Bahçeşehir Koleji
TÜRKİYE ULUSAL AJANSI
TURKISH NATIONAL AGENCY
Co-funded by the European Union

NGSS

Next Generation Science Standards through STEAM

The Digital Teacher's Toolkit (DTT)

Project information

Project acronym		NGSS
Project title		Next Generation Science Standards through STEAM
Project reference number		KA-201-3BD6F1AE
Sub-programme or KA		KA-201
Project website		https://ngss.erasmus.site
Authoring partner		Bahcesehir College
Document version	V2	2.0
Date of preparation		September 2021

Document history:

Date	Version	Author(s)	Description
04.10.2021	V1	Bahcesehir College	
29.12.2021	V2	Bahcesehir College	

Dissemination level: restricted to other programme participants (including Commission services and project reviewers)

Index

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

NGSS

1. The Digital Teacher's Toolkit

1.1 Introduction to the Digital Teacher's Toolkit

Nations invest in innovation to promote sustainable economic growth. While many countries are suffering from the effects of global economic difficulties, such as rising unemployment and soaring public debt, the role of labor input is decreasing in the 21st century economy. Only innovation-driven growth has the potential to create value-added jobs and industries (Organisation for Economic Cooperation and Development [OECD], 2010a). Because innovation is largely derived from advances in the science, technology, engineering, and mathematics (STEM) disciplines (National Academy of Sciences, National Academy of Engineering, & Institute of Medicine, 2011), an increasing number of jobs at all levels require STEM knowledge (Lacey & Wright, 2009). Nations need an innovative STEM workforce to be competitive in the 21st century. Innovation involves the integration of diverse STEM skills and transcends disciplines. Innovation is a highly interactive and multidisciplinary process/product that rarely occurs in isolation and is tightly connected to life (OECD, 2010a). Today, there is a clear consensus among stakeholders on the importance of STEM education to economic innovation (Kuenzi, 2008; OECD, 2010b). STEM education in K-12 settings fosters interdisciplinary knowledge and skills that are relevant to life and prepare students for a knowledge-based economy (National Research Council, 2011). The overarching goal of STEM education is to raise the current generation with innovative mindsets. STEM education includes the knowledge, skills and beliefs that are collaboratively constructed at the intersection of more than

The NGSS project aims to promote STEM+Arts in early education through a novel approach that will focus on Social and Emotional Learning concept (SEL), integrated with interactive approaches (e.g. drama, gamified learning, physical education etc.), involving social and emotional skills as well as cognitive skills. The main focus will be on the following four skills communication, critical thinking, collaboration, creativity.

2. STEAM Lesson Environments

There has been a growing emphasis on facilitating integrated STEM learning at the K-12 level. This is because there exist interdependencies between science, technology, engineering, and mathematics that provide a fertile ground for teaching core concepts in each discipline synergistically (Bryan et al., 2015). Leveraging the synergies present among the various disciplines helps students develop better understanding of the disciplinary concepts, and also enables knowledge transfer from one disciplinary context to another (Bell, 2016)

To implement STEM lessons in the classroom, teachers provide guidance in each of the design phases. In empathy phase students will engage in try, observe, and ask activities to understand the problem thoroughly. For define and ideate phases, open-ended questions and brain storming techniques will encourage students to reflect their empathetic understanding into their solution strategies by further research. Within prototype phase students are allowed to develop many rapid prototypes to take opinions from different audiences, so that they can improve their product and solutions according to the needs. For the test phase students both test their design products with respect to the problem and reflect on the overall design cycle. Teachers are also encouraged to use design, self- and peer assessment rubrics in the test phase.

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

3. Art Integration and SEL

Teachers will find many opportunities to integrate STEAM and socio-emotional learning skills when they focus on design thinking in their lesson plans due to the multifaceted goals and outcomes of the method. Coping with complex problems of 21st century, learning from others, synthesizing, building and developing with purpose and communication are among the design thinking skills which also corresponds cognitive process skills of STEAM education and socio-emotional learning.

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

4. Learning Approaches

NGSS (Next Generation Science Standards through STEAM)wants to integrate a 21st century education strategy for developing more creative learning environments in primary schools, through the adoption of interdisciplinary STE(A)M learning approaches.
Today, new approaches to teaching and learning have emerged from the STEMs with the aim of making connection with real life and help pupils understand and act in favour of societal challenges. For that purpose, the learning approaches in NGSS (Next Generation Science Standards through STEAM will incorporate the different skills pupils need to learn into a project that has an impact on the real world and at the same time help them to solve problems and work on real life dilemmas.

The approaches and pathways for learning, as part of the Digital Teachers Toolkit, will help teachers integrate STE(A)Ms in their classroom and will enable students to:

- ⇨ develop a better understanding of the world;
- ⇨ develop higher critical thinking;
- ⇨ gain experience in independent and self-directed learning;
- ⇨ observe and get innovative ideas and solutions;
- ⇨ test oneself by thinking about possible different solutions to one's own problem or that of others;
- ⇨ improve the students' ability to express themselves (in terms of concepts but also considering opinions, feelings, etc.)
- ⇨ boost empathy with the others and team building;
- ⇨ actively contribute to solve a problem in a cooperative manner, while improving networking as well as the ability to share and learn, to accept different points of views etc.

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

4.1 Inquiry-Based Learning

4.1.1 Definition

Inquiry-based learning is a learner-centered approach that channels learning through questioning and discovery. Students pursue their interests in search for answers to their own questions. They can collaborate to formulate their examination and then organize their quest for relevant information.

Main Components

1. Making observations;
2. Posing questions;
3. Examining books and other sources of information to see what is already known;
4. Planning investigations;
5. Reviewing what is already known in light of experimental evidence;
6. Using tools to gather, analyze and interpret data;
7. Proposing answers, explanations, and predictions;
8. Communicating the results and
9. Personal evaluation and response.

In a STEAM activity plan, students are involved in procedures similar to those followed by researchers. This means that they will use the main components of inquiry-based learning. An inquiry-based learning activity can be structured in accordance to the design phases that will follow the activity.

- Work in groups to solve a problem
- Pose questions
- Investigate
- Plan the next step
- Adapt, understand,
- Invent your own scientific instruments,
- Learn to use digital technologies in a creative manner

(primary):

PHASE ONE: Identification of the problem

PHASE TWO: Research into the roots of the problem

PHASE THREE: Development of possible solutions

PHASE FOUR: Choosing the optimal solution

PHASE FIVE: Construction of prototypes

PHASE SIX: Evaluation of the results of the solution

PHASE SEVEN: Different proposals of possible solution of each group (brainstorming solutions)

PHASE EIGHT: Redesign

4.1.2 Integrating STEAM with Social Emotional Aspects

STEAM promotes and strengthens children's social and emotional development.

- It promotes students' self-esteem, self-regulation, and self-efficacy
- It promotes meaningful engagement to learning, which means that children are emotionally involved in the learning activities.
- It enables children to develop a healthy reliance on each other, to experience vivid social interactions, good relationships and positive feelings towards peers.It fosters and develops communication skills.

4.1.3 Implementation In the Classroom (steps of the method)

PHASE ONE: Identification of the problem

In the first phase, based on the interests and needs of the students, the teacher - helped by the students - identifies the need or problem to which they should provide a solution.

