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Lightweight Learning Analytics Dashboard for Analyzing the Impact of Feedback & Design on Learning in Mathematical E-Learning

Summary. Enriching mathematical digital exercises with approaches like gamification or pedagogical agents should support the learning processes of students. However, measuring the actual impact of such interventions requires the collection and sophisticated analysis of learning data, referred to as Learning Analytics. Because this mostly requires programming skills or is limited by institutional restrictions, often only performance is measured, which does not take learning as a process into account. To facilitate holistic analyses the present work introduces a lightweight Learning Analytics approach that can easily be implemented by non-programmers. Focusing feedback and design measurement methods for mathematical e-learning, a dashboard interface in the learning management system Moodle is implemented using this approach.

Introduction

Facing mathematics as a predictor for success in engineering studies on the one hand [6] and lower and lower scores in entry tests on the other [9], methods to enhance mathematical learning become desirable. Digital exercises haven proven to be practical for students regarding self-paced learning and interactive elements like immediate feedback as well as novel learning experiences such as game-based [15] or tutored learning [2].

However, the effects of such approaches are still the subject of current research. Gamification, e. g., is known to raise motivation [11], but the findings are mostly too context specific to be reproducible and the inquiry periods too short to speak of evidence beyond a novelty effect [4].

Learning Analytics could serve as a facilitator to gain more insight into the outcomes of such approaches in specific contexts. But despite the many studies on Learning Analytics, its implementation still seems to be a long way off [1]. Possible reasons for this are strict data protection regulations, long decision-making processes or inflexible IT infrastructures.

Thus, to investigate design and feedback related effects of digital exercises on a broad scale, a Learning Analytics approach would be necessary that is easily implementable. Therefore, the main contribution of this work is the presentation of a solution to implement Learning Analytics methods easily into web-based learning management systems. To do so, studies with lightweight approaches from the field of design and feedback measurement are analyzed in the next section. Then a frontend-oriented Learning Analytics approach is derived from that and an example implementation in the learning management system Moodle is given. A concluding discussion points out the necessary future development.

Previous Work

Digital exercises' design [14] as well as automated feedback [3] have proven to be important factors for efficient learning processes. Even though many studies present interesting results for both of the areas mentioned, studies that enable their work to be easily reproduced either regarding the treatment method or the analysis are rare.

In a brief literature overview only two studies were found that offer the possibility to enrich mathematical digital exercises with design or feedback aspects in a lightweight way. [12] added simple non-interactive game elements to exercises and showed how marking exercises as "bosses" in combination with a difficulty-raising order of exercises leads to the most difficult tasks being repeated more often. With the help of error adaptive feedback this, in turn, led to a continuous increase of the learners' scores. [13] compared two experimental designs (pedagogical agent and gamification) with a control design and showed that the practice behavior of learners varies significantly among different designs. Both experimental designs foster the reattendance of exercises after not solving them correctly, whereas the gamified version additionally fosters repetition even after exercises were already solved correctly (i.e., practicing). Visualized in transition distribution charts (Figure 1) this results in higher values for repetition transitions (R) compared to sequential (S), non-sequential (N) or finish (F) transitions, independent of whether learners solved an exercise previously (T) correct (c), partially correct (p) or wrong (w).

The design aspects of these latter mentioned studies can be reproduced by pasting a script inside the texts of digital exercises in the learning management system. However, the analysis methods – although sufficiently described – are not part of the lightweight implementation which

