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Strategic Development of a National Pre-tertiary Learning Analytics System

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Abstract

This paper elaborates the design of a National Learning Analytics (LA) and Educational Data Mining System for pre-tertiary education in Croatia. The described approach consists of the following five phases: 1) objectives setting, 2) user needs analysis, 3) data availability analysis, 4) dashboards pre-design and 5) validation of functionalities. There is an evident research gap, as well as the lack of practical examples about the development of a Learning Analytics System (LAS) for pre-tertiary education on the national and/or regional level. Therefore, this research aims to make a scientific contribution by filling the recognized gap, but also contribute to solving the practical issues of national schools' LAS development. To increase the usability of an LAS, the involvement of all end users is essential. In the described case, six main user groups were identified: 10-18 years old students, teachers, school management and support staff, regional and national authorities responsible for education, strategic bodies and researchers and, finally, project partners that work on system development. For each of them, separate dashboard functionalities have been designed through several rounds of consultations. Consultations with users started with focus groups and panels, to brainstorm the most important issues they would like to answer in order to enhance learning and teaching. Between the two rounds of consultation, there was an evaluation phase of the relevance of the gathered questions. Finally, targeted users provided feedback on the pre-production functionalities of each dashboard and validated them. In this process, several challenges were detected, including data gathering and protection, ethical issues and interpretation of results for students who are underage, and continuous adjustments to the users' needs.

Keywords: Learning analytics, Learning analytics system, Pre-tertiary education, Needs analysis, Dashboard

1. Introduction

This paper presents the design of a National Learning Analytics (LA) and Educational Data Mining pre-production system for the pre-tertiary educational sector in Croatia, with a special emphasis on the methodology of gathering and validating user's needs. The methodology and the approach presented in this paper have been developed in the scope of the project entitled „E-schools: Establishing a System for Developing Digitally Mature Schools (pilot project)" (E-schools) (CARNet, 2018). The project is due to run from 2014 to 2022 with a budget of EUR 180 million, with 85% of funding coming from EU funds and 15% from national and local budgets. The coordinating body of the project is the Croatian Academic and Research Network – CARNet, and the University of Zagreb, Faculty of Organization and Informatics (FOI) is one of the project partners. The overall goal of the "E-schools" pilot project (2016-2018) is to establish a system for the development of digitally mature schools and to evaluate the application of information and communications technologies (ICT) in the educational and operational processes of 150 schools in the Republic of Croatia [2]. One of the project results is the development of an LA and Educational Data Mining System as a comprehensive and overarching system for pre-tertiary education in Croatia and that process will be elaborated in this paper. FOI, as a project partner, is responsible for the research and design of the scope and functionalities of the Learning Analytics System (LAS).

First, this introductory chapter shortly describes pre-tertiary education in Croatia, to sketch the educational environment that the LAS has to serve and help to enhance. The Croatian educational system consists of [16]: preschool, primary, secondary and higher education. Primary education is mandatory and free for all children aged six to fifteen and consists of four years of lower and four years of upper primary education. Secondary education is optional in Croatia, although there is a strong movement to make it compulsory, and the great majority of young people (85%) enter secondary education. There are different types of secondary education: grammar schools, vocational schools and art schools. Secondary schools run for 3 or 4 years and students finish them at the age of 18 (the age of the majority). Therefore, the LAS developed within the scope of this project will serve underage students.

According to the Croatian Bureau of Statistics data [3] for the school year 2015/2016, there were 2 806 schools (2 055 primary and 751 secondary schools) and the total of 498 510 students in Croatia. Within the project "E-schools", 150 schools were included in the pilot project phase from 2016 until 2018, but in the full rollout of the project foreseen to last until the end of 2022, all schools are included.

Higher education activities are carried out by higher education institutions (HEIs) (universities, faculties and art academies, polytechnics and colleges) and a prerequisite for admission is the state exam (matura). Since 2005, all study programs have been aligned with the requirements of the Bologna Process.

In 2014, based on the state analysis of the educational sector in Croatia, the Croatian Parliament adopted the Strategy for Education, Science and Technology, supporting five sectors: 1) early childhood and preschool, primary and secondary

education, 2) higher education, 3) adult education, 4) lifelong learning and 5) science and technology [15].

If we compare the digital development of Croatia with the EU, the results are as follows. Less than 10% of primary school students in Croatia are classified as 'digitally-supportive' and, on average, 26 students share one computer in Croatian schools, which means that, in both categories, they are lagging behind their EU peers [9].

Further, according to the results of the OECD's Teaching and Learning International Survey [19], in 2014, 96.8% of teachers in lower secondary schools participated in some kind of trainings and 58.2% of them were trained specifically within ICT, settling Croatia at the top end compared to other EU countries. On the other hand, the proportion of teachers who used ICT in teaching was 23.5%, which is below the EU average of 34%. Finally, the proportion of teachers assigning different tasks to students based on their individual needs was above the EU average (51.2% compared to 46%).

