Scaling Learning Analytics up to the national level: the experience from Estonia and Uruguay

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Abstract. This paper analyzes the key aspects in the implementation of national-level LA and the limitations that current initiatives present. With this purpose, we present a multiple case study that describes six national-level LA projects in Uruguay and Estonia. By means of a data value chain, we synthesize the steps followed by the LA projects to extract meaning out of data and discusses the main issues related to scaling up LA. We found out that these LA projects are driven by political - and not so much by educational- aspects. We also saw that integrating personal data from different educational institutions is a key step in these projects, which entails technical, legal and administrative issues. We also see a big potential in national-level LA to provide a macro perspective that supports teachers, students, parents or school leaders to take evidence-based decisions.

Keywords: national-level Learning Analytics, data integration, learning policy, data value chain

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1 Introduction

During the last few years hundreds of Learning Analytics (LA) initiatives were proposed all around the world. The vast majority of these proposals collect and process data related to a learning process or to an educational institution. Despite the vision of scaling LA across institutions was present from the very beginning of the LA vision[1] [6], few proposals faced this problem. In this sense, educational institutions become too often "data silos" whose data is not integrated to the data from other institutions [8].

This lack of scale reduces the potential of LA applications in three directions. First, it hinders the understanding of learning processes that involve multiple institutions; for example, if lifelong learning is to be assessed, learners should be tracked across multiple institutions. Second, it does not allow to share evidence across institutions for their mutual benefit; for example, it can be interesting to compare the outcomes of learning innovations that occur in two schools in the

[1] `http://iite.unesco.org/files/policy_briefs/pdf/en/learning_analytics.pdf`

same area. Third, it is not possible to get an evidence-based macro perspective of a whole educational system in a country; for example, policy makers, private companies and school leaders (but also teachers, students or parents) may be interested in the adoption and impact of an educational innovation that affects the whole education system. In order to enable these envisioned scenarios, it would be desirable to scale LA projects up to the national level. Thus, data from learning evidence collected in educational institutions all over the country can be shared, integrated and coherently processed. However, this sharing, integrating and processing data from multiple institutions entail additional technical, ethical, legal and administrative problems.

Some initiatives have already been done in this direction by the Open Data community. Some examples are the Education Research & Data Center of Washington[2], the National Center for Education Statistics[3] or the Open Data portal of the Ministry of Education in the Netherlands[4]. These portals offer aggregated data about educational institutions and dashboards to visualize it. However, they focus on administrative information about educational institutions and not so much on the learning processes. Thus, they do not face many of the problems associated to scaling LA processes to the national level (e.g. integrating personal data from learning processes across multiple institutions).

Unfortunately, there is still no clear guidance to pave the way for researchers and institutions to overcome the problems related to the national-level LA projects. As a step in this direction, this paper analyzes the key aspects and limitations in the implementation of national-level LA initiatives. This analysis is done by means of a multiple case study that included six LA projects carried out in two of the few countries that are currently scaling LA projects up to the national level: Estonia and Uruguay. They share the characteristics of being two small countries, and pioneers in the digital inclusion in the educational field [10]. At the same time, their educational systems and policies are significantly different, which makes them interesting cases to be compared. By means of a data value chain, the paper synthesizes the steps followed to extract meaningful educational information from data on the national level.

2 Learning policies in Uruguay and Estonia

The strategic lines of the **Uruguayan education system** are defined by the National Administration of Public Education (ANEP) in its National Education Plan 2010-2030[5]. This plan includes as strategical aspects the expansion of an egalitarian and participative education model, the strengthening of the institutional management, the universalization of compulsory education, the promotion

[2] https://erdc.wa.gov/
[3] https://nces.ed.gov/datatools/
[4] https://www.ocwincijfers.nl/
[5] http://www.polomercosur.org/grupoeducacion/wp-content/uploads/2017/07/Plan-Nacional-de-Educaci\%C3\%B3n-de-ANEP.pdf

of teacher professional development, and the transformation of educational centers to offer a quality education. In this plan, technology plays a fundamental role to enable new teaching and learning modalities.

