

THE FUTURE OF CONTENT

A New Generation of Hybrid Tangible Interfaces for Learning

FALL 2013

UPDATE

mediaX
STANFORD UNIVERSITY



mediaX connects businesses with Stanford University's world-renowned faculty to study new ways for people and technology to intersect.

We are the industry-affiliate program to Stanford's H-STAR Institute. We help our members explore how the thoughtful use of technology can impact a range of fields, from entertainment to learning to commerce. Together, we're researching innovative ways for people to collaborate, communicate and interact with the information, products, and industries of tomorrow.



A New Generation of Hybrid Tangible Interfaces for Learning

Future of Content Project Update October 2013

Research Team: Paulo Blikstein, Assistant Professor of Education; Ingmar Riedel-Kruse, Assistant Professor of BioEngineering; Zahid Hossain, Graduate Student, Computer Science; Sean Choi, Graduate Student, Computer Science; Brogan Miller, Staff, Graduate School of Education

Introduction

During this past year, the MediaX award enabled us to hire students and staff, acquire consumables and hardware development materials in order to develop the proposed hardware and software. We are now starting user studies in a Stanford class taught by Professor Riedel-Kruse. Very excitingly, based on these initial results, we jointly won a major NSF grant within the prestigious Cyberlearning Program. The flexibility of the MediaX funds enabled us to develop prototypes of new physical/virtual models which were key to convincing the National Science Foundation about the potential and feasibility of our project. This flexibility allowed us to pursue high-risk avenues in the project that would not have been possible with more restrictive sources of funding. As such, the MediaX funds fulfilled the important role of allowing us to develop “out of the box” prototypes that helped push the envelope on this research. We are excited now to go into the 2nd year in order to carry out a second user study, develop more advanced hardware and software, and publish our results.

In this project, we set out to develop and test a scalable and cost-effective online experimentation platform for science and engineering education, and measure learning outcomes using cutting-edge learning analytics techniques. Paulo Blikstein has been designing educational platforms for rich experimentation and the bifocal modeling framework as part of his NSF CAREER award, as well

as developing cutting-edge techniques in learning analytics. Ingmar Riedel-Kruse has been developing novel remote biology experimentation platforms and is the creator of Biotic Games.

This project connected in important ways with the “Future of Content” call from MediaX. First, we are anticipating a need that will inevitably happen within the next years in online education. Most players in this field have not realized that a great number of disciplines need “wet labs” and real lab experiences to promote deep learning. Especially at the K-12 level, familiarity with real scientific procedures and practices is fundamental: in real research labs, knowledge does not come ready and digested as in most online videos or traditional lectures; it presents itself to learners in complex empirical projects. Virtual labs are no match to the complexities of today’s science, especially in the life sciences. Therefore, when thinking about the future of content, inevitably much of it will happen in “bimodal interfaces” which integrate online and offline interaction.

At the same time, current “wet lab” technologies are impossible to scale. The commercial data loggers and sensors were designed for an era of shared equipment – high cost equipment that was used by many users. Whereas computing evolved from the timeshare model to the personal computer, scientific equipment still dwells in that outdated model in which investigators do not “own” the measuring devices. Science needs to be personal, just like computation is. The technologies for making science personal exist – low cost microcontrollers, inexpensive sensors, cloud storage, and flexible, media-rich web frameworks such as HTML5 – so our goal was to put that technology to good use with wet labs and online education.

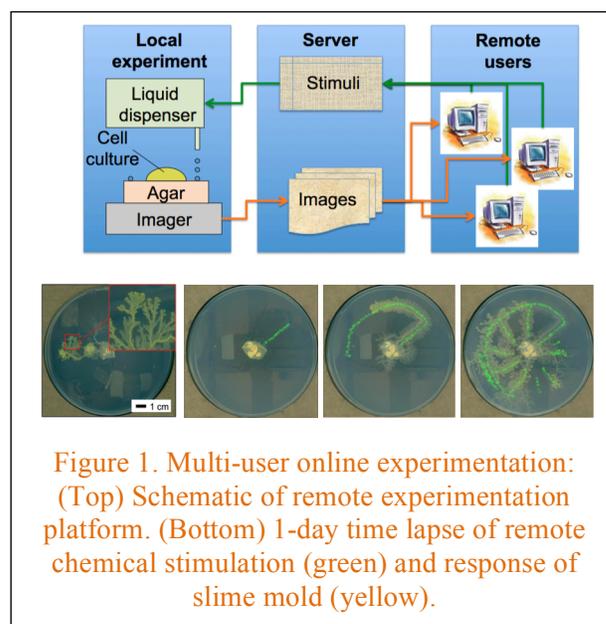


Figure 1. Multi-user online experimentation: (Top) Schematic of remote experimentation platform. (Bottom) 1-day time lapse of remote chemical stimulation (green) and response of slime mold (yellow).

