Improving online and blended Learning with Educational Data Analytics

Guidelines and recommendations for the framework application in different educational contexts

ILEDA Project Result 5

Project No. 2021-1-BG01-KA220-HED-000031121

Co-funded by the Erasmus+ Programme of the European Union

Project ref. number	2021-1-BG01-KA220-HED-000031121
Project title	**ILEDA - Improving online and blended learning with educational data analytics**
Document title	Guideline and recommendations for the framework application in different educational contexts
Document Type	Project Result
Document version[1]	Version 20.10.2023
Previous version(s)	Final
Planned date of delivery	25/10/2023
Partner responsible	Sofia University “St. Kliment Ohridski”
Author(s)	Temenuzka Zfirofa(SU) Pencho Mihnev(SU) Oleg Konstantinov(SU) Atanas Georgiev(SU) Tanya Yordanova(SU) Miguel Angel Conde (ULE) Miroslava Raspopovic Milic (BMU) Mohamed Abdelgalil (UEF) Sonsoles Lopez-Pernas (UEF)
With contributions by[2]**:**	<author, section(s)>
Abstract	<Noto Serif 10>
Keywords	<Noto Serif 10>
DOI	<Noto Serif 10>
How to cite[3]	<full citation>

[1] i.e. v1 <date>
[2] To be used when document contains sections by authors different from the main authors
[3] Use APA style

Internal project peer review process

Reviewed by	Role, Organisation	**Date**
Reviewer 1	Miroslava Raspopovic Milic	<20/10/23>
Reviewer 2	Pencho Mihnev	<25/10/23>

Table of Content

1. Introduction

This Guideline is defined in the context of the Project result 5. It consists of recommendations based on best practices derived from ILEDA project results for the implementation of designed instructional methods, learning analytics tools and models, for their implementation not only for the participating universities, but also to the wider group of courses and other higher education institutions.

Rapid technological development and the constant change of needs in new generations of learners have caused the need for teachers to adapt to new teaching modalities. This involves not only presenting the learning content, but also includes keeping student motivation, as well as monitoring and assessing the students in new learning environments. Future digital learning modes need to include relevant content, adequate instructional models, effective teaching practices, and a supportive learning environment.

Understanding students’ progress during their learning is a crucial step in achieving an effective and successful educational process and one way to comprehend student progress is through the use of learning analytics on student data.

As Universities increasingly use digital tools in their everyday activities, they gather a big amount of data. In order to understand better how this data, in the form of learning analytics, can support individual learning, enhance facilitation and teaching quality overall considering ethical principles comprehensive guidance is provided.

These guidelines also address potential issues and barriers for adoption of new instructional methods and new technologies within the institution.

Target groups include teachers in higher education institutions, graduate students, researchers, as well as any of the organisations whose work is related to education and is interested in implementing different forms of instructional teaching models, along with learning analytics.

2. Recommendations

2.1 Innovative instructional methods in blended and online courses

This document will focus on agile methodologies as they use student-centred/active learning techniques to get students involved in the learning process; focus on student’s needs, abilities, interests, and learning styles; acknowledge student voice as central to the learning experience for every learner; and require students to be active, responsible participants in the learning process.

During the research three types of methodologies were highlighted:

- Project based Learning (PrBL) [1].
- Challenge based Learning (ChBL) [2].
- Problem based Learning (PBL)[3].

Each of them has their own features and can be applied depending on the context, so it is essential to have a clear vision of how and where these methodologies are going to be applied.

Some common factors that should be clarified before applying these methodologies are:

- Context. The context refers to where the methodology is going to be applied and the constraints defined by the institution. This could include:
    - Learning Modality. How teaching and training is carried out, online, blended, face to face.
    - Learning Curricula. Which educational curricula is being taught, during how many years, to what type of students.
    - Learning Management System. What kind of learning environment will be used during the educational activity, what kind of resources it provides (forums, chats, tests, teamwork tools, etc.), what kind of reports and tools can the teacher use.
    - The university active learning policy. Whether the context has defined an initiative to apply active learning methodologies and has promoted them or not (this would apply to the scope level).
- Application level/scope. This factor is related with the level to which the active methodology is going to be applied. Depending on it some methodologies can fit better than others. For instance, ChBL can be applied to a part of a subject, a complete subject, a course in a degree or to the complete degree. This depends in many cases on the university policy related to these methodologies and the adaptation to educational curricula. It is possible to define the methodology depending on the time available to apply it, students’ knowledge, students’ and teachers’ experience working in groups, contents and tools to use, etc.
- Data access. The data should be accessible to later possible analysis, which is related to the other part of the framework that is Learning Analytics, so it is necessary to know the data protection law that is going to be applied, what part of the students and teachers’ activities can be stored and how much of that data will be accessible for further analysis.
- Technological support. For these types of methodologies, although it is not mandatory, technology has an important impact. Beyond the LMS it is necessary to know whether the institution would allow the use of other apps even if they are not the institutional ones. For instance, the institution could allow the use of Zoom institutional accounts for meetings but maybe they also allow the use of WhatsApp groups for students’ collaboration. Depending on the tools to use it is necessary to know whether the stored information within them could later be available.

2.1.1 Project based learning

Developing a course based on project-based learning involves careful planning and consideration of various factors to ensure a successful and engaging learning experience for students. Here are the main guidelines for developing a course using PBL:

- Clear Learning Objectives – define specific learning outcomes that students should achieve through the project. These objectives should align with the course curriculum and overall educational goals.
- Select Engaging Projects – choose projects that are relevant, interesting, and meaningful to the students. Projects should challenge their critical thinking, problem-solving, and creativity.
- Real-world Relevance – ensure that projects have real-world applications or connections. This helps students understand the practical implications of their learning.
- Establish a Driving Question – pose a central question or problem that the project aims to address. This question should be open-ended, requiring investigation and exploration.

- Provide Clear Guidelines and Expectations – clearly communicate the project requirements, including deliverables, timelines, and assessment criteria. This helps students understand what is expected of them.
- Foster Collaboration and Teamwork – encourage students to work in groups or teams. This promotes collaboration, communication skills, and the ability to work effectively with others.
- Supportive Learning Environment – create a classroom or online environment that supports inquiry, experimentation, and problem-solving. Provide necessary resources, tools, and guidance.
- Scaffold Learning – break down complex projects into manageable tasks or stages. Provide guidance and support as students progress through the project.
- Incorporate Reflection and Metacognition – encourage students to reflect on their learning process, challenges faced, and strategies used. This helps them develop metacognitive skills and self-awareness.
- Assessment and Feedback – develop assessment rubrics that align with the learning objectives. Provide timely and constructive feedback to guide students' progress.
- Promote Critical Thinking and Problem-Solving – encourage students to analyse, evaluate, and apply their knowledge to solve real-world problems encountered during the project.
- Encourage Inquiry and Exploration – allow students to take ownership of their learning by exploring topics of interest within the project's framework.
- Celebrate Achievements – recognize and celebrate the achievements and accomplishments of students throughout the project. This fosters motivation and a sense of accomplishment.
- Iterative Process – PBL often involves multiple iterations and revisions. Encourage students to refine their work based on feedback and new insights gained.
- Reflect on the Learning Experience – at the conclusion of the project, have students reflect on what they've learned, how they've grown, and how they might apply their newfound knowledge and skills in the future.
- Flexibility is key in PBL. Adapt your approach based on the needs and progress of your students. Additionally, providing a supportive and encouraging learning environment is crucial for the success of project-based learning.

2.1.2 Flipped classroom

According to the Flipped Learning Network (https://flippedlearning.org/definition-of-flipped-learning/) “Flipped Learning is a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter.” [4]. The Four Pillars of F-L-I-P™ are:

- Flexible environment - provides a variety of ways of learning. Students can choose where and when to learn. Teachers adapt their teaching methods - rearranging content, incorporating group work, independent research, presentation and assessment;
- Learning culture - it has changed from teacher-centred to student-centred. The student is at the centre of learning, the active part. Class time is used to explore topics more deeply and to create richer learning experiences;

- Intentional content - careful selection of learning content - what to teach directly and what to place in the independent learning space;
- Professional educators - teachers have a key role in this model regarding the preparation, selection and distribution of learning content, the structuring of the lesson, the design of activities and tasks, the guidance and support of learners.