Therefore, the "E-schools" project has had a very important role to be a ground-breaking initiative for the comprehensive digitalisation of the infrastructure, teaching and administration processes in schools in Croatia. Besides that, the project has had the role to support schools to take more autonomy and to be accountable for their development, while the LAS can particularly support those endeavours by providing school management with necessary data and analyses. This was especially important when project started since, according to the OECD index [18], school autonomy over resources allocation and over curricula in Croatia was below the OECD average. Further, schools need instruments for benchmarking. In primary schools, students are supposed to attend their neighbourhood schools, while enrolment in secondary schools depends on the admission criteria based on the student's achievements in primary school. In Croatia, over 98% of students attend public schools. The process of admission to higher education is based on numerus clausus and its competitiveness is based on the students' results on the state exam (matura). As a consequence, competition between schools is stronger on the secondary school level, especially between "elite" grammar-type schools.

To conclude, in Croatia, an LAS is essential to support students and teachers to enhance learning and teaching outcomes, schools to embrace more autonomy and national authorities to set, monitor and evaluate the strategic development of the whole pre-tertiary system.

In accordance with the presented issues regarding the school system in Croatia and taking into account the project aims, research questions are defined as follows: 1) What are the main national goals in the development of the LAS?, 2) What are the needs of LA user groups in pre-tertiary education? and 3) Which are the identified risks at the educational system level?

2. State of the art

This chapter gives a short overview of the literature on: 1) research that suggest frameworks for the introduction of LA and educational data mining (EDM) in a

standardized way (how to start?), 2) the application of frameworks in an education system and, finally, 3) the visualization of the analytics on the dashboard.

The information overload and the growing quantity of "Big Data" induced new opportunities for their use in different sectors. In education (formal and informal), there are two different but also closely related approaches: LA and EDM. According to [20] "LA and EDM constitute an ecosystem of methods and techniques (in general procedures) that successively gather, process, report and act on machine-readable data on an ongoing basis in order to advance the educational environment and reflect on learning processes" (p. 49) but they differ in their origins, techniques, fields of emphasis and types of discovery. The authors emphasise that "LA adopts a holistic framework, seeking to understand systems in their full complexity" and "EDM adopts a reductionistic viewpoint by analyzing individual components, seeking for new patterns in data and modifying respective algorithms." (p. 50) Finally, LA is mainly about students and their contexts, while EDM is related to decision making at different levels in an education system.

Authors in [4] stated that a small number of institutions had been able to implement large-scale LA programs with a demonstrable impact on their teaching and learning outcomes. Further, authors in [10][31] also researched the implementation of LA and stated that there is still a lack of systematic and large-scale implementation of LA in higher education, although funding opportunities for LA research and activities have increased.

The benefits of the implementation of LA are recognized, but the adoption of LA at the institutional level is complex and challenging. Authors [4] the challenges that should be considered during the LA adoption: 1) the importance of committed and informed leadership, 2) organizational culture recognized as a key mediator of LA implementation – shared, willing and receptive appreciation of LA potential; 3) staff and institutional capacity - the ability of staff to effectively "link" pedagogy and analytics; 4) strategy – a clear vision and purpose of LA through the development of policy and procedures.

Further, [32] developed the SHEILA framework (Supporting Higher Education to Integrate Learning Analytics), a policy development framework that supports systematic, sustainable and responsible adoption of LA at an institutional level, built using the RAPID Outcome Mapping Approach (ROMA). The SHEILA framework consists of a comprehensive list of adoption actions, relevant challenges and policy prompts, framed in six ROMA dimensions (Dimension 1: Map Political Context, Dimension 2: Identify Key Stakeholders, Dimension 3: Identify Desired Behaviour Changes, Dimension 4: Develop Engagement Strategy, Dimension 5: Analyze Internal Capacity to Effect Change, Dimension 6: Establish Monitoring and Learning Frameworks).

Authors in [26] presented a mix-method study using a group concept mapping (GCM) approach that was conducted with LA experts to explore the essential features of LA policy in HEIs in contribution to the development of the framework. The study identified six clusters of features that an LA policy should include, provided ratings based on the ease of implementation and importance for each of the six themes, and offered suggestions to HEIs on how they could proceed with the development of LA

policies. The six clusters identified in the study are: (1) privacy & transparency, (2) roles & responsibilities (of all stakeholders), (3) objectives of LA (student and teacher support), (4) risks & challenges, (5) data management, and (6) research & data analysis.

A framework for setting up LA services in support of educational practice and student guidance, in quality assurance, curriculum development and in improving teacher's effectiveness and efficiency based on six critical dimensions of LA is presented in [11]. The stated six dimensions of the proposed LA framework are: stakeholders (student, teachers, students, other), objectives (reflection, prediction), data (open, protected), instruments (technology, algorithm, theories, other), external constraints (conventions, norms) and internal limitations (competences, acceptance). The authors' conviction is that only the consideration of all six dimensions in the design process can lead to optimal exploitation of LA. Additionally, [11] stated that there are some problem areas that influence the acceptance and the impact of LA such as data ownership and openness, ethical use and danger of abuse, as well as the demand for new key competences to interpret and act on LA results. Ethical issues and dilemmas related to LA were also discussed in [28]. Authors proposed six principles as a framework for considerations to guide HEIs to address ethical issues in LA and challenges in context-dependent and appropriate ways.

Further, based on the results of the Group Concept Mapping study conducted with experts from the field of LA, [25] proposed a framework of quality indicators for LA. The proposed framework includes the following five criteria and quality indicators: Objectives, Learning Support, Learning Measures and Output, Data Aspects and Organizational Aspects. The aim of the proposed framework is to provide a means to capture evidence for the impact of LA on educational practices in a standardized manner.