PHASE TWO: Research into the roots of the problem

In the second phase, students comprehensively research the grid of factors that highlight the need to solve the problem.

PHASE THREE: Development of possible solutions

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

Students, after searching for possible solutions through all available resources (books, internet, and through observation), working within their brainstorming group, record what they think are plausible solutions.

PHASE FOUR: Choosing the optimal solution

In this phase, having identified a number of plausible solutions, the students will choose and justify the optimal solution.

PHASE FIVE: Construction of prototypes

Students build their own instruments, or create a program for digital devices.

PHASE SIX: Evaluation of the results of the solution

Students review their construction against the requirements of the problem.

PHASE SEVEN: Different proposals of possible solution of each group (brainstorming solutions)

Each group proposes a possible solution and presents it to the other groups.

PHASE EIGHT: Redesign

Each group redesigns their own solution, taking into account the observations received from the other groups.

4.1.4 Strategies for Girl-Friendly Approaches and/or to Include Disadvantaged Students

- Use multimodal methods to present material, so that you can address a variety of learning styles and strengths.
- Carefully structure the groups
- Build on students' strengths and interests
- Be a role model of persistence, communication, creativity, and collaboration.

4.1.5 Students' Role

- When they take responsibility for their own learning, students grow on a cognitive, social and emotional level
- Students develop analytical skills

Students strengthen their self-esteem, self-regulation, and self-efficacy

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

4.1.6 Teachers' Role

- Support student
- Care for the development of the whole student
- Lead towards situated and authentic learning

4.1.7 Assessment and Evaluation

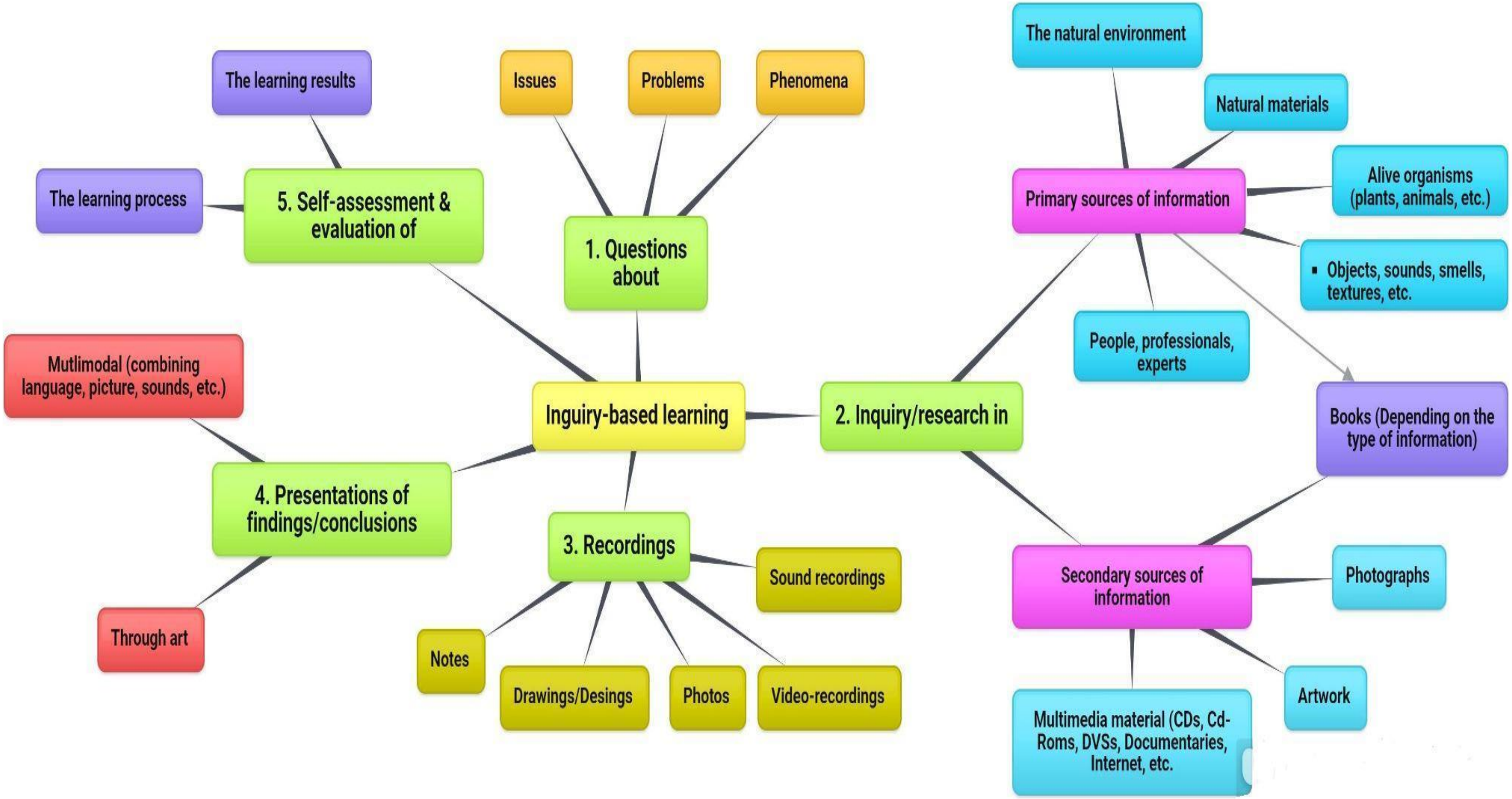
- When they take responsibility for their own learning, students grow on a cognitive, social and emotional level
- Students develop analytical skills

Students strengthen their self-esteem, self-regulation, and self-efficacy

4.1.8 Strengths and weaknesses

- This method enables learners to contribute to a co-constructed outcome, by making use of their individual differences in knowledge, skills and attitudes through collaborative work.
- The teacher's research into the topic of interest is of paramount importance for the success of the children's inquiry.
- It is very resource intensive

4.1.9 Inquiry-based learning Mind Map



4.2 Design Thinking

4.2.1 Definition

Design thinking is an approach to problem solving that uses tools, methods, and processes of professional designers (Elsbach & Stigliani, 2018). Originated in 1960s, design thinking refers to both what designers are thinking and doing while they work. From this perspective design thinking is about two different but related processes and concepts, a unique way to looking at the world and specific activities and methods that designers engage while they work (Clarke, 2020).

4.2.2 Main Components of the Method

The major focus of design thinking is problem solving. All problems that need creative solutions can be addressed by design thinking. Design thinking methods are organized into three broad categories of needfinding, idea generation and idea testing (Elsbach & Stigliani, 2018). More specifically the phases are empathize, define, ideate, prototype and test (Stanford d. school). To describe the problem context from different stakeholders' perspective, designers use human-centred and empathetic methods. With their empathetic understanding, they reframe the problem and start to generate solutions. With prototypes designers find opportunities to take stakeholders' opinions on the solutions and test the effectiveness. After the test phase, the cycle may end, or relevant revisions can be made to improve the product.

