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GaMINLab - Meaningful gamification to engage students in science inquiry practices through simulation labs

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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 however, come with their own set of challenges such as steep learning curves, learner 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 redesign simulation-based labs like OLabs to engage learners in science practices and to motivate learners to engage in science practices. Meaningful gamification is one of approaches that focuses on intrinsically motivating learners to find meaning in the given learning context. GaMINLab, which is this proposed redesign of simulation-based labs like OLabs, was informed by literature recommendations for fostering disciplinary practices, addressing challenges in simulation-based labs, and meaningful gamification. We discuss the design features 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 illustrating 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, having cookbook-based exercises, etc. 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.

OLabs is a significant initiative by the government of India to address concerns such as lack of basic lab infrastructure, limited practice opportunities, etc and supplement physical labs (M Sasikumar, 2016). OLabs, which is a set of simulation-based labs in various subjects at school level, has been adopted by thousands of state schools in India and lakhs of users access it 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 simulation-based labs like OLabs to a) provide opportunities for engaging in science disciplinary practices b) engage and motivate learners as they engage in these practices. This re-design, called GaMINLab (Gamification (Meaningful) in Inquiry Labs) is informed by literature recommendations for a) fostering disciplinary practices, b) addressing challenges in simulation-based labs, and theory of meaningful gamification. In this paper, we discuss GaMINLab design features.

2. Literature & Theory

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).

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, using mathematics and computational thinking, constructing explanations, engaging in evidence-based arguments, and obtaining, evaluating, and communicating information (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 encourage grappling with ideas for constructing meaning, and c) assigning tasks with essential procedures and relevant resources for completing investigations. Inquiry learning is recommended for effective science learning, where students engage in sense-making, discussions, evidence-based explanations, etc (Jaber et al., 2018) (Moore et al., 2013) .

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, mainly relies on extrinsic motivation and may not yield lasting changes, and can be potentially 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. Design

We propose a framework GaMINLab - Gamification (Meaningful) in INquiry Labs which derives its basis from the research recommendations for fostering disciplinary practices in science inquiry labs, theory of meaningful gamification. The design features are listed below:

- The learner will be given challenges in form of problems to be solved, each categorized in different problem scenarios like park, beach, etc. The system prompts learner for problem-solving activities that can be attempted in quest to solve the chosen problem.
- Learner is prompted for problem-solving activities which can be attempted in question to solve problem. These activities are adaptation of the problem-solving inquiry framework in technology enhanced classroom (Kim & Hannafin, 2011). Exploration, Reconstruction, Presentation/Communication are broadly mapped to tasks *Investigate using the Lab, Propose Answers and predictions and Share and Discuss your Lab Investigation Report.* The learner is provided access to specific OLabs simulation lab to investigate, make predictions, etc.in quest to solve the given problem. It is embedded in specific tasks.
- Learner is encouraged to prepare artifacts like investigation plan, interim and final lab investigation report comprising investigation plan, observations, proposed answers with reasoning, etc. Artifacts can be self, peer or teacher evaluated using given rubrics.
- There is no predefined sequence of problem-solving activities and at every stage the system prompts the learner with options to proceed further and learner can choose any one from those options, thus making a ‘choice’ in strategy to solve the problem. Potentially a learner can view the problem and directly jump to attempting the final assessment or go

through one or more problem solving tasks or restart all over again. Motivating learners to use variants & try other aspects of lab is an important need.

- Each disciplinary task completion is acknowledged by system in form of corresponding badge. These acknowledgments given in recognition to them as they are progressing towards their final goal fulfils their needs of mastery and also motivates them to try further problems, and activities including variants.
- Lab onboarding activities make learner familiar with the UI objects in the lab, lab variants, actions needed for taking observations, activities include interactive content using hotspots, quiz and awards badge on completion.
- Chat option is given to discuss ideas, clarify misunderstanding regarding predictions, investigations with peers. They can also share lab investigation reports with peers.
- In the system scaffolds are provided when learners are preparing the investigation plan and lab investigation report. When learners choose the options from alternate paths, system provides brief information indicating what can be expected in the chosen stage which will help learner to move ahead or retrack the action.

Conclusion

GaMINLab, a re-design of OLabs, offers opportunities for learners to engage participate in disciplinary practices such as planning and executing investigations within the simulation lab, analyzing and interpreting recorded observations, constructing explanations based on evidence (observations), and communicating information by discussing and sharing the lab reports with peers. Collaborative discussions address learners' need for connection, preventing feelings of isolation during tasks. Making autonomous choices regarding which path to follow and which problem to solve fulfils their psychological desire to make self-determined choices, autonomy. The freedom to retry or restart reduces the fear of failure, motivating learners to persist in solving problems even after initial setbacks. Acknowledgment in form of badges motivates them to repeatedly engage in various problem-solving activities. Lab onboarding tasks and scaffolding help prevent early frustration during initial lab encounters. The inclusion of badges and lab onboarding supports the learners' pursuit of mastery. Therefore, the design of GaMINLab seeks to intrinsically motivate learners (by fulfilling their needs for autonomy, mastery, and relatedness) to actively engage in given scientific practices.

. Currently GaMINLab is designed with two labs with one problem each. To validate the design a pilot study with 10-15 students is being planned. In this study we aim to gather information related to pattern of engagement of learners, motivation, degree of disciplinary practices reflected in learner artifacts, learner perception, usability etc. Study-2 will be conducted for larger set of learners (50-60), after incorporating suitable changes in system based on the findings of pilot study.

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