The Design Methodology Handbook

FERTILE

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More information is available at www.fertile-project.eu

Design Methodology Handbook

FERTILE

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Welcome to the FERTILE Design Methodology Handbook!

This handbook intends to assist you in integrating Educational Robotics and Arts into your teaching practice in a blended learning context.

It aims to trigger you to cultivate 21st-century skills, focusing on your students' Computational Thinking.

Let's get started!

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

Welcome to the FERTILE Design Methodology Handbook!

The FERTILE Design Methodology (FDM) provides a structured approach to creating interdisciplinary projects that develop students' Computational Thinking (CT) skills in a blended learning context.

As an Educational Robotics (ER) or Arts educator, following this methodology, you will be assisted to collaborate in co-designing projects that combine Arts and ER, creating engaging and innovative learning experiences for your students.

This handbook is organised into three sections:

- **What is the FERTILE DESIGN METHODOLOGY?** *A descriptive presentation of the FDM to familiarise you with its three dimensions and how they are interwoven in designing interdisciplinary projects integrating ER and the Arts.*
- **How to design interdisciplinary projects** *that integrate ER and Arts. Step-by-step guidance on designing Artful ER projects following the FDM.*
- **Design your own project!** *An exemplary project and a template to facilitate you in collaborating with your co-designer in designing your Artful ER project.*

By the end, you will have the knowledge and tools to inspire your students to think critically, solve problems creatively, and engage deeply with Arts and ER.

Let's begin this exciting journey into Artful Educational Robotics!

Symbols Explained

Art activity

Educational Robotics (ER) activity

Educational Robotics (ER) and Art activity (interdisciplinary)

– Computational Thinking (CT) Skill –

Abstraction

Decomposition

Pattern recognition

Algorithmic Thinking

Evaluation

– Modality –

Face to Face

On line

Plenary

Group

Individual

Tips

What is the FERTILE Design Methodology?

The FERTILE Design Methodology (FDM) unfolds seamlessly in three dimensions (see Figure 1): **Interdisciplinarity**, **Computational Thinking**, and **Blended Learning**. This threefold approach creates a cohesive learning experience that sparks creativity and fosters innovation.

The FDM is a means for educators of Arts and Educational Robotics to co-design interdisciplinary projects integrating Arts and Educational Robotics (ER), which we call Artful ER projects in this handbook.

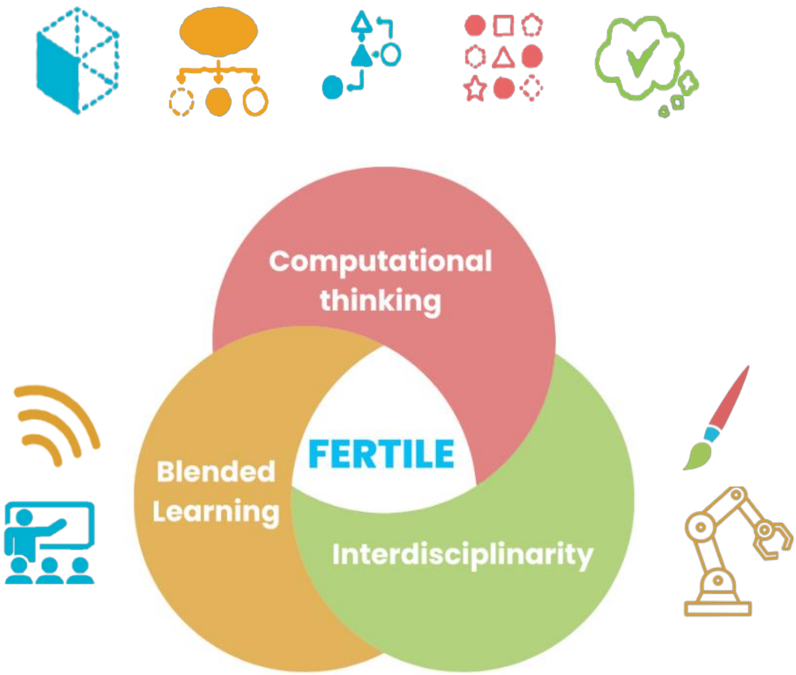


Figure 1. The three FDM dimensions

Interdisciplinarity of ER and Arts

What: Interdisciplinarity in ER and Arts refers to combining the precision of robotics with the fluidity of arts in interdisciplinary projects. The aim is to blend creativity, computational thinking skills, and pedagogy to foster innovation and new ways of thinking.

