

# Learning Analytics: Meeting the Needs of Students and Teachers in Pre-tertiary Education

**Blaženka Divjak, Petra Vondra**  
Faculty of Organization and Informatics  
University of Zagreb  
{blazenka.divjak, petra.vondra}@foi.hr

**Abstract.** *The aim of learning analytics is to use available data from different systems and data bases in order to support students and teachers in learning and teaching processes. In order to ensure that main groups of users get what they need the most by using learning analytics, there is an imperative to develop feasible needs analysis methodology as well as to perform the needs analysis according to it. There are far less research and prediction about the role and implementation of learning analytics in pre-tertiary education (schools) than in higher education. The research presented in this paper was performed in primary and secondary schools in Croatia. Final results are presented in form of most relevant questions posed by students and teachers that learning analytics system supposed to answer.*

**Keywords.** Learning analytics, needs analysis, students, pre-tertiary education, data mining

## 1 Introduction

There are not many examples of pre-tertiary learning analytics systems in place and research in this area is still sporadic. In this paper we will present the methodology for needs analysis of Learning Analytics (LA) System in Croatian pre-tertiary education with the special emphasis on needs of students (pupils) and teachers.

The methodology is developed within the result “Learning analytics” in the scope of the project „E-Schools: Establishing a System for Developing Digitally Mature Schools (pilot project)“ (E-schools). 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 purpose of the E-schools pilot project is to establish a system for the development of digitally mature schools through the pilot project and the evaluation of the application of ICT (information and communications technologies) in the educational and operational processes of 10% of schools in the Republic of Croatia (CARNet, 2015).

One of the project results is the development of Learning Analytics and Educational Data Mining being also main topic of this paper.

## 2 Learning Analytics for Tertiary and Pre-tertiary Education

In (Ferguson, 2012) learning analytics is defined as the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs.

According to (Johnson et al. 2016) “learning analytics is an educational application of web analytics aimed at learner profiling, a process of gathering and analysing details of individual student interactions in online learning activities. The goal is to build better pedagogies, empower active learning, target at-risk student populations, and assess factors affecting completion and student success.”

Considering learning analytics as one of the promising trends that leads to new insights on learners' behaviour, interactions, and learning paths, as well as to improvement of the technology enhanced learning methods in a data-driven way (Vahdat et al. 2015), some authors (Horizon, 2011), (Redecker, 2013) expected learning analytics to be mature and become a reality by 2016.

There are many references to learning analytics research and implementation in higher education. Providing high quality, relevant and widely accessible higher education is a fundamental goal of the European Higher Education Area (High Level Group, 2014). The report includes a list of new modes of learning and teaching to modernize higher education among which more personalized learning informed by better data. The advances in big data and learning analytics can help higher education system customize teaching tools and develop more personalized learning pathways based on student data. Bring Your Own Device (BYOD), along with learning analytics and adaptive learning, are according to (Johnson et al., 2016) expected to be increasingly adopted by higher education

institutions in one year's time or less to make use of mobile learning and student data that can be gathered through online learning environments.

Further, Kasemsap, (2016) highlights that application of learning analytics contributes to improvement of educational performance and reach strategic goals in information age. Further, in (Kasemsap, 2016) is presented the role of learning analytics (LA) in global higher education illustrating the theoretical and practical overview of LA, LA and educational data mining, LA and learning management system, LA and Course Signals, LA and knowledge perspectives, LA and social networking sites and significance of LA in global higher education.

Concerning application of learning analytics as strong driver for modernization of higher education, some universities in the United Kingdom, United States and in Australia have been deployed learning analytics at a national level. Currently there is not such a steep progress in pre-tertiary education.

The report Learning Analytics in Higher Education (Sclater et al. 2016) presents an overview of the evidence currently available of the impact that analytics are having on teaching and learning at universities in the United States, Australia and the United Kingdom. The case studies of some of the most prominent institutions presented in the report provide evidence that:

- Researchers have demonstrated the validity of the predictive models used by learning analytics systems
- The interventions carried out with students have been effective
- There are other benefits to taking a more data-driven approach to higher education provision.