The leading role of ICT introduction in education is carried out jointly by the ANEP and Plan Ceibal[6], a governmental agency in charge of the operation and deployment of the national-scale educational computing initiative. Starting in 2007, every student in primary and the first grade of secondary public education in Uruguay receives a laptop or tablet that is provided and maintained by Plan Ceibal. Moreover, Plan Ceibal provides access to the Internet and to a videoconference network used for distance learning to all public schools. In addition, Plan Ceibal provides a wide range of educational online resources, such as a Learning Management System (LMS) or a mathematics intelligent tutoring system. As a centralized provider of all these services, Plan Ceibal is able to exploit the data generated from these platforms and give feedback to the education system on the situation of various teaching and learning processes [1].

In the last decade, the resources allocated to education increased. As a consequence, Uruguay is top ranked in South America in the OECD PISA 2015 results [10]. However, there are still several problems to be solved[7]: the social stratification of the education system, the high drop-out rate and the large percentage of the students that fall behind in secondary education.

The direction of the **Estonian education system** in the last few years was defined by the Framework EOS2020[8]. It prioritizes sustainable lifelong learning processes, and the need for evidence-based decision making to achieve them. The aim of the digital focus in Estonian educational system is to integrate digital culture to the learning process instead of teaching some basic ICT skills in separate courses. Thus, Estonia focuses on promoting 1:1 computing and Bring Your Own Device approach to encourage learners to use their personal devices.

For these approaches to be successful, it is required to develop teachers' and learners' digital competencies and to ensure the availability of digital learning resources in different levels of education. These approaches also require the development, implementation and evaluation of national-level systems and digital learning resources that support evidence-based evaluation and decision making in different levels. This support is very relevant as educational institutions in Estonia are autonomous entities and responsible for their own decisions.

The Estonian educational system and its lifelong learning strategy made Estonia to be in the highest rank of Europe in the OECD PISA 2015 results [10]. PISA results also show that there is no stratification in Estonian educational system, it is based on equality and comprehensive school principle and students' socio-economic background has a low impact on their study results. But there are still several challenges to be addressed, such as a more learner-centered, inclusive education and the promotion of well being among students and teachers.

[6] `https://www.ceibal.edu.uy/en/institucional`

[7] `https://www.ineed.edu.uy/images/ieeuy/Informe-sobre-el-estado-de-la-educacion-en-Uruguay_Sintesis-y-desafios.pdf`

[8] `https://www.hm.ee/sites/default/files/estonian_lifelong_strategy.pdf`

3 Methodology

In order to detect the steps that are followed in national-level LA projects and the main difficulties they have to overcome, we carried out a multiple case study. We selected six national-level LA projects from Estonia and Uruguay taking into account the diversity of the projects in terms of country of origin, technology employed and the goal of the projects. For each project we analyzed its outcomes and its documentation. We also interviewed workers involved in the projects, including technicians, data scientists, researchers and project leaders. Out of this data we described the projects according to the dimensions proposed by [6]. We then offered back our descriptions and the analysis carried out to the interviewees, so they could cross-check our data.

4 Results

4.1 CS1: Impact of a new device in Uruguay

The deployment of national scale educational computing initiatives brings along the necessity to allocate resources for training, maintenance and new device deployment sensibly. In particular, it is important to assess whether the learners engagement with online educational resources is affected by receiving a new device and whether the benefits of obtaining these new devices justify their cost.

Ceibal Foundation conducted a study to measure the effect of new device deployment on LMS activity of primary school students in Uruguay, during 2015 and 2016 [2]. Plan Ceibal provided logs of the LMS activity of 6th grade students (11 year-old), as well information regarding new device deliveries. The data provided by Plan Ceibal was de-identified in order to guarantee the students privacy. Data trustworthiness was an issue, and the information regarding the device delivery dates needed to be checked against the logistics team responsible. For each delivery date, the LMS activity before and after device delivery was compared between the students who received a new device that day and those who received it later on time. Hence, the students identifiers were used to integrate the LMS logs and the device delivery logs. Later on, the researchers of Ceibal Foundation processed the data in R using negative binomial regression. A high LMS activity boost was observed during the month after the devices were delivered, with the effect almost disappearing two months later.

4.2 CS2: English teaching practice in Uruguay

Plan Ceibal offers remote English teaching and a LMS that includes an on-line library with digital and media contents for learning English as a Foreign Language (EFL). Because of the lack of English teachers in Uruguay, EFL programs in Uruguayan primary schools are delivered in two different modalities: either face-to-face or in a blended modality where some of the lessons are remotely given by an English teacher. In 2016 Plan Ceibal wanted to assess whether the teaching modality and the use of digital content had an impact on students outcomes. For this purpose, Plan Ceibal collaborated with the Statistic Institute of the Universidad de la Repblica and studied the 4th-to-6th-grade (9-11-year-old) students in 2015 learning processes and outcomes. They analyzed the LMS logs and the annual English test results (both of them provided by Plan Ceibal). However, in order to make sense of this study, they also distinguished students according to their socio-cultural context. For this purpose they also analyzed the student profiles (provided by ANEP). All in all, data from 115.715 students was analyzed.