How: ER and Arts integration: Design projects that allow students to elaborate on concepts from various subjects, such as arts, design, computer science, and engineering, resulting in outcomes that are both artistic and functional.

Encourage students to explore the connections and challenges between Arts and Technology. This exploration will help them appreciate both disciplines and foster the development of CT skills.

Computational Thinking (CT)

What: Computational thinking is the thought processes involved in formulating a problem and expressing its solution(s) so that the computer (human or machine) can effectively carry it out (Wing, 2014).

How:

- **Problem-Based Approach:** Students engage in a structured problem-solving process by tackling real-world challenges. The FDM follows a five-step problem-solving approach, which inherently supports CT skills development.
- **CT Skill Focus:** Each FDM step targets specific CT skills such as abstraction, pattern recognition, decomposition, algorithmic thinking, and evaluation, ensuring comprehensive CT development.

Ideas for cultivating CT skills appear in Figure 2.

Figure 2. How to cultivate CT skills

Blended Learning

What: Blended Learning combines traditional face-to-face instruction with online activities (synchronous or asynchronous) and allows for more personalised, flexible, and engaging learning experiences.

How:

- **Blend hands-on practice in class and online Activities:** The educators organise students' learning by switching between hands-on practice with physical robots and online activities using simulators in the classroom. Furthermore, the students may be assigned homework to program the robot using the simulator, study/explore critical concepts for their project, interact (synchronously or asynchronously) with peers using online environments/tools like Padlet, forums, or social media, and prepare for the upcoming in-class activities.
- **Flexible Scheduling:** Allow the students to complete tasks at their own pace remotely and come together in class for group hands-on activities. Flipped classroom is always an option!
- **Interdisciplinary Collaboration:** Blended learning also facilitates interdisciplinary collaboration, enabling the ER and Arts educators to participate in shared online activities, fostering a cohesive learning environment where Arts and Educational Robotics intersect.

How to design Artful ER projects following the FERTILE Design Methodology?

To co-design an Artful ER project, you may follow a three-level process. First, you describe your project by defining its category and elaborating on the contexts of ER and Arts. Then, following the five FDM steps, you organise your interdisciplinary project implemented in your Arts and ER classes. For each step, you must design several meaningful activities for the Arts and ER classes to inspire and empower your students to synthesise a final artefact.

As an educator, your role is crucial while co-designing interdisciplinary projects with your colleagues. Regardless of your discipline, Arts, or ER, apart from your discipline-oriented learning outcomes, you have the common goal of nurturing your students' Computational Thinking while supporting them in developing, step-by-step, the final artefact!

Figure 3. The 3-level co-design process

1st Authoring Level

Set a challenge as the project's core

How do we start designing an Artful ER project together?

Discuss the core interdisciplinary idea in which ER and Arts meet/overlap. Decide on the project category (e.g., Programming Robots to Create Art) and set learning objectives for ER and Arts class.

How do we formulate a project challenge?

1.1 Start by setting a challenge as your project's core that drives the learning process. Encourage students to engage deeply with real-world problems involving ER and the Arts.

Ensure your project always revolves around a meaningful and captivating challenge interweaving ER and Arts.

Consider that students may work in various modalities in Arts and ER classes to resolve the challenge, resulting in an artifact and developing CT skills.

Ideas for Challenges and Final Artifacts! To trigger educators' design ideas, the FDM incorporates the "project category." Project categories include:

- programming robots to create Art,
- programming robots to perform Art,
- creating Artful Robots, or
- programming Robots to respond to Artful triggers

Let's explore each category, analysing representative exemplars to support you in setting your project's challenge.

A. Programming Robots to Create Art

Students program robots to produce visual or performance art, exploring how technology can generate creative outputs.

Indicative Exemplars:

- **Abstract Painting Robot:** Program a robot to create abstract paintings using different brushes and colors, translating algorithms into artistic strokes.
- **Drawing Patterns:** Design algorithms for robots to draw intricate geometric patterns or replicate famous artworks.
- **Light Painting:** Robots with LED lights create light paintings in a dark room, capturing the movements with long-exposure photography.