In order to ensure the use of educational data for LA in an acceptable and compliant way, and to overcome the fears connected to data aggregation and processing, in their paper [7] described an instrument for educational institutions to demystify the ethics and privacy discussions on LA. The developed eight-point checklist named DELICATE (included points are Determination, Explain, Legitimate, Involve, Consent, Anonymize, Technical, External) can be applied by researchers, policy makers and institutional managers and institutional managers to facilitate trusted implementation of LA.

The above-mentioned research [11] was used by authors [21] and applied to a primary school classroom. The case study illustrated that legal and ethical issues related to data control and data ownership can become the main issues to solve when applying an LA approach to a primary school context. Additionally, in their paper [24] contextualized the goal of the PILARES project (Smart Learning Analytics Platform to Enhance Performance in Secondary Education) in the wider panorama of LA, with references to the situation in the Spanish context. The authors stated that one of the most pressing concerns within the educational system in the Spanish context is a high rate of school leaving with a lower secondary education or less. Additionally, they identified motivation as a key factor influencing achievement and the improvement of the quality of learning, which can be influenced by schools and teachers through early

intervention and adapting the learning path to the student's needs. Finally, the authors considered the implementation of LA as a promising way that can timely provide teachers with the information needed to early detect motivation issues.

The necessity for the introduction of LA in primary education is recognized by [8] who address the question of how LA can be helpful at the course level, i. e. for learning math in primary education. Their starting point was the expectation to improve the diagnostics of some problems with the multiplication table and multi-digit multiplications and the results show that automated precise testing and feedback can be seen as an individual assistance and an effort to achieve an effective learning process.

Further, [33] designed and developed an early version of an LA Dashboard based on the review and comparison of nine developed applications against a group of criteria (1) intended goals and target users, 2) data-extraction and mining, 3) visualization and 4) evaluation) and based on preliminary investigation on the need for such tools. After conducting the usability test and refining the dashboard, 73 college students participated in a pilot test of the first version of the dashboard. The perceived usefulness of the developed dashboard was low. According to the authors' opinion, the reason for such a result was the descriptive nature of the dashboard. They think that providing the prediction of students' final scores and sending signals to students would significantly improve the dashboard's usefulness and power.

Finally, even though there is a great number of LA studies published until 2020, there are very few that deal with pre-tertiary education and especially with the development of the national-level LAS. Most of the current studies have been performed on the individual school level. Therefore, there have been limited benchmarking possibilities for designing the pre-tertiary LA national system for the "E-schools" project in Croatia.

3. Design science methodology for the development of the LAS for the pre-tertiary education system in Croatia

Within the „E-schools" pilot project, the design for the development of the LAS for pre-tertiary education was prepared. The approach consisted of the following phases: 1) setting of overall objectives and vision, 2) user needs analysis, 3) data availability analysis, 4) dashboards development, including setting aims for each dashboard and designing dashboard functionalities, followed by 5) user evaluation of the dashboard design and functionalities example. These phases are explained in more detail in [5]. It is important to stress that users have been consulted three times: once in phase 2 and twice in phase 5. Hence, the results of the performed needs analysis presented later in the text served as a basis for defining dashboard functionalities for the identified user groups.

The proposed five phases of the LAS development follow the research steps which can be found within the design science paradigm for information systems, including: 1) awareness of a problem/identifying a new need (literature review and user groups identification), 2) defining the scope (focus groups with the recognized user groups and literature review), 3) designing dashboards, 4) evaluating the

dashboards and 5) reflecting the evolution [35][14]. The design science research is a common paradigm for the design of information systems focused on designing and evaluating innovative artefacts to solve complex problems from the real-world domain, considering the rigor, evident in research methods, and relevance, evident in the societal importance of the studied problem [13][1]. In this case, the relevance is evident in the recognized need for the development of a national LAS in Croatia and the involvement of all the end users' groups in the pre-design of dashboard functionalities. On the other hand, the rigor is evident from the provided state of the art related to the LAS development and the basis for certain steps in the LAS development in the findings from the scientific literature.

Moreover, the steps according to the design science paradigm also follow the logic of strategic planning, as they cover all the steps of the Deming PCDA (Plan-Do-Check-Act) cycle, which is characteristic for strategic planning. The planning phase includes identification of different user groups' needs, the implementation phase is evident in the dashboards design, the evaluation phase is focused on the user evaluation of the design dashboards, while ideas for further research indicate the need to reflect the evolution of the designed dashboards and improve them to the form of the final LAS that will be applied in schools in Croatia (Fig. 1).