As evident, the potential of LA in higher education is unquestionable and its outcomes are promising, but the application of LA in pre-tertiary education is lagging behind. There are several reasons for that, but first of all schools are, if compared to higher education, very dependent on initiatives coming from governments, ministries and governmental agencies. Secondly, LA is using data from primary and secondary schools' students (pupils) in who are predominantly under aged and therefore privacy and ethical issues are even more demanding than in HE. As a consequence, any considerable developments regarding the use of learning analytics in schools can be expected as a national initiative including ethical standards, sustainable long term funding and common framework of conduct.

Therefore, the application of LA in pre-tertiary education is not researched although many questions arise such as:

- What are the specific needs of teachers and students (pupils) in pre-tertiary educational sector?
- What are the possibilities of applying learning analytics in pre-tertiary educational sector?
- What are the similarities and differences between higher education and pre-tertiary education related to implementation and usefulness of learning analytics?
- What are the specific challenges of ethics and privacy issues of LA in pre-tertiary education?
- What are the most useful data sources about learners in pre-tertiary education?
- How to integrate data from f2f classroom with data from LMS and other e-sources?

Evidently, there is a considerable research gap in the pre-tertiary learning analytics area.

### 3 Goals of Learning Analytics in Pre-Tertiary Education

Learning analytics integrates research and methodology related to business intelligence, web analytics, academic analytics, action analytics, predictive analytics, data mining, social network analysis, data visualization, machine learning, learning sciences, psychology, semantics, artificial intelligence, e-learning and educational theory and practice (Kasemsap, 2016) (Papamitsiou & Economides, 2014).

According to very thorough literature consolidation of learning analytics presented in (Kasemsap, 2016), learning analytics can leverage improvement of learning process and their outcomes through the:

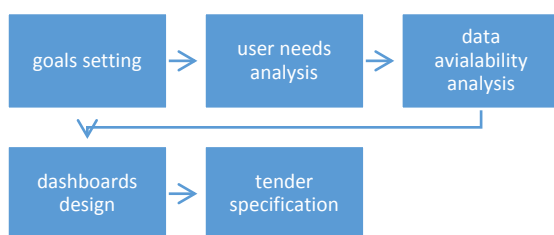
- improvement of educational decision making (Arnold, 2010), (Norris et al., 2013), (Vatrapu et al. 2011)
- more timely and frequent feedback for students and teachers (Hamalainen et al., 2004), (Merceron & Yacef, 2005), (Suthers et al. 2008)
- individualization of teaching and learning (Lu, 2004) (Talavera & Gaudio, 2004)
- generation of a richer set of data on student behaviour and learning (Baker & Yacef, 2009), (Mazza & Dimitrova, 2004), (Pavlik et al. 2009).

Furthermore, learning analytics can leverage improvement in educational system through deployment of early warning system that is early identification of students at-risk, preparing intervention strategies and predicting student success. Vahdat et al., (2015) also state that LA and Educational Data Mining (EDM) are valuable

concerning the prediction of the future learning behaviour in order to provide feedbacks and adapt recommender systems based on learners' attitudes.

Based on the assumption that possibilities offered by LA are applicable in pre-tertiary educational system, our research focuses on the challenges of introduction of LA system in pre-tertiary educational system in Croatia. Accordingly, we developed the methodology for introduction of LA system in pre-tertiary educational system in Croatia within "E-schools pilot project".

The approach for LA pre-production system development consists of the steps presented in the Figure 1.



**Figure 1.** Development of LA system

In this paper we deal with the first and second steps and focus on the students and teachers as user groups.