The researchers from Plan Ceibal and Universidad de la Repblica had the needed data processing skills and counted with the support by Plan Ceibal legal committee. After cleaning and cross-cheking the LMS logs from Plan Ceibal, the researchers integrated them with the annual English test results and the students profiles. The integration was done using student identifiers. They used R in order to process the resulting dataset using statistical methods. The researchers found correlations between the course modality, the LMS engagement and the learning outcomes for students of each socio-cultural context. The main results were published [7] and offered to Plan Ceibal decision makers. Again, the results showed that the use of LMS is useful to achieve learning outcomes, but the study was limited for the detection of causal relationships.

4.3 CS3: Use of an Adaptive Math Platform in Uruguay

In 2016, Plan Ceibal conducted a study to assess the impact of using an Adaptive Math Platform[9], called PAM, if provides to primary school children to learn mathematics. For this purpose, Plan Ceibal analyzed the use of PAM platform by primary school students born in 2005 between 2013 and 2016[10]. The use of PAM was then correlated to the student performance improvement and their National Evaluation grades in 2013 and 2016 (provided by ANEP). As comparison was done school by school, only the students that remained in the same school took part of the study (2143 students from 237 schools).

In order to improve the legitimacy of the study, Plan Ceibal subcontracted it to the Center for Economic Research as an external evaluation. These researchers had the needed data processing skills, as well as knowledge related to education and impact evaluation; regarding legal issues, they counted with the support by Plan Ceibal legal committee. After cleaning and cross-checking the PAM logs from Plan Ceibal, the researchers integrated the logs with the grades collected by ANEP by correlating de-identified students identifiers from both datasets. Later on, they used Stata[11] to process the datasets using a regression analysis. Even if they found correlations between the use of PAM and the grade improvement, the researchers reported several issues when interpreting their causes (e.g., third variables may have affected the results).

[9] http://www.ceibal.edu.uy/en/pam

[10] https://www.ceibal.edu.uy/es/articulo/el-efecto-de-pam-en-el-aprendizaje-de-matematica

[11] https://www.stata.com

4.4 CS4: ICT students drop-out in Estonia

There is a high rate of drop-out among ICT bachelor students in Estonia. An hypothesis was that the ICT industry is hiring too hungrily, thus causing students to drop out, but no evidence supported this belief. To assess this hypothesis, the Estonian Center for Applied Research (CentAR) correlated the students who work during university studies and those who fail graduate in time. This was done by integrating the tax payments record from the Tax and Customs Board and the students records from the Ministry of Education and Science (MoES).

Both datasets were very trustworthy but privacy should be guaranteed when integrating them. Hence, CentAR used Sharemind[12] as a database and application server for this integration, as it offers "cryptographic protection for data during both storage and processing". Sharemind provided a technical solution to overcome the legal restrictions related to the integration of these two datasets, but it is a complex solution that requires very specific technical skills. Thus, CentAR required the support of Cybernetica, the company that owns Sharemind. Furthermore, convincing the data owners and the Estonian Data Protection Agency that Sharemind guarantees privacy while enabling the data analysis was a long process that lasted 18 months. The analysis showed that ICT students are not working more than non-ICT students, thus rejecting the initial hypothesis. The Estonian Association of Information Technology and Telecommunication and the IT department of Tartu University became interested on these results, which were also used for a scientific publication [3].

4.5 CS5: Digital Mirror

Digital Mirror[13] is an application for the evidence-based self-evaluation of Estonian schools. It offers a 15-dimension rubric to assess technology adoption, defining 5 levels (from beginner to expert) for each dimension. Dimensions, inspired by Fullan [5], were grouped into three categories: pedagogy, change management and infrastructure. Estonian schools use Digital Mirror to evaluate themselves, asking their staff to evaluate the school's digital maturity providing evidences.

