SimSnap: Supporting Collaborative Learning through Reconfigurable Simulations

Aneesh P. Tarun[1], Veronica Andric[1], Lesi Yang[1], Tudor Tibu[1], Luigi Zaccagnini[1], Litong Zheng[2], Shafagh Hadinezhad[2], Xuesong Cang[3], William Goss[3], Samantha Baker[3], Dana Gnesdilow[3], Sadhana Puntambekar[3], Mike Tissenbaum[2], Ali Mazalek[1]
Ryerson University[1], {aneesh, veronica.andric, lesi.yang, tudor.tibu, lzaccagnini, mazalek}@ryerson.ca
University of Illinois at Urbana-Champaign[2], {litongz2, shafagh2, miketiss}@illinois.edu
University of Wisconsin-Madison[3], {xcang, wgoss2, srbaker2, gnesdilow, puntambekar}@wisc.edu

Abstract: SimSnap responds to the need for a technology-based tool that supports learning at three social planes—individual, small group, and whole-class—while being easy to deploy with minimal technology overhead costs during their uptake. While much research has examined the efficacy of large-scale collaborative systems and individual-oriented learning systems, the intersection of and the movement between the three social planes is under explored. SimSnap is a cross-device, tablet-based platform that facilitates learning science concepts for middle school students through interactive simulations. Students in physical proximity can 'snap' their devices together to collaborate on learning activities. SimSnap enables real-time transition between individual and group activities in a classroom by offering reconfigurable simulations. SimSnap also provides an environment where open-ended and task-specific learning trajectories can be explored to maximize students' learning potential. In this iteration of SimSnap, we have designed and implemented our first curriculum on SimSnap, focusing on plant biology, ecosystems, and genetics.

Introduction

Classroom learning that spans the three social planes—individual, small group, and whole class—has clear benefits to student learning. However, the intersection of and the movement between all the three social planes have rarely been examined together (Olsen, Rummel & Aleven, 2021). In addition, understanding when and why we should design for collaboration has been called a grand challenge in education research (Wise & Schwarz, 2017). Emerging technologies offer new modes of orchestration that support interweaving student activities of collaboration and inquiry in real-time (Tissenbaum & Slotta, 2019). We think that carefully developed and easily reconfigurable learning technologies can facilitate our understanding of the classroom dynamics on these three planes as well as supporting seamless transitions between individual and group learning modes.

In this paper, we present the design and features of SimSnap, a learning technology platform with a web-based learning environment. SimSnap, as a platform, offers a technical framework for connecting tablets together to create shared collaborative simulations. The device-agnostic SimSnap interface lets students run science simulations on off-the-shelf tablet devices (on any Chromebook, Android, or iOS device), seamlessly moving between individual and collaborative learning through cross-device interactions. SimSnap's simulations and a digital design notebook aid in individual and group inquiry, exploration, and reflection of the subject matter. Individual simulation data and reflections can subsequently be shared and collaboratively edited via the SimSnap cross-device environment to allow contributions from small groups and the entire class. SimSnap aggregates data and interactions spread across different devices, offering teachers an opportunity to gain further insights into how learning occurs across the different social planes. We have designed a curriculum and simulations, on the SimSnap platform, for middle school children to learn about the growth of healthy plants and virtual community gardens.

Motivation

There is a need to collectively examine classroom learning that occurs across the three social planes—individual, small group, and whole-class learning—while supporting student-driven learning (Dillenbourg & Tchounikine, 2007). The interweaving of individual work with collaborative work in a classroom can be beneficial as collaborative learning, preceded by individual learning, is beneficial for knowledge construction in children (Bopardikar et al., 2009). Student-driven learning can effectively support students in developing their interest in STEM and a range of 21st-century skills (Chu et al., 2016).

Emerging technologies offer new modes of orchestration that support such interweaving of student activities of collaboration and inquiry in real-time (Tissenbaum & Slotta, 2019). Research into the use of large tabletop computers, for example, demonstrates student-driven explorations while allowing for transitions between individual and collaborative learning. Tabletop systems increase the student's ability to compare and contrast their work, expand their individual and collective knowledge base, and encourage mutually beneficial mentorship relations between peers. However, due to their size, tabletop systems offer collaboration opportunities limited to groups of up to four individuals at one time.

Research in tangible interactive computing has explored using physical interactive objects (representing specific information) to navigate and explore data sets while encouraging learning and discovery (Gnoli et al., 2014). Unfortunately, these systems cannot often be easily adapted to diverse data types and learning contexts. Furthermore, they require interactive surfaces—tabletop computers or interactive whiteboards. These interactive surfaces present a limitation to individual learning when deployed in large group settings due to their limited visual and interactive real-estate paired with the cost and space overheads of having more than one such system per group in a classroom. Lastly, commercial learning platforms such as Google Classroom are not designed for seamless and real-time transition between individual and collaborative activities.

