Comparison with Self vs Comparison with Others: The Influence of Learning Analytics Dashboard Design on Learner Dashboard Use

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Abstract. This study uses log-file data to investigates how chemical process plant employees interact and engage with two distinct learning analytics dashboard designs, which are implemented in a virtual reality simulation-based training environment. The learning analytics dashboard designs differ by reference frame: the progress reference frame, offers historical performance data as a point of comparison and the social reference frame offers aggregated average peer group performance data as a point of comparison. Results show that participants who receive a progress reference frame are likely to spend less time reviewing their dashboard than those who receive a social reference. However, those who receive a progress reference frame are more likely to spend more time reviewing detailed task feedback and engaging with the learning analytics dashboard.

Keywords: Learning analytics dashboard · Social comparison · Virtual reality simulation-based training

1 Introduction

Virtual reality (VR) training environments are becoming popular tools for training employees because they offer advantages over other forms of training [1]. For example, these environments can be designed to take advantage of log-file data, which can be used with learning analytics tools such as learning analytics dashboards (LAD) [2]. While learning analytics refers to the collection and analysis of data to optimize learning [3], LADs aggregate data collected during the learning analytics process and displays

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it within one or multiple visualizations to help stakeholders make sense of the learning analytics data [4]. LADs are often designed to provide feedback on task performance to learner stakeholders [5]. Instructional designers can help these learners make sense of their feedback by including reference frames, which contextualize a learner's performance against a particular point of comparison [6]. Two types of reference frames are the progress and social reference frame [7]. The progress reference frame uses historical performance data as a point of comparison, while the social reference frame uses aggregated peer performance data as a point of comparison.

In this paper, we explore how workplace learners interact with feedback presented by two LADs, one designed with a progress reference frame and one with a social reference frame.

1.1 Potential Implications of Learning Analytics Dashboard Design

When designing workplace LADs for feedback, instructional designers must consider how they can help employees make sense of their feedback. One approach is to include learning analytics reference frames, which are comparison points learners can use to orient when examining their learning analytics [8]. When presented with a progress reference frame, learners are stimulated to engage in temporal comparisons, which take place when one compares their own performance at different points in time [9, 10]. Temporal comparisons can highlight progress over time and help learners determine if they have been improving. Therefore, it is feasible that temporal comparisons may influence learner interaction with LADs. For example, if given the opportunity, learners may wish to review detailed task feedback because they want to find out what they can to do to improve [10], which is representative of a mastery goal orientation [11]. When presented with a social reference frame, learners are stimulated to engage in social comparison, which takes place when one compares their own performance with that of their peers and do so to gauge how effective they are at particular tasks [12]. It is foreseeable that social comparison may influence learner interactions with LADs because it may impact their motivation [7, 13] and encourage them to focus on performing better than their peers instead of self-improvement, which is representative of a performance goal orientation [11].

2 Context of the Study

This study investigates two LAD designs implemented into a VR simulation-based training environment for employees of the chemical process industry. The LADs differ in design by reference frame. The Progress LAD incorporates a progress reference frame and the Social LAD incorporates a social reference frame. Both LAD designs include two buttons which can be selected. The 'detailed task feedback' button takes learners to a secondary screen which provides detailed task feedback on their task performance. The 'How is this calculated?' button triggers an indicator to be displayed which explains how the task score is calculated. The detailed task feedback screen and How is this calculated? indicator do not differ between the Progress and Social LAD.

3 Study Overview

To better understand how the progress and social reference frames influence LAD interaction, we designed a two-group experimental study in which participants completed a simulation based-based training task in VR and receive feedback via the Progress or Social LAD.

We operationalize LAD interaction by examining log-file data from participant interaction with their assigned LAD. First, we examined the time participants spent reviewing either the Progress or Social LAD. Next, we examined the time participants spent reviewing the detailed task feedback screen. Finally, we examined the frequency with which participants engaged with the LAD as measured by the number of times the detailed task feedback and How is this calculated? button were selected.

3.1 Research Questions and Informative Hypotheses

We propose three research questions, each with three competing hypotheses to address the overarching research question: How do reference frames influence LAD interaction?

RQ1: Are there between group differences in total time spent reviewing LADs with a reference frame?

