## Deliverable 1.3

**PBL_LA Educational Approach**

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This document presents a new educational approach that is proposed, which combines the student-centred Problem Based Learning (PBL) approach with novel developments in the learning domain such as Learning Analytics (LA) and Learning Semantics (LS). This approach, namely PBL_LA, combines each PBL step of the Aalborg University with LA methods and LS and can be mainstreamed to any educational and training domain.

In specific, an abstract PBL_LA framework is designed towards future applications and extensions, which can be used in any sector and discipline. The framework includes three layers, i.e. pedagogical, data, analytics and each layer includes a number of related concepts.

The framework’s concepts are then populated with instances, which comprise the new proposed PBL_LA approach. The
approach describes each PBL step in detail, along with the activities usually performed and the data usually generated. During this presentation, LA methods and interventions that can be integrated are presented, towards exploiting the generated data and providing insights that can enhance the learning process of each PBL step. The PBL_LA approach is examined and presented across the three steps of learning, i.e. course design, course execution and course assessment, so as to provide a holistic overview of how this new approach can enhance the learning experience for both educators and learners.

**Keyword List:**
Problem Based Learning, Learning Analytics, Learning Semantics, educational approach, course design, course execution, course assessment, educational framework
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TABLE 1 LIST OF PBL STEPS AND INDICATIVE ACTIVITIES (KHALID ET AL., 2012) ......................................................... 25
List of Abbreviations

The following table presents the acronyms used in the deliverable in alphabetical order.

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<td>LA</td>
<td>Learning Analytics</td>
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<td>LS</td>
<td>Learning Semantics</td>
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<td>PBL</td>
<td>Problem Based Learning</td>
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<td>PBL_LA</td>
<td>Problem Based Learning &amp; Learning Analytics</td>
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<td>WP</td>
<td>Work Package</td>
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Executive Summary
The overall aim of the PBL3.0 project is to enhance Problem Based Learning (PBL) with Learning Analytics (LA) and Learning Semantics (LS). Therefore PBL3.0 will produce a new educational paradigm and pilot it to produce relevant policy recommendations.

WP1 is responsible for the needs analysis of the project, providing state-of-the art input on the PBL strategy as well as the LA field that will guide the project in constructing the PBL3.0 educational approach. In particular, it aims to:

- Identify all educational data that are generated for each step of the PBL strategy.
- Analyse processes and techniques that transform educational data into meaningful, multi-modal information.
- Identify all intervention mechanisms that could be put into practice based on all LA feedback during PBL3.0 courses’ design, implementation and delivery.
- Construct the PBL_LA educational approach.

The present deliverable is the last deliverable of this WP and aims to exploit the results of the two previous deliverables and, combined with empirical experience, present the PBL_LA educational approach.

The methodology followed in this deliverable includes:

- Study of results introduced in D1.1 “PBL analysis” and D1.2 “LA analysis”.
- Brainstorming of all partners on the results of the aforementioned deliverables and on their possible integrations towards a novel educational approach.
- Design of an abstract PBL_LA framework based on the two previous steps constructed for mainstreaming purposes, so that it can be applied to any domain and any sector.
- Presentation of the PBL_LA approach, which is a detailed population of all concepts of the PBL_LA framework based on all aforementioned work and empirical experience on PBL courses and LA applications.

The PBL_LA framework is comprised of three main layers, namely the:

- Pedagogical Layer, which includes the activities carried out and the evidence produced during each PBL step,
- Data Layer, which includes all data that is generated during learning, i.e. learner – generated, educator – generated, system – generated.
- Analytics Layer, which includes all LA methods that analyse educational data and produce meaningful insights, visualizations and allow interventions for improving learning.
The framework’s layers and concepts are then populated with specific instances that can guide future endeavours of applying PBL in courses and employing LA methods that will exploit the generated data and enhance learning and teaching. More specifically, the PBL_LA educational approach elaborates how each PBL step works, what kind of activities are usually performed by the learners as well as what types of data are usually generated by the learners.

Next, the approach suggests a number of LA methods that can analyse the data and enhance learning. The analysis carried out shows that this support is particularly needed in PBL steps that require learners’ active involvement and engagement such as “Problem formulation”, “Task formulation” and “Problem analysis”. The enrichments of these steps with LA methods and LS can underpin the development of transversal skills (e.g. by allowing learners to communicate their ideas, analyse the formulated problem, participate in brainstorming sessions etc.) and the in-depth comprehension of knowledge (e.g. by allowing learners to discover rich and multimodal content through semantic annotation mechanisms). This new educational paradigm can also support educators by enhancing their courses (e.g. configure their future courses based on the LA insights provided), by enriching their learning materials (e.g. discover additional content that is relevant to the course’s domain through LS instruments) and by improving assessment (e.g. connect learning objectives and outcomes with relevant materials and skills through LS).

The PBL_LA approach is examined and presented across the three steps of learning, i.e. course design, course execution and course assessment, so as to provide a holistic overview of how this new approach can enhance the learning experience for both educators and learners. The suggestions provided aim to guide future endeavours in any sector (academia, business or public organizations) where courses will combine the PBL model with newer concepts such as LA methods and LS techniques. All concepts and instances included in the approach are domain-independent, allowing PBL_LA’s mainstreaming across all sectors and disciplines.

The approach includes representative but not exhaustive insights on how PBL can be integrated with these new concepts and can therefore be extended and expanded in the future. PBL_LA will be the basis for the project’s next steps, as the trials of all partners will be designed and ran based on the approach, thus assessing its validity and appropriateness for application in multiple sectors and domains.
1 Introduction

The aim of this section is to introduce the background of the work pursued with Task 1.3 “PBL_LA approach construction”. The scope and the objective that the current document has set out to achieve are presented in sub-section 1.1. The intended audience for this document is described in sub-section 1.2 while sub-section 1.3 outlines the structure of the rest of the document.

1.1 Scope

The present document is the Deliverable 1.3 “PBL_LA educational approach” (henceforth referred to as D1.3) of the PBL3.0 project. The main objective of D1.3 is to present all preparatory work carried out in order to construct a high quality PBL_LA educational approach. Furthermore, the report elaborates on the actual educational approach and presents all of its features that can be mainstreamed to any educational and training domain.

1.2 Audience

The intended audience for this document is the PBL3.0 consortium, the European Commission, and the public interested in combining the PBL learning strategy with LA methods in their courses.

1.3 Structure

The structure of the document is as follows:

- Section 2 presents the methodology followed in this deliverable.
- Section 3 provides a brief analysis of the main concepts identified and documented in the first two deliverables of WP1 and that were used as a basis for the construction of the PBL_LA approach.
- Section 4 presents the PBL_LA framework and its layers.
- Section 5 elaborates on the PBL_LA framework and approach by describing in detail each PBL step and how it can be enhanced with LA and LS features during course design, execution and assessment.
- Section 6 concludes the document.
2 Methodology

The main goal of this report is to present a pedagogical approach that would enhance and support each PBL step by exploiting the data that is generated towards improving the learning experience for both learners and educators.

Towards this end, two separate in depth literature reviews were carried out on the main topics that are covered by the PBL_LA approach, i.e. the PBL learning strategy (D1.1) and LA (D1.2). Next, a thorough analysis of the main results from each deliverable was carried out. This study aimed to derive the main concepts from each main topic which would be included in the PBL_LA approach.

The aforementioned research led to the construction of a generic framework that will guide the creation of the educational approach. To this end, the following steps on building a framework were followed:

- Choose your topic → Integration of the Aalborg PBL model with LA and LS concepts
- Do a literature review → PBL Analysis (D1.1) & LA Analysis (D1.2) & LS Analysis (Task 2.1)
- Isolate the important concepts → Brainstorming focus groups
- Generate the conceptual framework → Brainstorming focus groups

The last two steps were carried out through discussions and focus group sessions amongst the consortium, which generated a variety of ideas in regards to the content and structure of the approach. Figure 1 shows a representation of the work done towards the creation of the PBL_LA educational approach.

The proposed framework is then broken down and populated per PBL step, where the report details how course design, execution and assessment can be improved through the integration of PBL with LA and LS. The majority of the work documented in the detailed description of the PBL_LA educational approach derives from discussions, brainstorming sessions and empirical experience in PBL courses, LA methodologies and LS across the consortium.
3 Analysis of main concepts

This chapter will include a brief overview of the main concepts identified during the literature analysis for the two main topics related to this deliverable, i.e. PBL and LA. These concepts aim to support the creation of a pedagogical approach that will combine these two concepts as well as LS in order to enhance teaching and training. With this approach, educators will be able to design better courses, help learners during course execution, assess their performance on a more step-by-step manner and take into consideration the assessment results in the next course design. On the other hand, learners will be able to develop skills more easily due to their active involvement in the learning process, absorb knowledge more efficiently due to their engaged involvement with identifying, connecting and synthesizing new knowledge as well as be more confident in their learning abilities due to the ongoing reflection of their progress and feedback provided by the educator and the LA visualizations.

3.1 PBL model steps

PBL is a student-centred pedagogy in which learners learn through the experience of problem solving (Neville, 2009). In Aalborg University, Denmark, all university programs have been based on PBL, also referred to as “PBL - The Aalborg model” (Barge, 2010; Kjærdsam & Enemark, 1994). The PBL - Aalborg Model has become both nationally and internationally recognized and a trademark for Aalborg University.

The steps included in the Aalborg model can be viewed in Figure 2.
Each of these steps will be further described in the next chapters where we will suggest ways for enhancing their operation towards higher quality learning processes and highly educated learners.

Initially, learners form groups in order to work together towards solving a problem. In PBL, teamwork is one of the most important elements, and thus learners need to create a group environment that will increase their motivation to work and produce successful results. The way groups are formed can be varied; it is however usually the learners’ own responsibility to find members of their groups that suit their needs.

Once groups are formed, each group is required to formulate a specific problem to be solved. This problem requires all members to bring forth their prior knowledge and skills, study the generic field of the course and identify issues that would be considered as problems that need solving. The problem formed should be straightforward enough that it can be solved within the designated timeframe and complicated enough that it would require analysis, design, implementation and evaluation of a robust solution.