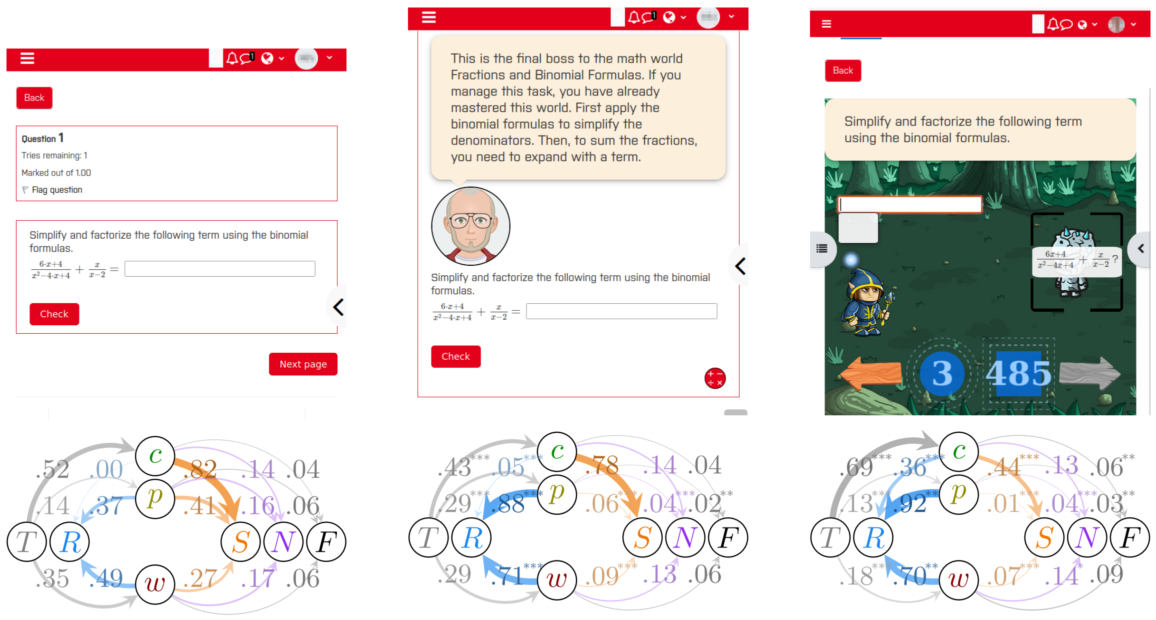

Figure 1: Different exercise designs and the according transitions charts [13]. Left to right: control, pedagogical agent, fantasy game.

makes it harder for researchers to build upon the findings. This gap can be closed with the solution described below.

Lightweight Approach & Example Implementation

Modern learning management systems offer course leaders interfaces that allow insight into learners' progression over time. Since this data is already displayed to users with the necessary rights, it can be gathered and visualized by making use of a frontend-oriented approach [12]. By interacting only with the frontend of the system (Figure 2) no server sided changes like the installation of a plugin are required. Researchers can, e. g. , paste Javascript code directly into the browser's console. By doing this, a system that gathers the already available data and visualizes them according to Learning Analytics methods can be implemented.

An example implementation in the learning management system Moodle is given below. By gathering users' response history data, the analysis of feedback and design effects as presented in the previous section can be reconstructed and visualized (Figure 3). The *quiz dimension* (upper part) gives an overview of learners' interaction with the quiz as a whole. The upper left chart shows the transition distribution chart as

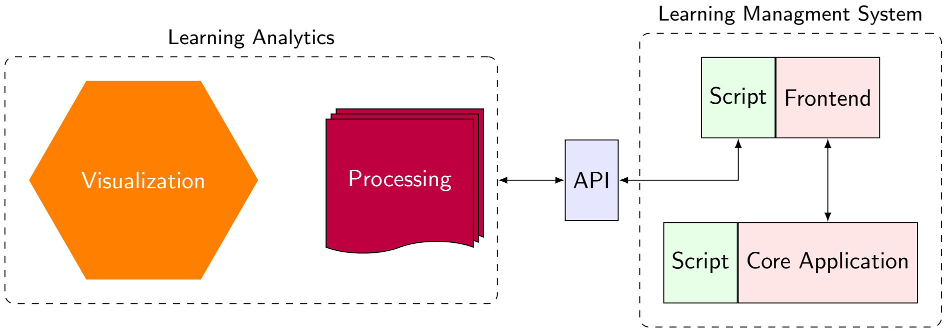

Figure 2: A frontend-oriented software architecture for Learning Analytics derived from [12].