## 4 Methodology

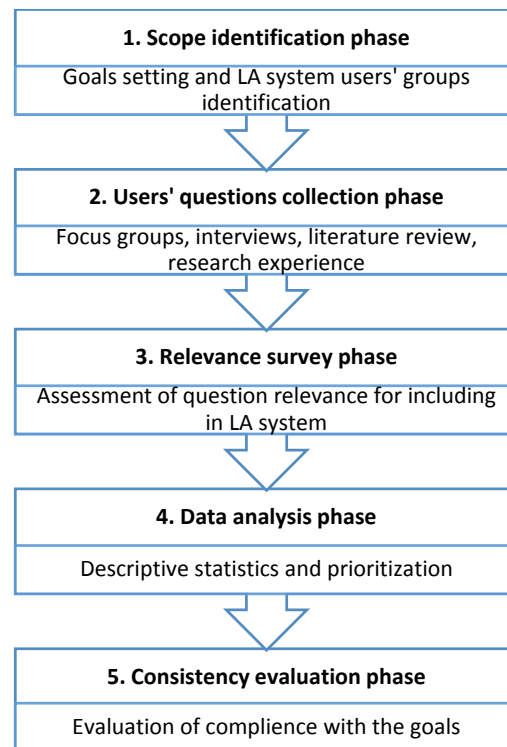
The use of learning analytics in schools (K12) is of growing interest (LACE, 2016) but still very much lagging behind development in higher education. One of the main issues in this new context is users' needs analysis.

Within E-schools pilot project we developed the methodology for needs analysis for learning analytics system in pre-tertiary education and we implemented it in Croatia. The methodology phases are presented in Figure 2 and are elaborated below.

### 4.1 Scope Identification Phase

#### 4.1.1 Identifying Goals of LA System

The cornerstone document for setting the goals of LA and EDM system in Croatia was The Strategy of Education, Science and Technology (MSES, 2014) that was adopted by the Croatian Parliament in 2014. In (MSES, 2014) is stated that one of the most effective ways for quality assurance in educational system are interventions at school level focused on students.



**Figure 2.** Phases of needs analysis methodology

These interventions are recognized as the potential mechanisms for identification of learning disabilities and mechanisms to provide additional support to students in order to improve their achievements.

Supporting Strategy goals (MSES, 2014), putting students, their needs and teachers in the focus of educational process and concerning LA as a promising tool for quality assurance and quality improvement of educational system, we defined the following goals of introducing LA system to pre-tertiary education in Croatia:

- **Goal 1:** To collect, measure and analyse data about students, their educational environment and teacher's activities to provide equal opportunities for realizing the potential to all students in Croatia.
- **Goal 2:** To continuously inform decision makers on the educational system level, founders and schools about quality of educational process, system efficiency, needs for investment and educational, financial, human resources and etc. Interventions in the system and any part of it in order to ensure each student the best possible conditions and support for successful learning and holistic personal development and to raise the quality of the educational process.
- **Goal 3:** To collect data, set metrics and analyse the implementation strategies at pre-tertiary education in Croatia to ensure quality and relevant education and equal opportunities.

- **Goal 4:** To monitor the introduction of the concept of digitally mature schools in pre-tertiary educational system in Croatia and its impact on achievement the Strategy objectives.

#### 4.1.2 Identifying LA and EDM System Users

In order to achieve the defined goals, it is critical to timely include all relevant target groups in the process of introduction the LA system in pre-tertiary education concerning national, institutional and course framework.

Shum, (2012) stated that it is not enough to include only technologists in the process of introduction learning analytics in education but also researchers in education, policy makers, educational practitioners, organizational administrators, instructional designers, product vendors, and learners who are the primary consumers of certain kinds of learning analytics.

(Gašević et al., 2015) (Kasemsap, 2016) also emphasize that learning analytics needs better connection with the existing body of research knowledge about learning and teaching. Researchers need to pay attention to learning sciences to enforce pedagogy and improve learning design (Ferguson, 2012) and intervention strategies.