The next step regards the formulation of tasks, where the problem is divided into small tasks and members of the group are assigned specific responsibilities for realizing these tasks. Within this step, learners take different roles and are introduced to additional skills such as project management, leadership, communication of ideas etc.
Problem analysis follows, where learners usually gather data on the problem they are investigating, analyse the information they have gathered and make specific decisions that lead to the design of the strategy for the solution of the problem they formulated.

Once the problem is analysed and a suitable solution has been designed, groups move towards the actual implementation of the solution. This implementation is then applied for validation and evaluation with different means, such as usability tests, interviews, technical tests etc. The results of the evaluation are recorded and learners form the assessment of their work.

Finally, learners report their project work where they formulate their conclusions and propose future work for their problem.

### 3.2 LA analysis

Based on the most commonly cited definition, “LA is 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.” (Long & Siemens, 2011).

The LA steps that were identified through the thorough research of LA frameworks and models can be viewed in Figure 3.

**Figure 3 LA steps**

The data gathering phase regards the selection and acquisition of educational data for their further analysis. Initially, the educational objectives should be set and defined, so that the data gathered will be in line with these objectives. It is important that we know what we want to achieve because that will guide us towards realizing what types of data are required that will help us reach our goals. Decisions made during this step include the data sources, data formats, data volume etc. Once the data is selected, it then is collected and stored into one or multiple data stores for future processing.

The next step in the LA lifecycle regards all operations carried out to the stored data so that they are transformed into appropriate formats for further analyses. Such operations can include cleaning of the data so that it includes only relevant and wanted data for analysis, aggregation for combining different datasets that will be appropriate for more homogenous results, transformation for changing the data structure so that it becomes more in accordance to the set objectives etc.

The next step regards the actual analysis of the stored and processed data, which can be carried out with multiple LA methods. Representative examples of LA methods are social network analysis, user modelling, patterns analysis, knowledge domain modelling etc. Specific techniques and tools are
available to support these kinds of methods that can process raw data and produce valuable insights.

Once the data is analysed, there are various ways in which they can be visualized so that they make sense to the stakeholders. Some of the most commonly visualized information regard:

- Learner activity
- Learner navigation pathways
- Learner interactions
- Learner interim scores
- Learner engagement levels
- Comparison amongst groups progress
- Hints, alerts and other scaffolding mechanisms (e.g. suggestions on learning materials)
- Common mistakes
- Learner profiles in accordance to their learning style, ongoing progress and recorded needs

The types of visualizations and their content are important because they provide meaningful information to the educators and learners that can improve their learning experience. If the visualization does not provide any insights on a learner’s progress then it provides no added value to learning.

The last phase of the LA lifecycle regards specific actions taken to achieve the set educational objectives. These include different enhancements in the learning process that improve course design, execution and assessment.

Relevant operations can be categorized into six main categories:

- Predictions and interventions. This regards the operations that answer previously asked questions about possible outcomes. Examples of such actions include estimations of a learner’s future scores, potential dropouts or at-risk learners, etc. These actions can be carried out through a number of LA methods such as statistical inference and machine learning.

- Recommendations and personalization. This regards the provision of suggestions to educators and learners based on specific learner-based LA information.

- Adaptations. This regards the tailoring of the course materials or learning activities based on a learner’s progress in order to ensure maximum performance. The types and number of adaptive actions to be performed is a decision made by the educators depending on the learning context and the specific learner.
• Mentoring. This regards all the actions that are performed by the educators in their facilitating roles, especially in student-centred learning strategies. In these cases, educators study the LA outputs and provide guidance and advice based on the LA information.

• Assessment and feedback. This regards the support of formative and self-assessment actions during the learning process as well as the provision of informative feedback to both educators and learners regarding the ongoing progress. Continuous assessment is an essential objective of PBL3.0 and such mechanisms will be studied during the project.

• Reflection. This regards the provision of visualizations and information that show educators and learners the ongoing progress, current achievements and mistakes made, comparison between learners and groups, across courses etc.
4 PBL_LA framework

This chapter provides a first overview of the PBL_LA educational approach through a generic framework. It is important that the guidelines provided within this new educational approach that combines PBL with LA mechanisms can assist all three phases of learning, i.e. design, execution and evaluation, as shown in Figure 4.

![Figure 4 Phases of learning](image)

The design phase regards the actual structure of the course, which consists of the design of all the learning elements before the course’s execution. This phase is usually carried out by the educators, who set the educational objectives, decide on the learning materials, activities and tools to be used for the course and form the evaluation methods. With the PBL_LA, it would be possible that learners will self-design the course, since their active participation in all PBL steps and their ongoing feedback through LA methods will allow their opinions and workflows to be documented and taken into consideration.

The execution phase regards the actual implementation of the course design. During course execution, the learners work towards fulfilling the course’s set educational objectives and producing the target outcomes. With PBL_LA, the incorporation of LA methods within each PBL phase will allow ongoing and constant evidence on the work carried out. This will lead the course to become more adaptable, and educators and learners to constantly attain insights on the learning progress. This way, educators will be able to scaffold learning when necessary, create multiple learning pathways based on the learners’ individual or group needs and reconfigure the workflows when a PBL step or process is not producing the target results.
Finally, the evaluation phase regards the assessment of all the evidence gathered, which includes knowledge acquisition and skills building. During this phase, educators also assess the effectiveness of the design phase and make decisions on configuring the next design iteration based on the evaluation.

The aim of the PBL_LA approach is to provide recommendations and guidance on how each PBL step can be enhanced with LA methods in order to support educators and trainers in designing and executing courses by using a well-structured learning strategy and applying it to any domain and educational level that allows for participatory learning (e.g. Math, Physics, Engineering, Business Administration, Project Management, Medicine, Information Technology etc.). PBL_LA will also empower learners in participating more actively in the learning process and thus developing necessary skills for their future careers such as problem solving, critical thinking, group work, communication of ideas etc.

Towards this end, a PBL_LA framework is proposed, which includes three main layers of the PBL_LA approach, as shown in Figure 5.

![PBL_LA Framework](image)

**Figure 5 PBL_LA framework**

The Pedagogical Layer consists of all the PBL steps identified in the work carried out and documented within D1.1. Within these steps, the PBL_LA approach will study the activities realized by the learners in order to successfully execute each activity as well as the evidence that show the level of performance.

The Data Layer consists of all the different data that is usually generated during learning.
The Analytics Layer consists of the LA methods available for gathering, processing, analysing and interpreting data into meaningful information. These LA methods generate insightful visualizations for both educators and learners so that they can make sense of the analytics results.

In the following Chapter, the concepts in each layer will be populated and relationships amongst concepts and across layers will be specified.
5 PBL_LA educational approach

This chapter will provide a thorough description of each PBL step and how it can be combined with LA mechanisms towards a more enhanced course design, execution and assessment. The project’s PBL_LA outcome aims to allow educators and trainers to apply learning processes where learners participate actively and are engaged throughout the course. This way, each learner can execute specific activities even if he/she is a part of a group, and thus his/her performance can be more easily measured and assessed as opposed to a traditional learning setting where individual contributions to a work project are usually unknown or difficult to assess. Furthermore, PBL’s step-by-step nature allows for more meaningful assessment, since educators can evaluate the work’s progress during each step and adapt the following steps accordingly. This also enables learners to reflect on each specific step and ensure they have obtained the necessary knowledge to progress effectively.

The PBL_LA model also aims to reduce the risk of likely-to-fail learners by encouraging their active participation which supports more in-depth comprehension of the subject course. Furthermore, this learning strategy can benefit different behavioural groups; PBL along with LA can detect and assist learning styles that are more introvert or too extrovert since different learners participate in multiple types of activities such problem analysis, task delimitation, discussion, solution planning, evaluation etc. By identifying such behavioural patterns, educators can adapt their individual learning pathways and enable effective personalized learning.

The PBL_LA approach also aims to allow direct feedback for educators and learners on the learning progress as well as in which areas need improvement. The structured nature of PBL allows for more concrete feedback based on the LA analysis, since the PBL_LA approach will further analyse and define each step in regards to the data generated, the activities that are executed as well as the skills developed (e.g. in the problem analysis step learners develop skills such as critical thinking, concept analysis, group work, communication of ideas etc.). The educators will be able to make more sense of the LA results in such a well-established learning environment and more informative decisions in regards to adapting the learning processes. The design of structured learning processes can more easily encourage and endorse academic programs and curricula to become accordingly more structured. This way, learners will be provided with clear routes to completion and concrete guidelines instead of being presented with an abstract course, with no guidelines or clear activities.

The Aalborg PBL model, which will be the basis of the PBL_LA educational approach, follows a specific structure flow, which can be seen in Figure 6.
More specifically, each group project relates to a specific problem the group is required to solve and a set of competences that are required to successfully pass the generic educational domain. During the project, learners go through the PBL model’s phases that are designed by the educator, and perform activities within each phase. Each activity comprises of relevant content, supporting tools and corresponds to a specific service. The proper realization of an activity covers a specific set of competencies and creates a set of artefacts as evidence for the activity’s outcomes. This evidence consists of the process carried out and the actual results produced within the activity. Finally, the evidence is used for assessment, which is carried out through data analysis and measures competencies acquisition levels.

During the aforementioned workflow, Learning Semantics will be incorporated for semantic binding of learning resources. This will enable personalization and adaptation of the learning process, allow discoverability of learning resources and underpin multiple learning pathways.

The PBL learning strategy aims to allow learners to work in their own pace and make their own decisions in regards to the tools and contents they will use to design, implement and assess the solution to their problem. In this process, the educator is supposed to guide, mentor and intervene when help is needed or when performance does not meet the set educational objectives. To this end, the design of each PBL step usually consists of two main parts, namely

a) setting educational objectives, i.e. what are the expected outcomes from the course and from each specific step and

b) suggesting a number of activities to be performed that will allow learners to deliver the target results.
At times, the educator can also incorporate learning materials in the course design phase, depending on the PBL step.