B. Programming Robots to Perform Art

Students program robots to act in artistic performances, such as music, dance, or drama, bringing scripted movements and actions to life.

Indicative Exemplars:

- **Robot Dance Troupe:** Program a group of robots to perform a synchronised dance routine, incorporating elements of choreography and rhythm.
- **Performing robots:** Create a scene from a play where robots perform alongside human actors, using precise movements and voice commands to deliver lines.
- **Musical Performance:** Design robots that can play instruments or produce sound effects in coordination with a musical score.

C. Creating Artful Robots

Students design and build robots with artistic elements, focusing on the aesthetics and creative aspects of the robot itself.

Indicative Exemplars:

- **Artistic Robot Design:** Design visually striking robots, incorporating elements of sculpture, color, and texture into their builds.
- **Role-playing Robots:** Build robots representing characters from literature or mythology, focusing on artistic details and creative storytelling.
- **Costumed Robots:** Create costumes and accessories for robots, enhancing the projects' visual appeal and thematic elements.

D. Programming robots to respond to artful triggers

Students program robots to react to specific triggers, such as lights, sounds, and movements used in an artistic context.

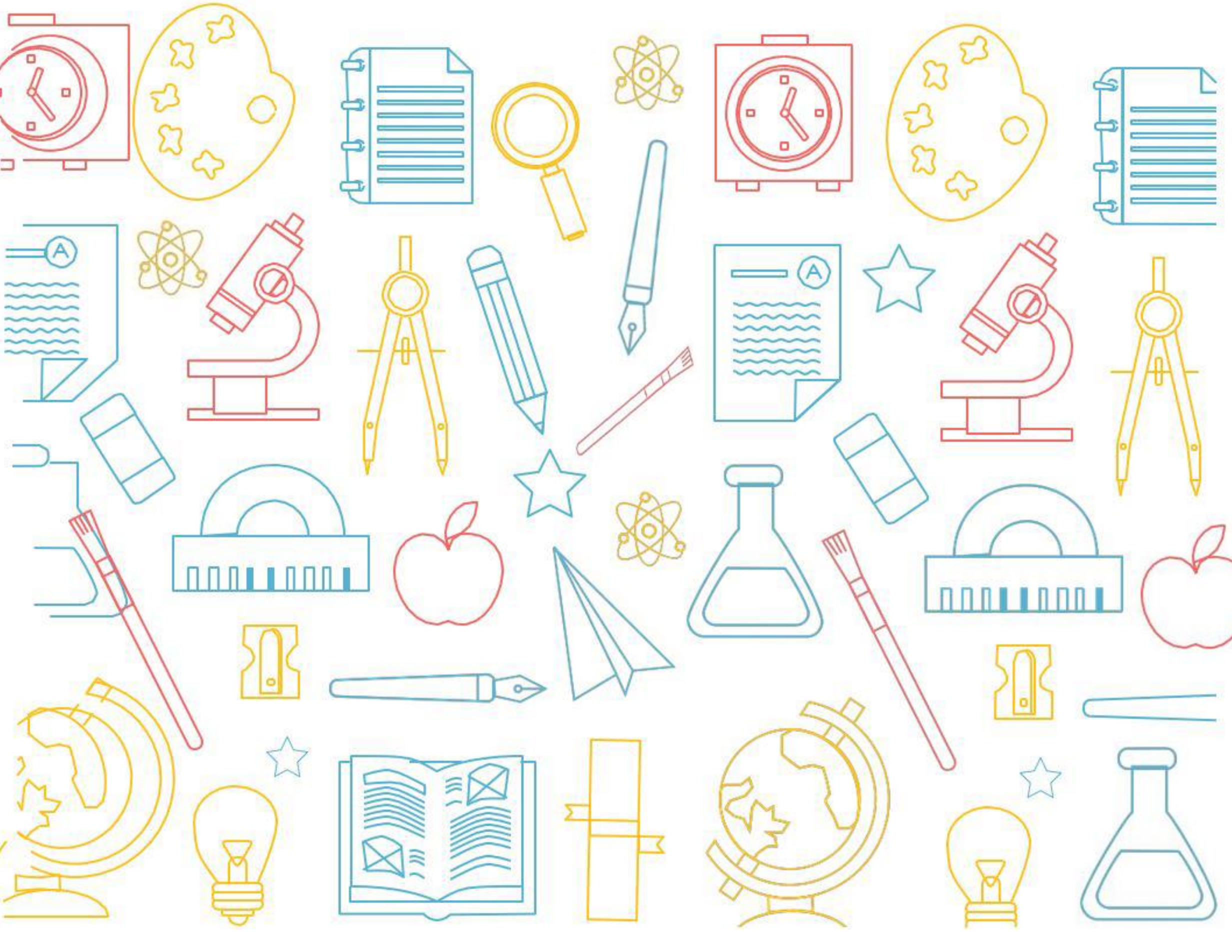
Indicative Exemplars:

- **Moving Robot:** Program a robot to change its movements according to the sounds/music it hears.
- **Art-enthusiast Robots:** Program robots, responding in various ways to every colour of a particular painting.

1.2 Then, consider the project disciplinary contexts for ER and Arts, i.e., the learning objectives and the materials you need.

Set learning objectives for each subject based on the curriculum. For example, ER focuses on specific programming skills, and Art focuses on a particular art technique.

Ensure these objectives align with the overall project challenge.



2nd Authoring Level
Follow the five-step FDM approach to organise your project

What are the five FDM steps?

FDM applies five steps that support you in designing new learning experiences for your students. In each class, ER and Arts, students implement the five steps through several activities that cultivate specific CT skills.

What should we focus on in the "Understanding the Challenge" step?

Introduce students to the project's objectives and help them grasp the key elements of the challenge/problem (e.g. concepts, techniques, functions) (**abstraction**) they need to solve, break down the challenge into smaller components (**decomposition**), and depending on the challenge, recognise patterns (**pattern recognition**) in the Artistic and ER requirements.

Ensure students can describe the requirements for each aspect of the challenge.

How do we guide students in the "Generating Ideas" step?

Encourage students to brainstorm and sketch ideas related to the challenges identified in the previous step, stimulating their creativity and problem-solving skills through hands-on practice and simulations; **abstraction**, **decomposition**, and, in some cases, **pattern recognition** are emphasised.

What is essential in the "Formulating the Solution" step?

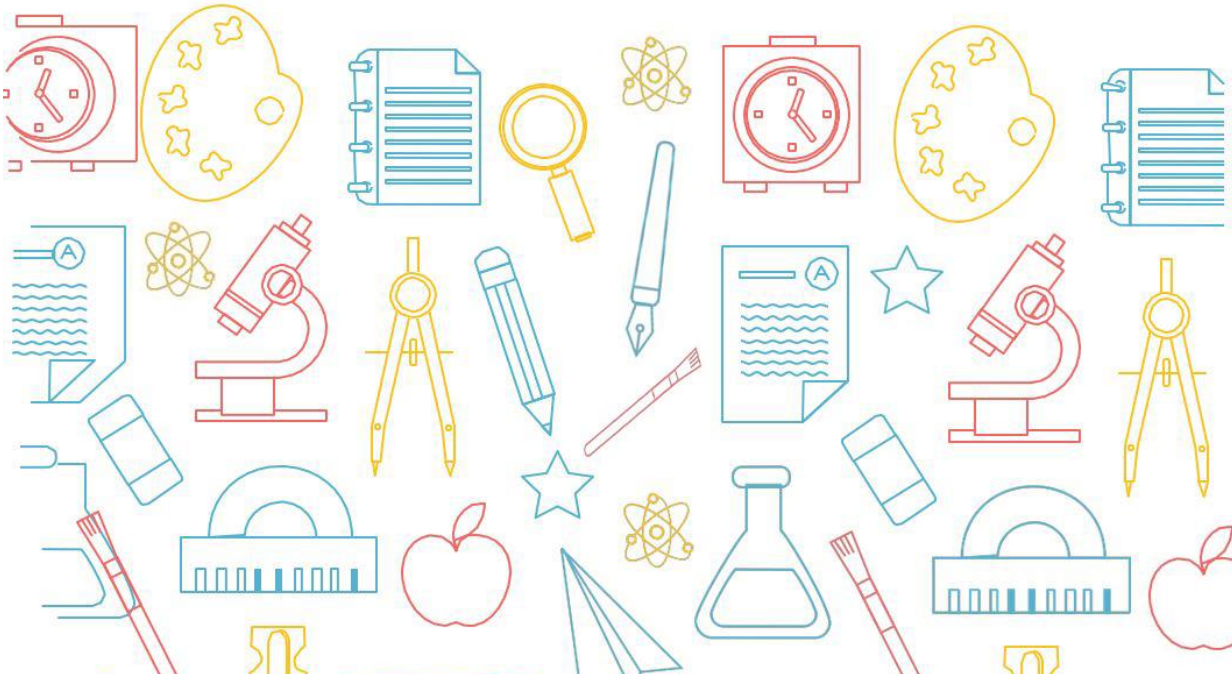
Help students create a detailed plan and develop algorithms, ensuring students have a clear roadmap for implementing their ideas; **algorithmic thinking** and **decomposition** are usually emphasised.

