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Toolkit 3: One model for mini-PBL

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PBL stands for **project-based learning**.

What exactly is Project-Based Learning (PBL)?

Project-based learning is a teaching approach that engages students in sustained, collaborative real-world investigations. Projects are organized around a driving question, and students participate in a variety of tasks that seek to meaningfully address this question.

Projects can be complex tasks, based on challenging questions, problems, events and or activities, that involve students in the design, implementation, reflection, problem–solving and decision making that give students the opportunity to work collaboratively and independently over a period of time, that concludes with a realistic product, presentation, activity or event.

The following criteria characterize project based learning:

- Projects are central and not peripheral to the curriculum;
- Project based learning projects are focussed on questions or problems or activities that "drive" students to encounter (and struggle with) the central concepts and principles of a discipline;
- Projects involve students in a constructive investigation;
- Projects are largely student driven;
- Projects add value and are realistic and authentic (not school like).

Designed properly, project-based learning will challenge all students to perform at the highest levels, requiring them to:

- think critically, creatively, and collaboratively,
- access the knowledge in the disciplines,
- develop effective oral and written communication skills,
- apply their learning by designing products and performances,
- assess their own learning,
- develop as a self-directed, independent and interdependent learner,
- integrate technology meaningfully.

Project-based versus Problem-based

So what's the difference? None, in a way. Problem-based learning is the first step of project-based learning. To get to the project-based aspect, you have to go through the problem-based aspect. It is not possible to do a project-based unit without the problem-based unit as the problem is the basis for the project.

Alternatively, think of it this way:
- In project-based units, students create a product, where the process of production of this product is as important as the final result.
- In problem-based units, students develop a solution.

How does this all connect? (Steps from problem-based to project-based)

Looking at project-based learning in the most general way, it can be broken down into the following nine steps (of course, teacher-coaches should modify the steps accordingly to suit the task and the students):

1. The teacher-coach **sets the stage for students with real-life samples** of the projects they will be doing.
2. Students **take on the role of project designers**, possibly establishing a forum for display or competition.
3. Students **discuss and accumulate the background information** needed for their designs.
4. The teacher-coach and students **negotiate the criteria for evaluating the projects.**
5. Students **accumulate the materials** necessary for the project.
6. Students **create their projects.**
7. Students **prepare to present their projects.**
8. Students **present their projects.**

9. Students **reflect on the process and evaluate the projects** based on the criteria established in Step 4.

PBL as center of the teaching-learning process

The PBL model has its origin in Medicine studies in MacMaster University (Canada). Here in Europe, Maastrich University (The Netherlands) and Aalborgh University (Denmark) are main examples of design of curricula on PBL model.

The education model of these universities is designed around the Project-Centered Learning (PCL) teaching method. In PCL, the students participate in one project per semester in which they apply and integrate selected content of the courses. This enables them to develop a variety of skills such as project management, writing, presenting and working in a team. Universities offer skill classes to further develop these competences, which are also important for your future career.

None of Pythagoras' partners follows this model, but this Erasmus+ project will allow them to acquire experience and skills on project design, how to implement in the classroom and start a complete organization transformation, moving from the classical methods to a more student-centered approach.

Student-centered learning[1] has been defined most simply as an approach to learning in which learners choose not only *what* to study but also *how* and *why* that topic might be of interest (Rogers, 1983). In other words, the learning environment has learner responsibility and activity at its heart, in contrast to the emphasis on instructor control and the coverage of academic content found in much conventional, didactic teaching (Cannon, 2000). Additionally, learners find the learning process more meaningful when topics are relevant to their lives, needs, and interests, and when they are actively engaged in creating, understanding, and connecting to knowledge (McCombs & Whistler, 1997).

Our proposal is in transition from a simple classroom practice to a complete change of paradigm on the teaching-learning process. We'll provide a Toolkit for teachers to design PBL which can be presented in regular classes, without changing programmes or objectives. Starting as a new dynamic for classes, we'll help teachers to introduce an adapted version of major PBL techniques, what we call mini-PBL, which avoid generating usual resistance to any innovations in education.