4.2.3 Suitability for Steam

Design thinking has a strong connection with STEAM education. Problem solving is at the core of both design thinking and STEAM. Problems in both approaches are ill-structured. Both in design thinking and STEAM the process begins with understanding the problem and generating the solutions. Both processes are iterative and new problems arise from the solutions. Engineering design process and design thinking have common theoretical aspects and enactment phases.

4.2.4 Integrating Steam and SEL Skills

Teachers will find many opportunities to integrate STEAM and socio-emotional learning skills when they focus on design thinking in their lesson plans due to the multifaceted goals and outcomes of the method. Coping with complex problems of 21^{st} century, learning from others, synthesizing, building and developing with purpose and communication are among the design thinking skills which also corresponds cognitive process skills of STEAM education and socio-emotional learning.

4.2.5 Implementation in the Classroom

To implement design thinking in the classroom, teachers provide guidance in each of the design phases. In empathy phase students will engage in try, observe, and ask activities to understand the problem thoroughly. For define and ideate phases, open-ended questions and brain storming techniques will encourage students to reflect their empathetic understanding into their solution strategies by further research. Within prototype phase students are allowed to develop many rapid prototypes to take opinions from different audiences, so that they can improve their product and solutions according to the needs. For the test phase students both test their design products with respect to the problem and reflect on the overall design cycle. Teachers are also encouraged to use design, self- and peer assessment rubrics in the test phase.

4.2.6 Gender Specific Aspects and Adaptations or Strategies for Inclusion of Disadvantaged Students

Following the equity principle of design thinking education, all students must be given opportunities to participate in activities regardless of their gender, academic achievement, socio-economic status, etc. Having high expectations from all students, teachers can use differentiated learning strategies to encourage participation of all students in the learning process. Research shows that design thinking helps students reduce cognitive bias in different categories such as projection bias, which is very valuable in terms of inclusion (Liedtka, 2015).

4.2.7 Students' Role

Students' role in design thinking is to participate in design thinking activities to create innovative solutions for complex problems. Students have individual accountability in all group activities. Developing a participatory approach to find and understand the complex problems of 21st century, developing an open, explorative attitude, willingness to take part in the solution process and developing an ethical mindset are also among the roles of students within design thinking practices (Beligatamulla et al., 2019).

The roles of the teachers in design thinking are to plan the process carefully to encourage all students' participation in the activities. By asking questions, providing resources and materials,

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

and creating opportunities for students to experience design thinking skills teachers create an effective learning environment. Teachers' monitoring and facilitator roles are prominent.

4.2.8 Assessment and Evaluation

Assessment and evaluation activities must provide evidence about students' learning process as well as learning outcomes. Formative and summative evaluation techniques will inform teachers both about students' learning and quality of overall experience. As teachers focus on both process and product evaluation students will find opportunities to identify problems, make plans, keep track of thinking, reflect on progress, make improvements, and synthesize thinking (The Center for Transformative Teaching and Learning).

4.2.9 Strengths and Weaknesses

Having strong goals and outcomes design thinking practices have also some limitations. Lack of creative confidence or mastery, wrong priorities, shallow ideas anxiety and frustration, creative over-confidence, and teamwork conflicts are among the major limitations that students and teachers can face during the implementation (Panke, 2019).

4.2.10 Design Thinking Mind Map

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

4.3 Problem Based Learning

4.3.1 Definition of the Method

Problem-Based Learning (PBL) is a student-centered approach to learning in which complex real-world problems are used as the vehicle to promote student learning of concepts and principles, as opposed to direct presentation of facts and concepts. The basis of PBL is that students learn by doing.

PBL is based on the messy, complex problems encountered in the real world as a stimulus for learning, integrating, and organizing learned information in ways that will ensure its recall and application to future problems. The problems in PBL are designed to challenge learners to develop effective problem-solving and critical thinking skills. It can also provide opportunities for working in groups, finding and evaluating research materials, and life-long learning.

4.3.2 Main Components of the Method

In PBL, learners encounter a problem and attempt to solve it with information they already possess, allowing them to appreciate what they already know. They also identify what they need to learn to better understand the problem and how to resolve it.

Once they have worked with the problem as far as possible and identified what they need to learn, learners engage in self-directed study to research the information needed by finding and using a variety of information resources (books, journals, reports, online information, and a variety of people with appropriate areas of expertise). In this way, learning is personalized to the needs and learning styles of the individual.

The learners then return and apply what they learned to their work on the problem, in order to fully understand and resolve it.

Once they have completed their problem work, the learners assess themselves and each other, thus developing skills in self-assessment and the constructive assessment of peers. Self-assessment is a skill essential to effective, independent learning.

Any subject area can be adapted to PBL with a little creativity. While the core problem will vary among disciplines, there are some characteristics of good PBL problems that transcend fields.

- The problem must motivate students to seek out a deeper understanding of concepts.
- The problem should require students to make reasoned decisions and to defend them.
- The problem should connect the content objectives to previous courses and knowledge.
- If used for a group project, the problem needs a level of complexity to ensure that the students must work together to solve it.

One of the most attractive features of PBL is that it helps develop both subject-specific skills (such as using diagrams and abstract models, acquiring and using relevant data, analysis of real-world issues, etc.) and transferable skills (like time management, teamwork, independent learning, decision taking, problem solving, communicating ideas and results, etc.).

4.3.3 Integrating STEAM with Social Emotional Aspects

Social and emotional abilities are critical in a child to not only find academic success, but also happiness and personal success. This requires to develop five cognitive and behavioral competencies: self-awareness, self-management, social awareness, relationship skills, and responsible decision-making. Through activities in the classroom, children take responsibility for their actions and make good choices in their education and beyond.

Implementation in the classroom (steps of the method)

What are the steps in problem based learning?

Step 1: Explore the issue.

Step 2: State what is known.

Step 3: Define the issues.

Step 4: Research the knowledge.

Step 5: Investigate solutions.

Step 6: Present and support the chosen solution.

Step 7: Review your performance.

4.3.4 Strategies for girl-friendly approaches and/or to include disadvantaged students

- Take time to explain instructional processes, answer the questions, consider their suggestions, and probe their hypotheses.
- Use project-based learning. Embed lessons with connections to the real world, and show relationships between the content/skills and the lives of real people.

Monitor them as they work, prod their learning and support them when they are hesitant.

4.3.5 Students' role

In PBL, learners are progressively given more and more responsibility for their own education, becoming increasingly independent of the teacher. PBL produces independent learners who can continue to learn on their own in life and in their chosen careers.

4.3.6 Teacher's role

The principal role of the teacher in PBL is that of a facilitator or educational coach guiding the learners in the PBL process. As learners become more proficient in the PBL learning process, the teacher becomes less involved.

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

4.3.7 Assessment and Evaluation

Through PBL, students not only strengthen their teamwork, communication, and research skills, but they also sharpen their critical thinking and problem-solving abilities, which are essential for life-long learning.

4.3.8 Strengths and weaknesses

Benefits of Problem-Based Learning

For students

•It is a student-centered approach.

•Typically, students find it more enjoyable and satisfying.

•It encourages greater understanding.

•Students with PBL experience rate their own abilities higher compared to the norm group.

•PBL develops lifelong learning skills.

For teachers

•Class attendance increases.

•It encourages students to spend more time studying.

•It promotes interdisciplinarity.

For institutions

•It makes student learning a priority.

•It may aid student retention.