How do we support students during the "Creating the Solution" step?

Assist students in bringing their plans to life by constructing, programming, and synthesising the project's final product as the solution to the initial challenge. Provide feedback and help them troubleshoot issues; **decomposition** and **algorithmic thinking** are emphasised.

What should students do in the "Evaluating the Solution" step?

Using specific criteria, guide students to critically assess their work from artistic and technical perspectives (**evaluation**). They should reflect on the effectiveness and efficiency of their solution, identifying what worked well and what could be improved based on the initial requirements.



3rd Authoring Level
Design activities for students

How to design activities for each FDM step?

Design activities that align with the scope of each step. Activities can be of various types: *Engagement with the key concepts*, *Exploring new content*, *Exploring the challenge*, *Planning*, *Programming*, *Constructing*, and *Evaluating.*

How to design activities that cultivate Computational Thinking skills?

Focus on specific CT skills in each step, as suggested by the FDM. The first two steps, i.e., “Understanding the Challenge” and “Generating Ideas,” emphasise abstraction, decomposition, and pattern recognition, as students need to understand the main concepts involved, the requirements of the particular problem, and the relevant issues they must face. The “Formulating the Solution step focuses on decomposition and algorithmic thinking, as students here need to propose detailed plans and algorithms. The “Creating the Solution” step highlights algorithmic thinking and decomposition as students follow their plans and make adjustments. Finally, the “Evaluating the Solution” step focuses on evaluation, as students must use criteria to assess the final artwork and robot performance.

How to design activities for blended learning?

Combine face-to-face, online synchronous and asynchronous activities. Use educational robotics simulators in the classroom and remotely as homework to provide a safe and interactive environment. Leverage Web 2.0 tools to facilitate collaboration and communication, allowing students to work at their own pace.

Exemplar project "Travel to Mars"

The exemplary Artful ER project "Travel to Mars" combines Theatre and Educational Robotics. It may trigger you to start designing your first Artful ER project!

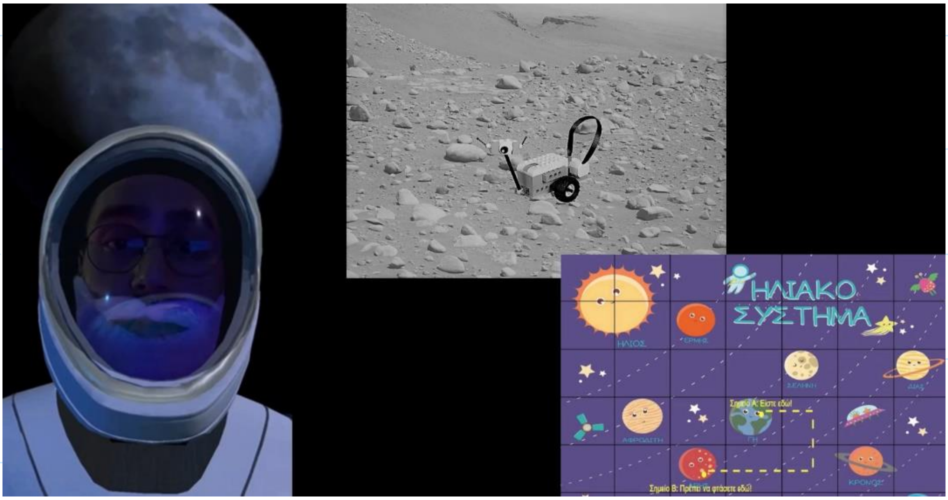
Project Title: Travel to Mars
Project Category: Programming robots to perform Art
Educational level: Lower Primary students (1st and 2nd Grade)
Duration: 6 hours
Art Type: Theatre
Educational Robotics: Beebots, Bee-Bot Online simulator

project context

Travel to Mars

The challenge given

"A rover landed on Mars some time ago but no longer communicates with Earth. Your challenge is to organise a mission to Mars to check on the rover. You will be the crew members and the robots, the spaceship engine."