Key concepts about mini-PBL

If we think in the PBL model from Maastricht University or Aalborg University, with designs of one semester long, we assume that it has to be a high level and sophisticated proposal, involving many contents (subjects from previous and such semester), tools and trying to develop several competences and skills on the students.

Our approach and proposal will be more humble, but at the same time ambitious in the sense of impact in the regular classroom, as an engine of innovation in the teaching-learning process.

[1] https://lincs.ed.gov/state-resources/federal-initiatives/teal/guide/studentcentered

These are the Key Facts on our mini-PBL model:

- It will be able to be done completely in **2-3 class sessions**, including always some autonomous activities (preparation and recording of final presentation, some tasks between class sessions, etc).
- It will be based on **2-3 content units**, as minimum.
- It will promote the **spiral curriculum strategies**, i.e., always trying to recall past contents worked, to be used at the same time with the new ones. Thus, the final semester mini-PBL proposal could have exercises and questions covering all the programme contents of the subject, and even from other subjects.
- It will promote the use of **mathematical dynamic tools** (mobile, CAS, etc), by posting questions and exercises which demand high level computation skills (graphics, massive evaluations, solving non-basic equations and systems, complex calculus computations, etc).
- Attending the core of this Erasmus+ project, the topic of the mini-PBL will be related with **real-life problems concerning the SDG**.
- ….

Before presenting our model, we recall that the design of activities around the SDG is the core of the Toolkit 1, the mathematical dynamic tools are the main content of the Toolkit 2. For this Toolkit 3, we deep the new concept we consider relevant in our approach: the spiral curriculum.

The Spiral Curriculum

The **Spiral Curriculum** is defined as a curriculum that returns to the same topics over time. It is juxtaposed to methods that involve learning something then moving on, perhaps never to engage with it again.

The spiral curriculum teaching strategy was developed by cognitive theorist **Jerome Bruner** in 1960. Bruner reflected on the fact that many teachers implicitly use this method. However, Bruner documented the approach and its great value for curriculum designers and, ultimately, student learning.

The spiral approach to curriculum has three key principles that sum up the approach nicely. The three principles are:

1. **Cyclical:** Students should return to the same topic several times throughout their school career;
2. **Increasing Depth:** Each time a student returns to the topic it should be learned at a deeper level and explore more complexity;
3. **Prior Knowledge:** A student's prior knowledge should be utilized when a topic is returned to so that they build from their foundations rather than starting a new.

Our approach puts emphasis in the following features of a spiral curriculum:

(1) Topics are revisited: Students revisit topics, themes or subjects on a number of occasions during a course. They may return to generalizable and transferable skills such as management or communication.

(2) There are increasing levels of difficulty: The topics visited are addressed in successive levels of difficulty. Each return visit has added objectives and presents fresh learning opportunities leading to the final overall objectives. Every visit can bring:

- new knowledge or skills relating to the theme or topic;
- more advanced applications of areas previously covered;
- increased proficiency or expertise through further practical experience.

(3) New learning is related to previous learning: New information or skills introduced are related back and linked directly to learning in previous phases of the spiral. Previous learning is a prerequisite for the later learning.

(4) The competence of students increases: The learner's competence increases with each visit, until the final overall objectives are achieved. This progressive gain in competence can be tested through the assessment procedures.

Figure 1: The spiral diagram which represent the Brunner's ideas

7j which describes six criteria, each of which must be at least minimally present in a project in order for it to be judged "high quality". Since our PBL model reduces the size and number of activities, to drive a mix of classroom activity with autonomous work of students, we select four from these six criteria in every HQPBL such that they must all be at least minimally present in a project in order for it to be judged as a Pythagora mini-PBL

INTELLECTUAL CHALLENGE AND ACCOMPLISHMENT

Students learn deeply, think critically, and strive for excellence.

Projects should not just be "fun activities" or hands-on experiences" requiring minimal intellectual effort. A high quality project requires students to think critically about a complex problem, question, or issue with multiple answers, and then work on that project over the course of days, weeks, and even months.

To complete a project successfully, students need to learn important academic content, concepts, and skills. They should also be challenged to produce the highest-quality work possible and guided and supported as they try to do so.