Key components of the flipped classroom

Educational technologies for content provision outside the classroom	Active learning during the class

● Use of appropriate online learning environments to organise learning content and activities and delivery to learners
● Use of different types of learning resources to present learning content - video, text, presentations, graphics, etc.
	● Variety of activities and tasks
	● Individual and group work
	● Two aspects:
	  ● clarification of arised questions
	  ● elaboration and reinforcement of the learned

Roles and activities - before the class session

Teacher's activities before the class session	Student's activities before the class session

● Selects which part of the learning content to present in advance
● Develops and/or selects ready-made learning materials for the relevant learning content (most often video)
● Prepares questions and tasks for additional studies to the learning content
● Develops quiz questions for relevant learning content
● Selects and develops activities and tasks to practices the learning content
● Announces the topic and motivates students
● **Provides materials for students' prior familiarisation**
● **Administers a quiz to pre-test what has been learned in advance**
● **Poses questions on the learning content**
● **Sets tasks for further study**
● Selects and prepares homework assignments
	● Familiarise yourself with the topic - **review the learning materials** (e.g. video, texts)
	  ● Learns new concepts and terms
	  ● Accepts, understands, and makes sense of the new learning content
	● **Answers questions to the learning content**
	● **Makes further investigations**
	● **Takes the preliminary quiz**
	● Prepares questions about what he/she has not understood

Teacher's activities before the class session - use of learning analytics:

- **Review the students' results on the preliminary quiz;**
- **Analyses the results, identifies the main gaps;**
- Plans which part of the learning content to focus on, during the class session.

Roles and activities - during the class session

Teacher's activities during the class session	Student's activities during the class session
● Makes a brief summary of the topic ● Highlights the most important points of the topic ● Clarifies the gaps identified in the analysis of the results of preliminary quiz ● Answers students' questions ● Initiates discussions ● Monitors, guides, develops, and enriches students' knowledge ● Sets assignments (individual and group) to work on the learning content, knowledge, and skills ● Provokes students' thinking and creativity ● Supervises and supports students' work on assigned tasks, providing help and assistance where necessary ● Pays individual attention to all students ● Gives homework assignments	● Asks questions about what they did not understood ● Participates in discussions ● Applies new knowledge and skills to the assigned tasks (individual and group) ● Performs the assigned activities and tasks ● Solves problems ● Systematises what s/he has learned, draws conclusions

Roles and activities - after the class session

Teacher's activities after the class session	Student's activities after the class session
● Assesses homeworks ● **Analyses and evaluates the conducted lesson** ● **Identifies the strengths and weaknesses of the conducted lesson** ● Identifies strategies to overcome weaknesses and plans further improvements of the lesson	● Completes and submits homework on time

2.2 Factors to consider when designing a lesson with learning analytics

Using learning analytics with active learning methodologies can be challenging. When one thinks of active learning methodologies, it does not typically mean that all of the learner activities will be online. However, for any learning analytics approach it is necessary to have learner data. Hence, including activities that are trackable for student progress, especially when certain metrics are considered, can be quite challenging. For instance, previously one of the active teaching methodologies that was discussed is flipped classroom. In this blended learning model, students have at-home activities, but also they have in-class activities. When designing a lesson, not only should activities be planned along with learning outcomes, assessments and other parts of the lesson, but the lesson designer should also consider how to track student progress, and what metrics will be used. In this case of flipped classrooms, we do not only want to track student activities and progress at home, but also on their in-class activities.

Having all of that in mind, the thing that should be considered is what active learning methodologies to implement. The advantages of using active learning methodologies are twofold: (i) students will be more engaged and active in their learning, and (ii) students will produce a great amount of learning shreds of evidence. As in blended and online learning contexts this data is going to be stored in the tools and Learning Management Systems as logs, it is more or less easy to access the data. The key issue in any of these applications is to decide what to analyse. For instance, for the ILEDA project, the important aspect for analysis was to track student progress during their learning. In order to do so it was necessary to define metrics and decide how these metrics will be measured (through which data). In order to collect the data on student activities and their progress, each lesson was carefully designed to have “break points” placed where the learner data should be collected. These breakpoints allow one to check the metrics at different moments during the course. Taking all of this into account, the chosen indicators were [5]:

- Grades
    - Final grade for the subjects.
    - Checkpoints (to measure percentage of progress considering the active methodology applied in each subject).
- Use of resources (video, documents, activities, reading material, etc.)
    - Clicks
    - Time spent
    - Attempts of tests (if some of the questionnaires allow several attempts, some-thing common in the checkpoint tests).
- Other
    - Students’ login (time of access, login)
    - Session time.

These indicators are shown here as an example, and derived from the courses that were pilotted during the ILEDA project, and should only be used as a guide, but not strict indicators that have to be used. Within the context of the institution, course, teaching method and the strategy defined for the analysis, these indicators should be redefined. Even within the ILEDA project, these were common indicators for all the partners, but in each case it had a different impact/meaning. For instance, in LAMS the log referring to “the time” spent was real, while in Moodle this log considered the first view of the course and the real time of use was difficult to track. Another example were test attempts. In some of the course contexts several attempts were allowed and in others they were not. Here it should be noted that for some methodologies several test attempts do

not make sense. Therefore, the metrics to analyse are going to be really constrained by the context in which the activity is being carried out and the methodology applied.

2.3 Good practice example from the ILEDA project

Part of the ILEDA project was to implement developed innovations in teaching methods along with using learning analytics to track student progress. Details about used metrics and context of the analysis are described in detail in Sections 3 and 4. This section outlines how the lesson design was implemented and what effects implementation had on student learning and teaching experience during the piloting.

2.3.1 Project-based learning lesson design

When designing the lessons where project-based learning teaching methodologies are planned to be implemented, one approach to planning the lesson is to initiate the lesson design with overall planning and later go into details for each lesson, and create lesson flow for each lesson. This also includes careful planning of the activities that will take place during the project-based learning, especially in regards to launching the project and initiating the brainstorming with students. Having in mind that our aim is to track student progress, it is important to think of how we want to collect data that will allow us to do so. Within the ILEDA project Edmonton Regional Learning Consortium’s Project-based learning guide[6] was used as an initial stepping stone, and can be used for further details on implementation of different steps in project-based learning.

Summary of the steps that should be taken during the planning are:

- Plan learning outcomes for each lesson
- Plan learning outcomes that you want to be achieved with the project
- Plan the project placement in the lesson (i.e. is the project lesson based, or does it cover more lessons)
- Plan how student feedback will be collected (i.e. rough drafts, journal reflections, requirements, brainstorming plans, entrance and exit tests, checklist, observations, participating in discussion, report submission, code submission)
- Create a project assessment plan (teacher graded, peer assessment, etc.)
- Create project calendar and timeline (date, lesson, what teacher does, what students do, assessment resources)
- Define an open-ended driving question.

Once the overall planning is complete, the next step is to focus on the design of each lesson. Specifically, the focus can be placed on the lesson flow and its content, and the following steps highlight important things to consider:

- In order for a lesson to be engaging and to increase student motivation, lesson should start with an Introduction that clearly states learning outcomes for that lesson and contains motivation segment (i.e. real-world problem or an example that implements things that will be learned in that lesson)

- Lesson has instructional material related to the learning outcome of the lesson (text, videos, code, etc.)
- Instructional material also contains different examples and solved problems that will help students achieve the learning outcome
- Students are introduced to the project through assignment definition for the lesson giving the project requirements, rules, deadlines, etc.
- Strategically place breakpoints where data on student progress will be collected. In project-based learning students can be asked to submit progress reports on LMS (requirements, brainstorming, observations, final report, etc.)
- Whenever possible, teacher should record grade for the breakpoints, or in this case progress reports (can be either teacher and/or peer assessment)
- Break point can also include individual student assessment for the lesson which will help student learning progress outside of the project work (this can be either self-assessment test or graded test)
- In addition to assessments, assignments and project work, students can be given participation grades at the end of the semester (this depends on the institution and course teaching context).

