Collaborative Research: Developing an Online Game to Teach Middle School Students Science Research Practices in the Life Sciences

David Gagnon[1], Ryan Baker[2], Shari Metcalf[3]

1.University of Wisconsin, 2.University of Pennsylvania, 3.Harvard University

ABSTRACT

Learning progressions allow researchers to describe key milestones along a pathway of thinking about a topic or practice that ranges from beginner to advanced. For science practices, some progressions can be abstracted from specific content; others are connected to specific science understandings. This paper describes the application of learning progressions research to the design of Aqualab, a middle school science game to support learning of science practices through simulated immersive experiences in which students engage in experimentation, modeling, and argumentation

I. INTRODUCTION

Digital games can address a current need for teaching science practices in school, through immersive experiences and active learning with simulated environments and tools. The Aqualab research project considers how game design can be informed by learning progressions for science practices.

In Aqualab, learners will take on the role of an ocean scientist who uses science practices of experimentation, modeling, and argumentation to investigate questions related to aquatic ecosystems. We aim to develop and scaffold layers of science practices within the gameplay, and then to explore how learning progressions can be empirically derived from game data and be operationalized to inform the design of the game itself.

II. THEORETICAL FRAMEWORK

Performance of science tasks requires both understanding of core *content* and the ability to use science *practices* (NGSS Lead States, 2013). Research in learning progressions for science practices faces the challenge of differentiating student performances of practice from student learning of content knowledge (Schwarz et al., 2009; Berland 2010; Osborne et al., 2016). Some performances of practice can be abstracted from science content, but deeper learning can also require more sophisticated practice and use of more complex tools.

Another dimension in which students can demonstrate progression in science practices independently of science content relates to *scaffolding*. Initial tasks can be structured or simplified to be easier for the learner to complete. As the learner progresses in expertise, scaffolding is faded so that the learner is more responsible for the cognitive choices involved in doing the task.

Learning progressions research resonates with how game designers think about progression in gameplay. Games can provide psychological immersive experiences in which players feel caught up in a virtual environment, through engaging situated learning, even on desktop or laptop screens (Dede et al, 2019). Games implement learning progressions through transitions from easier to more challenging levels (Koster, 2005). In order to achieve "flow" (Csikszentmihalyi, 1990), successful games seek to provide continuously challenging experiences within the narrow margin between boredom and frustration (Schell, 2015).

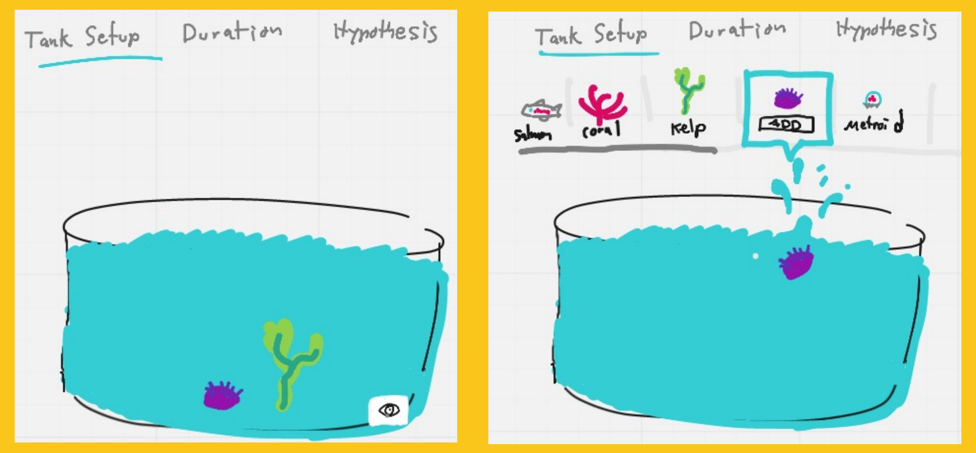
III. DESIGN

Aqualab situates the learner as a researcher on an ocean-research ship, selecting and completing "jobs" that require the student to investigate aquatic ecosystems using a submarine to observe and collect data and samples at different underwater sites (Fig. 1), and shipboard tools to conduct experiments, construct models, and develop scientific arguments. Aqualab focuses on the development of three core science practices for middle school students: experimentation, argumentation, and modeling. For each of these practices, we are designing the game with opportunities for students to engage in learning progressions in two ways:

(1) scaffolding of tasks that fades as students advance in levels of play and have more control over their engagement in science practices

(2) opportunities to engage with more advanced tools at deeper levels of complexity as they progress in game challenges.