Research and development goals

Our initial proposal was to employ the bifocal modeling framework for the online wet labs. In bifocal modeling, learners build a model of a phenomenon in the real world and attach sensors to it, and they build a virtual model (on the computer) of the same phenomenon using one of several modeling platforms. They run both models at the same time, explore and investigate the function and behavior of the device or phenomenon using them. The approach is designed to help learners construct explanatory mental models of phenomena while reducing cognitive load and freeing resources for hypothesis building. The need to reconcile the differences between the models focuses learners on details they might not have noticed if working with just one model. As they engage in bifocal modeling activities, learners encounter issues concerning the purpose and veracity of models, human error, sensors, and science practice. Thus, in addition to facilitating learning of the science behind the phenomenon they are exploring, learners have opportunities to

learn about the roles of models in science and how to design, construct, and use models scientifically.

In addition, our goal was to make use of the Biotic Games and remote experimentation technology developed and invented by Professor Riedel-Kruse (Figure 1) Biotic games enable human players to interact with true micro-biological processes by observing single celled organisms via a video screen and by influencing the cell's behavior using physiological stimuli with the goal to steer these cells into a specific direction. In contrast to a conventional video game, in which realism is always limited by the underlying computational model, biotic games are realistic by definition. We believe that the combination of these two technologies holds great promise to transform and shape the future of content in K12 environments, especially in science.

Research progress and achievements

Platform set-up

We have now setup two different remote experimentation platforms:

- **Platform 1:** Turn-based experimentation, in which a typical experiment lasts 2 days, and remote user receives experimental feedback every 10 min; typical experiments that can be executed are the chemical stimulation of cell culture systems. We have setup three independent machines, each of which can run six experiments in parallel. As each experiment can be multiplexed by up to six students, we can host up to 100 students in parallel. We are currently doing a small user study with Stanford undergraduate and graduate students.
- **Platform 2:** Real life interaction with microorganisms, in which a typical experiment lasts 30 seconds, and remote users receive real time feedback; typical experiments are the light-based stimulation of affecting the swimming behavior of microorganisms. We can technically run >1000 experiments a day. We plan to do the first user studies in early winter quarter.

Students and staff (partially) funded by the award

- Zahid Hossain (CS)
- Sean Choi (CS)
- Brogan Miller (Education)

Detailed description of the system

System architecture

In Figure 2 we can observe the overall system architecture. Users can utilize a variety of devices (mobiles, desktops, tablets) to interact with the system. They access the server to see the remote experiment webpage, and send commands to the robot, which are wirelessly transmitted to a Raspberry Pi computer controlling the LEGO-based robots. These robots can dispense any

chemical or biological substance onto the petri dishes; the whole system is imaged using a high-resolution flatbed scanner.

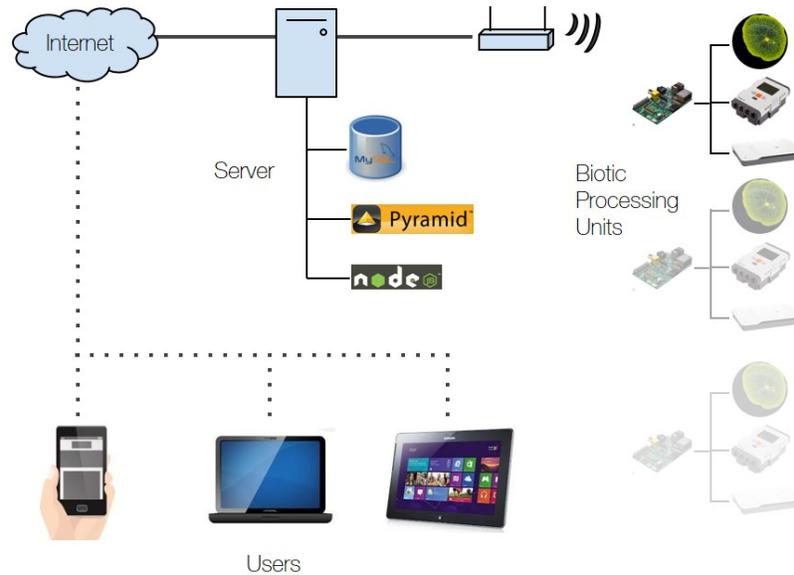


Figure 2. Overall system architecture.