Successful project outcome also depends on the support students are given in this process. Carefully planned activities within the course will contribute to the successful implementation of the project, and hence, easier tracking of student progress. Following activities should be planned:

- Launch event which is the key activity to launch the project and serves the purpose of informing students, engaging their interest and initiating questions (examples of launch event: discussion, guest speaker, educational video, etc.)
- Create groups (4-5 students) or continue as individual student work
- Teacher lead discussions on what students need to know to solve the driving question
- Students giving feedback during project work. Examples:
    - Each student shares what they are struggling with. Students discuss possible solution
    - Teacher generates the questions about the projects. Students are grouped in groups of 3-4. Students take turns in presenting their project to other students in the group (or part of the project). They discuss how to improve the project.
- Organise presentations where students will present their projects and will take full ownership of the work they have done.

Different templates can be used to design lessons and activities for the project-based learning, however, within the ILEDA project a template was developed that follows the planning of the lesson flow and activities, that allow learner data progress tracking.

Table 1: Template for lesson planning

Week number:	
Lesson title:	
Learning outcomes of the lesson:	
Learning outcomes of the project (for this week):	

In class activity type:	
Collection of student feedback on project work:	
Role of the teacher:	
Assignment:	
Assessment:	

Examples of lesson plans developed within the ILEDA project are uploaded at the Sofia University’s cloud and can be accessed through the following link- https://drive-cist.fmi.uni-sofia.bg/index.php/s/qE8YLMfP7cyPk3a

2.3.2 Flipped classroom lesson design

The application of flipped classroom strategy, combined with use of a LMS, gives the following benefits:

- Possibilities to provide the theoretical knowledge in advance, through the e-learning platform(s) that one uses;
- Possibilities to conduct courses in online and blended learning mode – all learning materials are provided through the e-learning courses, ensuring ubiquitous access, independent of time and place. This provides easy updating of the course content, supports course archiving and recording, as well as assures ease of reuse.

If the e-learning courses provide also access to virtual classrooms, these can be used for live online discussions, practical exercises, case studies, problem solving, and simulations of real situations. These activities enable the achievement of the course goals, and the acquisition not only of theoretical knowledge, but also of practical experience [7].

Planning of the lessons for the flipped classroom teaching approach can follow the following steps:

- Plan learning outcomes for each lesson
- Plan lesson topics that will achieve this learning outcome
- Plan what student activities will be given at home, and how they will be evaluated
- Plan class activities:
    - Determine what instruction is given in class
    - Determine what type of activity will be conducted in class (i.e. break-out activity)
- Plan how student knowledge will be assessed:
    - Plan what is “ticket into class”
    - Plan how to assess their learning “ticket out of the class”
- Keep in mind that all progress should somehow be tracked on LMS, including in-class activities.

Different templates can be used to design lessons and activities for the flipped classroom, however, within the ILEDA project and having learning analytics in mind, the template shown in Table 2 was used.

Table 2: Template for planning flipped classroom lesson design

Week #
Lesson title:
Learning objectives:
Student resources at home:
Student activities at home: *Define what activities students have to do at home (i.e. read, answer questions, watch videos, etc.)* *Plan how to submit their work and/or how to check they completed work (i.e. assignment submission, test, etc.)*
Classroom activities: *Student answers are reviewed in class. All misconceptions are discussed.* *After discussions and instructional teaching (covering parts that students struggled with and part of the material that was not included in home activities), students are given the break-out activity.* *Break-out activity: Define appropriate activity for this lesson.*
Assessments: *Diagnostic assessment:* *Formative assessment:* *Summative assessment:*

Examples of flipped classroom lesson plans developed within the ILEDA project can be found on the following link

https://drive.google.com/drive/folders/1wKVPAJ6JR2BhTxA8ClPONRELdarstL7P?usp=sharing

2.3.3 Course context examples from the piloting

This section outlines the context of the courses that were implemented during the piloting phase of the ILEDA project. All of the lesson plans and teaching materials for the courses described in this section can be found at

https://drive-cist.fmi.uni-sofia.bg/index.php/s/qE8YLMfP7cyPk3a

Context sample for project-based learning - Sofia University

The experience of the authors described in this good practice is related to teaching in piloted ILEDA courses. As an example we will point to "Human-computer interaction" (HCI) For students in *Software Engineering*, 3rd year (compulsory course). During the entire course (one semester), students work on specific projects, distributed in teams.

Projects general theme: Create reliable, efficient, easy-to-learn and easy-to-use computer systems with a robust and functionally adequate interface. Student projects should take the form of web-based applications, websites, games or other types of platforms.

Project assessment: teacher graded.

General organisation:

- Students form teams of 2-4 people to work on the projects.
- They choose the topics and type of their projects and consult them with the teachers.
- The work on the projects is divided throughout the course into 6 steps, formatted as separate assignments:
    a. Project description
    b. First prototype
    c. Prototype testing
    d. Needs analysis and scenarios
    e. Project upload (final version)
    f. Project presentation.

Context sample for project-based learning - University of Leon

The Project Based Learning approach at the University of León was carried out in “Web Applications Course”. It is a third year mandatory course for the Computer Science Degree. Teaching follows project-based learning through different projects, some of them individual and some developed in groups.

Projects general theme: Time management and ecommerce improvement

Project assessment: teacher graded.

General organisation:

- Students are assigned 3 projects
- The first project is individual and helps to understand methodology and concepts, the second one is also individual and is focused on time management, and the last one is carried out in groups and deals with ecommerce improvement.
- Each project is segmented in several parts (one part per week)
- Each week students submit progress
- The deliveries are evaluated at the end as the development is incremental
- For the last project it is presented in the class and also evaluated through an exam.

Students feedback about PBL is quite positive, it is not the first time they have been working with the methodology and building the solutions week by week help them to check their own progress.

Teachers have worked several years with this approach and something more critical for them is being able to check not only the final result of the project but students' progress.

Context sample for project-based learning - University of Eastern Finland

The PBL methodology was applied in the course Human Factors of Interactive technology at UEF. The course is part of the Master’s Degree in Computer Science. The aim of the course is to provide the basic knowledge and skills that a designer of interactive technology needs in their work. After

the course students are be able to analyse the interaction between man and machine, for example from the perspective of usability and user experience, understand how usability and user experience goals can be achieved through user-centred design, classify various devices and interaction styles used in human-machine interaction, and design and evaluate simple graphical user interfaces. The course is divided into an introductory week, a review week and four different themes, each of which lasts one to two weeks. Each section contains 20 independent study tasks that must be returned by the given deadlines. Assignments build up to the completion of a final project that deals with the design and evaluation of graphical user interfaces. The course does not have a final exam, but rather students are graded based on their progress throughout the weekly tasks and the final result of the final project.

Context sample for project-based learning - Belgrade Metropolitan University

The project-based learning approach at the Belgrade Metropolitan University was carried out in the “Computer Organization” course. This is a first-year mandatory course for the Information Technologies and Software Engineering degrees. Teaching follows project-based learning through different individual projects.

