Learning from Labdog: Best Practice for Laboratory Response System Questions

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Abstract

Labdog is a novel web technology designed to promote learning in and around the teaching laboratory. During a laboratory session, Labdog offers functionality similar to a Classroom Response System (CRS), e.g. 'clickers' or 'zappers'. Labdog focuses on a different environment: the teaching laboratory – and can therefore be referred to as a Laboratory Response System (LaRS). Results from piloting with students demonstrated that many of them hold misconceptions about the scientific principles relating to their actions in a laboratory setting. Unfortunately, it is rarely feasible to address all of these problems during the laboratory session itself. This paper first outlines the underlying educational theory and advantages that this LaRS approach offers, and then details four principles of good instructional design for using LaRS. Good question design should highlight students' misconceptions, while allowing adequate time and opportunities to address them.

1. Introduction

1.1 Minds-on practical work

Practical- and laboratory-based work makes up a considerable component of science education, both presently, and historically [1]. Unfortunately, the laboratory does not always produce the meaningful learning and conceptual understanding that educators intended. This can be attributed, at least in part, to the recipe-style activities employed by many educators [2]. Recipe-style practicals see students follow a set of actions, and while the underlying pedagogical assumption is that simple observation of phenomena will allow students to further their understanding [3], this is very often not enough to develop conceptual understanding [4].

1.2 Formative Assessment

Formative assessment (FA), sometimes 'question-based learning' or 'assessment for learning', is a pedagogically-founded educational tool. FA is any assessment of a student's understanding with the intention of providing constructive feedback. This contrasts summative assessment, wherein educators assess students solely to quantify or record a student's understanding. There is strong and long-standing evidence that formative assessment promotes improved conceptual understanding across ages, subjects, and abilities [5], and science education is no different [6].

Formative assessment is not only a worthwhile educational tool in its own right, but it also links strongly to other educational concepts. Most notable is its link to metacognition, i.e. formative assessment can enhance students' understanding of the state and extent of their own knowledge [7]. Further still, FA links to the concept of self-regulated learning [8]. A self-regulated learner is one who sets goals for their learning and understanding, and then works towards achieving them, their actions as they go, and reflecting on them in retrospect [9]. Formative assessment therefore plays a key role in developing skilful and adaptable learners [8]

1.3 Labdog

In efforts to connect practical- or laboratory-based work, researchers at the University of Southampton have created a laboratory response system (LaRS): Labdog (www.labdog.co.uk). Labdog is essentially a digitised platform for recipe-style practical activities, with the added benefits of allowing teachers to ask questions at a specific step. Labdog also offers a variety of other pedagogically-founded features, by hosting pre-lab activities, and acting as an e-portfolio and electronic lab-notebook. The scope of this paper is the question-based aspect.

Educators are able to pose questions at any point during a practical activity. When the student arrives at that point in the practical, they are unable to progress until they have responded to the question.

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Furthermore, all students' responses to all questions are gathered in real time and are viewable by the teaching or demonstrating staff through a web interface. These responses could therefore act as the starting point for Socratic dialogue between demonstrator and student.
This is rather like classroom response systems (CRS) [10] , also known as learner- (LRS) or audience- (ARS) response systems. Effective use of CRSs can promote students' understanding, while better focusing educators' teaching practice [11]. Labdog could therefore be considered a Laboratory Response System (LaRS), and as far as the authors are aware, it is the first laboratory specific technology to offer such functionality.

1.4 The Problem

During semester 1 of the 2016/17 academic year, Labdog was used with A-level equivalent students at the University of Southampton. User experience and usage data identified a number of instructional design challenges in relation to the use of Labdog to support provision of educationally- valuable, and practically-viable feedback. Specifically, providing real-time feedback to students during a laboratory became quickly unmanageable due to the rate at which student responses were being submitted, even with a relatively high student-demonstrator ratio (25:3).
This paper details four principles of good instructional design for questions posed with LaRS. These principles focus on allowing educators to identify broad areas of student misconception, and address them in a timely manner, at both individual and group level.

2. Best practices for LaRS question design

2.1 Avoid busy or highly demanding practical steps

The human brain has a limited working memory, i.e. our brains can only handle so much information at once - this is the idea of 'cognitive load'. Instructional design should not exceed the capacity of a student's working memory [12]. This means that educators should consider the cognitive and time cost of task-switching, as students move between practical activity and conceptual questions - a cognitively demanding task.
In our experience, questions which came at busy or complex moments in a practical were more likely to be unanswered, or answered poorly. A prime example was asking students about the impact of temporal resolution of data *as* we asked them to take the temperature of a solution every 30 seconds. Clearly students cannot be expected to engage deeply with this question if they are interrupted every thirty seconds. Students should be allowed to engage most their cognitive resources in any tedious or repetitive activity, where interruption runs the risk of invalidating students' efforts or actions.

2.2 Use pre-lab activities

Pre-lab activities are commonly used to prepare students for laboratory work. Labdog has an integrated pre-lab platform which allows educators to ask students open- and closed-answer questions, provide links to externally-hosted resources (e.g. videos), and allows students to preview the practical activity they are about to undertake. Students are expected to complete pre-labs before arriving to a practical session, and educators can easily view the progress of a group and individual in the web interface.
Questions were posed to students after they had watched any associated videos and read the script allowing us to assess students' understanding before they arrived at the laboratory. Pre-lab videos allowed us to introduce practical techniques or equipment, as to make the laboratory techniques more familiar. This was an attempt to reduce cognitive load associated with performing new or unfamiliar tasks. Furthermore, students' responses to questions could highlight areas of common (mis)understanding, which enabled us to use the first 10-20 minutes of a practical session to address any common errors, in alignment with the idea of just-in-time teaching [13]

2.3 Use post-lab reflection on complex or deep questions

During a laboratory, students would focus largely on the activity at hand. Asking them questions through Labdog as they completed a practical was met with some resistance: students wanted to continue their actions unimpeded. There is a fine balance to strike between students' discontent, and achieving the educational benefits discussed above. As the pilot programme continued, we as educators noticed we would take a great deal of time and effort constantly moving between students, often having similar conversations.

To combat this we built in a rating system to Labdog, wherein responses to certain questions could be rated with 1-4 stars. We paired this a self-assessment activity, where students log in to Labdog after they have left the laboratory to view all (anonymised) responses given during the session. We set students the task of reflecting on why their answers had been given the star rating they had, as a chance to develop understanding through metacognition.

2.4 Keep questions focused, and scaffold or prompt where necessary

Certain scientific processes present a veritable rabbit-hole of complexity, i.e. highly inter-related concepts. Energy and sub-atomic particles are prime examples of such concepts. In one practical session, students performed flame tests to identify unknown substances: small amounts of the substance are placed in a flame, with the resulting flame colour being characteristic of the substance. These different colours result, broadly speaking, from the emission of energy (light) when electrons move from an excited state to their ground state. One Labdog question asked students to explain this concept, which elicited a range of, frequently incorrect, responses.

Although we might wish for students to consider such complex concepts, the time constraints of laboratory work necessitate a focus on the most relevant aspects. We have achieved this by inserting prompts into questions, e.g. asking students to explain their answers ". . . using your knowledge of polarity" or ". . . using ideas about intermolecular forces". These prompts focused students and allowed us to use more consistent and widely applicable formative-feedback, helping students to stay on track.

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