Using meaningful gamification to redesign simulation-labs for engaging learners in science inquiry practices

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Abstract: Practical labs in science are expected to foster disciplinary practices of “doing science” in learners. Simulation-based labs which provide the convenience of conducting practical lab experiments online offer several technological affordances, however, come with their own set of challenges such as steep learning curves, working in isolation, lack of personalization which may adversely affect learner engagement and motivation. OLabs is a set of simulation-based labs for schools widely used in India. The main goal of this work is to re-design simulation-based labs like OLabs to engage learners in science practices and to motivate learners to engage in science practices using gamification. Gamification is known to have a positive impact on learner engagement and motivation. Meaningful gamification, a type of gamification approach focuses on intrinsically motivating learners to find meaning in the given learning context. We have designed a framework GaMINLab, which is the proposed redesign of OLabs and the preliminary design is informed by exploratory study findings and literature recommendations of disciplinary practices and simulation-based labs. Currently GaMINLab framework is built around 2 labs and study is planned to validate the design of GaMINLab.

Keywords: Simulation-based labs, meaningful gamification, science disciplinary practices, inquiry labs, scientific inquiry

1. Introduction

Practical labs, are expected to help learners learn science, learn about science, and learn to do science. In recent years, the extensive emergence of simulation-based labs has facilitated learners to do virtual experiments anytime, anywhere, and any number of times. These labs also offer possibilities to illustrate concepts beyond the boundaries of traditional labs, for example magnetic field intensity, lifecycle of mosquito, etc. Despite world-wide proliferation and advantages, there are reported challenges such as learner isolation, steep learning curves, lack of suitable guidance, lack of personalization, cookbook exercises, etc (Moore et al., 2013). The challenges may lead to frustration among learners, resulting in early dropout or loss of motivation and engagement. Thus, it is critical to give adequate attention to engage and motivate learners to do the underlying lab related activities.

The context of this work is OLabs, set of standard simulation-based labs for school level experiments in India. OLabs is a significant initiative by the government of India to address concerns such as lack of basic lab infrastructure, limited practice opportunities, and to supplement physical labs (M Sasikumar, 2016). OLabs has about 310 labs in classes 6-12 and is used by lakhs of students/teachers on a daily basis. In its current form, there are no tasks/problems built-in to engage learners in science disciplinary practices. The goal of this work is to re-design OLabs to a) provide opportunities for engaging in science disciplinary practices b) engage and motivate learners as they engage in these practices. This proposed redesign, GaMINLab, is informed by the literature recommendations for disciplinary practices, addressing challenges in simulation-based labs and meaningful gamification. The design features of GaMINLab are discussed and plan for validation of this design is proposed.

2. Literature and Theory

2.1 Simulation-based labs

Simulation-based labs facilitate conducting experiments online, overcoming the geographical and time limitations of traditional labs. To tackle challenges like steep learning curves, isolation, lack of personalization, design guidelines are recommended in literature a) providing investigation opportunities beyond the classroom, b) posing driving questions to focus learners' exploration, c) implicit scaffolding, d) encouraging reflection on findings, and e) promoting peer interaction and engaging in collaborative work (Moore et al., 2013).

2.2 Disciplinary Practices

Science education is increasingly focusing on involving learners in disciplinary practices, as emphasized in global curriculum recommendations. These practices include asking questions, developing and using models, planning and conducting investigations, analyzing and interpreting data, engaging in evidence-based arguments, and obtaining, evaluating, and communicating information, etc (Jaber et al., 2018). To foster disciplinary practices in a learning environment, literature suggests guidelines such as: a) providing direct experience with phenomena, b) making learner thinking visible to grapple with ideas and c) provide essential procedures/relevant resources for completing investigations. Inquiry learning is recommended for effective science learning, where learners engage in sense-making, discussions, evidence-based explanations, etc (Jaber et al., 2018) (Moore et al., 2013).

2.3 Meaningful Gamification

One of the goals for redesigning OLabs is to motivate learners to engage in lab related activities. Gamification, an established approach to fostering student engagement, uses game attributes to encourage game-like behavior in non-game contexts. Game-based mechanics can effectively engage learners, motivate their actions, and aid problem-solving. Reward-based gamification, a popular type of gamification, relies on extrinsic motivation and may not yield lasting changes, and can be unsatisfactory for some learners. Meaningful gamification, another type, employs game design elements to cultivate intrinsic motivation in non-game settings by creating an enjoyable learning environment where participants can explore and find meaning(Nicholson, 2015). This approach aims for sustained engagement compared to the short-term, reward-driven nature of extrinsic motivation. Meaningful gamification is based on self-determination theory (Ryan & Deci, 2000), which mentions competence, autonomy, and relatedness to form intrinsic motivation. The theory highlights that when these three psychological needs are fulfilled, people find tasks meaningful and continue participating.

3. Goal of Research

The broad goal of this work is to re-design simulation-based labs like OLabs to a) provide opportunities for engaging in science disciplinary practices b) motivate learners to engage in these practices. This re-design of simulation-based labs is currently named GaMINLab (Gamification (Meaningful) in Inquiry Labs. As a proof of concept, GaMINLab will be configured for select set of existing OLabs and guidelines for bringing in similar class of science OLabs under GaMINLab will be published. Design guidelines for meaningfully gamifying simulation-labs using this framework. GaMINLab framework can potentially be used by teachers to augment simulation-based labs like OLabs to engage learners in science practices in fun way.

