DojoIBL: Online Inquiry-based Learning

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Abstract. DojoIBL is a web based platform to support collaborative inquiry-based learning processes. It imitates real-world research processes and organizes inquiry activities into several phases. DojoIBL considers lessons learned from the weSPOT project and offers a cloud-based highly scalable infrastructure that has a strong focus on (mobile) data collection. In this sense, DojoIBL blends formal (desk-top based) learning and informal (mobile) learning. Within the course of 1 year, a design based research methodology was implemented in 10 national and international inquiry projects. Within this period, students were inter-viewed at regular times. Time and task management issues turned out to be critical functionalities and were thus implemented in several iterations.

Keywords: Inquiry-based Learning, cloud-based learning, Community of inquiry.

1 Introduction

A learning process has been defined as a sequence of interdependent procedures that aim at transferring new knowledge from the working memory to the long-term memory [5]. Inquiry Based Learning (IBL) builds upon this definition and establishes questions as a starting point for the learning process. Through a combination of formal and informal activities and a continuous exploration based on social interactions students generate new knowledge [3, 11]. IBL has been recognized by policymakers as an efficient vehicle to make students more proficient in STEM (Science, Technology, Engineering and Mathematics) subjects. Additionally, it has been considered essential for scientific innovation and the future knowledge society [1, 6, 15]. The usage of technology in the field of IBL has led to the development of solutions like DojoIBL, an open source implementation that enables flexible structuring of collaborative inquiry processes [13]. DojoIBL is a cloud-based redesign of the weSPOT [12] tool suite that has been conceived to address challenges like scalability, seamlessly and flexible inquiry support, access to open educational resources (OER) and intuitive orchestration support.

2 Inquiry design

IBL is a complex process and its implementation in real scenarios implies several practical considerations. This manuscript has transformed these considerations into the following design challenges that have been addressed by DojoIBL.

IBL is often based in ill-structured learning tasks that are open ended [4, 10]. So, it requires more support and structure than traditional educational setups. In this informal IBL process, students need freedom to investigate their essential questions and need closer process support and guidance. An essential question is any question that requires a student to develop a plan or to make a decision in order to answer it. Unlike scientists, students do not have a structured mindset with the steps needed to address an essential question. Thus, technology can help to fill this gap and to provide guidance to master applying these inquiry structures. However, there is not a unique inquiry model that supports every essential question. So, tools need flexibility to embrace a very diverse variety of inquiry models. Additionally, designing these flexible inquiry processes from scratch can be challenging for teachers. Following an OER (Open Educational Resource) approach, DojoIBL offers templates for inquiry structures to be reused.

Traditional Learning Management Systems (LMS) work with courses. When students enroll in a course, they usually participate in a shared space in which everyone sees each other's contributions. To enable independent group work within a course, LMSs use groups. In the context of IBL, collaborative group work has been proven to have positive influence of support on task and team regulation [9]. So, it is especially relevant to allow teachers to organize and to regulate groups within an inquiry structure. DojoIBL makes a clear distinction between, the inquiry structure –the equivalent of a course in a LMS– and the runtime –that refers to the space in which students work together–. This differentiation also facilitates the reusability of an inquiry structure. If a teacher wants to reuse only an inquiry structure with another group of students, there is no need to copy, clone or start a new inquiry from scratch. DojoIBL handles this situation very intuitively.

From a technical point of view, the role of technology bridging the gap between formal and informal learning is a key feature. IBL, as a combination of formal and informal activities, requires contextual support. In IBL students are often distributed across different places. Therefore, tools need to bring students together providing a shared space to exchange e.g. instant messages or data collected. An additional aspect when enabling a digital shared space for collaboration is scalability. Inquiry processes often have periods of high volume of data traffic, especially supporting in-field inquiry that requires sharing large amount of multimedia data files and simultaneous connections to the server. To address these challenges, DojoIBL provides a cloud-based scalable solution that bases its front-end in HTML5. The first characteristic makes DojoIBL to scale up with an increasing number of users. The second one enables run across different kinds of devices including laptops or mobile devices. This, in turn, can support a large number of students exchanging information in a shared space while working in their collaborative inquiry projects.