Project’s general theme: CPU Architecture
Student feedback: individual progress reports, individual assessments
Project assessment: teacher graded
General organisation: Students are assigned 2 projects during the semester

The first project is individual and helps students to understand the basic building blocks of modern processors. The second project is also individual and is focused on identifying improvements to old and new central processors with the usage of parallelism.
Each project is segmented in several parts. Students are all introduced to the general topic of the Processor Architecture, and through continuous decision the teacher drove them with different questions and pointed them to narrow down their project activities starting from basic architecture design, general characteristics and properties, processor benchmarking. Each week students submit progress reports through the LMS. Progress reports were graded by the professors, for the easier tracking of student progress and work, and at the same time for students to have continuous feedback. The first project was carried over five weeks, and the second project was carried over the remaining ten weeks in the semester.
The deliveries are evaluated at the end (first project at week 6, and second project at week 15) as the development is incremental. For both projects, each student presented their project in class with a discussion with the professor and other students. Projects were presented in weeks five and fifteen.
Students’ overall feedback about PBL was overall positive. This was their second time dealing with PBL, as they had a pilot course the previous semester. Mandatory weekly reports helped them stay on track and professors used them to check student progress and, when needed, give early correction suggestions.
For the professors and TAs, one group had previous experience with PBL and one did not; however, constant mutual communication between all professors and TAs ensured conducting PBL during this semester with no critical issues.

Context sample for flipped classroom - Sofia University

In the ILEDA project the flipped classroom approach was used in the elective Bachelor degree course “E-Learning”. The course “E-Learning” is taught mostly to students in Software Engineering, Software Technologies, Informatics, and Computer Science bachelor programmes, and to some students of the “Mathematics and Informatics” teacher preparation bachelor programme. The attending students are senior bachelor students in their 3rd or 4th (final) year of study. The average annual enrolment in the “E-Learning” course throughout the years is about 80 students each year [8]. 74 students took part in the pilot ILEDA flipped learning course. The course characteristics in the “normal” (not flipped classroom) mode are described in [9]. The course was delivered in the second semester of the academic year (February - June 2023), four hours per week distributed equally for lectures and practical work.

Application of flipped classroom methodology

We started to apply the flipped classroom approach during the COVID-19 pandemic [10]. When for the academic year 2022-23 we returned to the “normal” face-to-face course delivery, we continued to apply the flipped classroom mode with some necessary changes as to the previous entirely online mode of study. The flipped classroom methodology that we applied in 2022-23 is described in [11].

The theoretical knowledge of the course is acquired by means of flipped classroom methodology by providing in advance of the lecture materials (lecture notes, presentations, short preliminary quizzes, and external web readings and video materials). We added to the most important new themes by one short preliminary quiz to ascertain whether the students studied and comprehend in advance (before the lectures) the main materials for the new themes. The short preliminary quiz is an “open textbook” quiz. The marks, obtained in all preliminary quizzes form in total 10% of the final course grade.

During the class sessions, we conducted short discussion on the new theme and answered questions for about 10 minutes. The rest of the lecture time we used for interactive learning activities and exercises (group and individual tasks – active learning sessions, group work on different new topics, in-class exercises and assignments). After the class sessions students received home assignments on the studied topic, and a new short quiz for the next topic were opened, alongside with the materials for the new, next week, theme.

The following innovative teaching methods were used within the flipped classroom we conducted:

- All study materials - available online;
- Division of students into small groups for in-class discussions;
- Division of students into small groups for short assignments in class;
- Division of students into small groups for homework assignments;
- Work in teams on particular parts of the course final group project;
- Short preliminary online quizzes in Moodle, administered prior to each theme;
- Short homework writing assignments in Moodle, to hold students accountable.

Summary

Our conclusions for using the flipped method are that we gain the following benefits:

- More time in class to deepen the student understanding;
- More time for in-class activities, exercises, practical assignments, and problem solving;
- More personal interaction (more or less advanced) with different students;
- More groups’ and teams’ interactions, activities, and collaborative work;

- More time for teacher’s feedback to the students;
- More time for in-class discussions;
- Improved communication with students and between students.

In summary: True deep student learning is the main gain from the flipped classroom application.

Context sample for flipped classroom - University of Leon

The flipped classroom approach was applied to the mandatory second year course “Computer Architecture” of the Computer Science Degree. This subject aims that the student learn and understand computer architecture fundamentals and also their main components and that they know and apply methodologies and tools to estimate and compare computers performance. It is a second semester subject and has a theoretical part with weight of 50% of the grade, a practical part with a weight of 30% of the grade and exercises with the remaining 20% of the grade. One of the main problems of the subject is that students do not read the assignments explanations and they try to solve them just with what teachers tell them during the classes, so the practical classes fit very well with the idea of applying flipped classroom methodology. The practical part has 6 themes with 6 assignments that are developed during the 15 classes of the semester.

Given this context, the flipped classroom approach was designed for the practical part of the course. The implementation of the flipped classroom approach was done as follows:

1) Teachers developed contents for each of the sessions. They were mostly short videos explaining the sessions and the concepts to develop the assignments, some documents and questionnaires to evaluate if students have seen the videos and understood the concepts.
2) Students should view the videos before class and at the beginning of the sessions they fulfil a questionnaire about such videos.
3) With the information of the questionnaires teachers can check if students were or not seeing the videos and understanding the concept, so in class if some concept was not clear they spend some time explaining it deeply.
4) During classes students work on the assignment with teachers feedback and upload partial results of the development carried out.
5) At the end of each of the 6 assignments, students upload the whole version and complete a knowledge questionnaire about it. In this way it is possible to evaluate the final outcome for each assignment.

For the methodological application in the course 25 documents, 16 videos, 12 questionnaires and 6 assignments were developed. In addition external materials were also included.

Regarding the feedback with this methodology students felt very happy having the videos to check what they need to do and how to do it, but they argue that they have to complete too many questionnaires.

Teachers found the preparation of the course time consuming, especially with all the new contents but they understood the work was ready for next course editions. They have also seen that to pass all the questionnaires is not necessarily related to passing the practical part of the course. It is necessary to point out that this academic year, applying the methodology we have detected an improvement of 0,5 points in the general grade of the subject.

Context sample for flipped classroom - University of Eastern Finland

Flipped classroom was applied to the course “Advanced data management systems”, part of the Master’s Degree in Computer Science. The aim of the course is to teach students advanced topics in databases such as query optimization, NoSQL and security aspects. There are a total of 7 topics in the course. Practical assignments make up 70% of the final grade (10% each). The remaining 30% is obtained through a final project that students need to work on by themselves. The methodology was carried out as follows:

1. Teachers develop a slides deck, a video with the explanation of the slides, a self-assessment quiz, and a practical assignment every week and upload it to Moodle.
2. Before each lecture, students’ have to watch the video and, once they are comfortable with their knowledge, they take the quiz.
3. During the lecture, the teacher explains the practical assignment and shows how to solve the first half of it in an interactive way with students’ input.
4. At home, students need to complete the assignment on their own in a period of 2 weeks.

Teachers found this methodology quite demanding since it required a lot of pre-class preparation of the materials, especially since it was the first year the course was taught. However, the teachers are happy that the materials can be reused in the next year.

Students were satisfied with the methodology since class time was used in a more productive manner and they could always consult the explanations of the theory in the videos. Their main concern was about the deadlines for the assignments. Several extensions were given during the course and some students that turned in everything in time expressed that they thought that was unfair and that a penalty should be applied if the deadline was extended.

Context sample for flipped classroom - Belgrade Metropolitan University

At Belgrade Metropolitan University flipped classroom approach was implemented in the course Computer Networks. This is a mandatory course for the student studying the bachelor academic program Information Technology. The aim of this course is to teach students fundamentals about networking and networking protocols. This course covers 15 lessons, and contains both lectures and lab exercises. For the purpose of this piloting, flipped classroom methodology was implemented for the lectures portion. The following methodology was carried out:

- Students were given full materials for the lesson ahead of time. However, students were assigned with a set of questions at the beginning of the lesson in order to focus them on the specific material within the lesson. This was done due to the previous experience when students did not attend to reading the entire lesson, but focusing them to approximately 5 questions, they were then looking for the particular answer in the material.
- Lessons that were given to students contained videos, instructional materials, self-assessment tests, solved problems, assigned problems for individual works, homework assignments, and forums.
- Students were asked to write down their answers to the asked questions or posed problems to solve. Students submitted their answers to LMS. Teacher read and graded student answers. These answers served as their “ticket into class” assessment. If the answers were not satisfactory, students had an obligation to redo them.