The following Table includes a list of indicative activities that can and are usually realized during each PBL step.

**Table 1 List of PBL steps and indicative activities (Khalid et al., 2012)**

<table>
<thead>
<tr>
<th>PBL step</th>
<th>Activities</th>
</tr>
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<tbody>
<tr>
<td>Group forming</td>
<td>Brainstorming</td>
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<tr>
<td></td>
<td>Group creation</td>
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<tr>
<td>Problem formulation</td>
<td>Brainstorming</td>
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<tr>
<td></td>
<td>Literature searching</td>
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<tr>
<td></td>
<td>Literature storing</td>
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<tr>
<td></td>
<td>Argumentation</td>
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<tr>
<td></td>
<td>Writing</td>
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<td></td>
<td>Presenting</td>
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<tr>
<td>Task formulation</td>
<td>Scheduling</td>
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<tr>
<td></td>
<td>Diagraming</td>
</tr>
<tr>
<td></td>
<td>Resource allocation</td>
</tr>
<tr>
<td>Data gathering</td>
<td>Data collection / transforming / storing</td>
</tr>
<tr>
<td>Analysis</td>
<td>Data analysis</td>
</tr>
<tr>
<td></td>
<td>Argumentation</td>
</tr>
<tr>
<td>Design</td>
<td>Development / production / testing</td>
</tr>
<tr>
<td></td>
<td>Experimenting / modelling / simulating</td>
</tr>
<tr>
<td></td>
<td>Writing</td>
</tr>
<tr>
<td>Implementation</td>
<td>Application of the solution</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Perform evaluation techniques</td>
</tr>
<tr>
<td></td>
<td>Record evaluation results</td>
</tr>
<tr>
<td>Reporting</td>
<td>Report writing</td>
</tr>
<tr>
<td></td>
<td>Report submitting</td>
</tr>
<tr>
<td></td>
<td>Presenting</td>
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</tbody>
</table>
The following sub-sections provide a more detailed overview of the PBL_LA approach by studying each PBL step and providing guidelines on its design, execution and evaluation when it is combined with LA methods.

5.1 PBL_LA Group formation

Within Aalborg University, the formation of the groups takes place in the beginning of each semester, where learners are free to form groups as long as all learners belong to a group. The number of learners in each group depends on the program and the semester. All learners in one semester gather and discuss amongst them before finding a group. Learners are allowed to make arrangements before group forming but they have to be present on the day of group forming even if they have formed a group with the indicated number of members for the specific semester. Project supervisors are there to guide learners through project work. This step can also be realized in other ways for other settings (e.g. different universities, private or public training sessions etc.) which would involve an online environment with discussion boards, voting mechanisms, and other instruments to facilitate the formation of groups.

Figure 7 shows a general overview of the PBL_LA approach focusing on the Group Formulation step and covering all three learning phases, i.e. course design, course execution/delivervy and course assessment.

5.1.1 PBL_LA Group formation design

Course design for the Group formulation step of the PBL model regards the setting of educational objectives and the decision on the activities to be realized. During the design, the educator sets the
educational objectives that should be achieved in this PBL step. For this step, these objectives regard the formation of groups amongst the learners.

During group formation, learners build a variety of different skills, i.e.

- **Critical thinking**, when trying to identify the more suitable group dynamic for them.
- **Social interaction**, when argumenting on their competences that will make them suitable for a team.
- **Initiative**, when taking actions in forming a group or being a part of a group.

Thus, educators list the activities that are most commonly realized during this step and that support learners in building these skills. Such activities include discussing with the rest of the learners, argumenting on their competencies and goals for the course, placing votes on their preferences and creating the groups. This is not an exhaustive list of activities, and each group can realize all or a subset of them in order to successfully produce the set learning outcomes.

### 5.1.2 PBL_LA Group formation execution

The execution of the group formation step regards the realization of a set of activities as mentioned in the design phase. The activities produce specific types of data and evidence of work, which can be recorded, processed and analysed towards different analytics visualizations and interventions.

Figure 8 presents an indicative instance of the PBL_LA approach for the Problem formulation step’s execution. This instance is one of many that can populate the different Layers of the PBL_LA framework proposed in the previous chapter.

![Figure 8 PBL_LA Group formation execution](image)

More specifically, the **Pedagogical Layer** can include activities that are usually realized for group formation, such as:

- **Discussing / brainstorming.** All learners discuss with each other regarding what their goals are for the specific course and for the group they want to join. During these discussions,
learners also present their own qualifications and competences and declare what roles of members they wish for their group.

- **Voting.** Learners can also form different voting polls that can assist them in the identification of suitable group members. For example, a voting poll can regard different skillsets that a person has or is looking for.

- **Group creation.** Once all learners have identified the people that would fit well in their groups, they proceed in actually forming each group and notify their supervisors accordingly.

The **Analytics Layer** of the PBL_LA framework can be populated with different LA methods and intervention actions that are suitable for analysing the aforementioned data and providing helpful insights to educators and learners.

- **Learner model.** Educators and learners can view the different traits of each learner, which can help them identify learners with learning styles or knowledge and skills that are suitable for a specific group.

- **Engagement analysis.** Educators can view how engaged each learner is when trying to form a group and thus provide the necessary mentoring when identifying more passive learners.

- **Clustering.** Educators and learners can view the different clusters that are formed based on the data generated from each learner’s activities. This can help learners form groups faster and educators guide learners that have not yet been assigned in a group.

- **Discourse analysis.** Educators can view the workflows of a discussion and brainstorming session and provide relevant feedback to the learners.

- **Time spent on group creation.** The time spent on group creations can indicate how easy it is for learners to form different groups, and educators can try to identify the reasons behind groups that take a long time to form.

- **Reflecting.** Learners can reflect on their competences and needs for a group so that they can identify more easily other learners with similar aspirations and qualifications.

- **Feedback.** Educators can provide feedback to learners in need, for example when they notice conflicts or groups not yet filled out through the LA visualizations or are contacted by learners.

- **Guiding.** Educators can provide general guidance during the group formation, by encouraging all learners to participate in the discussions, providing tools that will help groups to be formed more easily and adapt the learning step as needed.

The **Data Layer** of the PBL_LA framework for this step can be populated with the specific data that is generated as well as the evidence that will be used for analysis and assessment. Such instances are:
• **Learner profile.** The documentation and visualization of learners’ profile can help other learners identify possible group members and educators guide and provide feedback to learners in need of group members.

• **Brainstorming / dialogues posts.** The discussion that is carried out towards the formation of a group. This kind of data can include the actual discussion posts from each learner, the interactions amongst learners towards forming a group, each learner’s ideas on future goals or possible problems, how engaged each learner is during group formation, voting polls that can help indicate learners with similar goals etc.

• **Time spent per group creation.** The actual time spent per group can help educators assess the process and adapt the step in a future semester. This data can also be compared with the respective group’s final performance, in case there is a correlation between the speed with which the group was formed and how well its members worked together.

A representative but not exhaustive population of the PBL_LA framework for the Group formation step based on the work presented above is shown in Figure 9.
5.1.3 PBL_LA Group formation assessment

The group formation assessment regards the group formed and the learners within a group. Supervisors assess whether each group comprises of the necessary number of learners, and also whether the group formation step was carried out without any incidents or conflicts.

5.2 PBL_LA Problem formulation

Problem formulation regards the decision of the problem to be solved. It is one of the most important PBL steps, as it guides all the next steps and provides specific context to the theme. During the problem formulation step, all members of the group are invited to suggest different ideas.
on possible problems and alternative possible solutions. Because of this, discourse, dialogue and brainstorming are vital activities along with literature research. Thus, the LA methods that are most relevant to this step focus on

i) identifying specific patterns during dialogue and discourse,

ii) monitoring learners’ behaviour and

iii) detecting possible learners that are either too aggressive or too passive in their problem suggestions.

The following figure shows a general overview of the PBL_LA approach focusing on the Problem Formulation step and covering all three learning phases, i.e. course design, course execution and course assessment.

Figure 10 PBL_LA instance for Problem formulation

5.2.1 PBL_LA Problem formulation design

Course design for the Problem formulation step of the PBL model regards the setting of educational objectives, the decision on the activities to be realized as well as the content to be suggested for study, as shown in Figure 10. During the design, the educator sets the educational objectives that should be achieved in this PBL step. For the problem formulation step, these objectives regard

a) On topic problem formulation per group.

b) Valid and comprehensive presentation of the formulated problem.

During problem formulation, learners build a variety of different skills, i.e.

- **Critical thinking**, when trying to identify relevant literature.

- **Sharing information**, when discussing and brainstorming around possible ideas and problems.
Social interaction, when argumenting on the problem to be formulated.

Communication of ideas, when presenting the formulated problem and attempting to prove its validity, importance and relevance to the knowledge domain.

Interpretation, when trying to identify an underlying problem that requires solving based on the read materials.

Synthesizing of information, when trying to formulate a robust problem statement by combining prior knowledge, new knowledge and ideas derived from brainstorming with other people.

Thus, educators list the activities that are most commonly realized during this step and that support learners in building these skills. Such activities include searching relevant literature and storing the identified resources, brainstorming and discussing possible problems and their respective solutions, argumenting on the course of actions towards solving the chosen problem as well as writing and presenting the formulated problem. This is not an exhaustive list of activities, and each group can realize all or a sub-set of them in order to successfully produce the set learning outcomes.

Finally, the educator can provide a list of learning resources that learners can study in order to research the domain and formulate a robust problem. These resources can be enhanced with learning semantics. For example, if the educator provides a variety of research papers on the e-learning system which cover diverse topics for all groups, the learners will have to search through all the resources and locate the ones relevant to their context. However, if all resources have been semantically annotated, learners can search the tool for a specific topic and the machine will bring out all papers relevant to the search, since now the machine understands the meaning of each resource. For example, if a group is researching the e-Participation field, then out of the following annotated papers:

- “Web2.0 tools for e-Participation” hasTopic “e-Participation”
- “Web2.0 tools for e-Participation” hasTopic “Web 2.0”
- “Information systems for Business Intelligence” hasTopic “Business Intelligence”

The group will be provided with the 1st paper as the relevant to their study. Furthermore, if the educator gets feedback from the LA methods that a learner has not accessed learning resources that are useful for his chosen problem domain, the educator can adapt the course and provide the learner with the necessary resources in a more effective way if the resources are annotated, since they will be more easily discoverable and accessible.