4. Methodology

4.1 Design of the GaMINLab Framework

The current design of GaMINLab is informed by a) literature recommendatins for fostering disciplinary practices and addressing challenges in simulation-based labs, and b) the theory of meaningful gamification. For a specific lab, learners will get categorized problem-solving challenges in scenarios like park, beach, etc and learners are prompted to attempt problem-solving activities associated with chosen problems. The problem-solving activities are aligned with the problem-solving inquiry framework (Kim & Hannafin, 2011), with tasks such as *Investigate using the Lab, Propose Answers and Predictions, and Share and Discuss your Lab Investigation Report*. The related OLabs simulation is embedded in specific tasks and can be manipulated for investigations. Learners are asked to create artifacts like investigation plans, lab investigation reports, for evaluation by self, peers, or teachers using rubrics.

Instead of predefined sequence for the problem-solving tasks, learners are prompted with options choose their strategy, encouraging flexible problem-solving approaches. System awards corresponding badges for each disciplinary task completion, acknowledging progress and motivating further engagement. Lab onboarding familiarizes learners with UI objects, lab variants, observation by including interactive content like hotspots, quizzes, chat/forums facilitate discussion, and report sharing among peers. Scaffolds assist learners in preparing investigation plans, lab reports and provide guidance for alternate paths, aiding progression or retracking actions. Currently GaMINLab has two class IX labs with one problem in each scenario. Corresponding OLabs simulation is embedded with the system. This allows learners to conduct investigations by manipulating variants and using other available controls. We plan to conduct series of studies to validate and refine the framework.

5. Study Design

A study for class IX students is being planned is to validate the design of GaMINLab. We plan to analyze the pattern of engagement of the learners, motivation, evidence of disciplinary practices, usability of the system, user perception, etc. The physical study will be done in two parts, a pilot (10 students) and main study (60 students). Separate schools will be selected for the pilot and the main study to avoid bias. The research questions for are - RQ-1 “What is the pattern of engagement of learners while using GaMINLab?;RQ-2 “How does GaMINLab contribute to motivation of learners; RQ 4.1 How usable is the system? RQ 4.2 What is the learner perception of system? In RQ-1 we are looking at the behavioral engagement of the learner in GaMINLab. Behavioral engagement (Fredricks, 2004) concerns learner participation and learner interest in academic tasks, in our context it is engaging in disciplinary practices. The study session will last approximately 2-2.5 hours. Participants will take a pre-test on disciplinary practices, followed by lab activities in the GaMINLab. Each student is expected to solve one problem in one lab during the allotted time. After interacting with the intervention, participants will complete a post-test on disciplinary practices, the SUS questionnaire, and a learner perception survey, followed by semi-structured interviews.

5.1 Data Sources and Instruments

In identifying patterns of engagement, we will find attempts/reattempts, badges earned, artefacts submitted, etc. We will be measuring intrinsic motivation using the Intrinsic Motivation Inventory a self-reported questionnaire on interest/usefulness, perceived choice, perceived competence, pressure and tension, relatedness, etc. Interest/usefulness is a direct indicator of motivation so it an appropriate metric to get insights of their motivation as they interact with GaMINLab. We are also interested to measure self-reported measures of perceived choice (autonomy), perceived competence (mastery), relatedness. These are also considered as positive predictors while pressure/tension is considered as negative predictor of intrinsic motivation. Table1 illustrates theoretical constructs, operational constructs and data sources.

We measure the disciplinary practices demonstrated in artifacts i.e. investigation plan, lab reports etc. using a 4-point rubric scale for each of the 4 disciplinary practices. Disciplinary practices manifested in interaction with the system will be identified. by thematic analysis of qualitative and log data for specific disciplinary practice. We will measure the learner perception of usability of the system, challenges faced by them and their experience with the system using SUS and learner perception survey. Thematic analysis of perception survey responses will be done and responses will be triangulated with interview responses to a) evaluate usability b) identify challenges c) confirm design considerations are being working as intended.

Table 1. *RQs, Theoretical Construct, Operational Construct and Data Sources*

	Theoretical Construct	Operational Constructs	Data Sources/Instruments
RQ-1	Pattern of Engagement	Paths taken, task attempts/reattempts, variants used, badges earned	Screen recording, logs, Attempts report, interview transcripts, notes
RQ-2	Intrinsic Motivation	Interest/Usefulness, perceived choice, perceived competence perceived relatedness	IMI survey responses, interview transcripts
RQ-3	Disciplinary Practices	Degree of Disciplinary practices: demonstrated in artifacts, interaction in system	Pre-test, Post-test responses, artifacts
RQ-4	Learner Perception	Usability, Challenges	SUS questionnaire Perception Survey

6. Conclusion

We believe that a framework like GaMINLab built around simulation-based labs would intrinsically motivate learners in “doing” science and cognitively engage them in the related activities. The planned pilot study will give us valuable insights about the design features and what impact these have on the intended goals. After studies, review by researchers in areas of scientific inquiry, learning sciences and researchers in areas of gamification/game-based learning in education is being planned. After analysing the findings from study, and inputs from researchers and teachers, the GaMINLab will be refined. Thereafter a longer duration study will be planned in atleast 2 schools and additional labs.

Within the GaMINLab intervention and related study design, we are seeking input from the community on the following points: a) are there any critical pieces of literature that have been overlooked in the context of our research goal? b) Is selecting gamification elements to address the needs of autonomy, mastery, and relatedness an appropriate strategy to enhance intrinsic motivation in learning activities? d) Is it essential to measure baseline motivation (pre-intervention) within our context? e) Would it be useful to conduct a study focusing on which gamification elements will be relevant and appealing for the chosen target audience and context? This feedback will provide valuable inputs refine the intervention and related studies.

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