

“What do students know, how long does it take them to know?” at a Glance for Teachers and Instructional Designers

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ABSTRACT: In this paper, we present the visualizations realized in the learning analytics service for the Learning Companion Application. User interactions stored by the application form the evidence for these visualizations. The diagrams for teachers enable them to grasp at a glance which topics their students master or not so that they can prepare their next class accordingly. The same diagram offers additional options, like the total number of attempts for instructional designers so that they can reflect on the difficulty level of the exercises. An additional visualization for instructional designers shows the time students spend on each learning object. The LA service is being realized as an LTI-Tool.

Keywords: traffic-light diagrams, xAPI statements, learning locker, elasticsearch, grafana

1 INTRODUCTION

The Learning Companion Application (LCA) is developed in the smart learning project¹ to fit the needs of full-time employees who take part in an Energy Consultant training in a Chamber of Crafts. LCA can be thought of as a learning management system (LMS) with two distinctive features. First, the digital learning resources are stored centrally in a repository and can be accessed without replication when a course is taught in different institutions. Second, it includes a recommendation service for learners which selects appropriate contents, as well as a learning analytics service to different stakeholders, in particular to teachers and instructional designers. LCA is independent of any topic and any institution and, therefore, can be used in other contexts and for other courses (Krauss et al. 2017).

A course in LCA as in many LMS can be divided into sections, which can be divided into learning units. A learning unit contains different learning resources also called learning objects (LO) such as texts, videos, animations, PDF files, other media-types, and exercises. These learning objects can be reused in other courses. To support the pedagogical concept adopted in LCA as well as to implement the recommendation and learning analytics services, metadata are associated with any learning object. These metadata contain among others at least one learning objective and a typical learning time. A learning unit is rendered as an accordion with a specific sequential structure, see Figure 1. The top item is the list of the learning objectives of all learning objects of that unit. A learner can rate each learning objective and so reflect on how much s/he knows already on that topic, from 1 (know nothing) to 5 (expert). This item is followed by the sequence of the LOs of that unit, which In Figure 1 includes

¹ <https://projekt.beuth-hochschule.de/smartlearning/>

a set of exercises. Following all LOs, the next item in the accordion-view is again the list of learning objectives. By rating them, a student can reflect on how much s/he knows after learning the unit. The follower item allows students to provide feedback on the typical learning time for that unit (from 1, way too little time to 5, way too much) and give comments. The last item opens a discussion thread on that unit. These last two items are marked a Communication-tools in Figure 1.

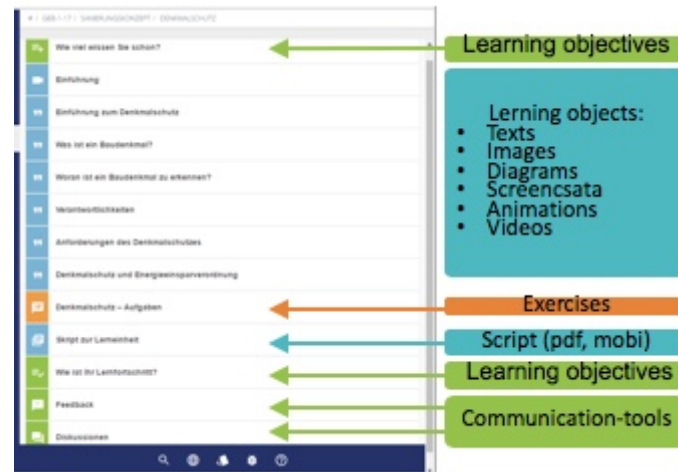


Figure 1: A learning unit in LCA

The first aim of the learning analytics (LA) service is to support teachers and instructional designers. During the project, three meetings with three teachers (N=3) of the Chamber of Crafts have taken place to sense their needs and to discuss proposed solutions. The outcome stressed the importance of a simple and unambiguous visualization: teachers should clearly understand what they see and not be overwhelmed with too much. Therefore, we have opted for well-known diagrams that teachers are familiar with. The LA service should enable teachers to be aware of how many students are mastering, are in the process of mastering or do not master at all the topics of a learning unit, so that they can prepare their next class according to the learning needs of their students. The LA service should enable instructional designers to improve the learning objects they create in cooperation with the teachers. For them too, it is important to understand what they see. However, they may need to explore more students' interactions to be aware of whether the resources they develop have the right length or the right level of difficulty.