2.1 Flexible inquiry support

An inquiry is a process with the aim to solve a problem, understand a phenomenon or to create knowledge. Scientific inquiry in empirical sciences answers the question of how phenomena are related. It is about cause-consequence relations, which can be tested in experiments. Recent literature [8] synthesized the most common inquiry cycles resulting in a framework that informs designers to model inquiry learning activities e.g. [16] suggest an inquiry cycle consisting of 5 steps: (1) ask, (2) investigate, (3) create, (4) discuss and (5) reflect. [2] present a 5-step variation: (1) question, (2) predict, (3) experiment, (4) model and (5) apply, [7] presents a slightly different 6-step model: Inquisition-acquisition-supposition-implementation-summation-exhibition. Similarly, the weSPOT project has defined an IBL-model that consists of six –optional- steps. One the biggest challenges for teachers is to use these models in practice to create inquiry based learning lessons. They need to shift from teaching content into directing kids to find their own learning paths. Thus, they need inquiry structures/models for students to let them experience what inquiry based learning is about.

Tafoya [14] suggested four kinds of inquiry-based learning differentiating student autonomy. The first level is a confirmation inquiry in which students are provided both with the structure of the inquiry as well as the answers. This is useful to become familiar and to have a first experience with an inquiry process. The fourth (most challenging level for students) is an open inquiry. Here students act like scientists, deriving a question, designing the operationalization and carrying out the investigation.

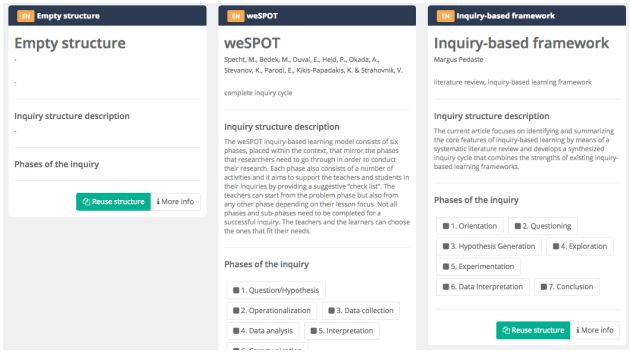

Fig. 1. List of inquiry templates available. Each template represents an existing inquiry model in the literature

There is quite a startup cost involved for a teacher to create a first inquiry structure. An experienced teacher wants maximum flexibility and the possibility to define custom phases and activities. A novice will want to start with an existing inquiry structure. DojoIBL provides both options. It enables teachers to create an inquiry from scratch (fig 1.1) or a user can select an inquiry model that is available in literature (fig. 1.2 and 1.3). In this sense the tool takes into account lessons learned from Tafoya [14]. A novice teacher can choose an existing -proven- inquiry structure and explore the demo activities that are offered. A more experienced teacher can create a custom

structure and has full control over phases and types of activities that are to be conducted within a phase.

2.2 Orchestrating inquiry group work.

DojoIBL makes a clear distinction between the inquiry model/structure, discussed in 2.1, and the runtime data that is produced by the learner. An inquiry structure can allocate various independent groups of students working with their own inquiry space. Each inquiry group share the inquiry structure (model), but participants in those groups can communicate (Figure 2: the chat is in the right side) and work independently from other groups.

The students' view has five screens; three (inquiry view, phase view and activity view) to visualize the structure and the content of an inquiry, the timeline view (section 2.3) and the calendar view (section 2.4). The inquiry view (Figure 2) shows the whole inquiry structure. Each grey block corresponds to a phase which is formed by inquiry activities. An inquiry activity is an extensible object in the DojoIBL framework. While, default activities are rich text, discussion, data collection and mind mapping activities, new type of activities can be easily created by the developers extending the activity object in the DojoIBL framework. Inquiry activities are authored by the teacher in order to guide learners through inquiry process. Often, they have a colored border that determines which role (a learner with a responsibility) is in charge of the given activity.

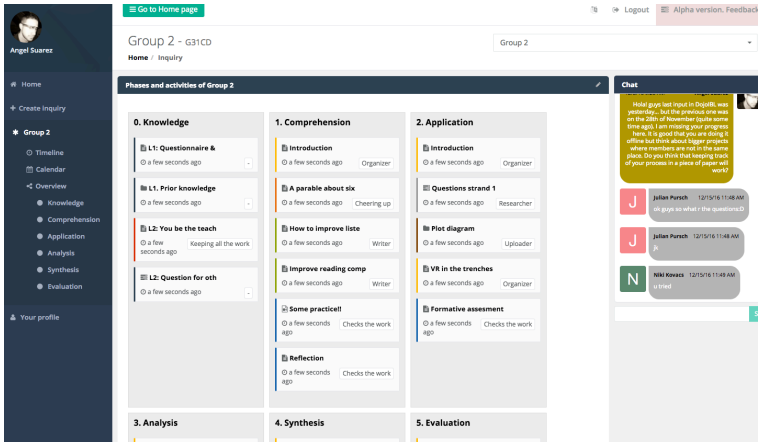

Fig. 2. Students' view of an inquiry. Chat on the right. Inquiry structure on the center.