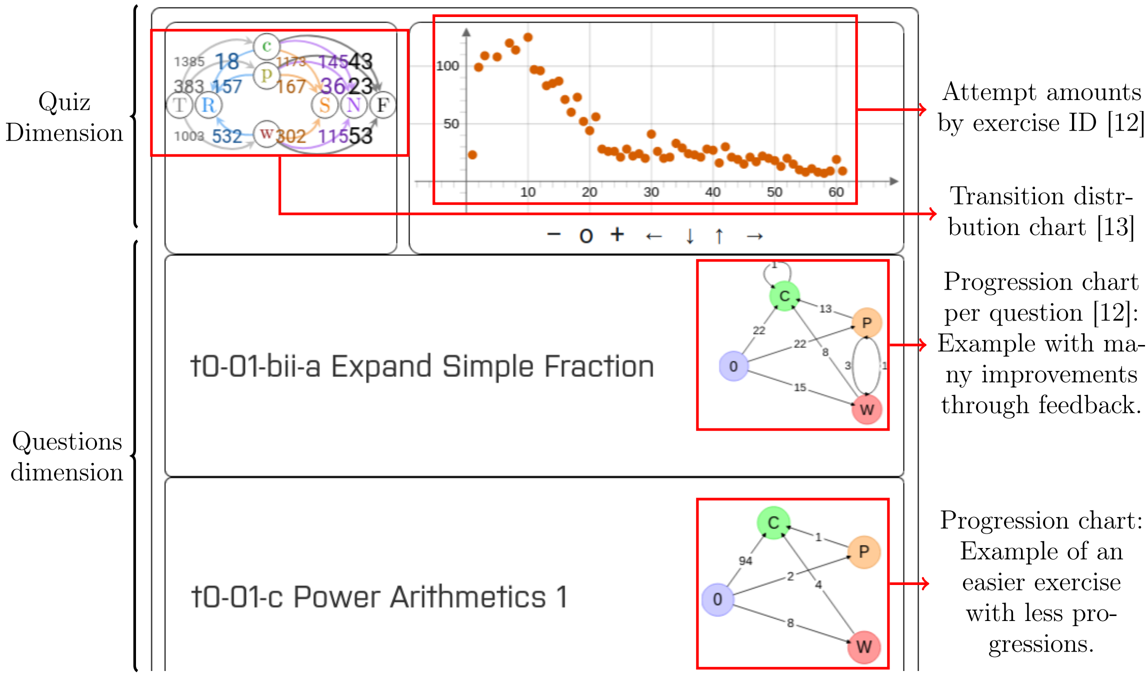

Figure 3: Screenshot of the dashboard.

introduced by [13] and described in the previous section. The upper right chart shows the amount of attempts for each question. Design-specific changes of, e. g. , repetition rates can be visualized this way [12]. Each question is shown rowwise below. In this *questions dimension* next to the question name a progression chart is displayed, showing the movements of learners toward a correct answer (C) after initally (0) giving a wrong (W) or partially correct (P) answer. The amount of progressions toward better scores sheds light on the efficacy of specific feedbacks and allows question designers and researchers to adjust it accordingly [12].

The code for this example and a step by step guide for the implementation can be found at the project's repository (https://bit.ly/3HRpyu0).

Discussion & Conclusion

Aiming on improving mathematical teaching and learning, a feedback and design efficacy measurement dashboard for mathematical exercises was presented that can easily be implemented without restrictions. Known challenges in implementing Learning Analytics dashboards could be overcome by making use of a frontend-oriented software approach, that makes use of data that is already made available by the learning management system.

Previous studies show that the features presented by the dashboard are relevant indicators for efficient learning processes in the domain of mathematics. However, testing the dashboard with practitioners in future studies will shed light on the dashboard's benefits and pitfalls for both question designers' everyday use as well as for didactic research.

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