From the aspect of introduction LA system in pre-tertiary education, it is very important to include parents, but also psychological and pedagogical support domain to ensure students the better understanding of information on their progress, to ensure interventions for “risky” behaviours as well as the quality support system in schools.

The effective use of learning analytics implies usage of large set of collected data on students and their learning activities. To ensure that learning analytics is carried out responsibly, appropriately and effectively, addressing the key legal, ethical and logistical issues which are likely to arise (Sclater & Bailey, 2015) it is important to consult Croatian Personal Data Protection Agency.

Apart from the aforementioned groups, the contribution to establishment the successful educational system through introduction of learning analytics in pre-tertiary education system requests input from external quality assurance and quality improvement system in Croatia, such as Agency for Education, Agency for Vocational Education and Training and Adult Education, and National Centre for the Evaluation of Education.

Based on the theoretical references for LA and EDM, four goals identified, study visits of project team and discussions of experts and project team, we identified users of LA and EDM system related to the two dimensions as it is shown in Table 1. The first dimension is the role of user in the system

where we distinguish between three different roles as follows:

- 1) directly participating in educational process
- 2) management of institutions or educational system on regional or national level
- 3) in charge of external quality assurance, support and research.

The second dimension deals with position of a user related to a school and according to these users can be divided in two groups:

- A) **Internal users:** users who attend school or are school employees
- B) **External users:** users who are engaged in schools in various aspects of their work and activities.

In Table 1 are presented the identified target groups of LA system in pre-tertiary education in Croatia and their representatives.

Here we can further reduce the number of target groups to four groups, based on analysing their needs for LA support.

The main users’ groups can be connected also to the four goals of LA and EDM system. The first goal is at the very heart of LA and the main users of results and beneficiaries are students and teachers. Needs of these two user groups are in the focus of this paper.

**Table 1.** Target groups and their representatives

	Teaching and learning processes	Institutional and system management	Quality assurance, support, research
Internal	Students (and parents) Teachers	School principal School board	Pedagogical support  Administrative-technical support
External	Expert Group for Strategy  Expert Group for Curricular Reform  Advisors	School founders  Ministry of Science, Education and Sport  Government  Parliament	Agencies and centres for quality assurance  Researchers  National Councils  IT support

## 4.2 Users' Questions Collection Phase

After identifying goals and users of LA and EDM system in pre-tertiary education, we collected user needs in two ways:

- Researching relevant literature on needs of user groups mentioned in Table 1 and personal experience of researchers in the project
- Recording user needs through focus groups and interviews using events such as conference, workshops, meetings with school, Ministry, agencies representatives and similar.

The main idea was to collect users' needs *in form of questions* set by users which are connected to their everyday learning, teaching, work and professional life. In that way we tried to motivate users to set relevant questions no matter if it possible to answer them or how we get an answer. The intention was to collect as many questions as possible that will be analysed in the following phases.

The result of collecting user needs from different sources was a list of 168 questions for all identified user groups.

After that, we performed analysis of collected question to:

- identify questions that are the most important for several users
- identify redundant and unclear questions
- identify questions that are impossible to give an answer having in mind forecasted development of LA system until 2020.

Finally, we compiled a list of 131 questions organized in six groups of users and some questions were relevant for several user groups. Specifically, there are 48 questions assessed as important for students and 90 for teachers.

## 4.3 Relevance Survey Phase

The purpose of survey was to assess question relevance for inclusion in the second phase of the LA system development. We used the 5 point Likert-like scale and asked the users to assess if the answer on a question would be relevant to their learning, teaching and work. They can answer with the following options: 1 – not at all relevant; 2 – not relevant; 3 - neither relevant nor irrelevant; 4 – relevant; 5 – very relevant.