•It may be taken as evidence that an institution values teaching.

Risks of Problem-Based Learning

For students

•Prior learning experiences do not prepare students well for PBL.

•PBL requires more time and takes away study time from other subjects.

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

•It creates some anxiety because learning is messier.

•Less content knowledge may be learned.

For teachers

•Creating suitable problem scenarios is difficult.

•It requires more prep time.

•Students have queries about the process.

•It raises new questions about what to assess and how.

For institutions

•It requires a change in educational strategy.

•Staff development and support are required.

•It generally takes more teachers.

•It works best with a flexible classroom space.

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

4.3.9 Problem Based Learning Mind Map

PROBLEM BASED LEARNING

It is a student-centered approach to learning in which complex real-world problems are used as the vehicle topromote student learning of concepts and principles as opposed to direct presentation of facts and concepts.

MAIN COMPONENTS OF THEMETHOD

- encounter a problem
- attempt to solve it
- identify what is needed to learn
- engage in self-directed study
- assess themselves and each other

ASSESSMENT ANDEVALUATION

Students not only strengthen their teamwork, communication, andresearch skills, but they also sharpen their critical thinking andproblem-solving abilities essential for life-long learning

Implementation in theclassroom

Step 1: Explore the issue.
Step 2: State what is known.
Step 3: Define the issues.
Step 4: Research the knowledge.
Step 5: Investigate solutions.
Step 6: Present and support the chosen solution.
Step 7: Review your performance.

Social Emotional Developing

Developing self-awareness, self-management, social awareness, relationship skills, and responsible decision-making helps children take responsibility

Girl and disadvantaged student-friendly approach

- Take time to explain
- Consider suggestions
- Probe hypotheses
- Use project-basedlearning
- Monitor
- Support

Students' role

- learners are given responsibility
- become independent of the teacher
- can continue to earn on their own in life and in their chosen careers

Teacher's role

Role of the teacher is that of a facilitator or educational coach guiding the learners in the PBL process. As learners become more proficient in the PBL learning process the tutor becomes less active.

Suitability for STEAM

The problem

- must motivate students
- require students to make reasoned decisions
- connect to previous courses/knowledge

PBL helps develop subject-specific and transferableskills

Strengths

- learners are given responsibility
- become independent of theteacher
- can continue to learn on their ownin life and in their chosen careers

Weaknesses

- it requires more time and takes away study time from other subjects
- it creates some anxiety because learning is messier
- less content knowledge may be learned

PANEVĖŽIO RAJONO ŠVIETIMO CENTRAS

NGSS

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

All CC licenses require that others who use your work in any way must give you credit the way you request, but not in a way that suggests you endorse them or their use. If they want to use your work without giving you credit or for endorsement purposes, they must get your permission first.

NonCommercial (nc)

You let others copy, distribute, display, perform, and (unless you have chosen NoDerivatives) modify and use your work for any purpose other than commercially unless they get your permission first.

NoDerivatives (nd)

You let others copy, distribute, display and perform only original copies of your work. If they want to modify your work, they must get your permission first.

More details on Creative Commons Licenses: https://creativecommons.org/about/cclicenses/

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

4.4 Scamper Methods

4.4.1 Definition of the Method

The Philosophy of SCAMPER is based on the concept that ''Any idea has emerged from another idea''.
SCAMPER is a practical and joyful brainstorming technique in the discussion method, leading to an actual implementation in real life and supporting creative thinking. The SCAMPER brainstorming technique uses steps to review an object.

4.4.2 Main Components of the Method

SCAMPER is the most convenient technique to use when students reach a dead end, or when they are about to steer away from the core of the subject. The questions used help to think fluently and flexibly, so as to lead to a creative thinking system. While implementing SCAMPER, a unique object is chosen and transformed, improved, disintegrated or compounded with other objects through a brainstorming process. Questions asked let a variety of opinions emerge, enabling learners to develop their creativity as they start thinking in new ways about an object .

4.4.3 Suitability for STEAM

SCAMPER is a technique that aims to guide the students to produce several opinions, engaging in higher order thinking to create more objective results. Besides, joyful gamification activities nourish students' creativity. SCAMPER games allow students to experience and learn the skills of authors, inventors and composers.

SCAMPER is particularly effective for inventions and animal adaptations. Through SCAMPER, imaginary exercises are applied in mathematics, chemistry, history, language and art classes. Furthermore, the enthusiasm and willingness to engage in creative thinking and design processes can foster engineering skills.

4.4.4 Integrating STEAM with Social Emotional Aspects

The SCAMPER technique is also known as a "divergent thinking process", a fun technique that can improve students' creativity and their creative confidence.

Their readiness, engagement, and willingness to participate in the hands-on activities 'as scientists' as well as exchanging ideas and supporting each other are evidence of their increased levels of interest in science learning and engineering design, and of their ability to address complex challenges.

SCAMPER is an activity-based thinking process that can be performed by cooperative learning.

SCAMPER is used during the initial ideation stage, so as to steer away from a conventional way of thinking in order to generate a wide range of new ideas that will lead to new insights, original ideas, and creative solutions to problems.

4.4.5 Implementation in the Classroom (Steps of the Method)

According to the English dictionary, SCAMPER means ''to run with quick light steps, especially through fear or excitement''. The acronym stands for an educational technique covering seven steps, as developed by Eberle in 1977. Lets' look at the letters which make up the acronym:

S: Substitute: Think about substituting parts of the product or process for something else.

Typical questions: What else instead? Who else instead? What other materials, ingredients, processes, power, sounds, approaches, or forces

might I substitute? Which other place may I use instead?

C: Combine: Think about combining two or more parts of the product or process to create something new or to leverage synergies.

Typical questions: What mix, assortment, alloy, or ensemble might I blend? What ideas, purposes or units might I combine?

A: Adapt: Think about which parts of the product or process could be adapted or how you might change the nature of the product or process.

Typical questions: Does the past offer a parallel? What else is like this? What other ideas does this suggest? What might I adapt for a solution? What might I copy? Who might I emulate?

M: Modify, Minify, Magnify: Think about changing parts or all of the product or process, or distorting it in an unusual way.

Typical questions: What other meaning, color, motion, sound, smell, form or shape might I adopt? What might I add?

P: Put to another use: Think of how you might put the product or process to another use or how you might reuse something from somewhere else.

Typical questions: What new ways are there to use this? Can this be used elsewhere? Which other people might I reach? If this product is modified, can it be used for something else?

E: Eliminate: Think of what might happen if you eliminated parts of the product or process and consider what you might do in that situation.

Typical questions: What might I miss? What might I eliminate? What might I streamline? What might I make smaller, lower, shorter, or lighter?

R: Reverse: Think of what you might do if parts of the product or process worked in reverse or were sequenced differently.

Typical questions: What might be rearranged? What other pattern, layout, or sequence might I adopt? Can components be interchanged? Should I change pace or schedule? Can positives and negatives be swapped? Could roles be reversed?

Whereas each letter is applied separately on different samples and subjects, all letters are used when addressing a situation, a challenge, or a defined subject. For instance, a familiar tale ispresented to the students asking them to dissect the tale in its different elements, and to re-compose an original tale using all the elements they previously found such as place, characters, time, events etc., following the SCAMPER questions.