H1.1 The mean time participants spend reviewing the Progress LAD will be greater than the mean time participants spend reviewing the Social LAD.

H1.2 The mean time participants spend reviewing the Progress LAD will be less than the mean time participants spend reviewing the Social LAD.

H1.3 The mean time participants spend reviewing the Progress LAD will be equal to the mean time participants spend reviewing the Social LAD.

RQ2: Are there between group differences in total time spent reviewing detailed task feedback?

H2.1: The Progress LAD group mean time spent reviewing the detailed task feedback screen will be greater than the Social LAD group.

H2.2: The Progress LAD group mean time spent reviewing the detailed task feedback screen will be less than the Social LAD group.

H2.3: The Progress LAD group mean time spent reviewing the detailed task feedback screen will be equal to the Social LAD group.

RQ3: Are there between group differences in engagement with LADs?

H3.1: The Progress LAD group mean LAD engagement frequency will be greater than the Social LAD group.

H3.2: The Progress LAD group mean LAD engagement frequency will be less than the Social LAD group.

H3.3: The Progress LAD group mean LAD engagement frequency will be equal to the Social LAD group.

4 Materials and Method

4.1 Participants

Study participants (N = 38) were chemical process plant employees located in Germany aged between 18 and 55 years. Participation was voluntary and all provided informed consent. Participants could exit the study at any time without consequence. The participants' working language was German and a German language version of the prototype was used.

4.2 Experimental Design

The study was a between two-group design in which the effect of LADs designed with a progress reference frame were tested against the effect of LADs designed with a social reference frame on three dependent variables associated with LAD interaction: time spent reviewing LAD with a reference frame, time spent reviewing detailed task feedback screen, engagement frequency with LAD. Participants were randomly assigned to the progress reference frame group (n = 20) and the social reference frame group (n = 18).

4.3 Description of VR Simulation-Based Training Prototype

The 'Operate your own reactor' VR training simulator runs on the Oculus Quest with Touch controllers. The training simulator was designed to train employees in the Butyllithium manufacturing process with commercial chemical reactor equipment.

The Butyllithium chemical production procedure consists of four steps.

4.4 The Learning Analytics System and Features of the Learning Analytics Dashboards

The learning analytics system automatically collects, and analyses log-file data linked to performance criteria including correct and incorrect actions, number of hints requested and the amount of time elapsed to complete each step. Depending on these variables, the learners receive a score out of five represented by stars (See Fig. 1 and 2).

Screenshots of the Progress LAD (Fig. 1) and Social LAD (Fig. 2) can be found below. The elements of the dashboard (Fig. 1) are described here in English: (1) name of the step which has just been completed, (2) message congratulating the participant on completing the step, (3) performance feedback summary, (4) How is this calculated? button, (5) detailed task feedback button and (6) Next button.

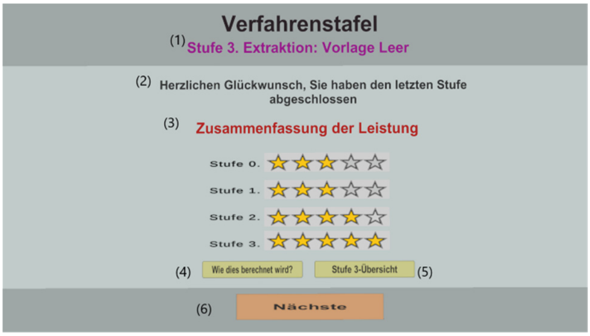

Fig. 1. Progress reference frame after step 3. Learners can compare how they performed on step 3 (Stufe 3) with previous steps (Stufe 0, Stufe 1, Stufe 2).

Fig. 2. Social LAD after step 3. Learners can compare how they performed on step 3 (Stufe 3) with the average score of their peers on step 3.

The performance feedback summary feature (3) is a means of communicating how well the learner performed a particular task. Stars are used to represent the learner's level of performance. The greater number of stars awarded, the better the performance.

When selected, the detailed task feedback button shows which sub-tasks were correctly or incorrectly performed (Fig. 3) and the 'How is this calculated?' (Fig. 4) button displays the formula used for calculating the performance outcome indicated by stars (i.e., 92–100% awards 5 stars).

