

Towards Configurable Learning Analytics for Constructionist Mathematical e-Books

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Abstract. This paper presents emerging requirements for learning analytics on interactive mathematical e-books and a framework that can be used for the seamless integration of complex learning objects with e-book platforms. We describe the opportunities that this approach opens up regarding interoperability and configurability of learning analytics and intelligent support. The framework is generic and can be used for any type of system with similar requirements. In this paper we present a case that covers configuration of learning analytics for teachers and intelligent support for students in constructionist mathematical e-books.

1 Introduction

The emergence of authoring software for e-books means that digital books with text, images and other interactive elements are increasingly being used on personal computers and other electronic devices for educational purposes. However, most of these e-books are simple transformations of traditional textbooks into a digital format and do not take advantage of the dynamic and computational affordances offered by this emerging technology. The MCSquared project¹ is investigating whether the affordances of state-of-the-art e-books can be exploited to support the learning of abstract mathematical concepts. We are looking into the design of highly interactive constructionist e-book widgets, and exploring their potential for providing learners with opportunities to construct mathematical artefacts in order to engage creatively with mathematical problems.

Within this context the increase of both process and product data collected provides unprecedented opportunities for knowledge discovery through state-of-the-art data analysis and visualization techniques. However, despite the fact that in the past two decades intelligent technology has become increasingly feasible, the power of these methods has not reached its full potential in education. For example, although it is now possible for intelligent pedagogical agents to monitor learners' interactions within educational applications and provide individualised support, only a handful of intelligent tools are employed in practice, yet they are tied to particular instructional approaches, domains and context.

¹ The Mathematical Creativity Squared project is funded by the EU, under FP7 ICT-2013.8.1 Project #610467. For more details see <http://www.mc2-project.eu>

We believe that one of the reasons that the promises of ubiquitous, individualised and adaptive technology has had a very small impact in education is that learning environments are often rigid and limited to specific learning contexts and pedagogical approaches. Our previous research [6, 7] and that of others (e.g., [9]) has primarily enabled the rapid revision and management of content. In line with previous research in the field (e.g. [8]), our vision is that teachers and educational organizations will be able to also mould the nature and type of support provided to a learner (cf. [2, 10]) and the information they want to glean from their interaction. Then the unrealised potential of the technology could begin to be exploited.

This paper presents our preliminary efforts towards this vision: a prototype where e-book pages and the widgets that they contain can be configured. First, we present below a set of emerging requirements for Learning Analytics in the context of constructionist mathematical e-books.

2 Emerging Requirements for Configurable Learning Analytics

With the advent of data science and analytics in general, there are several ‘analytics’ tools that have appeared. While we have looked into a large subset of them, we cannot review them all in detail here. However, we have been unable to find a tool that focuses on providing information from constructionist, exploratory mathematical environments (with the exception of our previous work in [3] where we also review related work in more detail).

In the context of commercial e-books in particular publishers and authors are interested in (and to some extent only have access to) high level information such the number of pages read, average reading times, exit rates and other details that reveal reading patterns that can correlate with, for example, sales figures. However, from an educational point of view teachers, designers and even students require a more in-depth analysis of learners’ interaction with the e-books.

The MCSquared project comprises four Communities of Interest (COI) across 4 EU countries (France, Greece, Spain, UK) and engaged their members in requirements elicitation and stakeholders’ analysis. Through several face-to-face workshops and sustained online interaction and communication between members of the COI we have identified many scenarios in which e-books are being used in teaching and other requirements of learning analytics tools and data visualisation that are emerging.

Digital resources like e-books are being used either directly in the classroom or in ‘blended’ learning scenarios (e.g. for practice exercises at home) or in a ‘flipped’ learning model where students read and interact with the e-book content online (e.g. at home) and complete other parts of the e-book in the classroom with the help of other students or the teacher. So neither context can be excluded. We present below high-level categories of the themes around which requirements have emerged:

- Usage and other book-level descriptive statistics

- the order of pages
- time spent on each page/activity
- how quickly students read a page
- the percentage of coverage of particular pages from a book
- Structured answer and related descriptive statistics
 - Student answers and performance in structured questions
 - Number of attempts to answer a question
 - Repeated wrong answers across students
- Constructionist Analytics
 - Constructionist descriptive statistics (i.e. number of objects constructed, moved, deleted, etc.)
 - Data regarding construction operations (achievements of key 'landmarks')
 - Specific patterns of interaction within a widget

While the first and second category of data analytics are interesting in their own right, we are focusing mostly on the third type of data that we refer to as 'deep' analytics of constructionist e-books for learning. This is particularly interesting because it goes beyond the 'low-hanging fruit' of descriptive statistics (which, in principle, are technically and conceptually well understood) and looks into extracting some meaningful information that could support decision making. Constructionist analytics opens up the door to real-time formative and summative assessment (as discussed in [1]). In our previous work, we found that even a simple traffic-light system could satisfy the teacher's need for finding out which students are progressing satisfactorily towards completing the task and which ones may be in difficulty [3].