The core elements of the system are the Biological Processing Units, in which the physical experiment happens. In Figure 3 we can see the actual system, with the Raspberry Pi computer, the imaging system, the robot and the petri dishes. This particular setup is running six

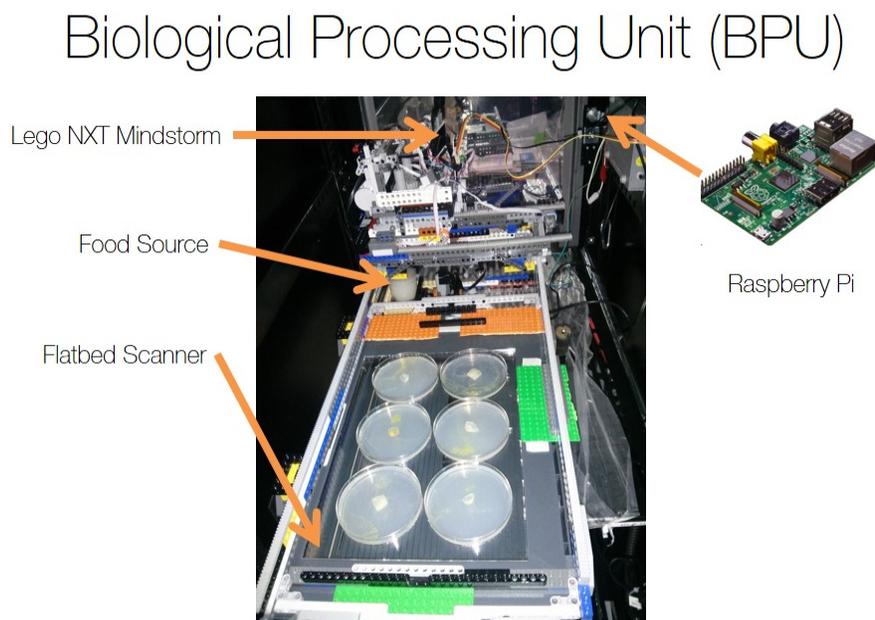


Figure 3. Close-up of the Biological Processing Unit

experiments at the same time.

User interface and forms of interaction

In Figure 4 we observe the current prototype of the user interface, with one example of an experiment after many “drops” (shown in light green). We can also see the user interface and the controls for the time-lapse movie and plot. Within the interface, users can add single drops, multiple drops, or time-controlled drops: users can instruct the robot to deposit a single drop, can “draw” a path for the drops, or program the system to place drops at regular time intervals, automatically (Figure 5).

Users can also control the time-lapse movie of their experiment using the VCR controls. The plots show the number of drops added at each time step during the lab. We are currently investigating other types of data analysis tools and the possibility of exporting the data to commercial software for further analysis.

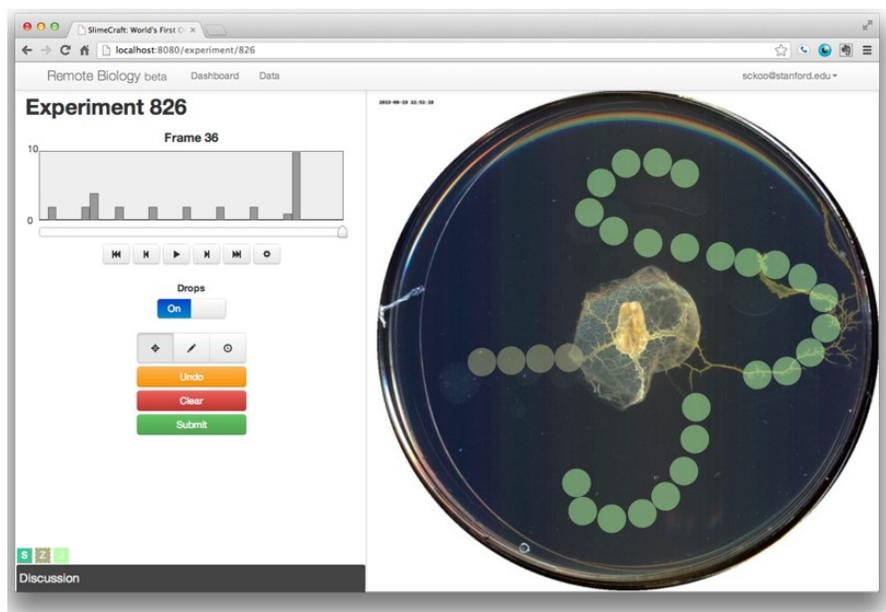


Figure 4 Example of an experiment after many “drops” (shown in light

green). Another feature of the user interface is a discussion board, with which students can talk in real time about the results of their experiments. The discussion board occurs in the same interface real estate, after the correct button is clicked. Even though this is still a design consideration for us, we believe that having an integrated chat feature within the software will make research a lot more effective (since we have control over the chat data), and promote conversation between students.

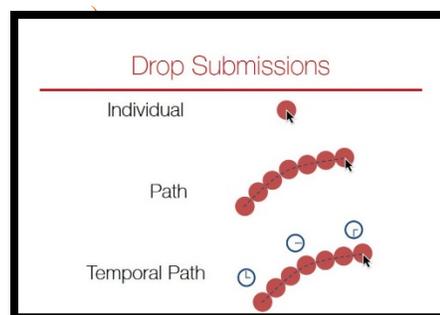


Figure 5. The three types of “drop submissions.”