4.4.6 Strategies for Girl-friendly Approaches and/or to Include Disadvantaged Students

When setting the scene, use gender-neutral language as far as possible. Using words like “everyone” and “class” to address the students are examples of good gender-neutral language. Ensure that everyone receives a similar share of air-time, and everyone is actively engaged; ask probing questions if needed. Criticise no idea, as wild as it might appear to be; in fact, try to encourage outlandish ideas, as they are very useful to open up the conversation. Encourage students to build upon one another’s ideas. Provide specific, repeated, evidence-based,

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

personal and collective encouragement. Be flexible in giving students opportunities to build and check understanding.

4.4.7 Students' Role

The questions make learners think about the defined subject, even if it is unfamiliar to them. These questions represent impulsive actions, intended to stimulate various thinking skills. They encourage students to discover by developing their higher order thinking skills. These questions also create an amazing atmosphere for students to develop their creativity and their own opinions. Furthermore, they teach to think flexibly and to discard stereotypes.

4.4.8 Teachers' Role

The teacher determines the specific problem students need to solve. The students then brainstorm a wide range of solutions using the different techniques defined by the acronym. Recording every idea expressed during the brainstorming without judging it increases the production of creative ideas. The students apply the technique, following each step indicated by the letters of the acronym. The teacher acts as an assistant by addressing any question, contradiction or conflict that may arise.

4.4.9 Assessment and Evaluation

In the SCAMPER approach, the learning outcomes are considered in terms of creative ideas generated, production of tangible artefacts and documentation of solutions found to given problems. Therefore, discipline-agnostic, validated and reliable formative assessments methods are better placed to effectively gauge the learning success.

At the same time, if students are provided with the data and rubrics used for the evaluation, they will be better equipped to speak specifically about their strengths and weaknesses and, together with their teacher, map a way forward to reach the mastery of the standards required.

Much of the learning requires the teacher to observe and to listen. The most useful evidence is gathered during the inquiry process. The teacher needs to be skilled in observing students and engaging them in conversation while they are working, to be able to understand the thought process they are following.

The work is assessed in terms of cognitive skills (learning how to learn), social skills (e.g. collaboration, dealing with conflict, etc.) and creative skills (e.g. originality, presentation skills, etc.).

4.4.10 Strengths and weaknesses

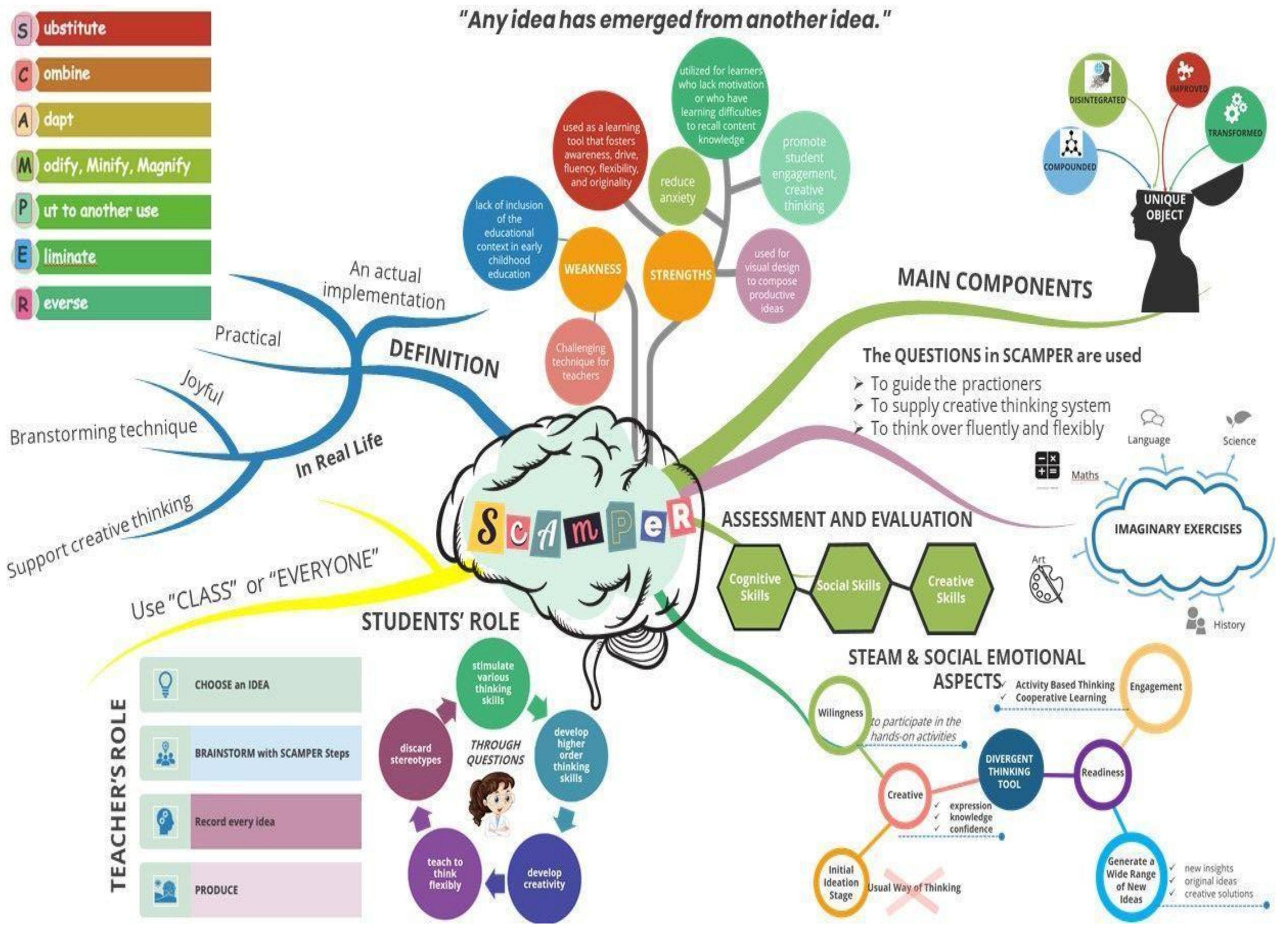
Whereas the SCAMPER technique has been used for visual design to compose creative, productive ideas, some shortcomings can be observed like the lack of inclusion of the educational context in early childhood education.

Although the new technique is challenging, lessons promote student engagement, creative thinking and the ability to recall content knowledge. SCAMPER can be utilized for learners who lack motivation or who have learning difficulties. SCAMPER is used as a learning tool that fosters awareness, drive, fluency, flexibility, and originality.

Using a rigid acronym approach to creative thinking may seem counter-intuitive as less extrovert individuals might choose not to speak. Individuals may hold back extravagant ideas for fear of judgment. People tend to agree because they don't want to disrupt the status quo. The technique can be adapted by having each student writing down their input to the various components before having a group discussion.

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

4.4.11 Scamper Methods Mind Map



4.5 The Montessori Three-Period Lesson

The Montessori method was developed more than 100 years ago in the beginning of the 20th century by Dr Maria Montessori – Italian physician and pedagogue. The method was created first to help the special needs' children, who society thought could not be educated**.** It was then developed for "street" children, who lived in the slums of Rome and usually came from illiterate families.