In addition, a requirement across all the types of analysis mentioned above, is the availability of a generic, interoperable framework that enables configurability of learning analytics and intelligent support. We present a prototype of this in the next section.

3 Prototype

In this section, using an example of an e-book page, we demonstrate a basic but complete integration scenario. The page is part of a mathematics e-book developed by the Greek COI and features a learning activity developed in Geogebra. The page is integrated in a prototype that has a local in-memory database that stores data generated from the student activities and a rule-based reasoner that provides real-time intelligent support to the students (fig. 1). The purpose of the activity is to get the student select an appropriate combination of variables in order to get both parts of the ladder to the same level. Converging the two parts can then display a single heart at the top (join the two halves). All of these heterogeneous components are pluggable widgets that operate in their own secure environment (sandbox). They are hosted in their own domains and they are executed concurrently without interfering with one another. Integration with the host page takes place through a lightweight set of mediator

Ladders

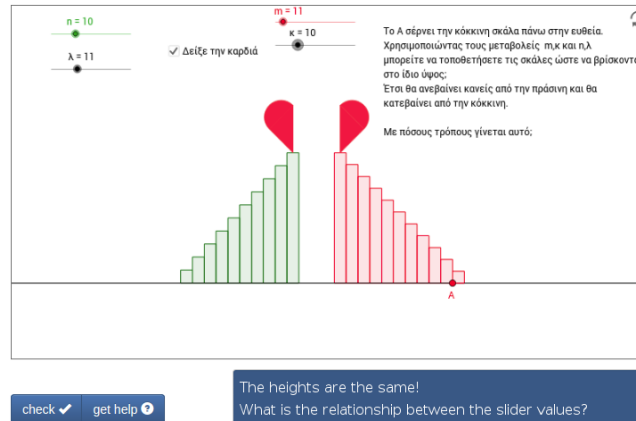


Fig. 1. The 'Ladders' Activity from Geogebra Tube

wrappers that enable full two-way communication over a simple and common interface. Each widget is allowed to expose its own functionality (or part of it) and make it available to the platform through a wrapper interface. This scheme allows better performance (multithreading), security (sandboxing), controllable interoperability (widget interface exposed through the wrapper) and seamless integration (common wrapper interface) [5].

This e-book page demonstrates an example of an activity that offers real-time intelligent support to students through visual controls and real-time formative and summative feedback to teachers through graphs. The activity widget offers interactivity through sliders and a checkbox. As the student interacts with the widget, action indicators are generated and sent to the page. The platform populates the local (in-memory) database which in turn incrementally synchronises with the back-end database through REST ² web-service endpoints (fig. 2). These updates are asynchronous for better performance. The local database serves as a buffer for data that needs to be immediately available and thus enables fast and more reliable responses. The local data is then sent to the rule-based reasoner for processing. If the reasoner identifies a case that justifies a discreet intervention, a message is displayed in the textbox and/or some visual indicator is presented in the activity frame (heart). The latter presupposes that messages are sent to the activity widget through the platform. This process may also be initiated by the student. If the student asks for help or wants the system to evaluate the work that has been submitted so far, then the reasoner responds with an appropriate message in the textbox. In parallel, the data generated from both the activity and the reasoner is sent to the database.