This exemplar Artful ER project was designed and implemented by Nafsika Pappa (ICT teacher) and Nikos Kladis (Theatrologist), University of West Attica.

Co-design your first project!

You can elaborate on your ideas for a new Artful ER project on this page.

Project Context

Project Title: ....

Project Category: ....

Educational Level: ....

Duration:

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Art Type: ....

Educational Robotics: ....

The challenge assigned to the students

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How do you come up with an exciting challenge?

- choose a real-world problem
- define clearly the project's final output (artefact)
- encourage the students to think in an innovative and creative way
- make explicit the evaluation criteria for both disciplines

Step 1: Understanding the challenge

Start with a clear vision! Help your students understand the artistic and ER aspects of the challenge. Students understanding the challenge will set a solid foundation for their project.
CT skills to focus on Step 1: Abstraction, Decomposition, Pattern Recognition

Step 1: Understanding the challenge in the project "Travel to Mars"

The students discuss the challenge of the project with the teachers. They elaborate on the key elements of the challenge, aiming to identify sub-challenges, such as their role as crew members and the role of the robots in the story. In each subject (ER and Arts), they concentrate on the main tasks they have to do.

How do students understand the challenge, cultivating at the same time **Abstraction, Decomposition**, and **Pattern Recognition?**

- focus on their role as crew members
- distinguish the movement of their bodies according to whether they are on Earth or Mars.
- simulate their movement in different weather conditions on every planet.

- focus on the role of the robots as spaceship engines
- consider various aspects related to robots (Beebots) acting as spaceship engines (movements, programming, synchronisation with the crew members)

Art Activity Example

Activity Title: Training day
Description: The students simulate their bodies' movement according to whether they are on Earth or Mars. They also adjust their movements depending on weather conditions on each planet.
Duration: 5'
Type of activity: Engaging
Subject: Theatre
CT Skill: Pattern Recognition
Modality: Face-to-face
Class Orchestration: Plenary

Design the 1st step: “Understanding the challenge” of your project on this page

How do students understand the challenge, cultivating at the same time **Abstraction, Decomposition**, and **Pattern Recognition?**

Activities

Tips for CT skills cultivation

Abstraction

1. Hide details of an idea, problem, or solution that are not relevant, to focus on a manageable number of aspects.
2. Create a representation (idea) of what you are trying to solve.
3. Choose a way to represent an artefact, to allow it to be manipulated in useful ways.

Pattern Recognition

1. Analyse the data and look for patterns that make sense.
2. Find the similarities or patterns among small, decomposed problems.
3. Make predictions about what will happen next.
4. Transfer ideas and solutions from one problem area to another.

Step 2: Generating Ideas

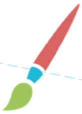
Let the creativity flow! Encourage your students to brainstorm and sketch out all their ideas. All ideas are welcome in this phase, and diverse approaches are encouraged!!

CT skills to focus on Step 2: Abstraction, Decomposition, Pattern Recognition

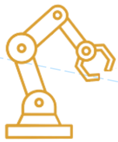
Step 2: Generating ideas in the project "Travel to Mars"

The students break down the tasks, brainstorm, and provide ideas about their accomplishments. In the ER class, they practice small missions with the robot simulator, and in the Theatre class, they get engaged with costume decoration ideas.

How do students understand the challenge, cultivating at the same time **Abstraction, Decomposition**, and **Pattern Recognition?**



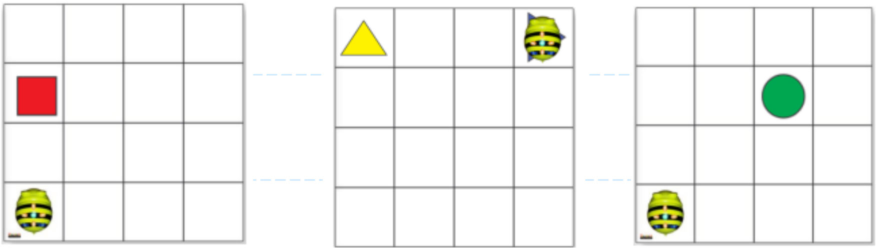
- distinguish the movement of their bodies according to whether they are on Earth or Mars.
- provide ideas for minor artefacts related to the identified parts, looking for relevant patterns in real spaceship contexts.