The method has since gradually gained popularity and has been used in many parts of the world, in public and private schools alike.

Popular elements of the Montessori methodology include:

- Mixed-age classrooms;
- Students' freedom (including choice of activity);
- Long blocks of uninterrupted work time;
- Specially trained teachers;
- Prepared environment.

Implementation of these elements in the traditional school requires investment in teachers' qualification, specially prepared materials and radical change of the curriculum.

However, there are many Montessori principles that can be adapted and implemented by the teachers in their mainstream classrooms.

For the purposes of the NGSS project, we chose to focus on the Montessori **three-period lesson**. Introduced at first by Dr Montessori as a method for learning vocabulary, this lesson identifies the three stages of learning: perception of a new information, processing and internalising of this information, and giving feedback (i.e. use of the information).

In the context of the cosmic education concept within the Montessori method, the three-period lesson for older children (6-12 years old) is:

First Period

The teacher inspires children by telling wonderful tales, or stories that relate the topic of the lesson to children's lives and experience. At the same time the teacher demonstrates different materials, activities and resources, and makes sure that the children understand how to use them and where to find them (in the classroom, in the surroundings, on the internet, etc.).
Children can ask questions and clarify the facts.

The aim of this period of the lesson is **to inspire**, to create **curiosity** and **to draw the attention** of the children.

During the first period teachers should focus on presenting practical skills to the children and to do that in a **precise** manner:

- showing the children exactly and accurately what to do;
- demonstrating how children should use different materials and media.

At the same time, the teacher should observe and note to herself if children fully understand the topic, the tasks and know what to do, so that they can work gradually towards independence, practicing their skills step-by-step.

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

Second Period
After the teacher's presentation, children should be given the opportunity to work with this story, materials and information. They study and manipulate materials that have been made available to them, or research – in groups or alone.

Their work can include simple tasks: drawing pictures, writing stories, doing mathematical calculations, making posters… Or they can engage in complex projects that require planning and research.

It is very important that children have an easy access to the resources and materials they need to carry out their independent learning activities. When they are younger and have not yet learned good research skills, children need to be able to refer for information to attractive books and materials in their surroundings. Later they will need access to a library, a computer or a telephone for online research. Going out in the yard or to a field trip will be an important part of the research too.

Painting, crafts, music, drama, creative writing, scientific experiments… There are so many activities to support the child's learning!

The length of this period will depend on the particular lesson – it can last from half an hour to several weeks.

Third Period
In the third part of the three-period lesson, children demonstrate their knowledge. This is the time to manifest their work to the world! They present to the entire class or just to their teacher.

The **active listening** of the audience during the presentation is an important skill, which should be gradually built to support the learning process during this part of the lesson.

The **active listening** skills include:

- attentive listening during the presentation;
- ability to formulate and ask questions regarding the working process, materials, results, challenges…
- ability to sincerely acknowledge the work done, the efforts and the outcomes.

It is equally important that these skills are demonstrated by the teacher and by the other children in the class. So the work on the active listening skills is an important part of the teaching and learning process.

During the third period of the lesson, supported by their audience, children master their presentation skills and receive valuable feedback which helps them to adjust and modify their ideas. This will support them to go further in their learning.

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

Suitability of the Three-Period Lesson for STEAM and Interdisciplinary Learning
STEM by default requires interdisciplinary work and the **Montessori three-period lesson** is extremely suitable for it.

Here are few ideas:

- If children are studying **geography** they can use a simple chemical experiment to make a simulated volcano, or they may take a field trip to study local geology.
- When studying **early human history,** they may build a model cave and stone implements, or they may experiment on ways to make fire.
- When studying **biology**, they can paint butterflies, or research classification on the internet.

The list of possibilities is endless, limited only by the teacher's ability to prepare the necessary resources. The practical and research part can easily be substituted or enriched with art, turning in this way the learning process into STEAM.

POSSIBLE MISTAKES

Some teachers make the mistake of presenting wonderfully exciting lessons but with no follow-up independent activities for the children.
The children need activities to help them to absorb the information that came with the inspiring presentation. Solving problems and doing tasks from the textbook are not sufficient for mastering good understanding and knowledge.
Doing the job for the children;
Restriction of movement;
Restriction to touching and handling things
are other possible mistakes.

Teachers have to remember: they should offer skills and inspire, and then – to stand back.
While children are engaged in independent activities, teachers should observe and take notes about their progress.
This is not so easy in practice. Teachers find it difficult to let go of complete control.

HOW CAN THIS BE APPLIED ON A PRACTICAL LEVEL IN A NON-MONTESSORI SCHOOL
It might be difficult to give time to children for independent and interrupted work on a topic or with certain materials.

Learning blocks – two consecutive hours of work on a subject – might provide both teachers and learners with sufficient time to focus on a topic and to do practical activities.

Another option is to implement it as an extra-curricular **integrated project-based learning activity** – a couple of times during the school year or per period.

The project work might also be organised as an extended lesson at the end or as a series of practical lessons **within a unit**.

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

It is important to follow the steps:

1. The children are introduced to a topic;
2. The children engage in research and discover more in order to internalise information (the research part can easily be substituted or augmented with art);
3. The children share their findings with the teacher or with the group.

This sequence applies to any and all subjects.
It is about inspiring and empowering children to discover!

HOW TO ACHIEVE BETTER RESULTS

The involvement of the whole body and, in particular, the hand is essential for learning to take place effectively and efficiently. Dr Montessori placed great emphasis on the **use of the hands in learning**. Furthermore, she firmly believed that **the school age child needs movement while learning**, in order to help concentration to take place and to help with coordinating the rapidly growing body.

Here are some Montessori-inspired recommendations for achieving best results in STEM education:

- Engage children in construction, manipulation of materials and work with their hands!
- Give children the opportunity to move freely, to interact with each other and to engage!
- Don't be afraid of activities that get hands, clothes or room wet or dirty! Involve children in cleaning and putting the room in order after the end of the activities, if necessary.

It is not enough that we provide physical education for part of the day and then confine children to desks while they "learn" intellectual things!

PRACTICAL ADVICE FOR THE ENVIRONMENT AT SCHOOL

- Avoid standard layouts of rows of tables facing the front of the room, focussing only on sitting to watch the teacher speak. Instead, use group tables and space for working on the floor;
- Allow as much movement as possible. Sitting in the same position all day is not optimal for concentration and learning;
- Learning materials should be available, within reach, for the children, whether it be a book, art materials, didactic materials, etc.;
- Allow the children to give their opinion about how the classroom should be set up. This can even be a lesson in democracy – children may submit proposals for floor plans and the class can vote!

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

4.5.1 Montessori Methods Mind Map

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

NGSS

5. STEAM Classrooms and Strategies For Involvement of Girls

STEAM is a growing and important approach in science education. Including the arts in the core components of science, technology, engineering, and mathematics, STEAM is transforming the ways in which we teach, learn and perceive science. (Howlett, 2021). What still remains, however, is a notable gender gap between those who pursue science and those who do not.