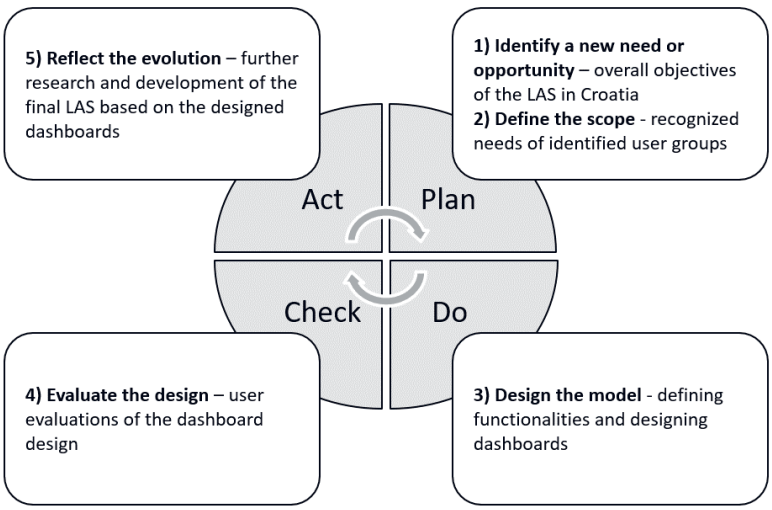

Figure 1. Connections between the strategic planning steps and the steps of the national LAS development according to the design science paradigm

3.1. Identify a new need or opportunity (overall objective and vision)

In the project preparation phase and the process of adoption of the Strategy for Education, Science and Technology (2014), all the stakeholders in pre-tertiary education participated and the overall goals related to the development of the LAS had been discussed and recognized. As it is argued in the Introduction of this paper, the national LAS in Croatia is essential to support students and teachers in enhancing

learning and teaching outcomes, schools to embrace more autonomy and national authorities to set, monitor and evaluate achievements planned in the Strategy for Education, Science and Technology. It means that a comprehensive system has to be developed considering LA and EDM approaches, to cover all available data sources, i.e. the Repository of Digital Learning Resources, National Data Repositories about students, teachers and schools on the national level as well as to analyse the risks that can arise, but also the virtual learning environment (VLE) Learning Management System (LMS). This elaboration of the situation on the national level provides an answer to the first step of design science research – awareness of the problem, which is further elaborated with the identification of the users' needs.

3.2. Define the scope via needs analysis

As presented in [5] the methodology for the needs analysis for the LAS in pre-tertiary education was developed and implemented in Croatia. In this respect, successful acceptance of LAS, it is of crucial importance that the development of LA takes a bottom-up approach focused on the interests of the students as the main driving force [11].

The main user groups were identified by the following simple analysis. Users were divided based on two dimensions: 1) in school/out of school and 2) involved in pedagogical/administrative processes. As a result, six target groups of users, for which the LA system has to provide useful data, information and analysis, were identified. These are: 1) Students (pupils) and their parents, 2) Teachers, 3) School management and support (principal/pedagogue/psychologist), 4) Local and national education authorities (School founders/the Ministry/Agencies for Quality Assurance), 5) Policy-making bodies and researchers and 6) Project partners within the "E-schools" project.

For all the six groups there were focus groups, panels and interviews organized in order to encourage users to identify the key questions to which they would like the LAS to provide answers, regardless of whether such answers are possible at the moment. In that manner, 168 questions were collected. Afterwards, the analysis of the collected questions was conducted, that included the identification of the most important, redundant and unclear questions as well as the questions that are impossible to be answered due to the technology state of the art or the availability of data. The final list included 131 questions grouped as relevant for different user groups (students and parents - 48, teachers - 90, school management - 52, school founders/the Ministry/agencies - 87, policy bodies and researchers - 60, project partners - 29).

Besides that, a questionnaire was formulated in order to detect the relevance of items collected in the previous stage. Users were asked to indicate whether an answer to a question is relevant to their learning, teaching and work, on a 5-point Likert-type scale, in order to assess the relevance for the inclusion of a certain question in the LA system. In that phase, 262 fully completed questionnaires from all target groups were received (students - 116, teachers - 39, school principals/pedagogues/psychologists - 32, local and national authorities - 50, policy bodies and researchers - 21, project partners - 4), along with some qualitative comments and recommendations.

The presented needs analysis contributes to the first step of the design science methodology: identify a new need or opportunity.

Further, the quantitative and qualitative data analysis and prioritization of items was conducted based on the questionnaire results. The description of the most highly ranked interests (according to users' responses to the questionnaire) of every target group are given in Table 1. The presented list of the most important interests contributes to phase 2, define the scope of design science research as further dashboard design is focused around these interests.

	Interest
Students and parents	• comparison of the student's achieved competences and competences required on the labour market • comparison of student's achievement and the preconditions for enrolment to secondary school/higher education • teachers' performance (survey results, students' course grades in previous school years, average grade on the course (historical overview)) • risks students have in achieving their goals • how a student can improve his/her performance • impact of various factors on student achievement (such as family social status, school equipment and design, working atmosphere, school practice, teamwork, absence from school, time spent on independent work) and • impact of various factors on the acquisition of competences (e.g. attending elective courses on digital competences).
Teachers	• their performance (survey results, students' grades, historical overview) • talented students and students who need additional support • students' achievement in continuing their education • students' learning activities • impact of various factors on students' activities (e.g. teaching methods, learning methods, evaluation methods) • impact of various factors on student success (e.g. time spent on homework, teachers' success in previous education) • recommendations for professional development to improve teaching performance
School management and support	• student performance and progress in school (difference between input and output competences) • teacher's performance and progress • talented students and students with special educational needs • feedback on student success in further education or in a chosen career • impact of various factors on student success and motivation (e.g. equipment, design, working atmosphere, teacher's professional development, teaching timetable, socio-economic status of students)
Local and national	• students who need additional support (talented students, students at risk, students with disabilities) • feedback on students' success in further education or in chosen