AUTHENTICITY

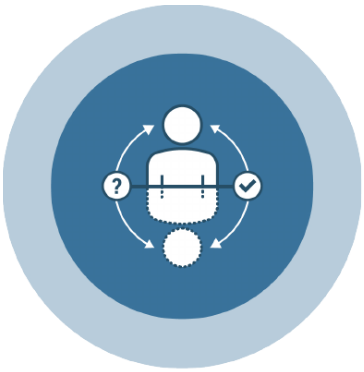
Students work on projects that are meaningful and relevant to their culture, their lives, and their future.

To motivate students and show them the relevance of what they are learning in school, projects should be experienced as "real." A high quality project reflects what happens in the world outside of school. It uses the tools, techniques, and technology found there. It can make an impact on other people and communities, and it can connect to the interests and concerns of young people. Students' voices should be heard in a project, and they should be able to make choices about their work.

COLLABORATION

Students collaborate with other students in person or online and/or receive guidance from adult mentors and experts.

Projects may be done as an individual activity, but in today's world – and workplace -- it is important to learn the skill of collaboration. In high quality PBL, some project work should be done as a team. This does not mean simply dividing up project tasks, completing them individually, then putting it all together at the end with no synthesis or discussion. When students truly collaborate, they are contributing individual voices, talents, and skills to a shared piece of work, while respecting the contributions of others. In some projects, students also collaborate online with students in other schools, and work with adult experts, community members, and organizations.



REFLECTION

Students reflect on their work and their learning throughout the project.

Learning is reinforced by reflecting on what we know and do. In a high quality project, students learn to assess the quality of their work and think about how to make it better. They pause regularly—not just at the end of the project, but throughout the process—to think about what they are doing and learning. By reflecting on what they have accomplished, students retain project content and skills longer, develop a greater sense of control over their own education, and build confidence in themselves.

The Pythagoras mini-PBL model

In this section we want to present the basic scheme of design of our mini-PBL model, to proceed later to construct several examples which can be used directly in the classroom.

But more interesting for us is to develop an active reflection on the new teaching-learning process where we should combine methodology (mini-PBL), thematic (SDG) and tools (dynamic math tools), the three pillars of our ToolKit.

The student-centered classroom involves changes in the roles and responsibilities of learners and instructors, in the delivery of instructional strategies, and in learning itself; these all differ from those in the traditional, teacher-center classroom.

The role of the professor

This section is only a brief review on something well known about the role of the professor in a learner-centered approach. Here follows some basic guidelines.

Learner-centered professors must:

- Act as Facilitators and Guides
- Provide Anytime, Anywhere and On-Demand Support
- Embody Core Values That Support Deeper Learning
- Truly Encourage Students Drive Their Own Learning
- Create Real-World and Authentic Learning Experiences
- Leverage Technology to Personalize Learning
- Commit to Professional and Personal Growth

If you encourage your colleagues to do all this, they will ask a very simple question: How? Well, mini-PBL allows students and professors to be involved completely on a learner-centered approach since it contains all the elements to provide a full experience on that.

However, we may clarify that we are not designing activities in a “complete and explicit sense” of a learner-centered process. In student-centered classrooms, students are directly involved and invested in the discovery of their own knowledge. Here, we start in general with a high level of previous knowledge, but what we get from the learner-centered approach is tha collaboration and cooperation with others, and students engage in experiential learning that is authentic, holistic, and challenging.

In practice, maintain in mind your role as professor as we guideline above, don’t worry so much in the beginning about the role of the students. The practices will provide you with signs to motivate and engage students in a way that will allow you to design new mini-PBL examples where the knowledge has to be constructed by the own students (e.g. discover how to solve optimization problems using derivatives), all as part of a evolutive process in the teaching-learning action of your course. As long as the students, and the professors, acquire experience on the format it would run better, the professor adjusts the info to provide students from high details at the beginning to lesser in the following.

The role of students

The role of the student in the student centered classroom is, quite literally, at the center of the learning process. The student is an active participant in virtually everything that happens in the classroom.