The second screen (Figure 3) is the phase view. It is organized in three columns: to-do, in progress and completed. Students can drag and drop activities in between these columns to set the status of the activities. Motivating students to reflect upon the status of an activity is important for both student and teacher. The teacher gets an indication of progress students have made. A student group receives insight on their productivity and can reflect on what remains to be done.

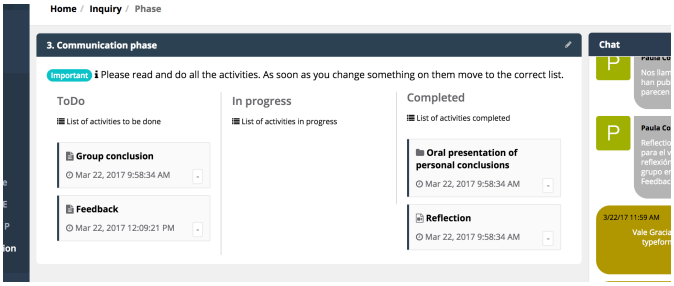

Fig. 3. Phase view of an inquiry. It provides three columns to monitor the status of the activity.

2.3 Students' awareness

DojoIBL builds upon a powerful notification system that sends server generated notifications to the desktop client, but also to Android and iOS devices. Notifications are broadcasted for various types of events. For instance, when a teacher alters or creates an activity, or when a student sends a new message a notification is sent. Once the notification arrives, it is visible for 2 seconds in right upper corner. When the user opens the notification, the corresponding information item (e.g. the chat) is opened.

The timeline (Figure 4) keeps the user informed of what is going on in the inquiry. When a user is not online, some notifications will not be received (e.g. when a user comments on an activity). Rather than having the user to check all activities for updates, the timeline lists progress for all activities.

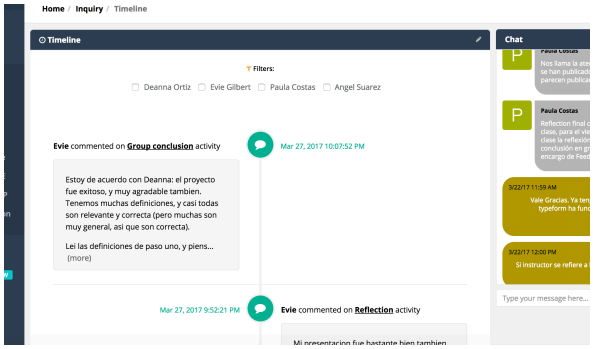

Fig. 4. Timeline of the inquiry with recent contributions. There is one per inquiry group.

Timeline entries are organized by date, and thus make easy overview of recent contributions possible. Clicking on an entry brings the user to the corresponding activity and provides more context information. For instance, it shows the message within the context of other messages in an activity.

Students and respondents indicated that although this is helpful, they would like the notification system to integrate with their mailbox. Future implementations will consider a configuration option to receive either an email each time something happens, a daily digest or no notifications at all.

2.4 Time management

During interventions with experts and teachers, time management was often pointed out as a crucial functionality. The DojoIBL calendar has been developed as a solution and displays activity deadlines as a visual indicator for tasks that lie ahead. The deadlines are defined at the level of inquiry group, so each inquiry group manages its time independently from the other groups. This enables better time management for groups and facilitates more self-regulated processes.

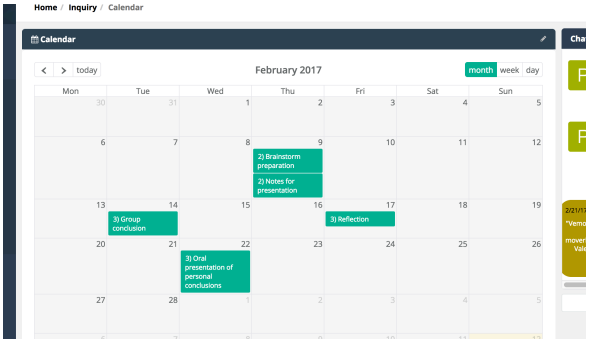

Fig. 5. Calendar view with the activity deadlines. There is one calendar per inquiry group.