In the next section, we describe the interactions data stored by the system. The diagrams for teachers and instructional designers are presented next. This paper ends with a conclusion and future works.

2 DATA AND TOOLS

Comprehensive user interactions are stored as xAPI² statements in Learning Locker³. Examples of stored interactions include the opening of a learning unit, opening and closing of every single learning

² <https://github.com/adlnet/xAPI-Spec>

³ <https://github.com/LearningLocker/learninglocker>

object, self-assessment of each learning objective, attempt in solving an exercise, starting, pausing or quitting a video etc. As an example, consider the following xAPI statement:

```
{ "actor": { "mbox_sha1sum": "13648454125cf6ef31a9e632389c9a806316c9ad" }, (1)
  "verb": { "id": "http://adlnet.gov/expapi/verbs/answered" }, (2)
  "object": { (3)
    "id": "https://vfh143.beuth-hochschule.de/...?itemID=U05LX0ZUU19BRkdfRmV1Y2h0ZXNjaHV0e18wMV9NQw",
    "definition": { "type": "http://adlnet.gov/expapi/activities/question",
      "name": { "de-DE": "Bauphysikalische Grundlagen" } }
  },
  "result": { (4)
    "score": { "scaled": 0.5, "min": -1, "max": 1 },
    "response": "[\"Die Wasserdampfsättigungsmenge ist die Höchstmenge an Wasserdampf die Luft bei einer bestimmten Temperatur aufnehmen kann.\"]",
    "duration": "PT0H1M11S",
    "extensions": {
      "https://slehwr&46;beuth-hochschule&46;de/xapi/extensions/questionType": "choiceMultiple",
      "https://slehwr&46;beuth-hochschule&46;de/xapi/extensions/correctResponsePattern": [
        "Die Wasserdampfsättigungsmenge ist die Höchstmenge an Wasserdampf die Luft bei einer bestimmten Temperatur aufnehmen kann.",
        "Der Wasserdampfdruck ist abhängig von der relativen Luftfeuchtigkeit und der Lufttemperatur."
      ]
    }
  },
  "context": { (5)
    "platform": "moodle.hwk-berlin.de", (6)
    "statement": { "id": "db36072e-6759-401a-bc7b-daad0677b683" }, (7)
    "contextActivities": { (8)
      "parent": [
        { "id": "https://vfh143.beuth-hochschule.de/...?itemID=U05LX0ZUU19BRkdfRmV1Y2h0ZXNjaHV0eg",
          "definition": { "type": "http://adlnet.gov/expapi/activities/interaction" } }
      ],
      "grouping": [
        { "id": "https://vfh143.beuth-hochschule.de/api/lcms/courses/GEB",
          "definition": { "type": "http://adlnet.gov/expapi/activities/course" } },
        { "id": "https://vfh143.beuth-hochschule.de/...?itemID=U05LX0ZUUw==",
          "definition": { "type": "http://adlnet.gov/expapi/activities/module" } },
        { "id": "https://vfh143.beuth-hochschule.de/...?itemID=U05LX0ZUU19BRkdfRmV1Y2h0ZXNjaHV0eg",
          "definition": { "type": "http://adlnet.gov/expapi/activities/interaction" } }
      ]
    },
    "extensions": {
      "http://adlnet&46;gov/expapi/activities/course": [ "GEB-1-17#GEB" ] (9)
    }
  },
  "timestamp": "2017-03-30T13:30:15.152500+00:00", (10)
  "id": "01a785e0-d77f-4268-860b-2b32883d6c7e" (11) }
```

The xAPI statement with the given *id* (11) above contains the information that a *specific actor* (1) did *answer* (2) a *specific question* (3) with the shown *result* (4) on a *specific timestamp* (10). The *scaled score* of 0.5 indicates that the given solution is partially correct; the question was displayed for a *duration* of 1 minute and 11 seconds. For further analysis, the given *response* and the *correct response pattern* are also stored. For the purpose of better understanding the data, further information is bundled in the *context* (5). The statement reference (7) links to the prior stored xAPI statement on a higher level which allows to build a graph of the learning behavior; xAPI statements on the same level, e.g. multiple attempts of *answering* the same question, will refer to the same higher statement (7) within this learning session – their *timestamps* (10) help to order the attempts. Information about the

parent **(8)**, like the exercise this question belongs to, and grouping helps to distinguish if a learning object, here the given question **(3)**, is used in several learning units or courses. As the same course can run several times, the *platform* of the host institution **(6)** and the internal *course short name/id* in that platform **(9)** help to distinguish between the instances.