In this model, learning is a constructive process that is relevant and meaningful to the learner and connected to the learner's prior knowledge and experience. The learning environment supports positive interactions among learners and provides a supportive space in which the learner feels appreciated, acknowledged, respected, and validated. Rather than trying to "fix" the learner, the learner has the power to master his or her world through the natural process of learn-ing (McCombs & Whistler, 1997).

In the student-centered classroom, the learner requires individualization, interaction, and integration. Individualization ensures that learners are empowered to create their own activities and select their own authentic materials.

Learners interact through team learning and by teaching each other. During the learning process, learners integrate what they have learned with prior learning
and construct new meaning (Moffett & Wagner, 1992).

Learners must:

- Are active participants in their own learning.
- Make decisions about what and how they will learn.
- Construct new knowledge and skills by building on current knowledge and skills.
- Understand expectations and are encouraged to use self-assessment measures.
- Monitor their own learning to develop strategies for learning.
- Work in collaboration with other learners.
- Produce work that demonstrates authentic learning.

The mini-PBL scheme

In this section we present the basic structure for construction of mini-PBL. This will be done by a working template.

But, don't take this model as monolithic. The content proposed is indicative, you can always modify upon your needs, your goals and the concrete problem to be posted. Please open a reflection on your more convenient format, but mainly for your students. In general, you will improve the models as long you, and your students, practice.

Your reflection and students' feedback will be critical for the adaptation of the model to your subject, your personality as teacher, the behavior of your students, and all those issues that impact on your teaching-learning process. At the end, the mini-PBL template will express your understanding of learning, and will become the way to achieve the goals of the subject by the students.

Here follows our basic template:

Teaching Guide for Teachers

Mini-PBL project	
Teacher data sheet: Teaching Guide	
Title	The Title declares most of the project and is probably the first spark to wake the interest of students. It must be direct, clear, motivating and descriptive of the real-life issue which it addresses.
SDG attended	Using this UN graphics, we mark such SDG which this project works. 
Content units	The project may cover **2 or 3 content units**, as minimum. As the course advances, more units can be considered, but we may take care not to design a too long activity. The key concept to attend is the spiral curriculum strategy, focusing the review processes to recover students on risk to fail, and remark the connection between the content units of the course.
Sessions	Here we advance the number of sessions in the classroom we dedicate to work on this project. However, the students may know in advance that, in general, all the projects will require autonomous work, following the ECTS metric.
Hours of autonomous work	Here we may pay special attention and be careful not to generate an overtasking project. This is relevant since if you don't measure this autonomous part, the students' attitude and performance will be seriously affected. The exceed of work out of classroom affects to another subjects, impact negatively on the next mini-PBL proposed and, more disheartening for us, the goals of the mini-PBL will be displaced by the urgencies and rush (deep reflections, careful writing, checking results by different ways, discuss with classmates, etc). The worst consequence of an overtaking proposal is the cheating between students. You can introduce ways to avoid or reduce this bad practices, but regular teaching generates a high stressing workflow for both students and professors, if you have to manage additional control of the students' ethics performance.
Competences to be	Your subject has a list of competencies to be achieved by your students. Here is the place where those related with this project should

developed	be listed. Recall always the sense of competences, don't mix with contents to be explained. These kinds of activities are one of the most favorable to work competencies since the combination of tasks and problems promote more the "know how to do" than the "know by repetition". Here follows a list that can be used as example[2]: **Reasoning and modeling** ● Develop thinking strategies to solve puzzles and play games ● Explore, analyze, and apply mathematical ideas using reason, technology, and other tools ● Estimate reasonably and demonstrate fluent, flexible, and strategic thinking about number ● Model with mathematics in situational contexts ● Think creatively and with curiosity and wonder when exploring problems **Understanding and solving** ● Develop, demonstrate, and apply conceptual understanding of mathematical ideas through play, story, inquiry, and problem solving ● Visualize to explore and illustrate mathematical concepts and relationships ● Apply flexible and strategic approaches to solve problems ● Solve problems with persistence and a positive disposition ● Engage in problem-solving experiences connected with place, story, cultural practices, and perspectives relevant to local First Peoples communities, the local community, and other cultures **Communicating and representing** ● Explain and justify mathematical ideas and decisions in many ways ● Represent mathematical ideas in concrete, pictorial, and symbolic forms ● Use mathematical vocabulary and language to contribute to discussions in the classroom ● Take risks when offering ideas in classroom discourse **Connecting and reflecting** ● Reflect on mathematical thinking ● Connect mathematical concepts with each other, other areas, and personal interests ● Use mistakes as opportunities to advance learning ● Incorporate First Peoples worldviews, perspectives, knowledge, and practices to make connections with mathematical concepts
ICT tools to be used	Here is probably one of the items where you show to the students how it is going to be your support. In this section we recommend to list the features which can be used in the PBL resolution. We don't list software to be used, this search by the students is part of the project. As example, we should provide a list like this: - Graphics: explicit, implicit, 2D, 3D,... - Solving equations and/or systems: graphically, numerically,