Personal computing technologies such as Chromebooks and tablets allow for easy uptake into classroom environments due to the increased spread of these technologies in educational settings. The emerging area of cross-device interactions leverages the power of consumer devices to support novel, cohesive, and complex interaction possibilities in a networked device ecology (Brudy et al., 2019). For example, multiple tablet devices can come together and share their computation resources and screen real estate to form a large interactive screen. Similarly, these devices can stay hyper-connected, sharing information or even mirroring information between devices within their ecology. The interaction possibilities afforded by cross-device systems forgo financial and classroom space drawbacks of large display systems while maintaining the positive impact of technology in supporting student STEM learning through collaborative engagement (Jeong et al., 2019).

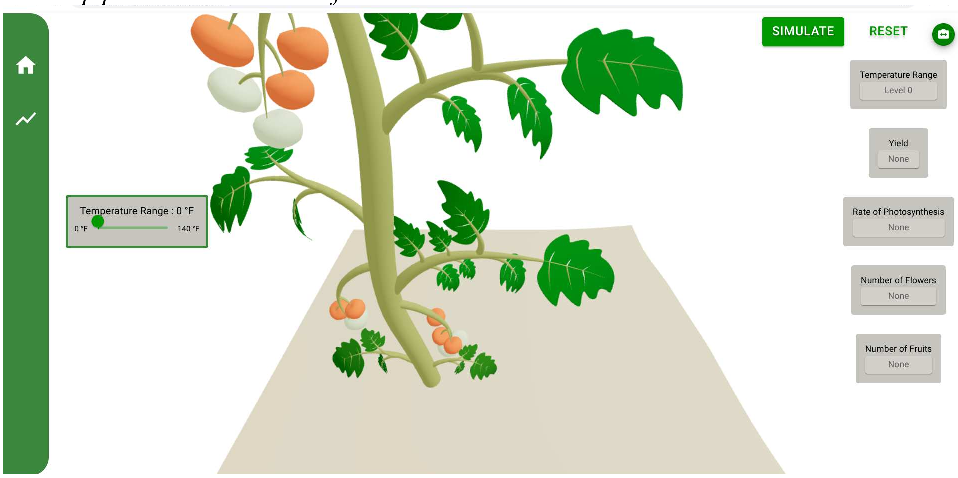
SimSnap

We developed the SimSnap learning platform guided by the need to support student-driven learning and seamless transition between individual, group, and whole-class learning. To address the classroom learning challenges identified by prior work, we set the following design goals for SimSnap.

- Support student-driven learning through interactive simulations
- Enable seamless transition between individual, group, and whole-class learning activities
- Reduce classroom deployment and orchestration overhead
- Understand student learning and engagement through the learning platform

To support these goals, we designed and implemented our first curriculum on SimSnap, focusing on plant biology, ecosystems, and genetics. As a part of our curriculum, we created plant simulations to offer middle school students a design challenge to construct a community garden that produces a lot of food while minimizing negative impacts on the environment. Below, we describe the different components of SimSnap and how they support student learning in the three social planes.

Figure 1
SimSnap plant simulation interface.



Reconfigurable simulations

SimSnap enables teachers to deploy science simulations (plant simulations in our current iteration) on tablets or Chromebooks in a classroom. Students drive the learning process by gathering science concepts and testing their hypotheses individually by modifying simulations on their devices. Students can run multiple iterations of the simulation and understand the relationship between different factors and how they impact the health of a plant ecosystem. The learning environment includes a web-based simulation interface (see Figure 1) and a 'Trials' page for data analysis and student reflection. Students in physical proximity can then bring their devices together and 'snap' them to form ad hoc groups for collaboration. Students can also 'soft snap' through the menu when collaborating at a distance. Students can initiate joining or leaving the group through touch gestures (see Figure 2 *(left)*) or the SimSnap menu. The devices are then interconnected and present a shared simulation experience, i.e., SimSnap shares the simulation controls and simulation data in real-time among a group's devices. In this scenario, students can discuss, share their learnings from prior simulations, and generate new hypotheses and test them by modifying the simulation parameters collaboratively (and simultaneously) on the shared session. Each student can view the changes made by other students and the simulation output on their own devices (see Figure 2 *(right)*).

Figure 2

(left) Students connecting two devices by using a 'pinch' gesture on the touchscreens. (right) Shared simulation experience where both the students see and interact with the same simulation in their personal devices.