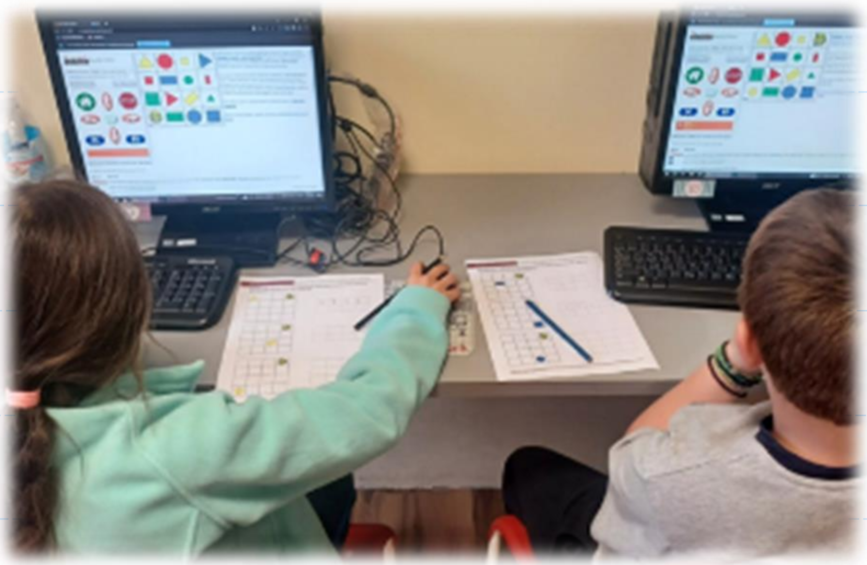


- analyse the robots' movements
- test their ideas in the simulator in developing smaller challenges that they try to solve

ER Activity Example

Activity Title: Practice on the simulator
Description: Following the instructions given in a worksheet, the students take on small missions to guide the Beebots to specific locations.
Duration: 20’
Type of activity: Challenging problem
Subject: ER
CT Skill: Decomposition, Algorithmic Thinking
Modality: Face-to-face
Class Orchestration: Groups





Design the 2nd step: "Generating Ideas" of your project on this page

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How do students generate ideas, cultivating at the same time **Abstraction, Decomposition**, and **Pattern Recognition?**

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Tips for CT skills cultivation

Decomposition

Break down a complex problem / artefact into smaller parts that can be understood, solved, developed and evaluated separately.

Tips for using simulators

- Design face-to-face and online activities with simulators
- Save time by testing and debugging on the simulator
- Design activities for individual practice at home
- Introduce robotic technologies that you do not have in your class (low-budget solution)
- Prepare students for face-to-face activities
- Use programming ideas for working individually or collaboratively at home

Step 3: Formulating the solution

Trigger your students to turn their best ideas into a detailed plan. This step is all about preparation.

CT skills to focus on Step 3: Decomposition, Algorithmic Thinking

Step 3: Formulating the solution in the project "Travel to Mars"

The students experiment with solutions for the movements of crew members and robots. They create instructions to solve the smaller tasks.

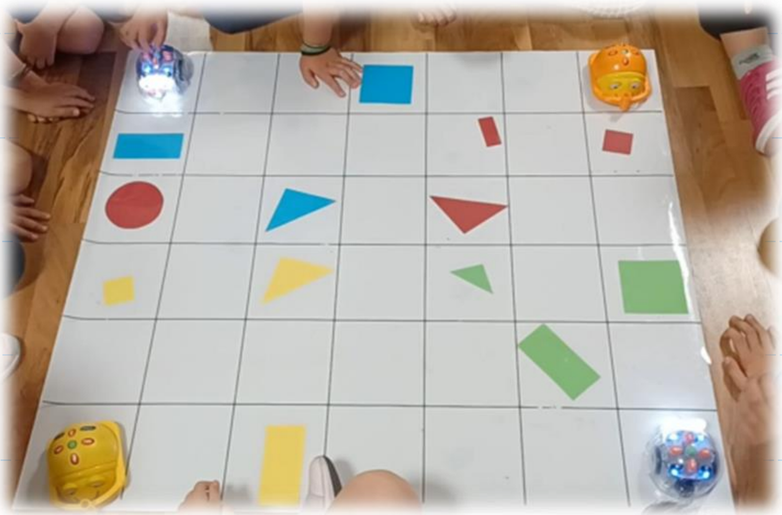
How do students formulate the solution, cultivating at the same time **Decomposition** and **Algorithmic Thinking?**