[2] https://curriculum.gov.bc.ca/curriculum/mathematics/12/calculus

	algebraically, … - Calculus calculator: derivatives, integrals,.. - Vector and matrix calculator: graphically, numerically,..
Context: project estatement	This section is where the project is presented to the student. The introduction, the core topic and all the information will help students to allocate the tasks and problems posted late. Here you may include the references, graphics, news from media, official reports (UN, EU, OCDE, UNICEF,...), and any source which helps to acquire a wider idea about the SDG problem we address. This effort to "put in context" the problem will connect mathematics with real-life, with Earth challenges and Humanity needs. Don't reduce this part too much thinking that students won't pay attention. When we teach mathematics by using SDG we are promoting the reflection of our students, future professionals, on the major challenges of Mankind and Earth. We are constructing Global Citizens.
Tasks and problems	Obviously, this is the section to collect all the aims of the project, by the activities and tasks to be done. In the format you prefer: classical problems, inquiries, modelization, generalization, etc. Here you have to be creative, diverse and stimulating, focus more on the competences to develop than the difficulty or the range of contents to cover. List the problems/tasks in crescent order, try to use previous results on the next ones, and drive along the content units selected (spiral curriculum) recalling the students the connection between such units.
Outcomes expected	This is a critical list: The student may know perfectly what you expect from him. PBL can't be a hidden game. This training will be useful in their professional life: the deep analysis of a problem, the design of the solution and the presentation of the results must be a well structured process, and PBL helps. However, this list can't limitate the creativity of the student, you should provide a guide of minimum output expected: - Graphics fitting the solution - Tables of data used/obtained in solutions - Numerical results explained and put in context - Capture of ICT tools solutions used - Sequence of steps followed - Remark computations done by hand and done by ICT tools - Provide complete answer to questions - All the results must be presented in the context of the problem
Guide for Learning	This section will evolve along you and your students would acquire experience on working in mini-PBL projects. We don't usually provide learning tips with our syllabus: Here is critical. Mainly at the beginning of the course, the students need guides on new activities, and feel your support on a well structured pack of suggestions on how to address the problems posted. Here some examples: - Read carefully the problem statement and the tasks posted. Always maintain a global view of all the projects. - Identify, or try to do a first draft match, the content units of your lecture notes involved in every task.

	Take your lecture notes open and review before starting to solve the problems. - Match output expected with the tasks posted, at least as first draft approach. This will give you ideas about which tools are needed (ICT tools, hand calculations, data collection, …). - Follow the order of the tasks, try to increase the knowledge of the problem while you are solving the activities. - Always think that maybe there are different ways to solve a problem. - Use ICT tools to avoid hard computations and check your solutions are correct in different ways if possible. - The solutions are always part of a context, expressing such a final solution totally integrated in the problem posted. - Be sure you answer the complete questions. Partial solving could generate missing information for the following questions. - Always try to solve the questions by yourself. If the project can be done in groups, discuss in groups to confirm and detect fails or weaknesses, confront strategies, discuss presentation format, etc. Working in groups doesn't mean work less but work better. - ……
Guide for Teaching	Here we should develop all the key facts and procedures which will guide the teachers to provide the advice, help and hints needed to present and launch the mini-PBL to students. From our point of view, this section also could be the place where we present the backoffice of the expected results and goals of the project, the desired strategies to be developed by students, the list of tools and phases in the development of the tasks. Here we can provide to teachers the mathematical insights we desire to be achieved by the students along the construction and solution of the mini-PBL project.
Assessment	One of the main items, which used to worry students and always affects students's perception of the activity. We recommend the following scheme: **Alternative Assessment** Assessment for learning starts with outcomes, proceeds with projects, products, and performances that map to the outcomes, and completes the loop with assessment and feedback to students. Alternative assessment provides avenues to assess projects effectively. Alternative assessment **assesses acquisition of knowledge and skills in ways other than the conventional methods such as traditional paper-and pencil tests. It actively involves students in a process that combines what is taught, how it is taught, and how it is evaluated.** *Characteristics of alternative assessment* ❖ Authentic, often in real-life environments, with real-world challenges.