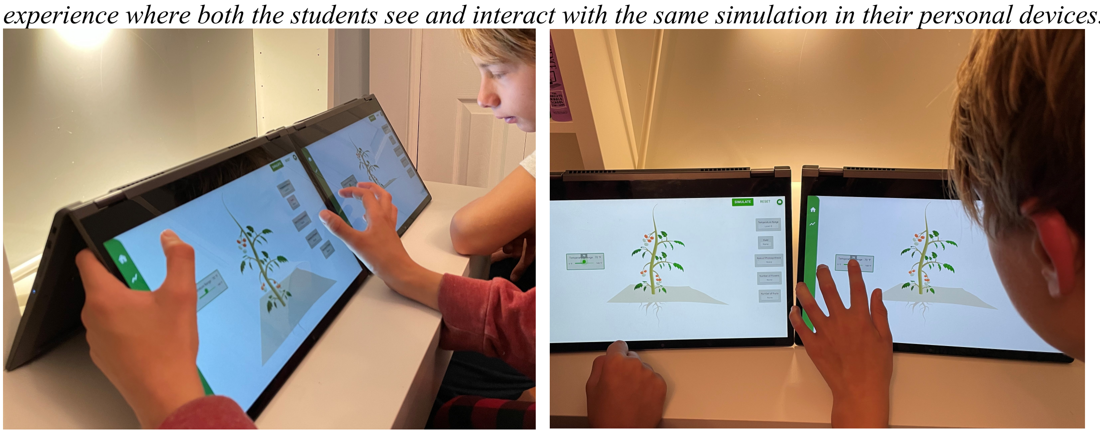
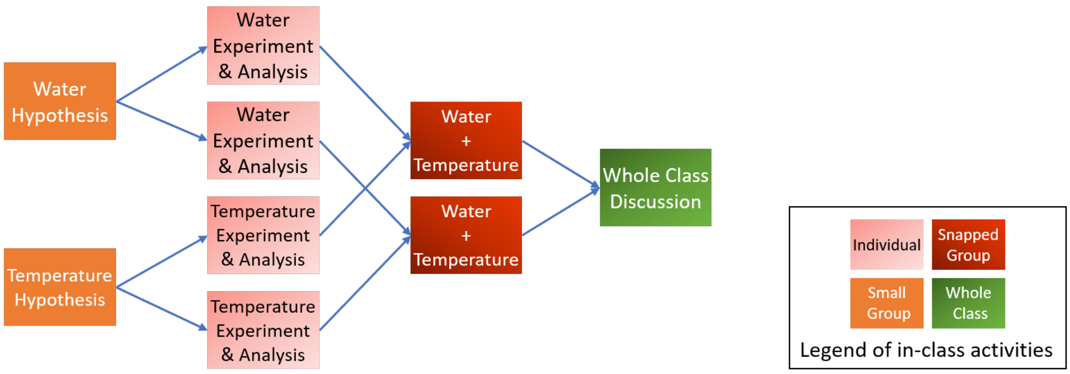


Figure 3

Example workflow of student activities with SimSnap.



Curriculum for deployment in a classroom

We have developed a multi-week curriculum interweaving classroom material, student prompts, and discussions with individual, group, and whole-class simulation activities. We will deploy the curriculum and SimSnap in a middle school classroom, with a partnering school to examine how students learn in individual and group settings using SimSnap. In our first stage, we have developed temperature and water simulations for a tomato plant. Students can run these simulations individually, manipulate the input variable (water or temperature) to understand the variable's effects on the growth of a tomato plant. Students can then snap the devices together to form ad hoc groups for collaborative learning. Figure 3 illustrates an example where students move between individual and group activities in SimSnap to learn the effects of water and temperature on a tomato plant. In the first stage, prompted by teachers, students form two groups, focusing on water and temperature, and hypothesize how their chosen factor will impact a tomato plant. Now, the students individually run multiple iterations of their selected simulation iteratively. They analyze the data and reflect on their hypothesis individually. Students with different learned expertise (water or temperature) form groups and snap their devices to run a higher-level two-variable simulation to learn how water and temperature impact a tomato plant's growth. Finally, the groups come together and share their findings with the class.

Reusable technical framework

We developed the SimSnap platform using a cross-device application toolkit, the RE/Toolkit (Bellucci et al., 2016). The underlying technical framework uses a MERN technology stack (MongoDB, Express.js, React, Node.js), primarily using the JavaScript programming language. The database (using MongoDB) stores information about the students, devices, and groups and simulation trial data generated individually and in groups. On the backend server (built with Node.js), Express.js framework handles the information requests from the student interfaces. A snapping module detects instances when students initiate 'snapping' and forms student groups accordingly. Simulation modules simulate the plant growth based on input parameters. All the devices interact with one another through the server using WebSockets. A logging module iteratively logs data from simulations and facilitates the students to reflect on their work and the teachers to track student progress. The student interface is built using the React.js and the Three.js library. Currently, SimSnap runs on multiple Lenovo Chromebook Flex 5 touchscreen devices. We used open-source, modular, and web-based technologies to ensure that SimSnap can be easily adopted in different learning contexts. We plan to make SimSnap available as an open-source tool.

Significance

SimSnap encourages student-driven learning and collaboration through reconfigurable simulations. SimSnap's logged data can offer insights into students' learning strategies in different social planes. The modular design of SimSnap allows educators to design new curricula and deploy them in classrooms with relative ease. SimSnap provides a practical solution to specific pedagogical and orchestration problems in the classroom.

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