- Within the class, discussion was formed around the misconceptions students had in their at-home activities, and also the material not covered with at-home questions were also covered.
- After the discussion and instructional teaching, students were given breakout activities. These activities varied from week to week, and sometimes were individual, while another times they were group activities.
- Each activity was assessed, mainly by teachers, but the peer-assessment method was also used. The assessment of breakout activities served as a “ticket out of the class.”

The entire experience was positive, for both students and teachers. Reading the answers and giving the feedback was time consuming, but it gave students a feeling that they were known, but also served as a motivation to do a good job. On the other hand, obstacles for the posed activities were within applications such as chatGPT, where students generated the answers rather than identifying their own answers from the lessons. These were, of course, the instances when the assignments were returned to students, because the generated answers were factually incorrect. Due to their excitement about the new technology, the last two activities were changed on the fly and students were asked to consult with chatGPT for answers, but to give their critical point of view about the given answers.

2.4.4 Lessons learned from the piloting

The LA-supported teaching methodologies implemented in the ILEDA Erasmus+ project were implemented in 9 different courses in four participating Universities of the ILEDA project, out of which 4 courses conducted flipped classroom model and 5 courses implemented project-based learning teaching methodology. At the end of the piloting, students and teachers were asked to fill out the survey questionnaire on the volunteer basis. In total, 859 students attended the pilot courses, while 133 student and 11 teacher responses were collected. In this section, we point out only some main findings, while detailed analysis can be found at

https://drive-cist.fmi.uni-sofia.bg/index.php/s/yTbcQ3CpBzZMbA9

Students pointed out several strengths of the implemented methodologies. For the project-based learning, students’ mentioned the ability to gain practical knowledge, working with real-life technology, receiving feedback from the teacher, and having weekly deadlines and questionnaires. For flipped classrooms, students mentioned the flexibility for accessing and studying the learning materials (especially the videos), and solving practical exercises and doubts in the classroom.

Students highlighted some challenges of the methodologies. For project-based learning, students highlighted the difficulty of applying the knowledge acquired in practice, dealing with conflicts in the group projects, and having to resort to external resources to solve some of the technical difficulties of the project. For flipped classrooms, students highlighted time management issues when estimating the duration of the activities and preparing the learning materials, and delayed feedback on the weekly assignments. Some students pointed out that it is challenging to follow the flipped classroom methodology if you are not already highly motivated to complete the course. This points out to the necessity of teaching active involvement in giving regular and timely feedback to students, otherwise they may lose motivation to be proactive and engaged in their work.

Students were asked for suggestions to improve the methodology. Project-based learning students asked for the learning materials to be uploaded with more time in advance, having more Q&A sessions, rewarding participation, mixing students of different levels in the same groups, and giving

more early feedback on the project work. Flipped classroom students suggested having flexible deadlines with a penalty system to avoid procrastination, and providing weekly feedback.

Overall teachers rated the experience as very positive. They mentioned the flexibility of flipped classrooms for students who have a job, and the advantage of giving continuous feedback in the case of project-based learning.

When talking about the main challenges, the teachers mentioned that developing the learning materials (especially for the flipped classroom) from scratch was very time consuming but hope to be able to reuse the materials in the next iterations of the course. They also highlighted that some students were not mature enough to accept these methodologies that require a lot of independent work. One teacher mentioned the central role of AI technologies (e.g., ChatGPT), which makes assessment more challenging and learning less motivating for students.

When it comes to positive aspects of the ILEDA approach, teachers highlighted less synchronous lecture-based teaching in favour of more individual work from students. The role of the learning analytics monitoring of weekly activities was also highlighted as a way to follow students more closely and identify knowledge gaps, at the expense, of course, of more time from the teachers.

Teachers disclosed how they are planning on improving or adapting their teaching strategies for the next semester based on their experience with piloting. One teacher pointed out enforcing that everyone has seen the weekly lectures before attending the face-to-face lesson in flipped classroom. Another teacher suggested implementing project-based learning in more advanced courses. Making students’ role in planning and organising their work more central was also highlighted, as an important part of self-regulated learning.

There were several lessons learned from the piloting experience. For example, one lesson was that flipped classrooms require discipline to follow weekly so it might benefit from hard deadlines. Another lesson is that students liked mixing at home and in-class activities. An important remark was that students in the upper grades would benefit from this approach more. Students might be reluctant to adopt the methodology at the beginning but end up liking it in the end.

Some aspects for improvement were highlighted such as collecting data from more sources than Moodle, for example, Youtube, or satisfaction surveys. At the same time, teachers highlighted the need for more support in interpreting the analytics dashboards.

3. Tools for learning analytics for student monitoring

Learning analytics is a rapidly growing field that aims to improve student success by using data-driven approaches. In this document, we provide comprehensive guidelines and recommendations on how to apply learning analytic tools effectively across different educational contexts. We will discuss the necessary steps to understand the context, how to decide what to measure, the possible tools available and the possibility to apply the learning analytics ecosystem defined during the project.

3.1. Understanding the Learning Analytics Context

When selecting a learning analytics tool for the educational institution, educational context and the context of applying learning analytics should be considered. Several key factors should be

considered: what should be measured, the access to the data, the privacy policy of the institution, the possibility to implement learning analytics tools depending on openness and flexibility of the institutional Learning Management Systems as well as institution policy on allowing these changes, etc.

This means that we need to reflect about the application context. Within the ILEDA project, institutional teaching context has been addressed through several course examples within PR3 and that was done through the use of a template
https://drive-cist.fmi.uni-sofia.bg/index.php/s/aNZ8PD4FCM6LCfb

Taking into account institutional context, it is possible to understand the context attending to the following issues, which should be considered in any LA tool implementation:

- **Technological systems employed.** It is necessary to be familiar with what technological institutional systems are used. For instance, LMS, educational tools, communication tools are available for both the teachers and the students. It is necessary also to understand if these tools are interconnected.
- **LA tools currently available.** Currently available LA tools should be identified based on their availability and their functionalities for different institutional roles (teachers, managers, students, etc.). The selection of tools depends on the specific application level in the technological educational ecosystem, and considering the inclusion of diverse tools such as dashboards, reporting tools, query tools, etc.
- **The institutional LA policy.** Prior to the implementation of LA tools, institutional protocols and policies to track students’ progress, teachers’ activities, content use should be assessed. and so on is something to take into account before applying any LA tool. Understanding the university's stance on supporting LA initiatives is essential. While a compelling tool for exploiting and presenting student logs may be available, its application may be restricted if the university prohibits the installation of such tools. In a case that the university does not have such a policy, one should be established, and its protocols should be followed.
- **Data access policy.** Data access policies and data protection laws should be investigated and well understood for the subsequent data access and analysis such as what part of the students’ and teachers’ activities can be stored, the extent to which data will be accessible for further analysis, and the necessity for data anonymization. This policy can be defined at different levels, from the university-specific regulations to compliances with European, local, regional, or national laws. When using the external applications for learning analytics process, it is important to know if the data collected from external applications can be seamlessly integrated and analysed within the institutional framework.
- **Possible application scope.** As previously mentioned, application of learning analytics requires clear identification of application level. The objectives of learning analytics at the institutional level may be significantly different from the objectives from a course or an activity level. This Identification is necessary for the definition of metrics or to explore metrics in a proper context. For an institution it could be interesting to explore the first-year students dropout rate, whereas teachers could be interested in investigating the correlation between this rate and the hours invested on the platform..
- **Ethical policy.** When using student learning data for tracking student progress, or in general in their learning process, it is necessary to consider ethical policies. Typically, ethical guidelines are established at the institutional level.. If any restrictions are in place for using

some or all learner data due to ethical reasons, this should be considered, especially at the beginning of the application of LA.

- **Expert support.** Implementation of the learning analytics tools and process will in large part depend on the expert knowledge needed for accessing the data, generating the reports and installing and integrating learning analytics tools. It is desirable to have a technical team to support teachers and staff members in this process, as well as to have a team with a data science background that can help the teachers to understand or to better explore the data.