- Interdisciplinary in nature emphasizing on specific knowledge as well as general skills such as transfer of information across settings.
- Involves negotiation and interpersonal skills as well as decision making skills.
- Involves mastery of a task before progressing to the next task.
- Involves mastery assessment of periodic performance
- Gives responsibility to learners for directing and managing their own learning.

Tools for Assessment			
Checklist	Anecdotal records	Calendar records	Exhibition
Oral Presentation	Performing a Skill	Conducting Experiments	Demonstration

Types of Assessment

- **Performance-based Assessment:** assess application of skills and competencies mastered in completing activities or tasks through observation.

- **Authentic Assessment:** assess “real-life” and planning skills, creativity, knowledge integration, and collabora- tion abilities outside the school environment. This can be achieved by using a predetermined set of criteria for instance rubrics, a scoring scale incorporating a set of essential criteria for the task and appropriate levels of performance for each criterion used.

- **Portfolio Assessment:** evaluates the compilation of work and processes attested in efforts and success of a particular project or area. Examinees are required to review and select items that best demonstrate their learning. Examples of portfolios can be paper-based, computer-based or a combination of both.

- **Journal Assessment:** assess the continual documenta- tion of examinee’s expressions, feelings, and experiences through checklists and keeping of logs.

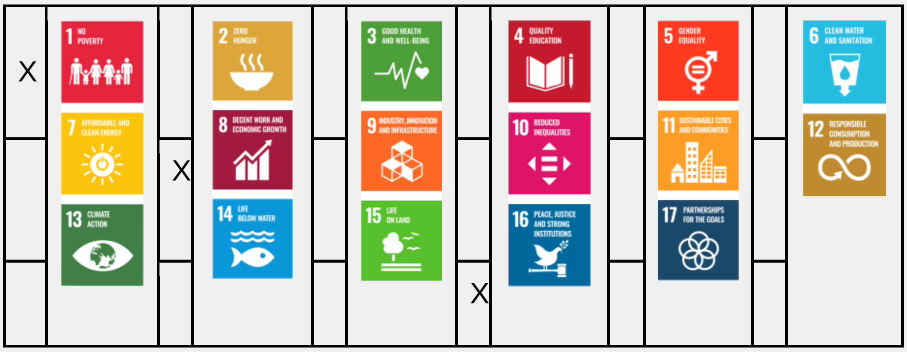
Rubrics

Rubrics are authentic assessment tools designed to simulate real-life activity where students are engaged in solving real-life problems. It is particularly useful in assessing complex and subjective criteria. Formative assessment best describes rubrics and it becomes an ongoing part of the whole teaching and learning process. Its assessment tools comprise the rating scale, a set of evaluation criteria and descriptors.

See ANNEX 1 for Rubric

Others: References	

Learning Guide for Students

Mini-PBL project	
Student data sheet: Learning Guide	
Title	It must be direct, clear, motivating and descriptive of the real-life issue which it addresses.
SDG attended	Using this UN graphic, we mark such SDG which this project works. 
Content units	The project may cover **2 or 3 content units**, as minimum.
Sessions	Number of sessions in the classroom we dedicate to work on this project.
Hours of autonomous work	The students may know in advance that, in general, all the projects will require autonomous work, following the ECTS metric.
ICT tools to be used	As example, we should provide a list like this: - Graphics: explicit, implicit, 2D, 3D,... - Solving equations and/or systems: graphically, numerically, algebraically, … - Calculus calculator: derivatives, integrals,.. - Vector and matrix calculator: graphically, numerically,..
Context: project estatement	This section is where the project is presented to the student. The introduction, the core topic and all the information will help students to allocate the tasks and problems posted late.
Tasks and problems	List the problems/tasks in difficulty crescent order. Activity 1: - *Problem 1.1* - *Problem 1.2*