5.2.2 PBL_LA Problem formulation execution

The execution of the problem formulation step regards the realization of a set of activities as mentioned in the design phase. The activities produce specific types of data and evidence of work,
which can be recorded, processed and analysed towards different analytics visualizations and interventions.

Figure 11 presents an indicative instance of the PBL_LA approach for the Problem formulation step’s execution. This instance is one of many that can populate the different Layers of the PBL_LA framework proposed in the previous chapter.

<table>
<thead>
<tr>
<th>ACTIVITIES</th>
<th>EVIDENCE / DATA</th>
<th>ANALYTICS</th>
<th>INTERVENTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brainstorming</td>
<td>Research resources</td>
<td>Sentiment Analysis</td>
<td>Scaffolding hints</td>
</tr>
<tr>
<td>Literature search</td>
<td>Versions of problem formulated</td>
<td>Discourse Analysis</td>
<td>Recommendations</td>
</tr>
<tr>
<td>Argumenting</td>
<td>Mind maps</td>
<td>Social Network Analysis</td>
<td>More resources on problem topics</td>
</tr>
<tr>
<td>Writing</td>
<td>Brainstorming / dialogues</td>
<td>Engagement analysis</td>
<td></td>
</tr>
<tr>
<td>Presenting</td>
<td>Problem presentation</td>
<td>Information Flow Analysis</td>
<td>Guide learners</td>
</tr>
<tr>
<td></td>
<td>Process data</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 11 PBL_LA Problem formulation execution**

More specifically, the Pedagogical Layer can include activities that are usually realized for problem formulation, such as:

- **Literature search.** Each member of a group searches the literature that is relevant to the generic domain of the course. This includes searching different sources and resources, such as websites, blogs, scientific articles, online and library books, social media entries etc. All these resources should be documented and stored for future reporting and reuse.

- **Brainstorming.** Members of a group brainstorm around different ideas on possible directions and problems. This includes identifying interesting cases from the studied literature, creating mind maps with the main concepts of the most relevant resources and deciding on the more suitable problem.

- **Argumenting.** Members of a group present arguments on their problem ideas and possible solutions and discuss their appropriateness based on the educator’s requirements. This leads to forming valid arguments that will reinforce the group’s decision of the chosen problem.
• **Writing.** Members of a group write the problem they have formulated by presenting their ideas and the literature that their ideas are based on.

• **Presenting.** Members of a group present their problem and communicate to their supervisor the reasons behind their decision.

The Analytics Layer of the PBL_LA framework can be populated with different LA methods and intervention actions that are suitable for analysing the aforementioned data and providing helpful insights to educators and learners.

• **Sentiment analysis.** During problem formulation, it is important that learners decide on a problem within a productive environment. Sentiment analysis can easily detect any arising arguments, where educators can intervene and prevent such cases. Sentiment analysis can also detect issues or ideas that the majority agrees or disagrees with. This would be valuable information to provide to the learners so that they can more easily identify which ideas they can work with.

• **Social network analysis.** During activities that are performed during problem formulation such as brainstorming and dialogues, social networks are automatically formed. These networks can help educators detect more easily learners that do not participate, measure the level of engagement for each learner and provide scaffolding features to learners in need.

• **Information flow analysis.** The analysis of the information flow can provide meaningful insights on the progress of discussions carried out towards the formulation of a robust problem.

• **Engagement analysis.** Educators can view engagement levels of each individual learner, a group and all groups within the PBL step. This way, they can provide scaffolding hints, guide at-risk learners and personalize the learning process when needed. Also, learners can reflect on their engagement in formulating a problem and adapt their efforts accordingly towards an improved performance.

• **Recommendations.** Educators can provide recommendations to learners when they need assistance and guidance. Such recommendations during problem formulation can regard increased participation in the brainstorming sessions, provision of more references in their arguments etc.

• **Scaffolding.** Educators can scaffold the problem formulation step with various ways that can improve learners’ performances. Such ways include helpful hints on interesting areas for problems study, compelling tasks that will allow productive brainstorming etc.

• **Additional resources.** A more specific intervention in this step regards the provision of additional resources. Since this step is heavily dependent on the literature study learners will carry out, it is important for the educators to be able to provide extra resources if the LA
visualizations show at-risk learners with low engagement or identifiable learning styles that prefer specific resources types.

- **Guiding / mentoring.** Educators can also consult the LA visualizations in order to guide and mentor the problem formulation step and facilitate the process for the entire group. This involves discussing with learners that may be experiencing difficulties in coming up with interesting ideas, changing the group dynamics when sub-networks are formed within the group that dominate the work etc.

The **Data Layer** of the PBL_LA framework for this step can be populated with the specific data that is generated as well as the evidence that will be used for analysis and assessment. Such instances are:

- **Research resources.** All resources that were accessed and chosen for further research should be gathered for future analysis. This includes documentation of the:
  
  - **Types of resource sources** gathered, e.g. online websites, university library, social media, scientific journals, conference proceedings, personal blogs etc. This information can indicate the most commonly accessed types of resources by learners. For example, if a LA visualization shows that the majority of the learners search only social media accounts for resources, the educator can scaffold the process by recommending that they search more scientific resource types, such as specific scientific journals, books etc., which will lead to a more evidence-based problem formulation.
  
  - **Content of resources** gathered, e.g. link URLs, book titles, scientific article names, scientific journal / conference names, social media accounts etc. This information can indicate if learners are searching literature that is relevant to the course’s knowledge domain or if they are researching an area that is either not interesting enough or too complicated for the course’s requirements. If educators have this information, they can intervene and personalize the PBL step by providing content to the learners that will assist them in their tasks.
  
  - **Number of resources** gathered, that is the total number of resources that each learner has gathered for future study. This information can indicate if some learners are not gathering enough resources to form a valid argument for their problem, or if they are gathering too many resources that will be challenging to study and analyse, leading to delays for the entire group in forming the problem.

- **Brainstorming ideas / dialogues posts.** The discussion that is carried out towards the decision of a problem is important for identifying issues and scaffolding the process. Possible specific data that should be gathered include:
  
  - **Content of discussions / posts.** This information can indicate the progress of discussions, highlight if there is prevailing negative or a positive sentiment during a brainstorming session, identify the main issues arising during a discourse etc. These
insights can be provided through LA visualizations to educators and group members, and assist the process of formulating an interesting problem. For example, educators can intervene if they see a discussion with high percentages of negative sentiment which might lead to unproductive arguments.

- **Content of ideas.** This information can indicate whether the ideas formed that will lead to the problem are relevant, interesting and appropriate. This way, educators can recommend different directions to the discussion and learners can reflect on the ideas they formed.

- **Number of ideas formed per learner.** This information can indicate if a learner is not participating equally within the group. It is important that educators are aware of individual efforts during each step so that they can encourage and help learners at risk of failing before the final step of the process and prevent work being carried out by only a few members of the group.

- **Votes.** This information can indicate learners’ engagement in the decision making process, allowing educators to guide the groups that cannot reach a decision through multiple votes or learners to reflect on their possible ideas and reach a decision faster.

**Mind maps.** Each group can create mind maps that will visualize all concepts that comprise their problem and the relations amongst them. This includes the gathering and analysis of data such as:

- **Number of concepts within each mind map.** This information can indicate the quality of a mind map, and educators can view if the concepts formulate an interesting and promising problem; for example, too many concepts can lead to an unsolvable problem and too few concepts can signify that the domain around the problem has not been studied enough.

- **Relations of connected concepts.** This information can indicate if the members of a group have correctly studied and understood the context of their chosen problem. If the data analysis through, e.g. information flow analysis, shows that the relations amongst the concepts are not correct, educators can notify the learners and mentor them towards correct domain comprehension.

**Versions of problem formulated.** Each group can formulate different problem versions before finalizing their decision. It would be interesting to gather information on the different versions and monitor their elimination process that led to the concluding problem. This includes data such as:

- **Number of problem versions.** The number of different problem versions can indicate if a group experienced difficulties in forming decisions on their problem. Furthermore, this can show either a problem in the group-work or a lack of
understanding of the domain area. This is an analysis that will most likely be carried out by the educator based on their experience, but by consulting the LA visualizations that will visualize this data; e.g. a diagram of number of problem versions per learner across time could show how often a group submitted a new problem and the educator would attempt to detect the reasoning.

- **Differences between each problem version.** If learners document the changes that are made within each version, educators could mentor learners by providing guidance and advice based on the types of volume of the changes in each version.

- **Problem presentation.** The way the problem that is formulated is presented shows the levels of knowledge comprehension and skills building. This includes data such as:
  - **Structure of presentation.** The different sections of the problem formulation document can indicate the proficiency of the group’s work and if they have taken into consideration all the different aspects of the problem. A visualization of all the different sections of a problem formulation across groups can show educators the most commonly included sections and which groups did not provide important sections.
  - **Content of presentation.** The content of the problem formulation is the most important evidence that indicates the quality of the work carried out within this step. The argumentation within the presentation can also show the presentation skills that have been built or highlight any noticeable inconsistencies.

- **Process data.** This data involves information that is traditionally recorded in e-learning and online environments in general, and can be analysed for improving the learning process. This includes data such as:
  - **Access to resources per learner.** This can indicate learners that have not accessed important resources, or highlight learners with a specific learning style, i.e. that usually access specific types of resources (e.g. only videos).
  - **Times spent on each activity per learner.** This can indicate how much effort each learner is putting in each activity and provide educators insights such as if specific learners are spending too much time to perform an activity.
  - **Navigation patterns.** This can indicate the ways in which each learner learns, by visualizing any prominent patterns of navigation across online environments.
  - **Engagement levels per activity per learner.** This can indicate how engaged each learner is when performing an activity. Learners can view their engagement in comparison to the group’s or course’s engagement and reflect on their own progress. Also, educators can make personalized interventions by scaffolding specific at-risk learners with low engagement levels.
A representative population of the PBL_LA framework for the Problem formulation step based on the work presented above is shown in Figure 12.