education authorities	careers • students' evaluation of teachers' performance • impact of various factors on student success/learning outcomes (practice outside school, teachers' professional development, field education and internship, school equipment, design, working atmosphere, socio-economic status of students)
Policy bodies and researchers	• identification of teaching, learning and evaluation methods that increase students' activity in learning • use of problem solving or inquiry-based learning approaches • evidence that students' assessment is based on achievement of intended learning outcomes • form and content of lifelong learning for teachers to increase their performance • support for students who need additional support (talented students, students at risk, students with disabilities) • students that achieved preconditions for enrolment to higher educational levels
Project partners	• impact of various factors on student success/learning outcomes (reminders on students' obligations, formative evaluation, use of ICT and digital learning materials, school equipment, ...) • impact of various factors on teacher's performance • the most popular digital educational materials in digital repository and LMS • impact of computerization of business, administrative and educational processes on school results • the school digital maturity level

Table 1: Highly ranked interests of every target group

Although the analysis of the available data sources is not in the scope of this paper, it is important to emphasize that it was a very demanding process due to the fragmentation and incompleteness of databases, data ownership issues, interoperability challenges, ethical concerns and integration of data collected online and in physical school environments. The complexity of the inclusion of data from different databases in terms of user identification, ethics and privacy is also mentioned in [20].

Altogether 11 potential data sources were identified: e-Dnevnik, e-Matica, the repository of Digital Educational Content, the CARNET survey system, the Classroom Management System (CMS), the Learning Management System (LMS), the Learning Record Store (LRS), Yammer, network logs, the database of schools' digital maturity assessment, the database with an overview of teachers' education and professional development. As those are not in compliance, there is a challenge to integrate and interconnect data. As stated in [22], since students' learning activities increasingly include resources out of the LMS, focusing the analysis on the LMS provides an incomplete view, so it is important that the LAS includes all the relevant data sources. In Croatian schools, most of the teaching and learning activities are face-to-face in classrooms and just recent developments due to the curricula reform (2018-

2020) and the COVID-19 pandemic involved the use of an LMS, learning repositories and other online tools and that have implications on data gathering in the first phase of the project until 2018. The curricular reform provided the preconditions for an agile and successful response to the COVID-19 crisis [30]. Moreover, at the onset of the pandemic, a series of guidelines was prepared at the national level in order to support schools in the rapid shift to digital distance education; more details are available in the Action Plan on Digital Education [17].

Besides that, there is one even more important data protection issue, which is dealing with the data of young people that are mostly underage.

3.3. Dashboards design

The third step according to the design science for the development of the LAS for pre-tertiary education is designing dashboards for identified target users. According to [29] the dashboard is the sense-making component of the LAS, presenting visualized data to assist individuals in making decisions about teaching and learning. According to the performed review of nine developed dashboards presented in [33], previously developed dashboards can be generally divided into three types: dashboards for 1) teachers, 2) both teachers and students and 3) students only. According to the conducted needs analysis of different end-user groups, it can be claimed that the comprehensive implementation of the LA country-wide in Croatia can give added value not only to students and educators, but also to other identified user groups within the project. Therefore, based on the results of the performed needs analysis and the available data sources, six types of dashboards were designed – one for each of the identified user groups. This phase consisted of two steps: 1) defining dashboard aims for each of the identified user target groups and 2) defining dashboard functionalities.

The overall objective of LA is to support learning and teaching and that has been followed by the LAS development. Besides that, there have been additional needs deriving from other user groups that involved data mining based on mostly the same datasets as for the basic LAS aimed for students and teachers. Still, the needs of students and teachers are given the highest priority in the design process and reflected in the goals for each dashboard. Table 2 presents the aims of dashboards for each of user groups identified by "E-schools" project partners based on the overall project objectives as well as on the results of the focus groups and panel discussions with potential users.

Finally, when the aims of dashboards for each target group of users were defined, it was possible to proceed with the third phase according to the design science approach, design of the dashboard. First, the pre-production examples of dashboards for all six user groups were designed. There are four dashboards presented here: for students, teachers, school management and local, as well as national, authorities responsible for the education system.

The dashboards described here are based on the needs analysis and available data sources, and represent current plans for the development of the final LAS functionalities. At the moment, it cannot be claimed that the same design will be implemented in the production phase, but these specifications became a part of the

tender documentation. There are several key principles applied in tendering the production development of all dashboards and the whole LAS:

1) Students are the main beneficiaries of the LAS.
2) Protection of students' and teachers' personal data takes precedence over functionality development.
3) Students' and teachers' personal data should be available only on the school level, while on higher levels, in principal aggregated data should be used.
4) The LAS uses existing data and only exceptionally and justifiably independent data collection particularly for LAS.
5) The LAS should be open for upgrading and further development and should apply the interoperability principles.
6) The LAS dashboards should allow personalization for of users from all target groups.
7) The LAS must be scalable because in several years it should serve around half a million students, 50 000 teachers and several thousand other users.

The design of the dashboard for students was initially presented in [6], while this paper further describes dashboards for end user groups.