	- … Activity 2: …… Activity n: - *Problem n.1* …..
Outcomes expected	Guide of minimum output expected: - Graphics fitting the solution - Tables of data used/obtained in solutions - Numerical results explained and put in context - Capture of ICT tools solutions used - Sequence of steps followed - Remark computations done by hand and done by ICT tools - Provide complete answer to questions - All the results must be presented in the context of the problem
Guide for learning	Here some examples: - Read carefully the problem statement and the tasks posted. Always maintain a global view of all the projects. - Identify, or try to do a first draft match, the content units of your lecture notes involved in every task. Take your lecture notes open and review before starting to solve the problems. - Match output expected with the tasks posted, at least as first draft approach. This will give you ideas about which tools are needed (ICT tools, hand calculations, data collection, …). - Follow the order of the tasks, try to increase the knowledge of the problem while you are solving the activities. - Always think that maybe there are different ways to solve a problem. - Use ICT tools to avoid hard computations and check your solutions are correct in different ways if possible. - The solutions are always part of a context, expressing such a final solution totally integrated in the problem posted. - Be sure you answer the complete questions. Partial solving could generate missing information for the following questions. - Always try to solve the questions by yourself. If the project can be done in groups, discuss in groups to confirm and detect fails or weaknesses, confront strategies, discuss presentation format, etc. Working in groups doesn't mean work less but work better. - ……
Assessment	See ANNEX 1 for Rubric
Others: References	

ANNEX 1: RUBRIC

Category	4=Excellent	3=Good	2=Low	1=Poor
Mathematical Concepts	Explanation shows complete understan- ding of the mathe- matical concepts used to solve the problem(s).	Explanation shows substantial understan- ding of the mathema- tical concepts used to solve the problem(s).	Explanation shows some understan- ding of the mathe- matical concepts needed to solve the problem(s).	Explanation shows very limited unders- tanding of the underlying concepts needed to solve the problem(s) OR is not written.
Mathematical Terminology and Notation	Correct terminology and notation are always used, making it easy to understand what was done.	Correct terminology and notation are usually used, making it fairly easy to understand what was done.	Correct terminolo- gy and notation are used, but it is sometimes not easy to understand what was done.	There is little use, or a lot of inappropriate use, of terminology and notation.
Strategy/Procedure	Typically, uses an efficient and effective strategy to solve the problem(s).	Typically, uses an effective strategy to solve the problem(s).	Sometimes uses an effective strategy to solve problems, but does not do it consistently.	Rarely uses an effective strategy to solve problems.
Completion	All problems are completed.	All but one of the problems are completed.	All but two of the problems are completed.	Several of the problems are not completed.
Mathematical Errors	90-100% of the steps and solutions have no mathematical errors.	Almost all (85-89%) of the steps and solu- tions have no mathematical errors.	Most (75-84%) of the steps and solu- tions have no mathematical errors.	More than 75% of the steps and solu- tions have mathe- matical errors.

Sources Checking				
Working with Others	Student was an engaged partner, listening to sugges- tions of others and working coopera- tively throughout lesson.	Student was an enga- ged partner but had trouble listening to others and/or working cooperatively.	Student coopera- ted with others, but needed prompting to stay on-task.	Student did not work effectively with others.
Neatness and Organization	The work is presen- ted in a neat, clear, organized fashion that is easy to read.	The work is presen- ted in a neat and organized fashion that is usually easy to read.	The work is presented in an organized fashion but may be hard to read at times.	The work appears sloppy and unorga- nized. It is hard to know what information goes together.
Diagrams and Sketches	Diagrams and/or sketches are clear and greatly add to the reader's unders- tanding of the procedure(s).	Diagrams and/or sketches are clear and easy to understand.	The work is presented in an organized fashion but may be hard to read at times.	Diagrams and/or sketches are difficult to understand or are not used.
ICT tools used				

Sources of examples

Special interest for any teacher is to have access to a high variety of sources for examples and problems to supply the mini-PBL projects. In fact, it is enough to give a basic applied problem to generate a bigger list of activities based on that.