5.2.3 PBL_LA Problem formulation assessment

The assessment of the problem formulation step regards three main aspects. More specifically, during Problem formulation, as in each step of the PBL model, the educators assess:

- **Individual performance.** In problem formulation, educators assess how active and engaged a learner was from the search of the domain to the identification of possible problems and the final problem formulation. This also involves the acquisition of skills relevant to this step, as presented in the beginning of this sub-section.
• **Group performance.** Educators assess how well the group worked together towards formulating a robust problem and how equally divided was the work carried out amongst the group members.

• **Outputs / results.** The quality of the actual outputs is also assessed in accordance to the specific educational objectives set in the course design phase. In this step, the outputs include a complete document with the problem statement.

This figure shows the identified concepts and their inter-relations, and can be used by instructional designers, educators or trainers in order to design, execute and assess courses that include a problem formulation step and that will follow the new educational approach proposed by this project, combining PBL activities with LA methods.

### 5.3 PBL_LA Task formulation

Task formulation includes a workload and possibly role distribution among group members, which are continuously adapted throughout the project. Common roles are the project leader, the chairman and the secretary. The leader is responsible for keeping an overview of the group’s progress and for making sure that agreed meetings and deadlines held. Moreover, the leader is responsible for creating and maintaining a nice atmosphere between members of the group.

The following figure shows a general overview of the PBL_LA approach focusing on the Task formulation step and covering all three learning phases, i.e. course design, course execution and course assessment.

![Figure 13 PBL_LA instance for Task formulation](image-url)
5.3.1 PBL_LA Task formulation design

Course design for the Task formulation step of the PBL model regards the setting of educational objectives and the decision on the activities to be performed, as shown in Figure 13. During the design, the educator sets the educational objectives that should be achieved in this PBL step. For the task formulation step, these objectives regard:

a) Comprehensive list of tasks relevant and appropriate to the chosen problem.

b) Homogenous and fair tasks distribution across the group members.

c) Successful execution of tasks and management of time and effort.

During task formulation, learners build a variety of different skills, i.e.

- **Collaborating on tasks**, when trying to carry out assigned tasks along with other members of the group.

- **Leadership**, when trying to manage the work progress and group efficiency as the group leader.

- **Time management**, when trying to make sure that deadlines are held across the group.

- **Critical thinking**, when trying to carry out assigned tasks efficiently and on time.

- **Planning**, when trying to plan the tasks that need to be carried out for the successful solution of the formulated problem.

- **Self-discipline**, when trying to carry out assigned tasks without getting distracted and on schedule.

Thus, the educator lists the activities that are most commonly realized during the task formulation step and that support the building of the aforementioned skills. Such activities include scheduling, diagramming and roles and tasks allocation. Again this is not an exhaustive list of activities, and each group can realize all or a sub-set of them in order to successfully achieve the set learning objectives.

5.3.2 PBL_LA Task formulation execution

The execution of the task formulation step regards the realization of a set of activities as mentioned in the design phase that will allow learners of each group to properly execute tasks for the analysis, design, implementation and evaluation of their problem. The activities produce specific types of data and evidence of work, which can be recorded, processed and analysed towards different analytics visualizations and interventions.

Figure 14 presents an indicative instance of the PBL_LA approach for the step’s execution. This instance is one of many that can populate the different layers of the PBL_LA framework.
More specifically, the Pedagogical Layer can include activities that are usually realized for problem formulation, such as:

- **Scheduling.** Learners schedule meetings that are to be held within the group regarding workload.

- **Diagramming.** Learners create diagrams that will assist them in deciding on possible courses of actions, different roles and tasks to be allocated.

- **Roles allocation.** Learners decide which roles are suitable for their problems and assign the different roles to specific members of the group. Ideally, roles change across learners during the project.

- **Tasks allocation.** Learners decide how many and which tasks will be designed for the proper execution and implementation of their problem. Also, they allocate each task to specific members of the group and assign deadlines and outputs for each task.

The Analytics Layer of the PBL_LA framework can be populated with different LA methods and intervention actions that are suitable for analysing the aforementioned data and providing helpful insights to educators and learners. Some of the LA methods and actions are:

- **Dashboards on tasks progress.** Dashboards can visualize progress on all the assigned tasks. Educators can consult these dashboards to measure each group’s and learner’s performance, get a graphical view of the tasks status, identify the tasks which are on track and those that are behind, etc. Learners can use task dashboards to track their own and their group’s progress, gather all important information in one place, and see which tasks require more efforts, and so on.
- **Social network analysis.** The analysis of discussions amongst each group’s members can indicate learners’ engagement levels as well as how active each learner is within a group relationship. This can also detect if all learners have passed through all assigned roles and how they communicate with the other group members during each role phase.

- **Dashboards on tasks allocation.** Dashboards can visualize the allocation of the tasks and provide an overall overview of which learner is assigned which tasks and when. Educators can also monitor if a learner is not assigned any tasks or if a learner is assigned too many tasks at the same time and make the necessary interventions.

- **Behaviour modelling.** This LA method can produce a behaviour model for the educators to examine, which shows patterns of behaviour per learner, and helps educators predict future behaviours of learners. This allows educators to take pre-emptive actions in order to avoid possible risks.

- **Warnings.** LA visualizations can provide warnings to educators and learners in the form of colouring (green for successful progress, yellow for needing attention and red for needing intervention), pop-up messages, e-mail notifications etc. Such warnings during Task formulation can regard when the data analysis identifies under or over-allocations of tasks, slow progress of tasks or low engagement in scheduling and diagramming.

- **Mentoring.** Educators can study the LA visualizations and guide learners that require assistance. This can include advice on different ways to formulate tasks, time management techniques, meetings scheduling guidelines etc.

- **Adaptations.** Educators can adapt the tasks that are formulated and their allocations as well as the roles when they observe inconsistencies in the workload amongst the group members. For example, they can re-configure the allocation of the tasks based on the learners’ individual learning styles and existing skill set, or assign additional roles to learners that have finished their own tasks.

The **Data Layer** of the PBL_LA framework for this step can be populated with the specific data that is generated as well as the evidence that will be used for analysis and assessment. Representative instances are:

- **Roles mapping.** The different roles that will be assigned across the group members should be recorded for monitoring. The following should be recorded:
  - **Number of different roles.** Each group can decide on a specific number and type of roles to be used within the project. The variety and appropriateness of the roles can indicate how wide a skill-set the group will be able to build and can allow educators to guide the learners towards identifying suitable roles.
  - **Allocation of roles across learners.** This can indicate the behaviour each learner must follow according to the role assigned as well as the skills to be built through
each role. Also, educators can view if a specific learner has not been assigned a role and make sure that all group members experience all different roles.

- **Tasks list.** The different tasks that each group decides to execute can indicate to what level they have understood the needs of their project and proper ways to address them. Insights on this can be shown through the documentation of:
  
  o **Number of tasks.** Each group is free to decide on the number of tasks that is appropriate for their project. A visualization of the total number can lead the educator to identify any extreme values (e.g. too few tasks to cover any problem solving, too many tasks that can create extra unnecessary workload).
  
  o **Types of tasks.** The actual tasks that are designed by each group can indicate the level comprehension on what is needed to be done to solve their problem. Educators can mentor, guide and provide recommendations to students within a group when they see visualizations that show tasks inconsistent with their problems.
  
  o **Allocation of tasks across learners.** The way a group allocates its tasks across its members can indicate if a team works fairly by providing work to all learners equally. Educators can highlight issues of under- or over-allocations and ensure that all learners are working on some aspect of the project during the step’s execution.

- **Tasks progress.** The visualization of the tasks progress is essential for monitoring the task formulation step.
  
  o **Tasks level of completion.** This data can indicate how close a task is to finishing compared to the given target deadline. Educators can adapt and personalize the process when they identify tasks left behind, when they study visualizations that for example use colour codes to indicate a task’s level of completion (e.g. green: on-time, yellow: close to deadline, red: failed to be completed on-time).
  
  o **Tasks workload progress.** This data can indicate the workload progress on a task per task participant. This way, educators can suggest changes in the allocation and workload as well as guide learners as to how to perform challenging tasks that are causing delay.
  
  o **Timesheets.** This data can indicate the amount of time it takes each learner to execute a given task. Educators can consult such visualizations and mentor learners that take too long to finish a simple task or detect inconsistencies on time spent within tasks amongst group members.

- **Meeting records.** During task formulation, members of a group should hold regular meetings to discuss tasks progress, allocation and efforts towards their goals. Insights on this can be shown through the documentation of:
### D1.3 PBL_LA educational approach

- **Number and duration of meetings held.** This data can indicate how often a group discusses the overall progress of the project and how long do these discussions take. Educators can consult this visualized information and identify any cases that meet too rarely, which could lead to group members not made aware of how the project is progressing, or that take too long to complete, which could mean difficulties in communicating within the group. Educators can then mentor these groups, find out if assistance is needed and adapt the process accordingly.

- **Participants in each meeting.** This data can indicate if certain members of a group do not participate in the workload equally. Educators can contact learners that are usually absent during meetings and encourage their engagement in the group work.

- **Meeting minutes.** The decisions made during each meeting can indicate how a group collaborates towards decision making processes and what kind of decisions they reach.

### Process data

- This data involves information that is traditionally recorded in e-learning and online environments in general, and can be analysed for improving the learning process. This includes data such as:

  - **Times spent on each activity per learner.** This can indicate how much effort each learner is putting in each activity and provide educators insights such as if specific learners are spending too much time to perform an activity.

  - **Participation in discussions.** This can indicate which learners participate more actively during discussions and which require scaffolding so that they can start participating more when collaborating.

  - **Engagement levels per activity per learner.** This can indicate how engaged each learner is when performing an activity. Learners can view their engagement in comparison to the group’s or course’s engagement and reflect on their own progress. Also, educators can make personalized interventions by scaffolding specific at-risk learners with low engagement levels.