Fig. 3. Display of the detailed task feedback dashboard which indicates performance on sub-tasks.

Fig. 4. Dashboard when the 'How is this calculated?' button is selected.

4.5 The Progress and Social Reference Frame

Figure 2 is a screenshot of the Progress LAD after completing step 3. This dashboard incorporates a progress reference frame because the learner's most recent performance outcome (step 3) is compared with their previous performances (step 0 – step 2).

Figure 3 is a screenshot of the Social LAD after completing step 3. This dashboard incorporates a social reference frame because the learner's most recent performance outcome (step 3) is compared with the average of their peers.

4.6 Timing of the Learning Analytics Dashboards

The LADs are presented after each step of the task, therefore, four LADs with reference frames are presented to the learner by the time they have completed the task. The detailed task feedback screens will only appear when the detailed task feedback button is selected. The calculation indicator appears as an additional visualization atop the Progress and Social LADs only when the How is this calculated? button is selected.

4.7 Procedure

Those participants who agreed to take part in the research were invited to a training room on their worksite which was equipped with the VR simulation-based training environment. Upon arrival, participants were asked to complete a series of questionnaires for another research project. Next, they were shown how to use the Oculus Touch controllers to navigate and interact with the virtual environment. Then, they were asked to follow an interactive tutorial within the virtual environment. Once the tutorial was complete, the participants were instructed to begin the simulation-based training.

Participants completed the simulation-based training task with either the Progress LAD or Social LAD. They were not aware there were two different LAD designs.

Upon completion of the training, which typically lasted between 45 and 60 min, participants completed additional surveys which were used for other research, they then returned to their regular work tasks.

4.8 Data Analysis and Statistical Models

Bayesian informative hypothesis evaluation was used to analyze the data. We formulated three competing hypotheses for each research question which used terms of equality (=) and inequality ($<$, $>$) [14]. One advantage to this approach over classical null hypothesis testing with p values is that it enables us to compare multiple hypothesis [15].

We compare the dependent variables means of the Progress LAD group with the dependent variable means of the Social LAD. The three dependent variables were associated with LAD interaction: time spent reviewing LAD with a reference frame, time spent reviewing detailed task feedback screen, engagement frequency with LAD as measured by the frequency with which the detailed task feedback button and How is this calculated? button was selected. To do this we conducted three ANOVAs with the LAD groups set as the fixed factors. We will do a sensitivity analysis using fraction 1, 2 and 3 and will report each result (the posterior model probabilities (PMPs) and interpret them at once.

Hypotheses for evaluation for each RQ are:

RQ1: H1: Progress $>$ Social, H2: Progress $<$ Social, H3: Progress $=$ Social.
RQ2: H1: Progress $>$ Social, H2: Progress $<$ Social, H3: Progress $=$ Social.
RQ3: H1: Progress $>$ Social, H2: Progress $<$ Social, H3: Progress $=$ Social.

The Bayesian error associated with preferring the best hypothesis in terms of PMPs will be reported. This is the sum of the PMPs of the other hypotheses.

5 Results

In this study we set out to examine evidence in support of three competing hypotheses for each research question. Firstly, we present descriptive statistics in Table 1. Then, Table 2, Table 3, and Table 4 report the PMPs which provide an indication of how much each hypothesis is supported for RQ1, RQ2 and RQ3 respectively. The higher the PMP, the more evidence there is that that hypothesis is correct.

Table 1. Descriptive statistics for interaction with LAD

	Seconds reviewing LADs with reference frame		Seconds reviewing specific task feedback		LAD engagement frequency	
	Progress	Social	Progress	Social	Progress	Social
Mean	26.7	35.2	2.2	0.3	1.1	0.3
StdD	9.5	17.2	1.2	1.2	1.5	0.6
Min	14	9	0	0	0	0
Max	54	64	15	5	6	2

Table 2. Bain ANOVA RQ1 Time spent reviewing LAD with Reference frame

	PMP a*	**PMP a****	**PMP a*****
H1: Progress > Social	0.018	0.020	0.021
H2: Progress < Social	0.659	0.728	0.753
H3: Progress = Social	0.323	0.252	0.216

Note. * denotes Fraction set to 1, ** denotes Fraction set to 2, *** denotes Fraction set to 3. Posterior model probabilities (PMP) (a: excludes the unconstrained hypothesis) is based on equal prior model probabilities.