Once the context is understood the next step will be to define the LA approach to develop, taking into account your context features.

3.2. Definition of the Learning Analytics approach

In order to carry out any Learning Analytics approach it is necessary to state an clarify at least the following issues:

- **Define aims and scope of the needed analysis**. It is necessary to understand the problem that needs to be solved and define the aims that should be addressed with data analysis, specifically, learning analytics. This issue is closely related with the “application scope” addressed in the previous section. Some of the possible scope levels that may be considered are: activity level (in a specific course), course level, inter courses, degree level, departmental level, institutional level, etc [12]. In each of these level instances different indicators will be most likely used, and therefore, approaches and tools will be different as well.
- **Data availability.** Understanding data availability is important, especially when considering what data can be used.. This involves identifying which data can be analysed, understanding the nature of the stored data, determining possible values of such data, assessing data availability, and addressing the potential null values, etc. In many cases the generated data is linked to the teaching methodology or to the scope of the planned analysis.
- **Metrics**. Metrics play an essential role in LA. Once the aims, scope, and data understanding are established, the next step is to identify the metrics that will be used in the analysis. This depends on the previous factors and could be related to other metrics. In order to understand which are the best metrics for a given approach it is necessary to answer, at least, the following questions:
    - What are the specifics and aims of the desired assessment?
    - What information, beyond raw data, is available for this assessment?
    - What tools or algorithms can be used to analyse the available data?

  For instance, if the decision is to assess students’ progress, the first step should include defining what is understood by students’ progress, and later assess the available data in order to determine what kind of analysis should be carried out. It should be noted that current and relative literature should be consulted, in order to check how to effectively track students’ progress.

- **Information representation.** Once the metrics are clearly defined, next to consider is how to represent them. We should be able to check the metrics with simple representation that allow us to make decisions at a glance.

- **Possible interventions.** If we have clarified all previous features it should be possible to pose potential interventions. This can be just tentative interventions that later could be updated during the development of our LA approach.

3.3 Evaluating and selecting potential Learning Analytics tools

Once the application context is defined and data are well understood, the next step is to evaluate potential LA tools that will be used. This means following the next steps:

1. Different learning analytics tools should be analysed in regards to their features, cost, ease of use, and compatibility with existing systems. Selected tools need to align with the institution's context. In order to do so it is beneficial to use templates such as the one provided by the project

   https://drive-cist.fmi.uni-sofia.bg/index.php/s/2ppgFxekWS7ejpc

   Necessary information should be compiled including:

   - Link to the tool.
   - Main tool functionalities and interactions with other educational systems.
   - Access to the data. Which data requires the tool to work, how the tool accesses it and what kind of analysis provides.
   - Installation procedures and technological dependencies.
   - Possibility to install the tool in the institutional context and possible reasons why this tool cannot be used.
   - Assessment whether the tool can measure and report what is needed to achieve the defined aims.
   - Possible problems in tool adoption, which should be described considering context-specific features.
2. Tool selection. Decisions on what tools should be selected should take into account compiled information and previously defined LA approach. In many cases, the solution will incorporate more than a single tool and in such situations it is interesting to be able to apply an open LA ecosystem such as the one defined in PR4, with its nature and usage described in the next section.
3. Pre-piloting. Once the tool or tools are selected, it is recommended to carry out piloting of the selected tools before the final implementation. Effective evaluation is better piloted in the small settings, which allows for solving any issues and making necessary adjustments.
4. Training. After the pre-piloting, educators, managers and/or students should be trained on how to use the tools effectively. Ensuring that all stakeholders understand the tools and their benefits is crucial for successful implementation.

3.4 How to use a potential Learning Analytics ecosystem

Sometimes the main difficulty in applying a LA tool lies in implementing it with the minimal impact on the institution, allowing the person in charge of the LA approach to leverage the functionalities of one or several LA tools. This requires in many cases defining ad-hoc tools. The problem of such tools is specificity to a particular LA approach, and making it challenging to scale employed efforts to other contexts. Potential solution that will avoid this issue is to use standards

and specifications and to employ not just a single tool but an entire LA analytics ecosystem. During the ILEDA project, a LA ecosystem tailored to the ILEDA LA framework was defined [5].

For Learning Analytics one of the potential standards to apply is xAPI. xAPI is a new specification for learning technology that makes it possible to collect data about the wide range of learner activities (online and offline). The Experience API (or xAPI) is a relatively new specification for learning technology that makes it possible to collect data about a wide range of learning experiences a person has (online and offline). This API captures data in a consistent format about a person or group’s activities from many technologies. Very different systems can securely communicate by capturing and sharing this stream of activities using xAPI’s simple vocabulary [13].This technology allows the definition of a tool that can collect information from the LMS but also from other data sources, so using it in LA guarantees an open solution, not only in the sense of open-source software but also in the sense of including new technologies or data sources. Implementing xAPI requires sending students’ data to a Learning Record Store (LRS), “a server (i.e. system capable of receiving and processing web requests) that is responsible for receiving, storing and providing access to Learning Records” [14]. Figure 1 shows a graphical description of xAPI application.

Fig 1. xAPI description

xAPI application requires a certain level of LMS adaptation in order to include this specification. Most commercial LMSs include supported plugins that can be easily downloaded and adapted [5].

Using xAPI also requires choosing a LRS. The LRS stores all e xAPI statements, and also, in some cases, allows the users to define visual representations of the stored data. Within the ILEDA project an analysis of different open-source LRS systems was carried out. This analysis considered 26 options (https://adopters.adlnet.gov/products/all/0), and the final decision was to use Learning Locker as it fitted in with the project’s requirements, has a well-maintained Moodle Plugin, and is easy to modify.

In order to follow a similar approach it is recommended to follow the next steps:

1. Check which LMS is being used and if it supports xAPI (if yes go to step 3).
2. If not, develop an xAPI wrapper to send your LMS learning evidence to a LRS.
3. Choose an open source LRS, install and deploy it.
4. Connect the LMS xAPI plugin/wrapper to the LRS.

5. Forward elearning evidences to the LMS.
6. Define Dashboards to explore the LRS stored data (some LRS such as Learning Locker facilitates this with open visualisation libraries such as re-charts).

3.5 Application of our Learning Analytics Approach

The application of any Learning Analytics approach is a cyclic process that requires several steps. A description of these steps are those proposed by Chiatti et. al. [15] that can be seen in Figure 2. This means first step is collecting and preprocessing data, so later data can be used for further analysis; after that, data is analysed using one or several LA techniques and presented to define if it is answering to the goals of the analysis; and finally postprocessing of the data to enrich followed approach in different cycles.

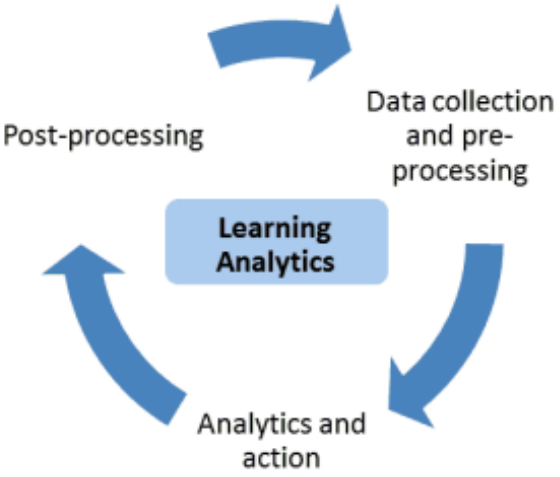

Fig 2. Chiatti et. al. Learning Analytics process

Adapting this cycle from the ILEDA project’s experience it is recommended to follow the next steps:

- **Collect relevant data**: Gather comprehensive data that aligns with defined LA approach and institution's goals.
- **Analyse the data**: Apply various analytics techniques to identify patterns or trends in the students’ behaviours that may indicate potential issues or areas for improvements. This data analysis should be ongoing and systematic.
- **Interpret results**: Analyse collected data by considering it within the context of your institution's goals and objectives. Identify the fields that can drive improvements.
- **Develop interventions**: Create data-driven strategies to support struggling students or enhance the overall experiences of learners.
- **Monitor progress and adjust as needed**: Regularly review data from learning analytics tools and make changes if needed. This iterative approach ensures that your institution remains responsive to students' changing needs. Continuous improvement is key.