Target users	Aims of dashboards
Students and parents	Data collection, data analysis and visualization adjusted to students in order to achieve better educational results (learning outcomes) and to raise their motivation for learning and learning self-regulation.
Teachers	Equip a teacher with information, analysis and recommendations as well as communication tools allowing her/him to better support students in a learning process and to improve his/her teaching performance.
School management and support	Continuously providing school management (principals) and support (deputies/pedagogues/ psychologists) with information about the quality and efficiency of the educational process at school, students' and teachers' needs and possibilities for improvement in order to ensure for every student the best possible conditions and support for successful learning and holistic personal development and enhance the quality of the educational process.
Local and national education authorities	Continuously providing local and national authorities with information about the quality of educational process, system efficiency, investment needs and educational, financial, personnel, etc. interventions in the system or any part of it, in order to ensure for every student the best possible conditions and support for successful learning and holistic personal development and enhance the quality of educational process.
Policy bodies and researchers	Continuously providing policy bodies with information on the state of the educational process at schools, implementation of strategies at the level of pre-tertiary education system in Croatia in order to assure quality, pedagogically justified and relevant education and equity for all students.
Project partners	Monitoring the introduction of digitally mature schools' concepts in pre-tertiary education system in Croatia and their impact on the achievement of goals from relevant strategies.

Table 2: Aims of dashboards for target users

3.3.1. Dashboard for students

The dashboard for students is very essential and fundamental because it answers the most important questions coming from students and it provides a starting platform for generating all other dashboards. The dashboard for students is shown in Table 3. Students have a central place to grasp all information about themselves, their teachers and school, including a personal development space and a parent corner. "Me" area consists of three parts: awareness and reflection, predictions and interventions. Students can see all the elements of progress on two levels: aggregated for all courses and separately for each course. Students will have insight into some basic information about teachers (CVs), but teachers can also allow students to see some extras, such as their hobby details, favourite teaching resources etc. Further, students and parents can get data about the school and compare it with similar schools in Croatia. A testing of a simple early warning system (predictions) based on elements such as grades, absence and teachers' warnings was also planned. Two-way communication between students and teachers and pedagogical and psychological support at school is planned in Interventions. In the scope of that, students can ask for help, get advices, receive tasks etc. Furthermore, students can set some educational goals for themselves and then trace their achievements by the use of gap analysis or obtaining badges (Personal development part). There is also the Survey module that can be used to ask students to assess or evaluate a school and teachers, but also their own motivation, attitudes and needs. Students' participation in the survey will be on a voluntary basis and results can be used just on an aggregated level by teachers, authorities and researchers. Student have unlimited access to their results and to see how they are used. Finally, the design was checked according to the DELICATE eight-point checklist [7].

3.3.2. Dashboard for teacher

Detecting problems in the learning process is a way to improve educational systems and provide feedback at the right time and in line with the situation [23] [34].

In order to provide students with timely and adequate support during their educational process and to detect problem zones in due time, teachers should be aware of students' behaviour and needs. Accordingly, the dashboard should allow them easy monitoring of students' progress, activities, obligations and networking with other students.

As already mentioned, teachers are allowed to see the majority of personal data and analytics for all their students (all elements presented in Table 3, except for Success Planner, Interventions and Learning more on the individual level), but the dashboard also provides a teacher additional analytical elements: successful and less successful students, class overview, comparison of success in different subjects if a teacher is a class headmaster etc.

3.3.3. Dashboard for school management and support

The school management and support was planned to have a possibility to see analytics for each course, for each class and for each student, including all dashboard elements

presented in Table 3 (except for Interventions, Success Planner and Learning more). Additionally, it was planned that school principals are also regularly provided with information such as:

- a list of successful classes/students according to different factors, such as the highest average grade, the highest average grade per subject, results of student competitions, the lowest absence rate;
- a list of less successful classes/students according to different factors, such as the lowest average grade, the lowest average grade per subject, the highest absence rate. This element indicates potential risks for students and requests timely interventions from teacher/pedagogue/psychologist.

It was planned that the school management would have the possibility to see analytics for each teacher (results of students' survey on teachers' performance, comparison of teachers according to different factors, teachers' trainings) and for other data with teacher consent (teachers' networks, interventions, competency testing).

Regarding the school, the school management and support services can see additional information such as:

- according to which criteria the school deviates compared to other schools in town, county and similar schools on the national level
- what is the status of the school regarding different factors (number of students, number of students per teacher, students' grade)
- the results of all performed data analyses related to the school
- the recommendations and proposed interventions for the school from local and national education authorities
- statistical reports about the educational system on the national level.

3.3.4. Dashboard for local and national education authorities

Local and national education authorities are provided with data and analyses about schools, students and teachers based on aggregated data and only exceptionally on individual level (by consent or by legal obligation). Analytics are planned separately for primary schools and for secondary schools on the town level, county level and national level. The dashboard for local and national education authorities provides a quick overview of successful and less successful schools based on the selected criteria as well as the overview of schools that need support for different reasons. Additionally, the dashboard allows following up the achievement of indicators for the strategic goals defined within national strategies. For instance: the number of students per teacher at school, the number of teaching assistants per student with disabilities at school, schools that have a high rate of drop out, teachers' participation in trainings and professional development, the number of active projects at school, the level of teachers' digital competences, the level of schools' digital maturity, the proportion of minorities at school etc. Finally, local and national education authorities are also provided with analyses performed on data from founders of schools (sample description, methods, results) and statistical data in form of a report.