The visualizations are realized in the LA service as a plug-in of the Grafana⁴ framework. We use the *statement-forwarding* feature of learning locker since version 2 to sync the statements with elasticsearch⁵ from which Grafana reads the data. Initial import is realized using an own tool.

3 VISUALIZATION

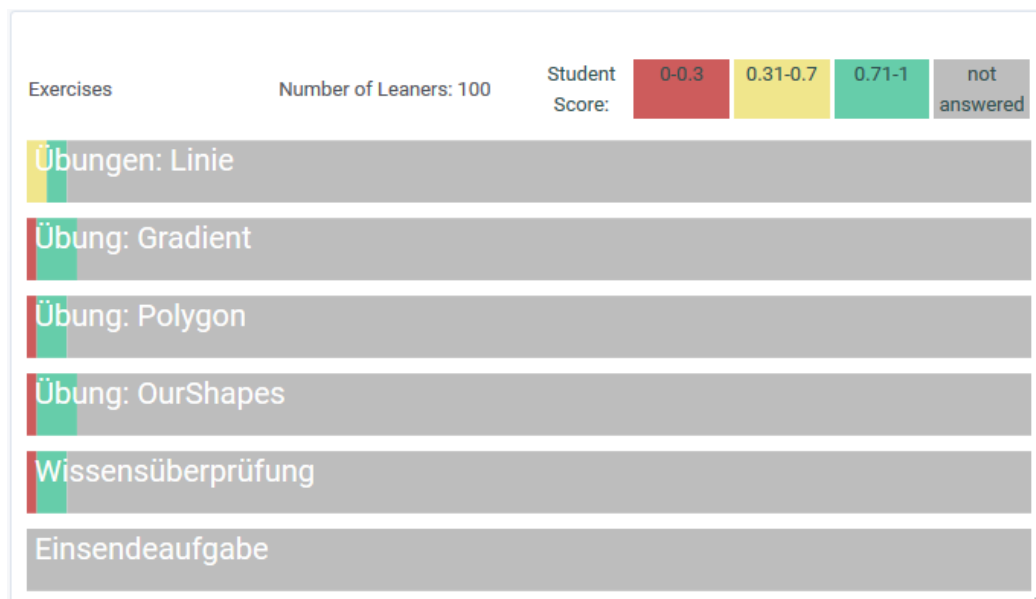


Figure 2: Many of the 100 students did not attempt any exercise (long grey bars). The exercises Gradient and OurShapes were attempted the most and mostly correctly solved (large green area)

The visualization depicted in Figure 2 enables teachers to grasp at a glance the performance level of their students at the level of a learning unit. It uses the well-known traffic-light metaphor used in other works as well, for example in (Dollár & Steif 2012). Teachers see for each exercise of the unit how many students are in green – correct solution –, yellow – solution partially correct –, red – wrong solution –, or grey – no attempt. The graphics are in responsive design. Rectangles are used instead of bar plots side by side to enable a comfortable view when a small device like a smartphone is used. The time span and the threshold values from red to yellow and from yellow to green can be chosen by the user. Figure 1, top corner right, shows the threshold values 0.7 and 0.3: if an exercise has got between 31% and 70% of the maximal score, it counts as partially correct and is color-coded in yellow. There are several options to calculate the performance of a student on an exercise. The default value set for teachers is simply the score of the last attempt as it reflects the best the current knowledge of

⁴ <https://github.com/grafana/grafana>

⁵ <https://github.com/elastic/elasticsearch>

students so that teachers can adjust their next lesson accordingly. Other metrics are available and can be chosen in a drop-down list. They are primarily for instructional designers to give them awareness on how difficult or easy it was for the students to solve that exercise. As an action, instructional designers in cooperation with teachers might rework that exercise to make it easier or more difficult to solve, or, leave it as is. These metrics are the average, minimal and maximal score on all attempts, as well as the total number of attempts.