Specifically, students (pupils) and teachers were asked to assess the relevance for including in LA systems for questions related to:

- Student success (comparison of students, talented students, students at risk, students with special needs, predictors of success, predictors of risk, motivation)

- Teachers performance (comparison of teachers, possibilities for improvement – vocational training and lifelong learning)
- Teaching methods and used materials
- Various impacts on learning outcomes
- ICT in education, digital maturity and digital educational materials
- School success (comparison of schools and programs)
- School equipment, resources and teaching organization

Finally, 116 students and 39 teachers completed the questionnaires. Due to the time and resource constrains students and teachers are from primary and secondary schools from Slavonia and Northwest Croatia. Students (N=116) that fill out the questionnaire attended two primary and three secondary schools from Osječko-baranjska County, Vukovarsko-srijemska County and Varazdinska County.

Teachers (N=39) that participated in the survey teach in primary and secondary schools in three above mentioned counties.

## 4.4 Data Analysis Phase

Finally, we approached data analysis and performed descriptive statistics and prioritization. The list of questions with highest average relevance for "Students" and "Teachers" is presented below (Table 2 and Table 3).

The students' answers (Table 2) show that they are mainly concerned with what are their opportunities for success in school, further education and/or in labour market as well as what are the risks threatening their goals. In that respect they took into account their personal characteristics (grit, motivation, prior knowledge), socio-economic background and quality of the school they attend (quality of teachers, timetable, equipment etc.).

The answers collected from teachers show (Table 3) that their main concern is how to support their students in learning and achieving their goals regarding the higher level of education and/or employability. They recognized that their training is one of the critical success factors for their students' achievement along with facilitate students' active learning (teaching and evaluation methods, material etc.).

Other user groups also participated in the survey assessing their "own" list of collected initial questions and their results are also analysed. Altogether 252 participants completed the questionnaires.

As it is shown in the Figure 1, the next step in the LA system development is the analysis of the available data sources. It has been very demanding process due to fragmentation and incompleteness of

data bases, data ownership issues, interoperability challenges, ethical concerns and last but also very important the integration of data collecting on line and in physical school environment. Further development of these issues exceeds the scope of this paper.

**Table 2.** Top 10 questions according to average for group „Students“

Question	Average
Is this program (high school, higher education) that I want to enrol good for me?	4.33
Are teachers in particular school successful in teaching?	4.17
To what extent knowledge or competences that I currently acquire correspond to labour market needs for certain professions/jobs?	4.09
Is it my grit/motivation enough to keep long term interest and passion for curriculum and activities?	4.06
How equipment, design, working environment impact teachers and students' motivation for work and learning outcomes?	4.01
Does the number of school hours' impact students' success?	3.98
How family social status impact the achievement of learning outcomes?	3.91
What is the impact of practice outside school to professional learning outcomes and employment possibilities?	3.87
How attending optional courses in computer sciences in primary school impact students' digital competences and success in other courses?	3.87
What is my grit at the end of each academic/school year?	3.85

**Table 3.** Top 10 questions according to average for group „Teachers“

Question	Average
Which students are talented and need additional support?	4.31
Does student achieve preconditions for admission to the desired higher level of education?	4.31
Am I getting better in teaching on my course (historical overview)?	4.30
Which professional training is the best for me to be more successful?	4.25
Which teaching methods increase students' activity?	4.24

Which teaching and evaluation methods increase students' activity?	4.19
How successful are my students in continuing their education, i.e. are they employed in their profession?	4.16
How quality of teachers/their success in previous education impacts students success?	4.16
What materials are interesting to students?	4.16
How the estimated time that students invested in their independent work impacts their success?	4.16

## 5 Dashboards for Different Groups of LA Systems Users

Based on the user needs, the analysis and the availability of data sources, the dashboards for different users have been designed. According to (SOLAR, 2011) the dashboard is the sense making component of the LA system, presenting visualized data to assist individuals in making decisions about teaching and learning. The dashboard consists of four basic views: learner, educator, researcher and institution. Needs analysis can serve as a base for identifying the functionalities available on a dashboard for particular groups of users.