On	Aim	Element	Description
Me	Reflections	Success and progress	A review of student success and progress – overall student grade average, grade average per subject, obtained badges. A review of student grades for the previous school year.
		Me and others	Comparison with other students in the classroom (statistically aggregated), in the school and students from other "similar" schools, according to different factors (e.g. average grade, students' activities, absence rate).
		My network	Students' positions according to centrality measures in different networks (e.g. teamwork, informal communication, sharing documents, activities in different systems such as an LMS, forum activities, group membership etc.).
		My obligations	Students' past, current and future activities, such as homework, tests, self-assessment, essay presentations etc.)
		Attendance	Students' presence in the classroom (justified and unjustified absences).
	Predictions	How am I doing?	An early warning system. A review of possible risks that could threaten student success (e.g. too many negative grades, too many absences from school, teachers' warnings).
	Interventions	My needs	Allows students to request help from a teacher/pedagogue/psychologist.
		Tasks and recommendations	A review of tasks and recommendations assigned by a teacher to a student (e.g., attending supplementary classes).
My teachers		Info point about teachers	Information about teachers, such as results of students' evaluation of teachers' work, teachers' professional development, students' results in competitions in a subject, students' average grade, teachers' networking, cooperation with other teachers, project activities etc.).
My school		School particularities	A review of factors according to which a school is positioned as the best in the city, county, country (e.g., results in the national students' competition in Mathematics).
		Comparison with other schools	School status according to different factors (e.g., student success, teacher performance, external evaluation etc.)
Additional	Personal development	Success Planner	Allows students to define their educational goals, the desired overall average grade, an average grade per subject, the maximal number of absences, the student discipline grade, conditions for enrolment in high school/HEI. At the system level, students get motivational messages and badges depending on their current success and progress and set plans.

	Parental involvement	Parents Corner	Allows insight for parents into possibilities for consultations with teachers, parents' meetings with a headmaster and Parents Council meetings.
	Learning more	Survey module	Allows teachers, schools or authorities to survey students on their learning, motivation and needs, to create better teaching and supporting strategies.

Table 3: Elements of the dashboard for students

3.4. Evaluation of dashboards design

The created dashboards were presented to 160 participants of all user groups in September 2016, followed by discussions in smaller groups, with the purpose of gathering additional inputs from users. Finally, 102 written evaluations, with a rather favourable final evaluation (4.3 out of 5), and numerous suggestions and concerns were collected and considered when designing dashboard examples. The collected user evaluations present a contribution to step 4, evaluate the dashboard of the design science research.

4. Discussion

4.1. Basic functionalities

In Croatia, the national LAS has been planned to have a rather wide grasp, from supporting students and teachers in enhancing learning and teaching outcomes, schools to embrace more autonomy, and national authorities to set, monitor and evaluate the strategic development. Having that in mind, all the user groups have a wide range of information and analyses available. There are many similarities between the user groups in their needs and wishes. Although from different aspects, all the user groups focus on students' success, students' problems, e. g. potential risks and their needs, special educational needs, which gives the impression that students really are at the very centre of the whole LAS development. There is also a considerable interest for various predictions. But some of the questions they posed were very complex (e.g., students: Am I on a good track to be employable?) and there are no available data sets to support predictions so far. Bearing in mind that the LAS provides great help in discovering hidden information and patterns from raw data collected from educational environments [27][34], throughout the process of dashboard design, an emphasis was put on providing user groups with data relevant for their area of activity, being realistic about the availability and reliability of certain data sets. However, based on the performed literature review and needs analysis, several issues came up as the ones that should be given a special attention. Therefore, except for the presented dashboards, three additional modules were proposed within the LAS architecture: Consent System, System for Warning and Intervention and Success Planner.

4.1.1. Privacy, data control, data ownership - Consent System

As evident from the performed research review, legal and ethical issues related to data control and data ownership can become the main problem in the process of an LAS implementation.

In order to facilitate trusted implementation of LA [7][22] and considering that the largest user group of the LAS is underage, we planned the Consent System as a part of the LAS. The Consent System, concerning the Consent and Anonymise points of the DELICATE checklist [7], allow users to see how their personal data have been used (what data, for what purpose, on which locations they are stored and what systems use them). The Consent System also allows users to give or refuse their consent to use personal data for a specific purpose (users can give a permission for using all personal data, only a particular set of personal data or only anonymized data).

4.1.2. Prediction-System for Warning and Intervention

Motivated by the potential and opportunities offered by LA, especially in the field of students' success prediction, the System for Warning and Interventions has been planned as a supporting module to the LAS. This system serves students, to improve their learning processes and results, to complete certain parts of their learning processes, as well as educators, to provide individualized guidance in students' educational processes. Prediction elements are incorporated in several functionalities, such as How am I doing?.

Some authors [33] stated that the "descriptive dashboard" they developed was not recognized as significantly usable from the students' aspect. Probably, some of the problems derive from the fact that students do not know how to interpret presented data and therefore do not consider a dashboard as a helpful tool. Otherwise, the personalized motivational messages planned within the LAS in Croatia should guide students in their learning processes. Except on the system level, teachers can also consult and guide students through their learning processes. Teachers do not have time to interpret educational events immediately and in detail, since in the classroom they have to observe and react to many different events at once [12][36]. Bearing this in mind, the prediction elements incorporated in this system play an important role in providing timely and adequate support to students in semi-automatic ways.