Fig. 2. Initial experiments with simple observation tanks



Initial Aqualab experiments involve only one choice - simple "observation" tanks where players collect specific behavioral data about organisms (Fig. 2). In later jobs, players will be able to access a variety of tanks, in which they can set up experiments with environmental variables that have increasingly complex implications for ecological systems, such as light, pH, or dissolved oxygen (Fig. 3), and have access to new tools such as microscopes and water chemistry probes. These experiment options will help players solve more complex challenges around phenomena such as photosynthesis. Scaffolding will both restrict initial access to options and provide support from a non-player character (NPC) in suggesting tank setup and identifying experimental outcomes. As students progress in expertise the scaffolding of science practices will fade.

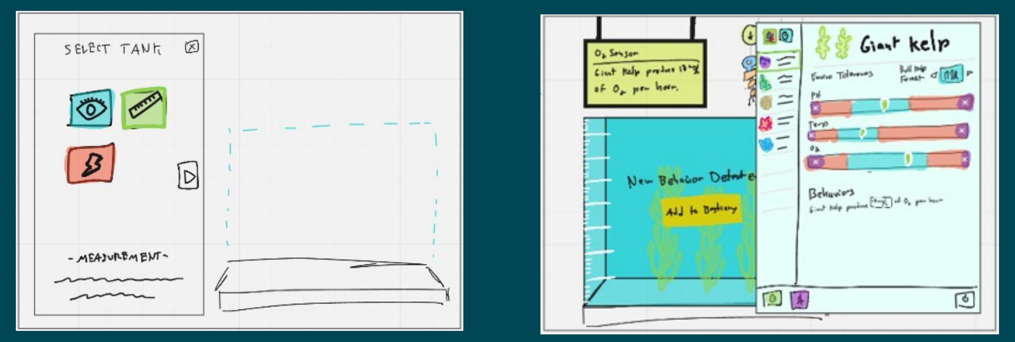


Fig. 3. Choices of tank set up to support experiments related to more complex phenomena. During play of the game over time, players will be exposed to experiments that are increasingly complex in both dimensions – increased complexity and decreased scaffolding – and the expectation is that student understanding of the practice of experimentation will also progress through game play.

SHIP EXTERIOR VIEW

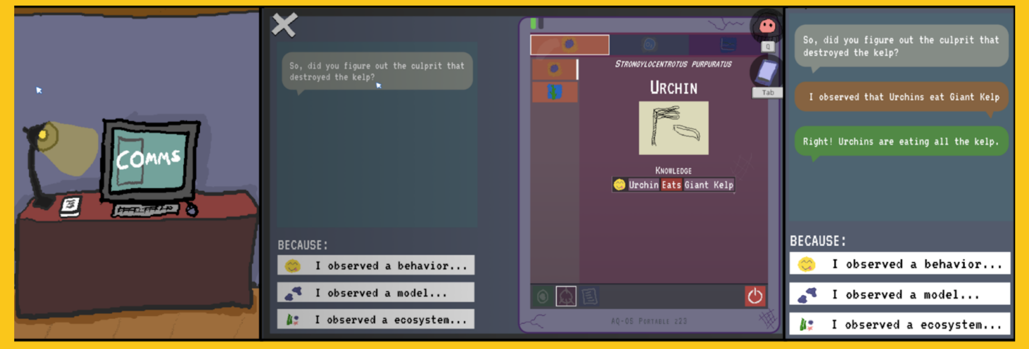
Modeling Mechanic

Dialogue Prompts | Comms Screen | Evidence Tablet

Experimentation Mechanic

Observation Tank

Argumentation Mechanic



Comms Screen | Evidence Tablet | Dialogue Prompts

Fig. 1. Immersive ocean exploration for observation and data collection.

Table I provides examples of some of the ways in which learning goals for experimentation are mapped onto game design. In experimentation tasks, players need to construct an experiment that will provide the information needed to solve the problem presented in the current job. As the student progresses, more variability and options will be unlocked.

TABLE I. EXAMPLE LEARNING GOALS MAPPED TO GAME DESIGN FOR THE PRACTICE OF EXPERIMENTATION

Learning Goals	Learning progression implemented in game design
Understanding of how to set up a good experiment that involves varying only one thing, independent of content.	Game sets up the experiment correctly for the learner / NPC guides the learner in setting up the experiment.
	Learner sets up experiment on their own.
Understanding of experimental practices related to investigation of more complex science content.	Game provides only one option for experimentation, suitable for simple content.
	Game provides advanced options for experimentation, necessary for phenomena involving more multiple variables or more complex relationships.

IV. PILOT TESTING AND NEXT STEPS

Through our teacher fellowship program we recruited 18 teachers across the state of Wisconsin for an Aqualab fellowship held virtually this year. The 18 fellowship teachers are playtesting the game this spring, and some are also participating in a research study involving surveys of student understanding of science practices and student think-aloud interviews during game play. Findings will support development of the full version of the game. Over the next two years, we will explore how embedded assessments within the game will be able to evaluate student learning progressions in modeling and scientific reasoning, and be used by the game to identify learner types and provide personalized interventions that improve learning outcomes.

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