By following these extended guidelines and recommendations for the framework application in different educational contexts, institutions can effectively benefit from learning analytics tools to monitor student progress and improve overall learning. By selecting appropriate technologies, adopting them into existing systems, and utilising data-driven insights, educators can create

personalised learning experiences that support the diverse needs of all students. This holistic approach to learning analytics empowers educational institutions to adapt, innovate, and enhance the quality of education they provide.

4. How to understand and interpret collected learner data

Learning management systems and other educational tools collect vast amounts of data on students' interactions with course materials, assignments, discussions, and other activities. Once raw data from learners have been extracted from such tools, it is necessary to derive useful information from the data in order to gain relevant knowledge to better understand and support students and teachers. Frequently, simple visualisations and data aggregation (counts, percentages, means, etc.) are enough to gather meaningful insights, although on occasions, more complex statistical methods are needed to test hypotheses and prove theories. Regardless of this, the most important aspect when analysing and interpreting the data is to understand it in the context in which it was captured to be able to derive accurate conclusions. This of course is inline with the context of the teaching in the institution and the course, as well as the defined aims of the analytical approach and identified indicators, as mentioned in the previous sections. As such, when analysing the data for a given course, it is crucial that the instructor interprets the data in light of the learning design of the course and the technological constraints of the online learning environment.

4.1 Theoretical lens

There are several lenses from which we can analyse students’ trace log LMS data according to the course implementation and to our objectives as teachers, researchers or other stakeholders. Below we provide the main learning theories that we can use as a lens for analysis.

Behaviourism: Behaviorism is a learning theory that focuses on observable behaviours and the contextual factors that influence those behaviours. When analysing LMS log data from the perspective of behaviourism, the emphasis is on identifying and understanding patterns of behaviour, reinforcement mechanisms, and the impact of external stimuli on learning outcomes. The most basic analysis examines the frequency, duration and periodicity of student interactions with the LMS. Behaviorism suggests that repeated interactions with learning materials contribute to the reinforcement of learning. Furthermore, behaviourism suggests that responses to stimuli contribute to the formation and modification of behaviours. As such, it is key to understand how different stimuli and reinforcement patterns such as prompts, cues, and feedback have an impact on students. Lastly, analysing assessment scores and performance data provides a measurable indicator of the effectiveness of the learning experience, as behaviourism places importance on observable outcomes and assessment scores.

Engagement: Engagement has been referred to as the holy grail of learning as it is a crucial determinant of students’ success. Engagement can be roughly defined as the energy that students put into learning. In blended or online learning environments, log data serves as a proxy to measure how students engage with the available learning resources and tasks. Of special relevance is to analyse the temporal patterns of engagement. For instance, examining whether engagement patterns follow the course planning is crucial to detect students who are lagging or those who may drop out. For example, in the specific case of flipped classroom, examining the LMS data can be useful to identify whether students are meeting the requirements (e.g, watching a video lecture) before each

face-to-face session. In project-based learning, the data allows to understand if students are progressing through the project’s milestones and accessing the recommended learning resources.

Learning strategies: Learning strategies can be defined as the set of student’s behaviours intended to impact how information is processed. When it comes to LMS data, the choice of learning resources —as well as the order, transitions, and temporality with which they are consumed— can greatly influence the learning process. Hence, analysing such patterns, teachers can identify whether certain behaviours are associated with positive outcomes. Understanding the sequence of resource consumption can provide insights into the strategies students employ to build on previous knowledge, highlighting the relevance of sequencing in the learning process.

Self-regulation: Self-regulated learning (SRL) —understood as students’ ability to understand and control their learning environment— is an important skill that helps students plan their learning tasks, monitor their progression, reflect on their performance, and adjust according to circumstances. Transferring SRL skills between courses helps students acquire lifelong skills that accompany them beyond formal education. SRL is commonly considered to have three main phases: forethought, performance and self-reflection. According to students’ access to the different resources available on the LMS, instructors can assess whether students are enacting the three SRL phases. For example, consulting the calendar or the learning objectives of the course may indicate that students are planning their learning activities (forethought). Opening the learning materials and working on the assignments and exercises is an indicator of performance. Using self-assessment resources or consulting the feedback received from the teacher are signs of self-reflection.

Socio-constructivism: Socio-constructivism is a learning theory that emphasises the importance of social interactions and collaborative activities in the learning process. It posits that knowledge is constructed through social interactions and that learners actively engage in the learning process within a social context. When analysing LMS log data from the perspective of socio-constructivism, one can focus on aspects that reflect social interactions, collaboration, and the construction of knowledge within the online learning environment. If the course under analysis includes collaborative activities —as is often the case in PBL—, students’ interactions in discussion forums, wikis or other similar tools can provide very valuable information on knowledge building as well as team dynamics.

Cognitivism: Cognitivism is a learning theory that focuses on the mental processes involved in learning, such as memory, perception, problem-solving, and information processing. Hence, when analysing student data from the perspective of cognitivism, the emphasis is on understanding cognitive processes, the organisation of information, and how learners actively engage with and process information. Cognitivism suggests that the time individuals invest in processing information can be indicative of cognitive engagement and effort. Hence, from LMS data, we can examine the time spent on specific tasks within the LMS to determine how challenging they might be to students. Moreover, we can investigate which learning resources (e.g., documents, videos, quizzes) students access the most. This can offer insights into their preferences and the types of information they find most valuable to aid their cognitive processes. Lastly, indicators of cognitive engagement can be identified within the log data, such as active participation in discussions, thoughtful responses to prompts, or evidence of critical thinking.

4.2 Analytical methods

From the previous section, one can derive that many forms of data analysis are shared by multiple theoretical lenses. In this section, we highlight the most relevant analytical methods according to the purpose they can be used for:

- **Measuring resource usage:** Descriptive statistics to represent the information and inferential statistics to statistically compare between items or students.
- **Understanding the sequence of learning activities**: Sequence analysis can be used to represent the sequence of clicks on the LMS and detect distinct patterns of interaction
- **Mapping the temporal learning process:** Process mining can be used to visualise students’ learning process and map the frequency and timing of the transitions between learning activities. Moreover, conformance checking can be applied to compare students’ enacted process to the one designed by the teacher
- **Inspecting group interactions:** Social network analysis methods are commonly utilised to analyse group interactions, since they allow to identify the most influential contributors to the discourse as well as isolate nodes. Moreover, community detection algorithms can be used to detect subgroups within the broader network that are more likely to collaborate with one another.
- **Conversation analysis:** If we are more interested in what is being said rather than in the relationships between students, epistemic network analysis can be used to analyse topic co-occurrence during conversations in order to evaluate which topics are often discussed together.
- **Tracking score evolution:** Growth models can aid in representing students’ progress towards their final grade by representing score as a function of time.

The aforementioned methods are not often utilised in isolation but used in combination with other methods to serve a broader purpose. Below are some examples:

- **Measuring student progress**: What constitutes “progress” depends highly on the course context. It can be engaging with certain learning materials, completing a series of tasks, achieving a passing score, or a combination of all. There is no single method for measuring such progress, but rather a combination of the above-mentioned methods can be used to measure whether students’ are on the right track towards academic success.
- **Detecting heterogeneity in students’ profiles**: From resource usage, sequences of activities, or positions in the networks —among others—, we can use clustering techniques to identify distinct students’ profiles that share some characteristics among them but differ from the rest of profiles. Both dissimilarity-based techniques (e.g., k-means, agglomerative hierarchical clustering) and model-based ones (e.g., latent profile analysis) are used for this purpose. Clustering is extremely useful to create targeted interventions for groups that present undesired behaviour, e.g., to prompt isolate students in discussion forums to be more participative.
- **Predicting outcomes:** One of the most common goals of LA since the inception of the field has been to predict students’ outcomes, or students at risks of dropping out. Engagement patterns, strategy use, and early assessments are often operationalized as predictors of academic success. Machine learning methods such as regression, decision trees or neural networks are used with this purpose.