Discussions with teachers have shown that they also need a general overview to plan remediation classes like at the end of a course to tackle again questions that have not been well understood by their students. They need an overview at the course level; if they detect an important part of students in the red or yellow area, they might want to spot the problematic topics, drilling down at the section level, then at the learning unit level, and then into the unit itself and get the visualization presented in Figure 2. For this situation, we have developed a similar visualization: green, yellow, red and grey. Starting from the visualization depicted in Figure 2, the aggregation at the learning unit level uses the well-known method of mapping the values of an ordered categorical variable to ordinal numbers, as for example explained in (Han, Kamber & Pei 2012) p. 74. The values grey, red, yellow and green in this order are mapped to 0, 1, 2 and 3 respectively. Take the example of a unit with three exercises. Consider a student who solved correctly two exercises – green color code – and did not attempt the third exercise – grey color code. The aggregation value at the unit level for this student is $(3+3+0)/3 = 2$, which is color-coded in yellow. If the third exercise was wrongly solved, the aggregation value will be $(3+3+1)/3 = 2.3$, which is also color-coded in yellow. However, if the third exercise was partially correct, the aggregation value will be $(3+3+2)/3 = 2.6$ and color-coded in green. The same procedure is used to produce the visualizations at the section or course level. This procedure can be applied whatever metrics have been used to produce the visualization of all the exercises of a learning unit. The same kind of visualization has been implemented for the self-assessments on the learning objectives. Teachers can see at a glance how their students assess their own knowledge on each learning objective of a learning unit, and, as above, obtain an overview at the course, section and learning unit level.

For instructional designers as well as for the recommender service, it is important to know whether the typical learning time indicated in the metadata for each learning object is realistic. To this end, we propose a visualization that shows not only the central tendency but also the dispersion of the overall time students spend on a learning object. The visualization is a sequence of simplified box-plots; each box represents a session with the bottom of the box being the minimum time spent by a student on that object in that session and the top of the box the maximal time; average time is drawn as a line in the box; the typical learning time as given in the meta-data is also represented, see Figure 3. A supplementary view adds all sessions together and show the total time spent on a learning object across all sessions. On higher levels, such as a learning unit, each box represents the time spent on all learning objects and each student is considered by the overall time spent (sum of all sessions).

4 CONCLUSION AND FUTURE WORKS

The visualizations presented in this paper are for teachers and instructional designers. By showing them how many students are in the green, yellow, red and grey areas, teachers can prepare their next

class according to the needs of their students. By showing them evidence of how long students spend on learning resources or how many attempts they make on exercises, instructional designers can reflect on the length and difficulty level of the resources and adapt them. Students can see the same diagrams as teachers do, but with their own data instead of the full class.

An obvious prerequisite for the diagrams to be useful is that the exercises have a high quality and learning objectives are well formulated. This requires some effort. The diagrams support a more active pedagogy style like the inverted classroom. Experience shows that it requires some training for teachers to integrate the diagrams in their daily routine. Further works include diagrams showing to instructional designers the paths that students follow while navigating through the learning objects and the learning units. This learning analytics service is being realized as an LTI-Tool so that it can be used with any LTI-compliant learning system.

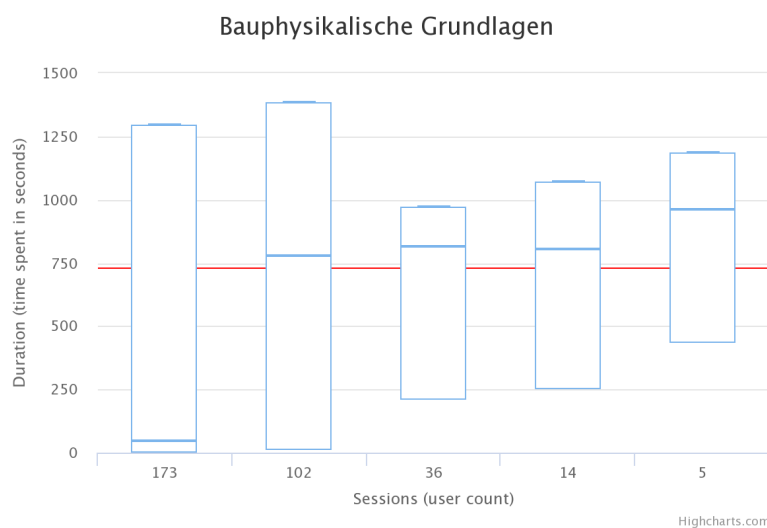


Figure 3: In the first session, 173 students accessed the object. The minimal time spent was about 1 second, the maximum above 1250 seconds and the average about 20 seconds. In a second session, 102 students accessed that object. The typical learning time is given by the red line

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