The data collected by Digital Mirror is aggregated to get an overall self-assessment of the schools, and it is published together with administrative data about the schools obtained from Haridussilm (see CS6). It offers a public dashboard where anyone can see the self-evaluation of each school, if the school has published this information. Otherwise, only logged-in users can see the evaluations. For each dimension of the rubric, the dashboard compares the level of each school to the mean of all the schools in its municipality and in Estonia. Digital Mirror was developed using well-known open technologies, such as PHP, Javascript, and MariaDB. It is currently maintained by Tallinn University.

408 schools in Estonia were self-evaluated using in Digital Mirror and local municipalities used it to understand school situation and allocate resources accordingly. The graphical representation of the results is simple enough as to be

[12] `https://sharemind.cyber.ee/`

[13] `https://digipeegel.ee/`

easily understood by all the potential data consumers. Additionally, it makes the data creators explicitly aware of what their data is going to be used for. Despite all this, the Ministry of Education does not take into account Digital Mirror data for school assessment or decision making support. The reason is that they do not trust the opinions of stakeholders for national-level evaluation.

4.6 CS6: School performance indicators in Estonia

MoES calculates performance indicators for educational institutions in annual bases[14] to enact the evidence-based decision making. These indicators were defined for pre-, primary-, secondary- and vocational schools to describe the performance, satisfaction and effectiveness of education and training. The indicators are agreed politically and inline with the aforementioned Estonian Lifelong Learning Strategy. Local governments and educational institutions are aware of the indicators, but they are not directly involved when defining them.

The main data source that MoES exploits to calculate the performance indicators is the "Estonian Education Information System" (EHIS)[15]. It includes information about educational staff, students (from primary to higher education), educational institutions, curriculum and academic certifications of all Estonia. Other close state-level datasets are analyzed to calculate some of the indicators: results of the different exams from the Centre for Coordinating National Examinations (INNOVE), the registries for unemployment, social benefits and defence forces. School-level registries are sometimes needed to be retrieved to obtain additional data (e.g. school satisfaction of parents and students). The dataset integration is done by Statistics Estonia -an area of the Ministry of Finance-following the guidelines of the Data Protection Agency. Once the datasets are integrated, it is the MoES which processes them to calculate the indicators.

The performance indicators provide information about many different aspects: learning outcomes (e.g. the results of the final exams in each schools); learning processes (e.g. frequency of using digital solutions by each school); lifelong learning (e.g. the percentage of students that get the degree in higher education once they leave the school). Many of these indicators are published in Haridussilm[16] with an open license. Several actions are taken to avoid issues in their publication: the data is checked with school heads to increase its accuracy; data is not published unless it is aggregated from more than five individuals, to guarantee anonymity; and some more-sensitive indicators (e.g. he satisfaction of the students with the school environment) are not published to avoid side-effects. These performance indicators are consumed by a wide variety of stakeholders: the Agency for Quality Assurance (EKKA) takes them into account to carry out educational inspections; local governments and educational institutions use them to monitor their performance; learners, parents and the third sector, obtain reliable information about the education in the local and the national level.

[14] https://www.riigiteataja.ee/akt/119052016012

[15] https://www.eesti.ee/eng/services/citizen/haridus_ja_teadus/isikukaart_eesti_ee_portaali

[16] http://haridussilm.ee/

5 A data value chain for national level LA

The steps followed by the case studies previously described are summarized in the data value chain represented in Figure 1. It is similar to others proposed for more general purposes (e.g., [9]) and coherent with other definitions of LA steps [4]. But new challenges appear when scaling up LA to the national level:

Fig. 1. National-Level Learning Analytics data value chain.

Information need definition is always the first step in a LA process. The six case studies provide a wide variety of information needs, including comparisons of educational institutions (CS5, CS6) and the assessment of learning processes (CS1, CS4) and outcomes (CS2, CS3) on a national scale.

Data creation is carried out by different actors, which are typically in the learning process level: students (CS1, CS2, CS3, CS6), teachers (CS5, CS6) or other workers (CS4, CS6). Many times, the data is not created for LA purposes, but reused from existing datasets (CS1, CS2, CS3, CS4, CS6).

Data discovery is a big problem when scaling up LA projects, as reported by all the case studies. For this reason, Plan Ceibal is creating an inventory of available datasets and an internal registry of the metadata they use. Similarly, Estonia has recently established an Open Data portal[17] where educational databases are also published, and the metadata to describe educational learning resources has been standardize in the national level[18]. Data ownership also entails legal and ethical responsibility, which is sometimes (CS1, CS3) solved by de-identifing learners before offering the datasets for its analysis.