3 The DojoIBL cloud based architecture

In a traditional physical deployment setting, an institute is responsible for acquiring software and hardware to implement e.g. an LMS. With cloud computing, these resources are made available through a network. Hardware, software and data are made available on demand. Cloud applications come in three service models. Software as a service (SaaS) cloud applications offer an application to the customer. The cloud based service provider offers this service (e.g. email, project management, customer relationship, …) to a customer that can often configure the software to his needs. Platform as a service (PaaS) often standardised services (e.g. access management, data storage, database management…) The service provider maintains the framework and infrastructure but often offers facilities for development in languages like Python, .NET or Java. PaaS customers do not get direct access to the operating system but operate with the definition of the platform. Infrastructure as a service (IaaS) introduces most flexibility but comes with more maintenance for the customer. Infrastructure such servers, network and data storage is offered to the customer that has complete freedom in how to use the hardware.

DojoIBL has been developed to run using PaaS services and offers its functionality as SaaS cloud application. Building on a PaaS service comes with the advantage of not having access to the operating system, which lowers administrative burdens. The PaaS service offers unlimited access to both processing power and information storage. As more users use the system simultaneously, the system can allocate more

servlet containers. The database is implemented as a schemaless NoSQL store that provides scalable retrieval and storage of data.

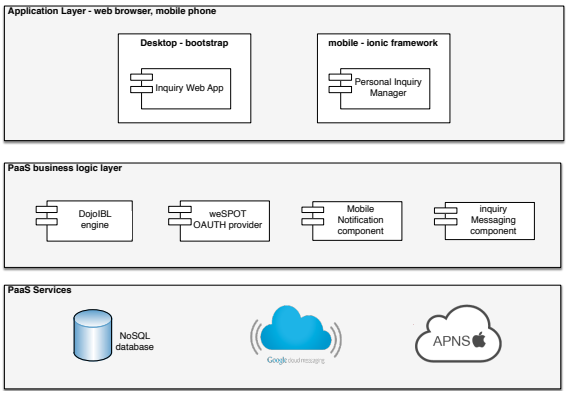

Fig. 6. Simplified DojoIBL architecture

Figure 6 shows a simplified overview of the DojoIBL architecture. Application layer components have been developed either in AngularJS for web browsers or in Ionic for mobile devices. The front-end applications communicate with a REST based web service stack that is offered by the DojoIBL engine. All components in the business logic layer rely on third party services offered either by the PaaS system or by external providers. The mobile notification component for instance relies on external providers such as Google Cloud Messaging (GCM) to broadcast notification to Android devices, while Apple Push Notifications (APN) sends notifications to iOS devices.

The NoSQL database makes inquiries, groups and other objects persistent. The DojoIBL class diagram relates the most important classes that are required by the different components. After authentication by weSPOT identity provider, user details are represented by an Account object. Every user can create an arbitrary amount of Inquiries or can participate as a student in an Inquiry Group. The inquiry messaging component manages a chat. Through a Thread, a chat is bound to an Inquiry Group. Within this group, users can post an arbitrary number of messages. The messaging component relies on the notification component to broadcast new messages to various devices.

4 DojoIBL usage

During the last year, the DojoIBL platform has been used in different types of collaborative IBL processes. During this period, a design based research approach was set up with several trials at Dutch and European level involving almost 200 participants. Table 1 shows an overview of the pilots conducted between June of 2016 and March 2017. The structures created for the pilots varied from 2 up to 7 phases with a different number of activities per phase. Often these pilots went also beyond the IBL approach and were characterized as group work. This shows the flexibility of DojoIBL