A representative population of the PBL_LA framework for the Task formulation step based on the work presented above is shown in Figure 15.
5.3.3 PBL_LA Task formulation assessment

The assessment of the Task formulation step regards three main aspects, as shown in Figure 13.

- **Individual performance.** In task formulation, educators assess how each learner performed within each assigned task and each assigned role. This also involves the acquisition of skills relevant to this step, as presented in the beginning of this sub-section.

- **Group performance.** Educators assess how well the group worked together towards formulating a comprehensive list of tasks, holding regular meetings for tasks progress monitoring and how equally divided was the work carried out amongst the group members.
- **Outputs / results.** The quality of the actual outputs is also assessed in accordance to the specific educational objectives set in the course design phase. In this step, the outputs include a calendar with all the held meetings, and a work plan with the formulated tasks.

### 5.4 PBL_LA Problem analysis

The problem analysis step usually consists of three separate steps, i.e. data gathering, analysis and design, and thus is one of the most challenging steps of the PBL model. Firstly, learners gather data on the problem they are investigating (e.g. scientific and non-scientific publications, conducting interviews, administrating questionnaires/surveys etc.). Learners have to learn to be efficient and to be able to filter the available information in order to gather only relevant data.

During the analysis of the problem, learners examine the gathered information in order to decide to a direction towards the solution of the problem. The analysis ends with the creation of a list of design requirements – that means requirements for the proposed problem solution. These requirements guide the design, which is the next phase.

During design, learners develop the strategy for a solution to the chosen problem. The design activities depend on the specific field (e.g. blueprint of technical implementations, service-design, artistic design etc.).

The following figure shows a general overview of the PBL_LA approach focusing on the Problem analysis step and covering all three learning phases, i.e. course design, course execution and course assessment.

![PBL_LA instance for Problem analysis](image)

**Figure 16 PBL_LA instance for Problem analysis**

### 5.4.1 PBL_LA Problem analysis design

Course design for the Problem analysis step of the PBL model regards the setting of educational objectives, the decision on the activities to be realized as well as the content to be suggested for
study, as shown in Figure 10. During the design, the educator sets the educational objectives that should be achieved in this PBL step. For the problem formulation step, these objectives regard:

a) A refined and final problem statement.

b) A comprehensive design requirements list.

c) A detailed design strategy for the problem to be solved.

During problem analysis, learners build a variety of different skills, such as:

- **Critical thinking**, when trying to identify new relevant literature.
- **Sharing information**, when discussing and brainstorming around ways to refine the problem statement, create the design requirements and design a robust strategy.
- **Social interaction**, when argumenting on the aforementioned main step’s issues.
- **Filtering of information**, when trying to identify which of the new data gathered is relevant to the more mature version of the problem.
- **Interpretation**, when trying to make sense of the data gathered and to translate it into design requirements and a design strategy.
- **Synthesizing of information**, when trying to formulate a final robust problem statement by combining prior knowledge, new knowledge and ideas derived from brainstorming with other people.
- **Creativity**, when designing a strategy for the proposed solution.

Thus, educators list the activities that are most commonly realized during this step and that support learners in building these skills. Such activities include searching new literature that is relevant to the formulated problem and can refine the problem statement, gathering data through surveys or interviews, discussing and argumenting on the course of actions towards designing a proper strategy for a solution, preparing a comprehensive list of design requirements as well as a robust strategy that will lead the implementation step. This is not an exhaustive list of activities, and each group can realize all or a sub-set of them in order to successfully produce the set learning outcomes.

Finally, the educator can provide a list of learning resources that learners can study in order to refine their problem statement and design their strategy. As in problem formulation, these resources can be enhanced with LS to increase discoverability and provide adequate knowledge to learners.

### 5.4.2 PBL_LA Problem analysis execution

The execution of the problem analysis step regards the realization of a set of activities as mentioned in the design phase that will allow learners of each group to properly execute tasks for the analysis, design, implementation and evaluation of their problem. The activities produce specific types of data
and evidence of work, which can be recorded, processed and analysed towards different analytics visualizations and interventions.

Figure 17 presents an indicative instance of the PBL_LA approach for the Problem analysis step’s execution. This instance is one of many that can populate the different Layers of the PBL_LA framework proposed in the previous chapter.

More specifically, the Pedagogical Layer can include activities that are usually realized for problem formulation, such as:

- **Literature studying.** Learners study the relevant literature more thoroughly in order to refine their problem statement.
- **Conducting surveys / interviews.** Learners conduct surveys and interviews in order to gather data in regards to design requirements for their solution.
- **Filtering and analysis of data.** Learners study the data gathered, filter out the unnecessary or irrelevant data and analyse the information relevant to their problem domain.
- **Brainstorming.** Learners discuss and schedule brainstorming sessions in order to analyse the information acquired from literature studies and feedback data.
- **Argumenting.** Learners argue their opinions on the different refinements needed to their initial problem statement, the design requirements relevant to their solution and the design strategy that will lead the implementation step.
• **Design strategy.** Learners construct a design strategy that will support the implementation of their solution in the next PBL step.

The **Analytics Layer** of the PBL_LA framework for the problem analysis step can be populated with different LA methods and intervention actions that are suitable for analysing the aforementioned data and providing helpful insights to educators and learners. Some of these LA methods and actions are:

• **Sentiment analysis.** The analysis of the different sentiments during a brainstorming session or an argument can help educators locate situations where they need to intervene and prevent any impending conflicts. Furthermore, a prominent sentiment on a specific topic can indicate the main concepts of the group’s chosen problem.

• **Discourse analysis.** The analysis of the posts during a discussion can indicate the main topics that will need to be taken into consideration by the group in the analysis of the problem. Educators can also identify learners with low participation levels, and encourage their more active involvement in the discussions.

• **Knowledge domain analysis.** The structure and mapping of the knowledge domain of the problem can enable educators to personalize and adapt learning for specific students. This way, educators can gather and exploit data about learners, their profiles, navigation patterns, interaction trails etc. The analysis of all these data in correlation with the specific concepts of the knowledge domain can generate informative insights on learners’ knowledge in relation to the domain’s structure as well as predictions, adaptations and personalization of the learning processes.

• **Semantic analysis.** The semantic analysis of the data gathered can enable educators to support similar learning objectives or similar skills that are relevant to similar learning subjects. For example, a learning subject “computer programming languages” that is relevant with a group’s problem can be relevant to a skill named “Proficient in Java”. If educators are aware of this semantic binding, they can search for resources that are also related to the specific skill and scaffold learners.

• **Trends analysis.** The analysis of educational data such as engagement levels, resources accessed, scores, interactions etc., can indicate different trends and patterns of behaviour and performance that will allow educators to intervene when they detect at-risk learners or learners in need of scaffolding.

• **Learner modelling.** The creation of learner models based on data analysis can enable educators to configure their curricula and learning activities based on the needs of their learners. This analysis can identify different learning styles and allow more adaptability and flexibility during the problem analysis step.

• **Clustering.** As problem analysis is a step that requires in depth discussions and collaboration, clustering based on various variables (e.g. knowledge levels, engagement levels, main
concepts of discussion etc.) can help educators adapt and personalize the learning process for each cluster based on their specific characteristics.

- **Recommendations.** Educators can monitor all LA visualizations available during the problem analysis step and make corresponding recommendations to learners. Such recommendations can include literature resources to study for refining their problem statement, different stakeholders to interview for gathering design requirements, examples of methodologies for designing their strategies etc.

- **Scaffolding.** Educators can also provide scaffolding to learners in need of further assistance through various means, such as providing hints when they are making specific mistakes, providing compelling tasks that will help them analyse the problem in a more sufficient way, giving advice when they ask for assistance etc.

- **Guidance.** Educators in PBL and especially in the problem analysis step which requires great effort can guide learners based on the LA insights available. Such guidance can include personal meetings with discussing the problem formulation or design strategy, encouraging learners with low participations to engage more actively etc.

The Data Layer of the PBL_LA framework for this step can be populated with the specific data that is generated as well as the evidence that will be used for analysis and assessment. Representative instances are:

- **Research resources.** All resources that were accessed and chosen for further research on the initial problem formulation should be gathered for future analysis. This data is described in detail in the Problem formulation step and includes: types of resource sources gathered, content of resources gathered and number of resources gathered.

- **Survey data.** All data that is recorded from the survey questions should be gathered for future analysis. This data includes information on the participants (e.g. user profile), the actual answers in each question as well as statistical analysis of dependant and non-dependant variables that can help learners make decisions on their problem and design solution.

- **Interview data.** All data generated during an interview should be recorded for further analysis. This data includes information on the participants (e.g. user profile), an analysis of their feedback in main concepts and an overall conclusion on their opinions regarding the questions asked.

- **Brainstorming / dialogues.** The discussions carried out towards the refinement of the formulated problem, the design requirements and the design strategies are important for identifying issues and scaffolding the process. This data source is described in more detailed in the previous steps.
- **Refined problem statement.** The content of the final version of the problem statement is one of the main outputs of this step, and will indicate to a great extent the group’s achievement of the step’s educational objectives.

- **Design requirements.** The list of design requirements is another main output of this step and will allow educators to assess the group’s performance. Specific data include:
  - **Number of design requirements.** The actual number of requirements can be indicative of how much effort the group’s members dedicated into making the list.
  - **Content of design requirements.** The content of the design requirements can indicate how much the group comprehended the way in which the solution should be implemented as well as how successfully they translated the data they gathered into design requirements.

- **Design strategy.** The design strategy is the last main output of this step, and involves the group’s proposal of how the solution to their problem should be implemented. This strategy is important to be properly assessed as it will guide the next three steps of the PBL model.

- **Process data.** This data involves information that is traditionally recorded in e-learning and online environments in general, and can be analysed for improving the learning process. This data is also described in the previous steps and includes: access to resources per learner, times spent on each activity per learner, navigation patterns, engagement levels per activity per learner etc.