Table 3. Bain ANOVA RQ2 Time spent reviewing detailed task feedback

	PMP a*	**PMP a****	**PMP a*****
H1: Progress > Social	0.705	0.768	0.799
H2: Progress < Social	0.015	0.016	0.017
H3: Progress = Social	0.280	0.216	0.184

Note. * denotes Fraction set to 1, ** denotes Fraction set to 2, *** denotes Fraction set to 3. Posterior model probabilities (PMP) (a: excludes the unconstrained hypothesis) is based on equal prior model probabilities.

Table 4. Bain ANOVA RQ3 LAD engagement

	PMP a*	**PMP a****	**PMP a*****
H1: Progress > Social	0.659	0.728	0.763
H2: Progress < Social	0.018	0.020	0.021
H3: Progress = Social	0.323	0.252	0.216

Note. * denotes Fraction set to 1, ** denotes Fraction set to 2, *** denotes Fraction set to 3. Posterior model probabilities (PMP) (a: excludes the unconstrained hypothesis) is based on equal prior model probabilities.

As we can see in Table 2, the hypothesis which states that less time is spent reviewing the Progress LAD is most supported (H2) and the hypothesis stating more time is spent reviewing the Progress LAD (H1) is substantially unsupported. Therefore, it is most likely that learners with a Progress LAD spend less time reviewing their LAD than those with a Social LAD. However, due to the error probability, (0.341, 0.272, 0.247), we cannot rule out that the two LAD groups spend an equal amount of time reviewing their LADs (H3).

As we can see in Table 3, the hypothesis that states that the Progress LAD group spends more time reviewing the detailed task feedback screen than the Social LAD group is most supported (H1). The hypothesis stating that the Progress LAD group spends less time reviewing the detailed task feedback screen than the Social LAD group is substantially unsupported (H2). Therefore, it is most likely that the Progress LAD leads to more time being spent reviewing detailed task feedback. However, due to the error probability for H1, (0.295, 0.232, 0.201), we cannot rule out the hypothesis which states that two groups spend an equal amount of time reviewing detailed task feedback (H3).

As we can see in Table 4, the hypothesis that states the Progress LAD group engages more with the LAD than the Social LAD group is most supported (H1). The hypothesis that states the Progress LAD group engages less with the LAD than the Social LAD group is substantially unsupported (H2). Therefore, it is most likely that the Progress LAD leads to more engagement with the LAD. However, due to the error probability for H1, (0.341, 0.272, 0.237), we cannot rule out the hypothesis which states that the two groups engage equally with the LAD.

6 Discussion

The results in RQ1 indicate that learners receiving LADs with a progress reference frame spend less time reviewing their LADs compared with those receiving a social reference frame. This suggests that the time it takes for learners to decide to move to the next step in their learning process is at least partly influenced by temporal comparison. The results from RQ2 and RQ3 provide an indication on what these learners do next. RQ2 results show that the group who are engaging in temporal comparison via the progress reference frame were more likely to spend more time reviewing the detailed task feedback screen. This suggests that temporal comparisons may stimulate learners to consider how they can improve and therefore, seek out information to aid self-improvement via the detailed task feedback screen. This aligns with a mastery goal orientation because it concerns learners wanting a deeper understanding of their task performance [16]. On the other hand, the social reference frame, and its stimulation of social comparison, may encourage surface level learning, a feature of a performance goal orientation, which may in part explain why the detailed task feedback LAD was reviewed for a shorter amount of time in this group. The proposition the group receiving the progress reference frame seem more likely to adopt mastery goal orientation behaviors and the social reference frame to adopt performance goal orientation behaviors is further supported by RQ3 which indicates that the progress reference frame group likely engaged more with the LAD than the social reference frame group.

7 Conclusion

This paper presents the empirical results of a study which examined how workplace learners interacted with two distinct LADs for a VR simulation-based training environment. The study compared two groups, one which received an LAD with a progress reference frame and one which received an LAD with a social reference frame. The results are an early indication that learners may be more likely to interact with aspects of LADs that help them gain a deeper understanding of a task, if they are designed with a progress reference frame compared with a social reference frame.

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