Based on the needs analysis we identify that students (learners) are interested to use his/her dashboard information to learn about:

- comparison of the student's achieved competencies and competences required in the labour market
- comparison of student's achievement and the preconditions for enrolment at secondary school/higher education
- teachers' performance (survey results, learners grades at course 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.

Besides, students (learners) are also interested in impact of various factors on student achievement (such as family social status, school equipment and design, working atmosphere, school practice, team work, absences from school, time spent on independent work) and impact of various factors on competences achievement (e.g. attending elective courses in informatics on digital competences). Further, teachers (educator) are interested to use his/her dashboard information to learn about:

- 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.

Besides, they are also interested in 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) and recommendations for professional development to improve teaching performance.

## 6 Conclusion

Croatia takes advantage of EU funding available to start with systematic development of national Learning Analytics and Educational Data Mining system in the scope of wider goal of digitalization of Croatian schools. That gives the project team an opportunity to develop sound methodology for LA system planning, producing, implementing and monitoring.

The whole process started with setting the goals of LA system as well as with the identification of main user groups. Among altogether six user groups the highest priority has been given to students (pupils) and teachers.

The users' needs identification was conducted in two phases: collecting the set of their possible questions and assessing their relevance for different user groups.

Historically, learning analytics has been developed in three stages where the first stage was describing results, the second stage was diagnosing learner's situation, and the third and current stage is predicting what will happen in the future (Johnson et al., 2016). The needs analysis performed in the scope of E-schools pilot project shows that students and teachers recognized elements from all three stages as important and relevant.

Based on students' and teachers' needs further analysis of availability and reliability of data can be performed. Finally, taking into account the results of this analysis, different dashboards for different users can be designed.

## Acknowledgement

The research was conducted within the pilot project "E-Schools: Establishing a System for Developing Digitally Mature Schools (pilot project)" being co-funded from the European structural and investment funds - Operational Programme Competitiveness and Cohesion (OPCC) of the European Regional Development Fund (ERDF) and the Operational Programme Efficient Human Resources (OPEHR) of the European Social Fund (ESF).

## References

- Arnold, K. E. (2010). Signals: Applying academic analytics. *EDUCAUSE Quarterly*, 33(1), n1.
- Baker, R., & Yacef, K. (2009). The state of educational data mining in 2009: A review and future visions. *Journal of Educational Data Mining*, 1(1), 3–17.
- CARNet (2015). E-schools pilot project. Retrieved from: <http://www.carnet.hr/e-skole>
- Ferguson, R. (2012). Learning analytics: Drivers, developments and challenges. *International Journal of Technology Enhanced Learning*, 4(5/6), 304-371. Doi: 10.1504/IJTEL.2012.051816
- Gašević, D., Dawson, S., & Siemens, G. (2015). Let's not forget: Learning analytics are about learning. *TechTrends*, 59(1), 64–71. doi:10.1007/s11528-014-0822-x
- Hamalainen, W., Suhonen, J., Sutinen, E., & Toivonen, H. (2004). *Data mining in personalizing distance education courses*. Paper presented at the 21st ICDE World Conference on Open Learning and Distance Education, Hong Kong.
- High Level Group on the Modernisation of Higher Education (2014). Report to the European Commission on New modes of learning and teaching in higher education. Luxembourg: Publications Office of the European Union
- Horizon Report, 2011. Retrieved from: <http://www.nmc.org/pdf/2011-Horizon-Report.pdf>
- Johnson, L., Adams Becker, S., Cummins, M., Estrada, V., Freeman, A., and Hall, C. (2016). NMC Horizon Report: 2016 Higher Education Edition. Austin, Texas: The New Media Consortium. Retrieved from: <http://cdn.nmc.org/media/2016-nmc-horizon-report-he-EN.pdf>