A representative population of the PBL_LA framework for the problem analysis step based on the work presented above is shown in Figure 18.
5.4.3 PBL_LA Problem analysis assessment

The assessment of the Problem analysis step regards three main aspects, as shown in Figure 16.

- **Individual performance.** In problem analysis, educators assess how each learner performed regarding the formulation of a solid design list, a well-updated problem statement and a comprehensive design strategy. This also involves the acquisition of skills relevant to this step, as presented in the beginning of this sub-section.

- **Group performance.** Educators assess how well the group worked together towards producing the set results and how equally they divided the work carried out.

- **Outputs / results.** The quality of the actual outputs is also assessed in accordance to the specific educational objectives set in the course design phase. In this step, the outputs
include a refined and testable problem statement, a list of design requirements and a design strategy for the proposed solution.

5.5 PBL_LA Implementation

The implementation step belongs to the problem solving phase of PBL. During implementation, learners implement the actual solution to the problem that corresponds to the analysis they carried out in the previous steps.

Each solution is dependent on the specific sub-domain the group has chosen, the problem they formulated as well as the design requirements and strategy they drafted during problem analysis. Thus, a solution can be software, a service, a device, a blueprint etc.

The following figure shows a general overview of the PBL_LA approach focusing on the Implementation step and covering all three learning phases, i.e. course design, course execution and course assessment.

![Figure 19 PBL_LA instance for Implementation](image)

5.5.1 PBL_LA Implementation design

Course design for the Implementation step of the PBL model regards the setting of educational objectives, the decision on the activities to be realized as well as the content to be suggested for study, as shown in Figure 19. During the design, the educator sets the educational objectives that should be achieved in this PBL step. For the implementation step, these objectives regard:

- d) A comprehensive solution (prototype, software etc.).
- e) A detailed description of the solution.

During implementation, learners build a variety of different skills, such as:

- **Creativity**, when trying to find all the different ways in which a solution can be implemented.
- **Resourcefulness**, when trying to find ways to get the best results for the goals set.
- **Application of knowledge**, when applying the studied theory in order to produce a comprehensive solution.

- **Organizational skills**, when trying to structure the work needed towards the implementation of the solution for the best possible results.

- **Commitment**, when trying to stay focused on the set goals and perform their tasks on time and correctly.

As implementation is a step that varies a lot depending on the semester, domain, problem and designed solution, the activities usually proposed by the educators are more domain-independent and supporting in nature, while learners decide within their group on the more specific activities that will underpin the implementation. Some of the proposed activities include development, experimenting, simulating, prototyping etc. This is not an exhaustive list of activities, and each group can realize all or a sub-set of them in order to successfully produce the set learning outcomes.

### 5.5.2 PBL_LA Implementation execution

The execution of the implementation step regards the realization of a set of activities as mentioned in the design phase that will allow learners to develop their solutions in a way that they are testable and ready for evaluation. The activities produce specific types of data and evidence of work, which can be recorded, processed and analysed towards different analytics visualizations and interventions.

Figure 20 presents an indicative instance of the PBL_LA approach for the implementation step’s execution. This instance is one of many that can populate the different Layers of the PBL_LA framework proposed in the previous chapter.
More specifically, the **Pedagogical Layer** can include activities that are usually realized for the solution’s implementation, such as:

- **Developing.** Learners develop the solution for their problem based on the design requirements and the design strategy formed in the previous step.

- **Testing.** Learners test their developed solution and fix any identified errors, bugs, misconceptions etc.

- **Simulating.** Learners can also simulate their solution in order to assess its functionality in a simulated environment.

- **Experimenting.** Learners can perform a number of experiments with different values for their solution in order to determine its validity.

The **Analytics Layer** of the PBL.LA framework for the implementation step can be populated with different LA methods and intervention actions that are suitable for analysing the aforementioned data and providing helpful insights to educators and learners. Some of these LA methods and actions are:

- **Engagement levels analysis.** Educators can view the different engagement levels of learners in order to detect learners that are participating more actively in the implementation process and intervene when specific learners are not engaging in the process.

- **Knowledge domain analysis.** The analysis of the knowledge domain during implementation can be useful for educators and learners towards identifying concepts of the domain that can be used in the experiments or tests of the solution.

- **Clustering.** The visualization of clusters that share similar characteristics can indicate different ways of working that are more suitable for specific learners within a group. For example, learners that are more knowledgeable on simulations can perform simulations on the solution whereas learners that are more proficient in development can develop the solution.

- **Recommendations.** Educators can monitor the implementation process and provide recommendations to learners that are either at risk of not performing well or in need of additional resources or recommendations on ways of testing the solution.

- **Scaffolding.** Educators can monitor the LA visualizations and scaffold learners by providing helpful hints and designing compelling tasks that will help them implement an interesting solution.

- **Guidance.** Educators can guide the entire implementation step by meeting and discussing with the group members and adapting the process based on their needs.

The **Data Layer** of the PBL.LA framework can be populated with the specific data that is generated as well as the evidence that will be used for analysis and assessment. Representative instances are:
• **Testable prototype.** The actual prototype implemented is the main output of the step and should be in complete alliance with all the previous outputs provided by the group.

• **Description of solution’s implementation.** The description of the solution’s implementation regards the details of the different tests, simulations, experiments etc. carried out towards the final version of the solution as well as the presentation of the solution’s added value.

• **Process data.** This data is also described in the previous steps and includes: access to resources per learner, times spent on each activity per learner, navigation patterns, engagement levels per activity per learner etc.

A representative population of the PBL_LA framework for implementation step based on the work presented above is shown in Figure 21.

![Figure 21 Populated PBL_LA framework for Implementation step](image)
5.5.3 PBL_LA Implementation assessment

The assessment of the Implementation step regards three main aspects.

- **Individual performance.** During implementation, educators assess how each learner contributed to the development of the problem’s solution. This also involves the acquisition of skills relevant to this step, as presented in the beginning of this sub-section.

- **Group performance.** Educators assess how well the group worked together towards formulating a comprehensive testable solution that corresponds to the results provided so far in the previous steps, and how equally divided was the work carried out amongst the group members.

- **Outputs / results.** The quality of the actual outputs is also assessed in accordance to the specific educational objectives set in the course design phase. In this step, the outputs include a testable solution and a comprehensive description of all the workflow and tasks carried out towards the solution’s implementation.

5.6 PBL_LA Evaluation

The evaluation step regards the actual assessment of the implemented solution. During this step, learners refine the evaluation strategy they had drafted in the start of the project, since it is heavily associated with the problem they formed and refined. Furthermore, learners perform different types of tests, depending on what type of solution they created, and carry out various evaluation techniques to gather feedback on the solution (e.g. observations, interviews, surveys, usability tests etc.).

The following figure shows a general overview of the PBL_LA approach focusing on the Evaluation step and covering all three learning phases, i.e. course design, course execution and course assessment.

![Figure 22 PBL_LA instance for Evaluation](image-url)
5.6.1 PBL_LA Evaluation design

Course design for the Evaluation step of the PBL model regards the setting of educational objectives and the decision on the activities to be realized, as shown in Figure 22. During the design, the educator sets the educational objectives that should be achieved in this PBL step. For the evaluation step, these objectives regard:

a) A refined evaluation strategy.

b) Evaluation results that show the solution’s appropriateness to the formulated problem.

During evaluation, learners build a variety of different skills, such as:

- **Creativity**, when trying to find all the different ways in which a solution can be implemented.
- **Resourcefulness**, when trying to find ways to get the best results for the goals set.
- **Oral communication**, when interviewing stakeholders for gathering important information on the evaluation of the solutions.

Thus, educators list the activities that are most commonly realized during this step and that support learners in building these skills. Some of the proposed activities include refining the initial evaluation plan and performing a variety of evaluation techniques such as interviews, surveys, user tests etc., documenting all data and discussing the derived results etc. This is not an exhaustive list of activities, and each group can realize all or a sub-set of them in order to successfully produce the set learning outcomes.

5.6.2 PBL_LA Evaluation execution

The execution of the evaluation step regards the realization of a set of activities as mentioned in the design phase that will allow learners to test their solution and evaluate its validity. The activities produce specific types of data and evidence of work, which can be recorded, processed and analysed towards different analytics visualizations and interventions.

Figure 23 presents an indicative instance of the PBL_LA approach for the step’s execution. This instance is one of many that can populate the different Layers of the PBL_LA framework proposed in the previous chapter.
More specifically, the Pedagogical Layer can include activities that are usually realized for the solution’s evaluation, such as:

- **Performing user tests.** Learners perform different user tests in order to evaluate the validity and appropriateness of their implementation. This involves utilizing and applying the solution in different settings and contexts and recording the results in regards to different variables such as usability, ease of use, intention of future usage, accessibility etc.

- **Getting feedback from interviews.** Learners ask feedback from different stakeholders that use the solution and respond to a variety of evaluation related questions.

- **Getting feedback from surveys.** Learners gather data from surveys that ask questions in regards to the evaluation of the implemented solution.

- **Documenting results.** Learners gather all above data and document the results.

The Analytics Layer of the PBL_LA framework for the evaluation step can be populated with different LA methods and intervention actions that are suitable for analysing the aforementioned data and providing helpful insights to educators and learners. Some of these LA methods and actions are:

- **Learner modelling.** The analysis of each learner’s profile can help educators detect particularities such as specific learning styles and provide the necessary adaptations and personalization. For example, if a learner is more reserved and is not comfortable with lengthy face-to-face discussions such as interviews, educators can include the availability of a survey for evaluation data gathering.

- **Performance dashboards.** General performance dashboards can indicate the overall progress of the evaluation step and allow educators to make the necessary interventions when they identify at-risk learners or low evaluation results.
• **Guidance.** Educators can study the LA visualizations in the available dashboards and provide general guidance to learners in need.

• **Reflecting.** Learners can reflect on the evaluation process and take necessary actions when they realize that they e.g. require more rich evaluation results.

• **Feedback.** Educators can provide feedback to learners when they need help (e.g. when they are not using the appropriate evaluation methods, when they have not gathered enough participants for feedback etc.).