Although women represent the majority (60 %) of higher education graduates in the EU, their employment rate and promotion trajectories do not reflect their full potential. There is the need to promote equal gender representation where there is under-representation as in STEM subjects, as this will provide role models for girls. (European Parliament, 2015). The lack of women participation in STEM careers poses a real challenge to educational processes, on the one hand, and to the girls, on the other, for that fact that girls grow up believing they can`t do all the things others (respectively males) can, and it also challenge key decision making in policies of our society.

Results of research conducted in the frame of the first NGSS project IO – the Concept Paper – showed that an earlier age kids do not perceive themselves as having different (gender specific) powers or abilities, they are equally curious and open to engage in various activities, and there is no difference between boys and girls in engaging into STEAM activities in pre-primary and primary school. Teachers and STEAM professionals reported that the interests and performance of the kids in different STEAM lessons/activities depend on their abilities, temperament and talents and these are not gender related. Most of the research respondents (teachers, parents and STEAM professionals) outlined that STEM+ARTs approach facilitates to a greater extent the discovery of a child's talents and abilities. Some respondents admitted that there are some parents and older teachers that have biased gender expectations and tend to guide or encourage the participation of boys and girls in activities traditionally considered specific to one gender or another.

But all respondents agreed that **formal STEAM education should (and does) offer the framework and the space for both gender children to learn and develop on equal opportunities, according to their talents and interests.**

In order to ensure girls participation and involvement in STEAM activities and lessons, teachers should:

- Offer not only learning materials and learning tasks for each students, but also the opportunity to work in mixed pairs and teams, where boys and girls can interact and collaborate;

- Avoid the presence in the hidden curriculum[1] of the gender biased attitudes;

[1] ”implicit academic, social, and cultural messages,” “unwritten rules and unspoken expectations,” and “unofficial norms, behaviours and values”(...) ”of the dominant-culture context in which all teaching and learning is situated.” (Boston University, 2020).

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

- Offer STEAM role models/mentors of both genders, both women and men, that can be invited and participate in STEAM lessons/activities with students; if STEM professionals participation is not possible, than teachers can add images of female mathematicians or scientists throughout classroom materials and assign individual or group work that summarizes or contextualizes women's achievements in these subjects can also shift perceptions about who belongs.

- Stimulate children to read books (or read to them those books) that tie in well to STEM (such as *The Boy Who Harnessed the Wind*, or *The Martian* for older students), books that feature strong women who get stuff done (such as *A Wrinkle in Time*); Complementary to reading books, children can watch movies presenting the role of women in STEM careers.

- Offer out-of-school time (OST) programs or extracurricular activities about STEAM (e.g. Science Club, Astronomy Club, Cooking Club, science summer school, science contests/competitions etc.) after school, on weekends, and/or during the summer.

In conclusion, in order to ensure the involvement and interest of girls in STEAM activities and careers, teachers and parents alike must respect the principles of equal learning and development opportunities for both boys and girls and the principle of Montessori education, "***Help me to help myself*** ", that is to encourage and support independent learning, but also collaborative learning.

6. Evaluation and assessment of the learning outcomes in STEAM activities

Evaluation and assessment are components of the educational process along with teaching and learning; this is considered a complex process, oriented by goals and objectives, carried out over time. Assessment is the activity of collecting and analyzing information about students` skills, knowledge and attitudes to develop a deeper understanding of what they know and of what they can do with their knowledge as a result of the educational experiences; the process culminates when assessment results are used to improve further learning (Huba&Freed, 2000). Any evaluation involves at least three steps:

1. Measurement of students` skills/ behavior/knowledge,
2. Results analysis and
3. Decision making on further changes or development of the instructional process.

The evaluation is performed by means of data recording tools, such as: check and control grids, observation sheets, worksheets, evaluation tests etc. Some of these tools offer a direct measure of the knowledge and skills via verbal and motor behavior (e.g. check lists, observation sheets, standardized tests, portfolio, poster presentations, oral tests, etc.), and some of them offer an indirect measure through investigation of perceived student learning (e.g. surveys , interviews targeting teachers, parents or even children).

Evaluation in STEAM activities is performed in relation to three dimensions:

- the dimension of the process which considers how and to what extent the students are involved in the tasks: if they came prepared for the task with the necessary materials and information, if they manage the time well enough, if they plan correctly the tasks, if they know all the necessary steps, their collaboration, depending on the nature of the tasks.
- the dimension of understanding, where students demonstrate that they have understood the concepts, the nature of materials and tools and can use them appropriately;
- the dimension of the final product in which the product obtained at the end of the activity is evaluated according to general criteria, such as aesthetic, related to the appearance of the work, but also specific, related to the nature and purpose of the product.

There are some similarities, and differences between assessment in primary education and preschool education. In primary education, assessment focuses mainly on skills and specific competencies. At the preschool level, it aims to assess behaviours as a prerequisite for later competencies. In both primary and preschool education, all types of assessments can be carried out.

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

There are several types of evaluation:

- Depending on the criterion of the temporal dimension of the evaluation action, we distinguish three types of evaluation: the initial or predictive evaluation, the formative or progress assessment, the summative or balance sheet assessment. In STEAM activities, we value a lot the formative evaluation, which can focus especially on the dimension of the process (the assessment can be done through a self-assessment sheet, or reflective journal etc.), but also on the dimension of understanding concepts, materials (using oral evaluation methods like conversation, debate, or written/visual evaluation methods – e.g. paper tests/questionnaires or digital tests/questionnaires (via different applications or digital games).

