - Chemical Driving Force (CDF):** Random diffusion which occurs if a K^+ ion gets close to the potassium channel.
 - Electrical Driving Force (EDF):** The difference between the membrane potential and the equilibrium potential
- EDF is dictated by the **Nernst equation** and is typically **more challenging for students** to grasp because of how rapidly it changes.
- The EDF information is visualized in the graph on the bottom left of the interface where the **purple line depicts the equilibrium potential and remains constant** (computed at the start) and the **black line depicts the membrane potential**, updating in real-time as the simulation runs. **At equilibrium, the two lines converge.**
- Another important concept visualized in the simulation is **the phenomenon of K^+ and Cl^- attracting each other across the membrane**. Implemented based on alignment of K^+ and Cl^- in a sticky zone (visualized above).

Hand Tracking

- The most important feature of the simulation is **allowing the learner to embody a designated K^+ with their hand ($K^+, *$)**.
- Hand tracking is **accomplished with the Leap Motion controller** which is placed on a desk facing upward below the learner's hand.
- To increase the visual saliency of $K^+, *$, **it is shaded with a lighter hue of purple and the positive symbol is colored white** (as opposed to black).
- The **(x, y, z) position of the palm is transmitted to the simulation and is used to localize $K^+, *$** .
- The corners of the gesture plane correspond to corners of the monitor** allowing the $K^+, *$ to reach all parts of the simulation without gesturing across large distances



User Testing



Result 1 – Survey (out of 5)

Category	Mean (SD)
Ease of use	4.19 (0.96)
Usefulness	4.6 (0.67)
Immersion	4.29 (0.87)

Result 2 - Interview

- Students had **no trouble interpreting the various elements**.
- Students **predicted the behavior of the CDF** before opening channel.
- Some students **discussed the concept of the EDF** after opening channel.
- Few students **made connections between the ion movements and graph**.
- All students **reported that controlling the ions was easy and intuitive**.

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