4.3 Limitations of LMS data

Although LMS data allows to collect fine-grained information about students’ online learning activities in an unobtrusive way (i.e., without disturbing students’ learning), it presents several limitations that need to be taken into account at the moment of analysis. The most obvious one is that the LMS doesn’t capture the activities that happen offline which, especially in blended teaching, can take a significant share of student activities. Moreover, even if a student “clicks” on a link to a learning resource, it does not mean that he or she is consuming the resource. LMS data are still considered an acceptable proxy of online behavioural engagement, but are missing other key aspects such as emotional engagement, which can be evaluated through surveys and interviews. Such aspects are key when analysing the data from more human-centred theoretical lenses such as humanism or andragogy, which are commonly applied in adult education. As such, LMS data should be interpreted in combination with other sources of data to get a more accurate picture of students’ learning and the factors that influence thereof.

5. General ethical guidelines that need to be considered when using learner data[16]

In order to safeguard the personal data and privacy of the students the following points outline privacy policies within the ILEDA project should be taken into consideration:

1) Support and Guidance: LA presents a valuable opportunity for partner universities to provide valuable support and guidance to the students.
2) Data Protection Regulations: The learning analytics policy fully aligns with the European General Data Protection Regulation (GDPR) to ensure data protection and privacy compliance.
3) Implementation Process: The implementation of LA is an adaptable process that evolves through feedback from stakeholders to allow for continuous improvements and refinements to better achieve the intended goals.
4) Data Collection: Data collected about students does not serve as official records of their academic achievements or work and will not be used for assessment purposes.
5) Transparency: ILEDA is committed to maintaining transparency in the data collection methods, types of data collected, and data processing techniques.
6) Consent: Students will be informed about the objectives, limits, and extent of actions taken based on data and LA.
7) Validity and Accuracy: ILEDA acknowledges the potential limitations in the data collected and analytical methods. Thus, ILEDA is dedicated to enhancing data validity and accuracy.
8) Zero-Tolerance Policy: ILEDA maintains a strict zero-tolerance policy against profiling students based on data related to abilities, gender, race, religion, or socio-economic status.
9) Opting out of Programs: While opting out of core data services is not possible due to their integral role in enrollment and record-keeping, students will have the option to opt out of programs or interventions based on learning analytics.
10) Data Anonymization: Whenever data is processed, anonymization will be prioritised, and access to students; private data will be strictly limited.
11) Protection of Non-anonymized Data: Non-anonymized data will not be shared, transferred, or handled by third parties without explicit consent from the students.
12) Ethical Approval: Any usage of data beyond the scope defined by partner universities will require separate ethical approval or informed consent.

13) Involvement of Student Representatives: Students; representatives are integral to the process of formulating and establishing policies for data collection, usage, and implementation.
14) Informing Students about LA Services: Students will be informed about LA services during the enrollment process and given the opportunity to consent to additional services not covered in this policy.

6. Conclusion

Blended and online learning has demonstrated its necessity and benefits in educational systems.

This necessity has become evident through the requirement for flexible teaching modalities applicable to various settings, study fields, and learning styles not only within a single country but also on an international scale.

This precisely aligns with the objective of the ILEDA project, which addresses numerous challenges in online and blended teaching while considering the needs and requirements of different institutions in four different countries, particularly in collecting and analysing student data using learning analytics.

One pivotal component of this project, and perhaps one of the main challenges, was finding solutions that benefit all participating institutions while identifying patterns, common challenges and solutions.

7. References

[1] Blumenfeld, P.C., Soloway, E., Marx, R.W., Krajcik, J.S., Guzdial, M., Palincsar, A.: Motivating Project-Based Learning: Sustaining the Doing, Supporting the Learning. Educational Psychologist 26, 369-398 (1991).

[2] Nichols, M., Cator, K.: Challenge Based Learning. White Paper. Cupertino, California: Apple. Inc (2008).

[3] Savery, J.R., Duffy, T.M.: Problem-Based Learning: An instructional model and its constructivist framework. Educational Technology 35, (1995).

[4] Flipped Learning Network (FLN). (2014) The Four Pillars of F-L-I-P™ Reproducible PDF can be found at www.flippedlearning.org/definition.

[5] Conde, M.Á. et al. (2023). Definition of a Learning Analytics Ecosystem for the ILEDA Project Piloting. In: Zaphiris, P., Ioannou, A. (eds) Learning and Collaboration Technologies. HCII 2023. Lecture Notes in Computer Science, vol 14040. Springer, Cham. https://doi.org/10.1007/978-3-031-34411-4_30

[6] Fleming, D. S. (2000). A Teacher's Guide to Project-Based Learning. Scarecrow Education, Attn: Sales Department, 15200 NBN Way, PO Box 191, Blue Ridge Summit, PA 17214

[7] Zafirova-Malcheva, T., Boytchev, P., Stefanova, E., Mihnev, P., Stefanov, K., Inclusive Education Course Design for Informatics Teachers, BCI'19 Proceedings of the 9th Balkan Conference on Informatics, ACM International Conference Proceeding Series, Publisher: ACM,

New York, NY, USA, 2019, pages:1-4, ISSN (print): 978-1-4503-7193-3, doi: 10.1145/3351556.3351591, SCOPUS, SJR (0.2 - 2019), ACM Digital Library (dl.acm.org/citation.cfm?doid=3351556.3351591)

[8] Mihnev, P., Zafirova-Malcheva, T., A General Model for Educational Software Design and Development, Proceedings of EDULEARN15, 7th International Conference on Education and New Learning Technologies, editor/s: GomezChova, L; LopezMartinez, A; CandelTorres, I, Publisher: IATED, 2015, pages:4079-4089, ISSN (online): 2340-1117, ISBN:978-84-606-8243-1

[9] Mihnev, P., Zafirova-Malcheva, T., (2016). E-Learning activities in a blended learning mode: experience in teaching computer science students, iCERi2016 Proceedings, editor/s:L. Gómez Chova, A. López Martínez, I. Candel Torres, Publisher: IATED Academy, pp. 7126-7134, ISSN (online): 2340-1095, ISBN: 978-84-617-5895-1, doi:1 0.21125/iceri.2016.0628

[10] Mihnev, P., Zafirova-Malcheva, T., (2022). Higher education courses transformation from blended to entirely remote learning – experiences in time of covid-19 crisis, INTED2022 Proceedings, Publisher: IATED Academy

[11] Mihnev, P., Zafirova-Malcheva, T., (2023). Higher education courses – before, during and after the COVID-19 crisis. INTED2023 Proceedings, Eds: Chova, L.G., Martínez, C.G., Lees, J., Publisher: IATED Academy, pp. 7422-7432, ISSN (online):2340-1079, ISBN: 978-84-09-49026-4, doi: 10.21125/inted.2023.2028

[12] Long, P.D., Siemens, G.: Penetrating the Fog: Analytics in Learning and Education. EDUCAUSE Review 46, 31-40 (2011)

[13] xAPI solved and explained https://xapi.com/ (Last accesed 10/11/2023)

[14] Experience API https://github.com/adlnet/xAPI-Spec/blob/master/xAPI-About.md#partone (Last accessed 10/11/2023)

[15] Chatti, M.A., Dyckhoff, A.L., Schroeder, U., Thüs, H.: A reference model for learning analytics. Int. J. Technol. Enhanc. Learn. 4, 318–331 (2012)

[16] Abdelgalil, M, Privacy principles of Learning Analytics for ILEDA project