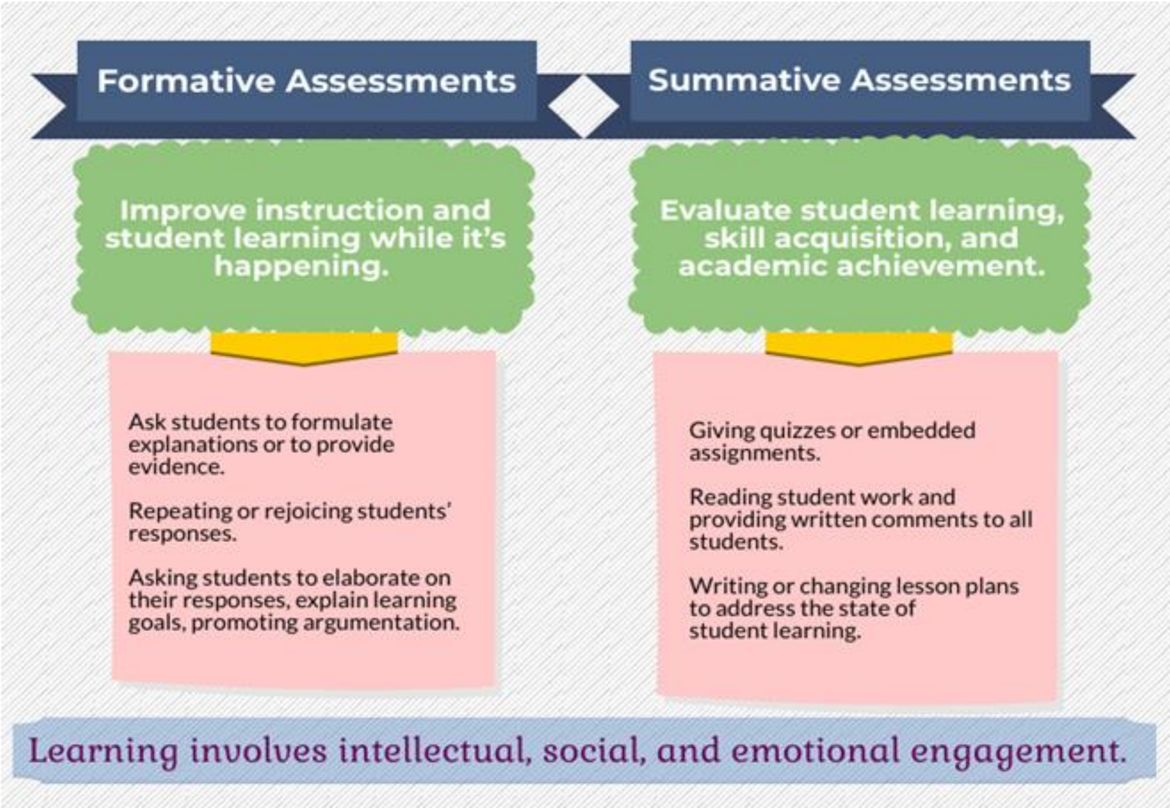


Fig. 1 – Formative vs. summative assessments retrieved from https://usergeneratededucation.wordpress.com/2019/12/08/assessing-steam-l5earning/

- Depending on how the evaluation is performed, we distinguish: oral assessment, written assessment, practical assessment. In the STEAM activities, the methods of practical assessment are used more frequently, which also allows the evaluation of the dimension of the product that facilitates the appreciation of the extent to which different knowledge is assimilated and the degree of development of the abilities targeted by the respective activity.

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

- Other categories of assessment methods are quantitative vs qualitative:

	Quantitative (Readiness and achievement Data)	Qualitative (Profile Data)	
1	Tests	Surveys	1
2	Quizzes	Questionnaires	2
3	Exit Slips	Checklists inventories (interest, satisfaction, ..)	3
4	Rubrics (scoring)	Class discussions (Socratic Seminar)	4
5	Self-marking quizzes on projects	Constructions and crafts	5
6	Benchmark Tests	Focus groups	6
7	Diagnostics	Reviews	7
8	2-minute (subject) check	Consensus Models	8
9	Summarizing	Feedback pipelines	9
10	Personalized tests and quizzes	Sketching	10
11	H.O.T. Question of the Day	Interviews	11
12	Other personalized methods	Be a scientist/Programmer/mathematician Activity	12

Fig. 2. – Quantitative vs. qualitative evaluation methods used in STEAM education

Retrieved: from: https://www.youtube.com/watch?v=mBX3pSJvYQk

Some examples of modern evaluation methods which can be used in STEAM lessons/activities are the project, the portfolio, the reflective journal, the debate, the systematic observation, self-assessment etc. Also, In STEAM education we can use **digital tools** that offer easy and fun assessment methods. This is but a short list of the most used digital assessment tools in primary education: Kahoot, Gimkit, Quizlet, Coggle, Miro, Padlet etc. More examples can be found on this page:

https://www.nwea.org/blog/2021/75-digital-tools-apps-teachers-use-to-support-classroom-formative-assessment/

Also, the teachers need to be aware of the factors that influence the assessment or the whole process of evaluation. These can be divided in two categories: personal and contextual factors. Personal factors refer to a teacher`s belief, attitudes, skills, perceptions of the child or the task performed etc. Due to these factors, errors may occur during the evaluation (e.g. halo effects, stereotyping, the Pygmalion effect etc.). Contextual factors are found on a micro-level (the class climate and physical environment) or macro-level (institution rules and procedures, government educational policy, parents` expectations/pressure etc.).

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

Bibliography Bell, D. (2016). The reality of STEM education, des ign and technology teachers' perceptions: A phenomenographic study. International Journal of Technology and Design Education, 26(1), 61-79.

Breiner, J., Harkness, M., Johnson, C. C., & Koehler, C. (2012). What is STEM? A discussion about Conceptions of STEM in education and partnerships.School Science and Mathematics 112(1), 3–11.

Boston University. (2020). *bu.edu*. Retrieved: March 5, 2022, from Teaching the Hidden Curriculum: https://www.bu.edu/teaching-writing/resources/teaching-the-hidden-curriculum/

Bryan, L. A., Moore, T. J., Johnson, C. C., & Roehrig, G. H. (2015). Integrated STEM education. STEM roadmap: A framework for integration, 23-37.

Crismond, D. P., & Adams, R. S. (2012). The informed design teaching and learning matrix. Journal of Engineering Education,10 1(4), 738-797

Capraro, R. M., & Corlu, M. S. (2013). Changing views on assessment for STEM project–based learning. In R. M. Capraro, M. M. Capraro, & J. Morgan (Eds.). STEM project-based learning: An integrated Science, Technology, Engineering, and Mathematics (STEM) approach (2nd Edition). (pp. 109-118). Rotterdam, the Netherlands: Sense Publishers.

Çorlu, M. A. (2013). Uzman alan öğretmeni eğitimi modeli ve görüşler [White paper]. Retrieved January 20, 2014, from http://fetemm.tstem.com/gorusler

Çorlu, M. A., & Corlu, M. S. (2012). Scientific inquiry based professional development models in teacher education. Educational Sciences: Theory & Practice, 12(1), 514–521.

Corlu, M. S. (2012). A pathway to STEM education: Investigating pre-service mathematics and science teachers at Turkish universities in terms of their understanding of mathematics used in science, (Unpublished doctoral dissertation), Texas A&M University, College Station, Texas.

Corlu, M. S. (2013). Insights into STEM education praxis: An assessment scheme for course syllabi. Educational Sciences: Theory & Practice, 13(4), 2477-2485. doi: 10.12738/estp.2013.4.1903

European Parliament. (2015, June 23). *Report on on empowering girls through education in the EU*. Retrieved March 3, 2022, from European Parliament website: https://www.europarl.europa.eu/doceo/document/A-8-2015-0206_EN.html

Furtak E., Pasquale M., Aazzerah R. (2016). How Teachers can develop formative assessment that fit a three-dimensional view of sceince learning. UW Institute for Science + Math Education. Retrived from:

http://stemteachingtools.org/assets/landscapes/STEM-Teaching-Tool-18-3D-Formative-Assessment_a11y.pdf

Howlett, J. A. (2021, September 28). *5 Science Educator Approved Ways to Support Girls in STEAM*. Retrieved March 2, 2022, from: https://samlabs.com/us/5-science-educator-approved-ways-support-girls-in-steam/

Huba, M. E., & Freed, J. E. (2000). Learner-centered assessment on college campuses: Shifting the focus from teaching to learning. Boston: Allyn and Bacon

Rohde A. (2019). ASSESSMENT AND ENGAGEMENT STRATEGIES FOR STEM . University of Nebraska. Retrieved: from: https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1115&context=teachlearnstudent

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

NGSS

This document is prepared in the frames of the international project “Next Generation Science Standards Through STEAM” (NGSS), implemented with the financial support of the European Commission under Erasmus+ Program, through the Turkish National Agency Erasmus+ (ref. No 2020-1-TR01-KA201-094463). The content of the document reflects the views only of its authors, and the Commission cannot