- Kasemsap, K. (2016). *The Role of Learning Analytics in Global Higher Education, Developing Effective Educational Experiences through Learning Analytics*, IGI Global
- LACE (2016). *Schools*. Retrieved from: <http://www.laceproject.eu/schools/>
- Lu, J. (2004). Personalized e-learning material recommender system. International Conference on Information Technology for Application ICITA '04, Harbin, China.
- Mazza, R., & Dimitrova, V. (2004). *Visualizing student tracking data to support instructors in web-based distance education*. 13th International Conference on World Wide Web WWW '04, New York City, NY. doi:10.1145/1013367.1013393
- Ministry of science, education and sport (MSES) (2014). *The Strategy of Education, Science and Technology - The new color of knowledge*, Retrieved from: [http://www.novebojeznanja.hr/UserDocsImages/datoteke/KB\\_web.pdf](http://www.novebojeznanja.hr/UserDocsImages/datoteke/KB_web.pdf)
- Merceron, A., & Yacef, K. (2005). TADA-Ed for educational data mining. *Interactive Multimedia Electronic Journal of Computer-Enhanced Learning*, 7(1), 267–287.
- Norris, D. M., & Baer, L. L. (2013). *Building organizational capacity for analytics*. Louisville, CO: EDUCAUSE.
- Papamitsiou, Z., & Economides, A. (2014). Learning analytics and educational data mining in practice: A systematic literature review of empirical evidence. *Journal of Educational Technology & Society*, 17(4), 49–64.
- Pavlik, P., Cen, H., & Koedinger, K. (2009). Learning factors transfer analysis: Using learning curve analysis to automatically generate domain models. *Second International Conference on Educational Data Mining EDM 09*, Cordoba, Spain.
- Redecker, C., (2013). *JRC Scientific and Policy Reports, The Use of ICT for the Assessment of Key Competences*. Luxembourg: Publications Office of the European Union
- Sclater, N., Bailey, P. (2015). *Code of practice for learning analytics*, 2015, Retrieved from: <https://www.jisc.ac.uk/guides/code-of-practice-for-learning-analytics>
- Sclater, N., Peasgood, A., & Mullen, J. (2016). *Learning Analytics in Higher Education, A review of UK and international practice (Full report)*, Retrieved from: <https://www.jisc.ac.uk/reports/learning-analytics-in-higher-education>
- Shum, S.B. (2012). *Learning analytics*. UNESCO Policy Brief. Retrieved from: <http://iite.unesco.org/pics/publications/en/files/3214711.pdf>
- SOLAR Society for learning analytics research (2011). *Open Learning Analytics: an integrated & modularized platform*, Retrieved from: <http://www.solaresearch.org/OpenLearningAnalytics.pdf>
- Suthers, D. D., Ravi, V., Medina, R., Joseph, S., & Dwyer, N. (2008). Beyond threaded discussion: Representational guidance in asynchronous collaborative learning environments. *Computers & Education*, 50(4), 1103–1127. doi:10.1016/j.compedu.2006.10.007
- Talavera, L., & Gaudioso, E. (2004). *Mining student data to characterize similar behavior groups in unstructured collaboration spaces*. Paper presented at the 16th European Conference on Artificial Intelligence ECAI '04, Valencia, Spain.
- Vahdat, M., Ghio, A., Oneto, L., Anguita, D., Funk, M., & Rauterberg, M. (2015). *Advances in Learning Analytics and Educational Data Mining*, European Symposium on Artificial Neural Networks, Computational Intelligence and Machine Learning, Bruges (Belgium), ISBN 978-287587014-8
- Vatrapu, R., Teplovs, C., Fujita, N., & Bull, S. (2011). *Towards a visual analytics for teachers' dynamic diagnostic pedagogical decision-making*. First International Conference on Learning Analytics and Knowledge LAK '11, Banff, Canada. doi:10.1145/2090116.2090129