Every course, in all universities around the world, graduate students present thousands of degree, master and PhD thesis where you can find for sure a list of examples/applications where a graphic or dataset can be the start point for constructing a mini-PBL project.

We encourage you to find your own sources, ask colleagues from your university for precise use of mathematics in any scientific area. Then connect such applications with SDG and construct your mini-PBL.

For help in such searching, in the following table we group basic scientific areas with the SDG to provide a list of suggestions for search math applications with SDG's interest label. Obviously, this is not a closed list, the items are interchangeable, and anyone can find an application of interest in the thousands of research papers and reports published every year all round the world.

SUSTAINABLE DEVELOPMENT GOALS	**Scientific areas or studies**
1 NO POVERTY	❖ Population studies and databases ❖ Incomes & Costs reduction ❖ Logistic & Transportation ❖ Equality studies
2 ZERO HUNGER	❖ Agriculture ❖ Nutrition ❖ Plagues ❖ Pollution
3 GOOD HEALTH AND WELL-BEING	❖ Medical databases ❖ Epidemiology ❖ Pharmacokinetic ❖ Microbiology ❖ Genetic ❖ Sports ❖ Aging

4 QUALITY EDUCATION	❖ Education databases ❖ Psychology ❖ Neuroscience ❖ Human & childhood behavior ❖ Economy of Education ❖
5 GENDER EQUALITY	❖ Incomes inequalities ❖ Population proportion on labor sectors ❖
6 CLEAN WATER AND SANITATION	❖ Water supply databases ❖ Pollution ❖ Microbiology ❖ Engineering ❖
7 AFFORDABLE AND CLEAN ENERGY	❖ Energy production and consume databases ❖ Engineering ❖ Consume ❖ Optimization of resources ❖ Penetration of renewable energies
8 DECENT WORK AND ECONOMIC GROWTH	❖ Labor databases ❖ Social studies ❖ Share market ❖ Bank products ❖ Economy and enterprise ❖ Tourism ❖ Digital business
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	❖ Industry and production databases ❖ Engineering ❖ Mobility ❖ Artificial Intelligence ❖ New Materials ❖ Nanotechnology ❖ Connectivity ❖ Logistic & Transportation ❖ 4th Industrial Revolution: Industry 4.0

10 REDUCED INEQUALITIES	❖ Social lacks and gaps databases ❖ Social studies ❖ Population studies ❖ Incomes/costs reduction ❖ Digital access
11 SUSTAINABLE CITIES AND COMMUNITIES	❖ Quality living databases ❖ Population studies ❖ Optimization ❖ Logistic & Transportation ❖ Civil Engineering ❖ Architecture ❖ Baggage management ❖ Energy ❖ New materials for urban furniture: maintenance, cleaning, preventing damage,... ❖ Electric and autonomous mobility ❖ Air pollution ❖ Noise reduction ❖ Mobility ❖
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	❖ Consume and human behavior databases ❖ Marketing ❖ Social networks ❖ Raw and new materials ❖ Energy ❖ Engineering
13 CLIMATE ACTION	❖ Climate change databases ❖ Deforestation ❖ Desertification ❖ Atmospheric physics ❖ Overheating ❖ CO2 reduction ❖ Carbon footprint
14 LIFE BELOW WATER	❖ Climate change and oceans ❖ Acidification of oceans ❖ Sustainable fishing ❖ Microbiology on oceans ❖ Microplastic and oceans ❖ Waste and biodegradable materials
15 LIFE ON LAND	❖ Climate change and land sustainability ❖ Sustainable farming ❖ Residues and waste processing ❖ Waste and biodegradable materials

	❖ Social studies databases ❖ Economy ❖ Cooperation for development ❖
	❖ Social studies ❖ Social networks ❖ Civil movements ❖

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