Dataset integration is a critical step faced by all the case studies. Integrating datasets is known to entail technical difficulties [9] and requires complex techniques. Moreover, as LA sometimes deals with personal data, ethical and legal problems may arise. All the case studies reported the need of legal and administrative effort that sometimes required professional advice (CS1, CS2, CS3, CS4) and delayed the projects for months (CS4). Fortunately, this effort reduces significantly once a trust relationship among institutions is established.

Decision making support is a step that involves the data consumers. In many cases (CS1, CS2, CS3, CS4) they are national-level decision makers to whom results and conclusions are presented as a report. C5 and C6 involve other stakeholders, who are offered graphical dashboards for their awareness. In all the cases the data literacy is seen as a problem to understand the results.

[17] `https://opendata.riik.ee/en`

[18] `https://wiki.iktsenteret.no/xwiki/wiki/bak/view/NORLOM/WebHome`

6 Discussion

Scaling-up LA to the national level enables to satisfy information needs that could not be satisfied otherwise. In the cases analyzed, these information needs are defined by national-level institutions and are mainly driven by political aspects. In this sense, we can see Estonia and Uruguay as examples in opposite poles. The Estonian educational system promotes educational innovation and competitiveness among educational institutions. Hence, Estonian case studies assess the differences between educational institutions (CS5, CS6) or between curriculums (CS4), and their results are published. Instead, Uruguay is more concerned on reducing social inequality and looks for a uniform and centralized educational system. Hence, Uruguayan case studies analyze the educational system as a whole and the results are only offered to national-level decision makers.

The LA projects analyzed follow the framework used for their description. However, the scale of these projects entails considering additional stakeholders and increasing their complexity. Nevertheless, the relatively small datasets and the well-known data processing methods used do not open new technical problems. The exception is the data integration, the most challenging step in the data value chain from the administrative and the technical points of view (CS4).

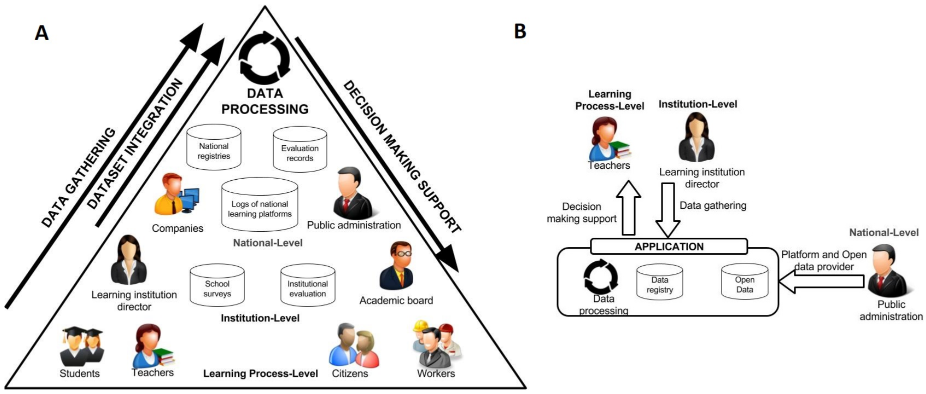

Fig. 2. Stakeholders and databases disposition.

Another aspect to reflect upon is how the stakeholders are displayed in the data value chain. The stakeholders in the learning-process level (teachers, students, parents) are only seen as data creators and subjects to be analyzed. They do not play an active role in the case studies even if their final aim is to improve learning processes. Instead, the national-level actors are always the ones who take full control of the LA project: they define the information needs to be satisfied, the steps in the data value chain and they make decisions according to the results. This stakeholders disposition is depicted in Figure 2A.

While the current disposition of stakeholders may be coherent with politics that look for a centralized decision making, we see an urgent need to connect LA at national scale with current ideas of Responsible Research and Innovation (RRI)[19]. This would mean to enable institutional level stakeholders, teachers and students to be more strongly involved in using national-level data. For example, school leaders could assess the impact of certain innovations introduced in their schools and compare the effect to other schools; or teachers would benefit from learning resource recommendations for innovative learning scenarios based on the use of these resources in other institutions. Our plan is to work in this direction, changing the stakeholder disposition as represented in Figure 2B: national-level stakeholders would be data and platform providers, while institution- and learning process-level stakeholders would be the ones who create and consume data, taking evidence-based decisions accordingly.

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