² http://en.wikipedia.org/wiki/Representational_state_transfer

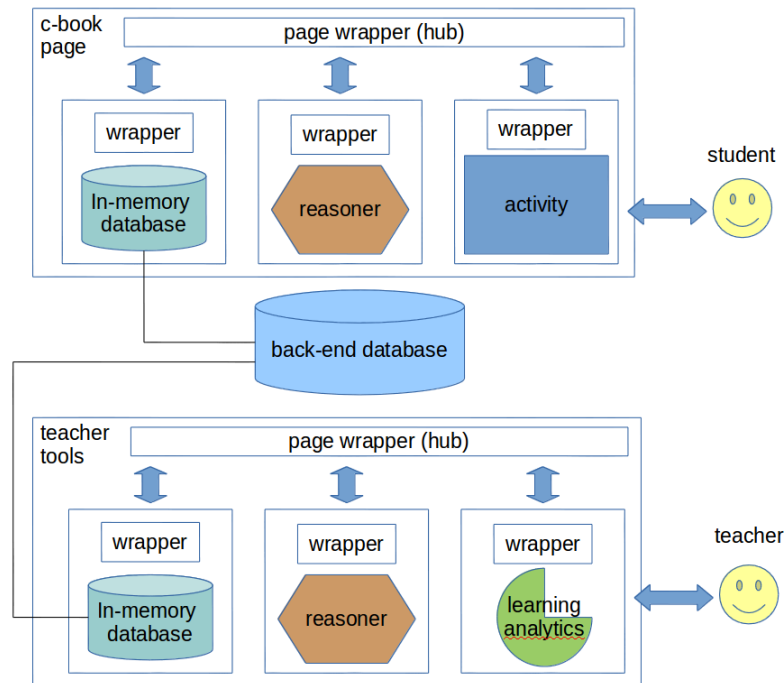


Fig. 2. The Architecture

The page that hosts the teacher tools has a similar structure. It also contains a local database widget and a reasoner. As the back-end database gets updated with student actions and reasoner findings, the local database incrementally retrieves the changes. Some of this data is used as a direct feed to other widgets that host learning analytics visualisations. In this particular example we have visualisations that measure student activity and performance (fig. 4). Both measurements are presented as histograms and provide real-time feedback to the teacher. The first visualisation measures what has been used in the activity and how much. For example the elements n , m , k and l are numeric variables that correspond to sliders in the construction. The visualisation shows which of these sliders and how many times have been used by the student. The second visualisation presents a comparative measurement of effort and levels of achievement. Some of the local data is then processed by the reasoner and new data may be inserted into the database. This data may be used to populate other visualisations or provide some intelligent support to the teacher.

The teacher tool is both an authoring and a monitoring environment. The teacher has the ability to dynamically configure the system to log actions performed by specific widget elements. Widget instances can be dynamically inserted into the authoring environment in the same way they can be integrated with a c-book page. The widget communicates with its host through the wrap-

pers and makes available its internal structure to it. The metadata extracted from the widget is then used by the host to dynamically construct an authoring graphical user interface that is presented to the teacher (fig. 3). The teacher can then select the widget elements deemed necessary to log their actions. This information is sent to the database along with the id of the c-book the widget belongs to. When the widget is invoked in a c-book, the page uses this information to dynamically register event handlers in the widget in order to intercept student actions for the selected elements.

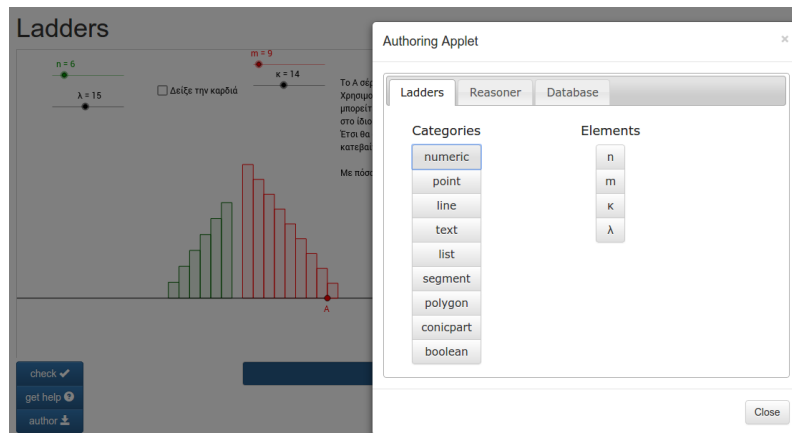


Fig. 3. Authoring Applet for the Teacher

4 Conclusion and Future Work

In this paper we presented a prototype authoring environment that enables configurable learning analytics and intelligent support in educational e-books. The specific example used in this presentation focuses on constructionist mathematical learning activities and the configuration of appropriate analytics for them. The system has been implemented and used by members of COIs and preliminary results show that it meets its original design objectives. It can be used effectively for rapid integration of learning objects and dynamic configuration of learning analytics and intelligent support. The next step is to specify how this data will be processed by the reasoner in order to provide effective support to the students. This part requires the use of a rule editor by a domain expert. Preliminary work towards this aspect has been undertaken in [4].

A distinguishing characteristic of the prototype presented here is the ability to dynamically generate user interfaces that enable the configuration of learning analytics on heterogeneous learning objects. Heterogeneity is hidden behind the mediator wrappers. A possible future enhancement would be to analyse a number

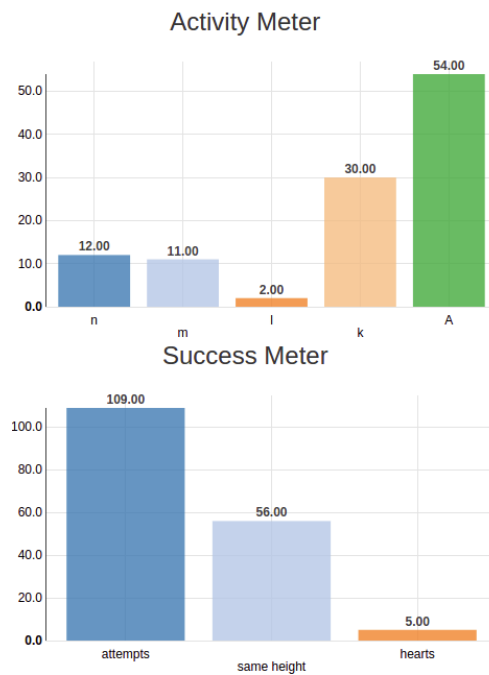


Fig. 4. Teacher Visualisations. In this example the x axis represents the different aspects that the teacher selected to log and the y-axis the number of logged cases.

of representative learning objects and create a learning component description language that can be used as a standard description of the construction that represents an activity. This language could then be used to semantically enhance the component in the wrapper in a standardised way.

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