to offer support in different contexts. For example, 12 students from the MP4 (Middle Program Year school) course at the International School of Eindhoven, carried out an investigation about World War 1 using the levels of Bloom's taxonomy as phases (6 levels = 6 phases). The goal of the inquiry was to learn more about reading and listening comprehension skills through inquiry activities related to the WW1. Within each phase -from Knowledge to Evaluation- students acquired understanding about their evaluation criteria for the inquiry, and they finished the inquiry applying the criteria in the context of WW1 e.g. reading and listening fragments from soldiers in the trenches. In another trial at the Agora school, DojoIBL was used to conduct an inquiry challenge to design the logo of DojoIBL. In this case the process was divided in two phases: the design and the implementation phase. The tool was used to keep track of the decisions made and the improvements done in the logo. In a trial at the Open Universiteit, students carried out an inquiry with 7 phases. In this case, although it was not purely an inquiry, the 7 participants used DojoIBL as a personal space to discuss and receive feedback about their PhD. Each phase was assigned to one participant, and each participant was responsible for facilitating a brainstorm on their topic. In addition to the flexible inquiry structure support, table 1 shows a great variety of group work arrangements. For instance, continuing with examples described, different configurations of groups can be found. The first two trials –at the school in Eindhoven and Agora– only have one group defined, while the third trial has two groups of 6 students each. In this case, they follow the same Bloom's taxonomy structure but they worked independently at a different pace. Ultimately, these examples illustrate the flexibility of DojoIBL supporting very diverse inquiry processes.

In order to get more insights on the user experiences in DojoIBL, and to assess its effectiveness in collaborative settings, three questionnaires and semi-structured interviews were distributed during schools' and university's trials. At the University, experts in IBL showed a great degree of acceptance: UX scores were high. Moreover, the experts' feedback led to significant improvements in the DojoIBL interface –implementing a better inquiry structure overview– that were discussed in the chapter 2.2 of this manuscript. In the school context, preliminary results about the group efficiency showed high scores in the 'coordinating' and 'trust' scales, while the 'personal understanding' and 'adapting' scales did not score so well. Since there was no experimental group and the population was limited, interpretations have been taken cautiously. Nevertheless, qualitative data from the semi-structured interviews with students confirmed the general positive acceptance and the adequate support that DojoIBL provides for the collaborative inquiry process.

Table 1. Summary of the pilots carried out the first year.

Organization – duration – topic	Users	Structure	Message - comments
Open University – 2 weeks Internal organization	19 researchers (4 groups)	Phases: 5 Activities: 45	M: 512 – C: 407
Int. School Eindhoven – 1week Ancient Rome	34 11yo-students (18 groups)	Phases: 4 Activities: 7	M: 206 – C: 39

Int. School Eindhoven – 4 months Spanish Satirical Magazines	2 17yo-students	Phases: 4 Activities: 25	M: 182 – C: 282
Int. School Eindhoven – 3 months World War 1	12 13yo-students (2 groups)	Phases: 6 Activities: 28	M: 185 – C: 59
Int. School Eindhoven – 2 months Spanish Language Learning	28 9yo-students (12 groups)	Phases: 3 Activities: 18	M: 949 – C: 314
Open University – 3 months 'PhDs Round Table'	7 researchers	Phases: 7 Activities: 12	M: 173 – C: 42
Workshop with Teachers – 1 day DojoIBL Demo	40 teachers	Phases: 6 Activities: 20	M: 2 – C: 3
Agora School – 1week Design DojoIBL Logo	4 13yo-students	Phases: 2 Activities: 4	M: 12 – C: 14
Escola Sadako – Planned International Exchange	40 14-yo students	Phases: 3 Activities: 12	M: 0 – C: 0
Agora School – Planned International Exchange	12 14yo-students	Phases: 6 Activities: 10	M: 0 – C: 0
Total	**199**		

5 Conclusion

Inquiry based learning (IBL) has been suggested as an efficient approach for STEM subject teaching, however it is a complex endeavor for teachers and students to implement in real settings.

This manuscript has collected results in the field of IBL and has transformed them into design challenges that have been addressed in DojoIBL. As a result, a flexible cloud based solution with special focus on process structure, simplicity, awareness and time management has been implemented. The design based research approach took place in close collaboration with school stakeholders. After 10 Dutch and European trials with 200 students including teachers, students and researchers, DojoIBL has finally reached a stable phase.

All in all, the retrospective evaluation of DojoIBL after one year of work is promising. The users' feedback confirmed that DojoIBL could assist teachers and researchers to shape new effective collaborative inquiry structures in which students generate more individual and collective meaning. This, together with the non-project basis maintenance culture, has led DojoIBL to a sustainable model that encourages the team to strive for a scaling up phase.

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