As for the further development, a careful process of data interpretation as well as the education scenarios shall be further designed to give students and teachers possibilities to use the information meaningfully.

4.1.3. Success Planner

The final system that supports the LAS is the Success Planner. The Success Planner is foreseen as embedded in the LAS and aims to encourage students' reflection on their learning goals, desired success and competences they want to acquire, i.e. to develop their metacognition skills and approaches. In that way, the Success Planner provides students with the sense of where they are, where they can be and how to get there in an early phase of their educational process.

4.2. Interpretation of the results

Finally, a short discussion of the potential hazards related to the implementation of the LAS is provided. A potential danger of using educational datasets for the purpose of LA stems from a possible misinterpretation of LA results presented within a dashboard. As stated in [11], a data analysis could have dramatic (and unwanted) consequences if not used with the necessary care. Concerning the fact that this system, together with regular upgrades, is foreseen to be used by half a million of underage students, this issue should be taken very seriously. The correct interpretation of data presented within a dashboard provides a basis for conclusions and decision-making, which follow the analytics process. This implies the development of skills and competencies for all LAS users.

Besides that, the LAS can provide school management with the necessary data and analyses to support their decision-making processes, and consequently support schools to be more independent and take responsibility for their development. To support all the users in maximizing the benefits of the LAS implementation, use scenarios are developed.

5. Limitations of research

Due to financial and time constrains, there are several limitations of the needs analysis research and the results can therefore be biased. Some of the functionalities planned for the dashboards will probably not appear in other national environments because all the participants in the needs analysis are from Croatia. Further, even though the representatives of all user groups and around 500 participants have been involved in the consultations and evaluations, the research sample was not representative. In order to incorporate broader perspectives, the analysis included research studies and practitioners' references as well as experiences of the international experts engaged to work with the national teams within the "E-schools" project.

6. Further research

Regarding LA for pre-tertiary education, there are still many gaps in contemporary research and numerous possibilities for further research. From the technology and LA methods point of view, there is no big difference between tertiary and pre-tertiary education, but from the pedagogical and methodological point of view, there are much more difficult challenges in pre-tertiary education, starting with ethical issues, aggregation of classroom data with online data, to interpretation of LA results and justification of their use. For future research, the idea is to analyse pedagogical scenarios for the use of dashboards, such as interpretation of data for all target groups, ways of using the Success Planner in the classroom, preparing reports on student success for parents' meetings and how to get badges. Further work should also consider broad research of how, why and when some information or visualization can be delivered to students, but also how to protect students from the misuse of information. Finally, if something can be prepared from the technological point of

view, it should not necessarily be given to users without a clear goal and a confirmation that it is not harmful.

Here, it is important to emphasize the last phase within the design science research, Reflect evolution, which implies a need for the presentation of the system evolution to the appropriate audience and collecting inputs for further improvements. In the context of this research, that is accomplished through presentation at conferences and workshops, in publications, etc.

Additionally, further research should be related to: 1) specific challenges of institutional adoption at the pre-tertiary level; 2) students' and teachers' data literacy necessary for meaningful data interpretation and 3) ethical and pedagogical issues related to the institutional adoption of LA.

7. Conclusions

The majority of the existing research on LA has been done in the last decade and its value is unquestionable. However, the vast majority of the research concerns higher education settings, without any extensive research on the application of a LAS in pre-tertiary education. Moreover, no national LASs on the level of primary or secondary education in practice have been identified. Therefore, the objective of designing the pre-production National LA and Educational Data Mining System as a comprehensive and overarching information system for pre-tertiary education in Croatia within the "E-schools" project has been demanding and complex.

At the very beginning, this paper clearly defined the objective of the LAS, with the primary focus on improving students' learning and motivation, but also supporting schools in accountability and national authorities in setting, monitoring and evaluating the strategic goals. After that, six target user groups (stakeholders) were identified: students (pupils), teachers, school management and support, regional and national authorities responsible for education, strategic bodies and researchers and, finally, project partners working on system development. The main requirements from the six main groups of users are to support student success, to allow identification of students at risk based on different factors (such as negative grades, too many absences, low rate of engagement in the course), to allow educators to friendly monitor students' success, progress, needs and provide timely interventions to prevent students' failure. In the development of functionalities and dashboards for the six identified user groups, special attention was given to the needs and opinion of users. Based on that, six examples of dashboards were designed, including the description of main functionalities and the associated methods. Besides the data analysis part of the system, there is also the Consent System, giving students and teachers the possibility to control the use of their personal data, the System for Warning and Intervention, helping students and teachers to deal with risks, as well as the Success Planner, that enables the development of students' metacognitive skills.

There are several issues which have to be considered with special care, such as data collection, control and preventions, the analysis of usability (and harmfulness of the presented information and analyses. Furthermore, students, teachers and other users should be trained to interpret the analysis results and other information available

via the dashboards. Finally, the whole process of production of the LAS and the implementation of that system should be closely monitored and evaluated.

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