The **Data Layer** of the PBL_LA framework for this step can be populated with the specific data that is generated as well as the evidence that will be used for analysis and assessment. Representative instances are:

• **Refining evaluation strategy.** The evaluation strategy that will be used to carry out the evaluation process is representative of the work done by the group.

• **Evaluation results.** The actual evaluation results gathered and documented by the group will lead to the informative reporting in the next step and allow learners to form interesting conclusions on whether their developed and tested solution was appropriate for their formulated problem.

• **Process data.** This data is described in the previous steps and includes: access to resources per learner, times spent on each activity per learner, navigation patterns, engagement levels per activity per learner etc.

A representative population of the PBL_LA framework for the evaluation step based on the work presented above is shown in Figure 24.
5.6.3 PBL_LA Evaluation assessment

The assessment of the Evaluation step regards three main aspects.

- **Individual performance.** Educators assess how each learner contributed to the evaluation of the solution’s implementation. This also involves the acquisition of skills relevant to this step, as presented in the beginning of this sub-section.

- **Group performance.** Educators assess how well the group worked together towards testing the solution developed, gathering appropriate and valid results, and discussing them. Educators also assess how equally divided was the work carried out amongst the group members.
• **Outputs / results.** The quality of the actual outputs is also assessed in accordance to the specific educational objectives set in the course design phase. In this step, the outputs include the evaluation plan and evaluation results.

## 5.7 PBL_LA Reporting

The final step of the PBL strategy regards the reporting of all results to the supervisor, the drawing of conclusions and their presentation in a comprehensive and valid manner. Each learner contributes to the reporting step and presents a part of the work done to the supervisor and other members of the assessment team. Learners also propose paths for improvement and future work.

The following figure shows a general overview of the PBL_LA approach focusing on the Reporting step and covering all three learning phases, i.e. course design, course execution and course assessment.

![Figure 25 PBL_LA instance for Reporting](image)

### 5.7.1 PBL_LA Reporting design

Course design for the Reporting step of the PBL model regards the setting of educational objectives and the decision on the activities to be, as shown in Figure 25. During the design, the educator sets the educational objectives that should be achieved in this PBL step. For the reporting step, these objectives regard:

a) A report with all the work done.

b) Conclusions drawn.

c) Proposals on future work.

During this last PBL step, learners build a variety of different skills, such as:

• **Data interpretation and analysis**, while drawing interesting and innovative conclusions from all the work done in the previous PBL steps and the evaluation of the solution's implementation.
• **Group-work and collaboration**, while working together to decide on the report sections to include, the presentation to design, the conclusions to draw etc.

• **Written communication**, while writing the report in a comprehensive way that includes scientific references, valid arguments and added value to the problem domain.

• **Oral communication**, while presenting the report to the exam committee and defending the work done on an individual and group level.

• **Creativity and innovation**, while identifying existing gaps and proposing interesting and promising future work.

Thus, educators list the activities that are most commonly realized during this step and that support learners in building these skills. As reporting is the final step of the PBL model, it is important that the group works together towards properly presenting all of its members’ efforts and the added value of their solution. Some of the proposed activities that can help them towards this goal include writing, drawing conclusions, presenting and argumenting.

### 5.7.2 PBL_LA Reporting execution

The execution of the reporting step regards the realization of a set of activities as mentioned in the design phase that will allow learners to test their solution and evaluate its validity. Figure 26 presents an indicative instance of the PBL_LA approach for the step’s execution. This instance is one of many that can populate the different Layers of the PBL_LA framework proposed in the previous chapter.

<table>
<thead>
<tr>
<th>ACTIVITIES</th>
<th>EVIDENCE / DATA</th>
<th>ANALYTICS</th>
<th>INTERVENTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Writing</td>
<td>Report</td>
<td>Clustering</td>
<td>Guide learners</td>
</tr>
<tr>
<td>Drawing conclusions</td>
<td>Presentation</td>
<td>Learner modelling</td>
<td>Feedback</td>
</tr>
<tr>
<td>and proposing future work</td>
<td>Future work</td>
<td></td>
<td>Recommend</td>
</tr>
<tr>
<td>Presenting</td>
<td>Process data</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Argumenting</td>
<td></td>
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</tr>
</tbody>
</table>

**Figure 26 PBL_LA Reporting execution**

More specifically, the **Pedagogical Layer** can include activities that are usually realized for the reporting, such as:

• **Argumenting**. Learners discuss on the overall work done across all the PBL steps and form arguments on how to report their efforts and results in this step.
• **Writing.** Learners write a detailed report of all the work done in all the PBL process and steps in a way that the report describes all major tasks and activities as well as the solution itself.

• **Drawing conclusions.** Learners analyse the evaluation data gathered, reflect and discuss on the results and draw interesting conclusions that show the solution’s appropriateness to the problem formulated by the group.

• **Proposing future work.** Learners identify existing gaps that have not been addressed by the work carried out and make interesting suggestions for future work that will lead to promising solutions for the subject domain.

• **Presenting.** Learners present their work to the exam committee and defend their results.

The **Analytics Layer** of the PBL_LA framework can be populated with different LA methods and intervention actions that are suitable for analysing the aforementioned data and providing helpful insights to educators and learners. Some of these LA methods and actions are:

• **Clustering.** The availability of different clusters that show groups of similar characteristics can help educators perform more adaptable assessments during reporting and provide flexibility in the ways reporting can be documented and presented.

• **Learner modelling.** The identification of different learning styles and profiles can enable educators to adapt the reporting step in accordance to the specific particularities of each learner and scaffold the process based on each learning profile identified.

• **Guiding.** Educators can monitor all the LA visualizations and provide general guidance to a group and individuals while they are trying to report their work in a comprehensive and valid manner.

• **Feedback.** Educators can provide feedback to learners while they are working on their report, and mentoring them when they need assistance in e.g. different ways of presenting the report, sections to include in the report etc.

• **Recommendations.** Educators can provide various recommendations based on the LA visualizations available, which will allow learners to generate a suitable report documentation and presentation.

The **Data Layer** of the PBL_LA framework can be populated with the specific data that is generated as well as the evidence that will be used for analysis and assessment. Representative instances are:

• **Report.** The report that is written by each group presents all the work done across all PBL steps and also includes the conclusions drawn from the evaluation of the solution developed.

• **Future work.** Each group presents various proposals for future work based on the gaps they have identified that would be interesting to address in further research. This includes the
number of proposals suggested as well as how relevant or promising they are for the subject domain.

- **Presentation.** The presentation includes the main points of the work done by each group and each member is called to defend their overall and specific effort as well as validate all the activities carried out and results produced. This includes the content of the presentation, the layout (e.g. template used, presentation structure etc.) as well as the learners’ oral communication skills.

- **Process data.** This data is described in the previous steps and includes: access to resources per learner, times spent on each activity per learner, navigation patterns, engagement levels per activity per learner etc.

A representative population of the PBL_LA framework for the reporting step based on the work presented above is shown in Figure 27.
5.7.3 PBL_LA Reporting assessment

The assessment of the reporting step regards three main aspects.

- **Individual performance.** Educators assess how each learner contributed to the overall work done as well as in the reporting of his/her efforts. This also involves the acquisition of skills relevant to this step, as presented in the beginning of this sub-section.

- **Group performance.** Educators assess how well the group worked together towards drawing conclusions from the evaluation results, proposing future work as well as writing and presenting the overall report of their work. Educators also assess how equally divided was the work carried out amongst the group members.

- **Outputs / results.** The quality of the actual outputs is also assessed in accordance to the specific educational objectives set in the course design phase. In this step, the outputs include the report document, the report presentation, the conclusions drawn and the future work proposed.

This is the last part of the PBL_LA approach, which concludes the presentation of the proposed integration of PBL with LA and LS concepts. The approach includes only domain-independent information, not focusing on any discipline or sector, thus enabling PBL_LA approach’s mainstreaming ability. Educators and trainers can design their courses by including the PBL steps, adding the suggested activities in each step, and exploiting the aforementioned educational data towards the proposed LA visualizations and intervention mechanisms for enhanced course execution and assessment.
6 Conclusions

The present deliverable aimed to exploit the results of the two previous deliverables and, combined with empirical experience, present the PBL_LA educational approach.

The methodology followed in this deliverable included the study of the two previous deliverables (i.e. D1.1 “PBL analysis” and D1.2 “LA analysis”), brainstorming sessions amongst all partners on the information identified as well as design of an abstract PBL_LA framework that includes a variety of inter-related concepts and that can be applied in any sector and domain.

The PBL_LA framework is comprised of three main layers, namely the:

- **Pedagogical Layer**, which includes the activities carried out and the evidence produced during each PBL step.
- **Data Layer**, which includes all data that is generated during learning, i.e. learner – generated, educator – generated, system – generated.
- **Analytics Layer**, which includes all LA methods that analyse educational data and produce meaningful insights, visualizations and allow interventions for improving learning.

The framework’s layers and concepts were then populated with specific instances that can guide future endeavours of applying PBL in courses and employing LA methods that will exploit the generated data and enhance learning and teaching. Next, the approach suggested a number of LA methods that can analyse these data and enhance learning by providing different types of visualizations and insights on the learners’ progress. Based on the analysis, it seems that PBL steps like “Problem formulation”, “Task formulation” and “Problem analysis” include a variety of different activities, produce multiple types of evidence, generate the majority of data and require the most support from LA visualizations and interventions. This is expected as in these three steps learners perform activities that require their active participation and involvement and they build a diverse and wide set of transversal skills (e.g. critical thinking, problem analysis, creativity, innovation, communication of ideas, organizational management etc.).

The PBL_LA approach was examined and presented across the three steps of learning, i.e. course design, course execution/delivery and course assessment, so as to provide a holistic overview of how this new approach can enhance the learning experience for both educators and learners.

The suggestions provided aim to guide future endeavours in any sector (academia, business or public organizations) where courses will combine the PBL model with newer concepts such as LA methods and LS techniques. All concepts and instances included in the approach are domain-independent, allowing PBL_LA’s mainstreaming across all sectors and disciplines.
References