Finally, we have made great strides in also developing a mobile application. In Figure 6 we have screenshots of the interface on a mobile device. Because of the set of technologies we used for web development, deployment to mobile devices is possible and seamless. This opens up many interesting possibilities for students to interact with the system, since they do not have to be in a

classroom or in their homes—not only manipulation of the experiments can happen “on the go,” but the use of mobile phones and tablets also helps reduce the cost for schools.

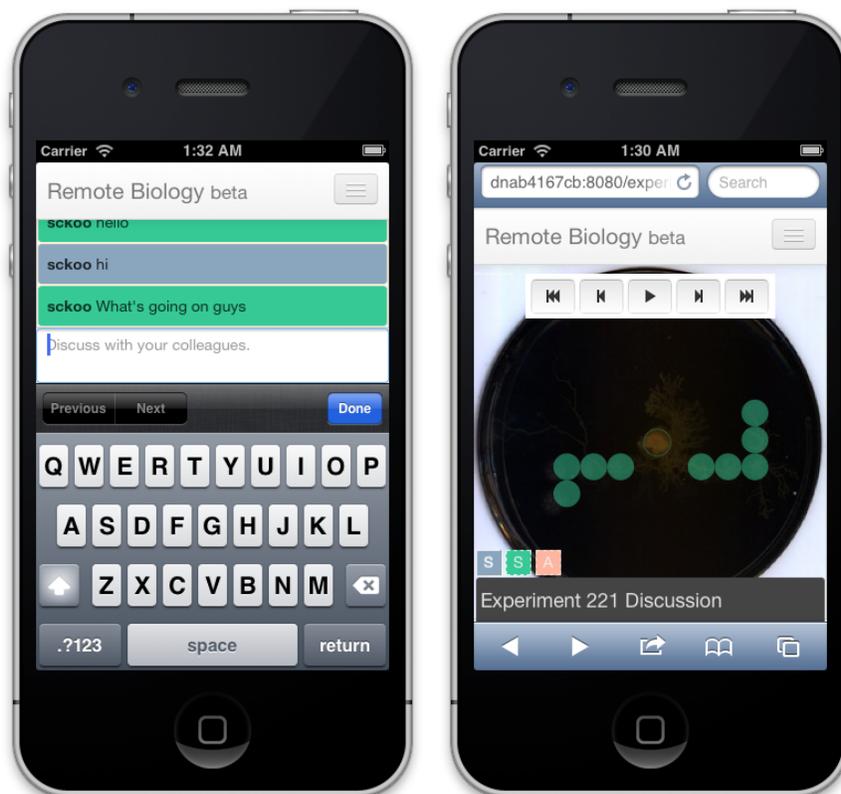


Figure 6. Examples of the user interface on mobile phones: the “drop” interface (left) and the discussion board (right).

Conclusion and future work

For the past several months, we have been hard at work creating the technological infrastructure of a transformative learning technology: massive wet labs. Our attempt was to take the best features of online open education and merge them with the established research on the benefits of physical, wet labs for learning in a variety of disciplines. The current conundrum in online education is that many scientific classes do need labs, and virtual/simulated labs are often not enough to teach more advanced concepts that only emerge in the real manipulation of real lab materials and specimens. Our project breaks new ground by offering a possibly low-cost version to a very high-cost problem, and if we succeed we could have a sizeable impact in the education community. As future work, we intend to run a study in a local high school, and another at Stanford (winter quarter), continue developing the system independently, and try for a massive system in about 6 months.

Additional Reading:

Future of Content Research Theme
<http://mediax.stanford.edu/FOC/concept>

For more information:

- membership
- research themes
- events (conferences, seminars, workshops etc.)

Please visit our website - <http://mediax.stanford.edu>

Like us on Facebook -

<https://www.facebook.com/MediaXatStanford>

Follow us on Twitter -

<https://twitter.com/mediaXStanford>

Join us on LinkedIn -

<http://www.linkedin.com> (search for MediaX at Stanford)

Watch us on YouTube -

<http://www.youtube.com/user/mediaxstanford>



or contact:

Martha Russell, Executive Director - marthar@stanford.edu

Jason Wilmot, Communications Manager - jwilmot@stanford.edu

Adelaide Dawes, Program Manager - adelaide@stanford.edu

Acknowledgements

Many thanks to mediaX Members and Partners, whose contributions have supported this Research.

Special thanks to the professors and researchers who provided these research updates. Thanks also to Addy Dawes, Program Manager, and Jason Wilmot, mediaX Communications, for editing and putting this report into the format you are reading.