- experiment with the crew members' movements by doing small flight tests (resulting in particular instructions that describe the movements on Mars and Earth)

- practice with the physical robots to test the take-off and landing of the engines
- focus on the concept of scale to compare their movements in steps to the robots' steps
- practice to synchronise their movement with the robot.

ER Activity Example

Activity Title: Testing the Engines
Description: The students practice with the physical robots to test the take-off and landing of the engines. They program the robots to move and turn. To facilitate the transition from the simulator to the real robots, the teacher creates colored, paper geometric shapes like those in the simulator activity and puts them on the white Beebot carpet.
Duration: 15’
Type of activity: Programming
Subject: ER
CT Skill: Algorithmic Thinking, Decomposition
Modality: Face-to-face
Class Orchestration: Groups



Design the 3rd step: "Formulating the solution" of your project on this page

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How do students formulate the solution, cultivating at the same time **Decomposition** and **Algorithmic Thinking?**

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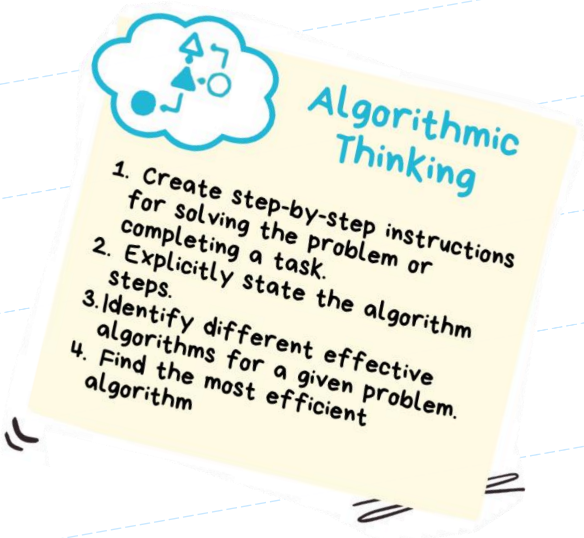
Tips for CT skills cultivation



Blended learning tips

- introduce robotic simulators in face-to-face or online activities
- use your e-class to communicate and give feedback to your students
- flip your classroom so that students study theory remotely and do practical activities in face-to-face meetings
- create educational videos for remote use on art history or various theoretical concepts or explain the functionalities of the robot you are using

Step 4: Creating the solution

Bring it to life! Now, it's time for your students to execute their plans and see their ideas in action.

CT skills to focus on Step 4: Decomposition, Algorithmic Thinking

Step 4: Creating the solution in the project "Travel to Mars"

The students try to find the optimum solution, apply it to accomplish the challenge, and make possible corrections. They travel to Mars, collect the evidence, and return back to Earth.

How do students create the solution, cultivating at the same time **Decomposition** and **Algorithmic Thinking?**

- try on the costumes and do flight tests, deciding on the optimum way to move

- create a step-by-step solution for robots' movement and find the optimum way to synchronise human with robot steps

- solve the challenge by completing the mission and gathering any possible evidence. Integration of solutions created in both subjects.

ER and Arts Activity Example

Activity Title: Launch day: From Earth to Mars
Description: The students complete the first part of the mission by traveling from Earth to Mars. They wear their costumes and integrate solutions created for both subjects.
Duration: 15’
Type of activity: Constructing
Subject: ER and Arts
CT Skill: Algorithmic Thinking, Decomposition,
Modality: Face-to-face
Class Orchestration: Groups

Design the 4th step: "Creating the solution" of your project on this page

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How do students create the solution, cultivating at the same time **Decomposition** and **Algorithmic Thinking?**

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Tips for designing ER and Arts activities (co-teaching)

- When designing joint activities, you should be careful about several organisational issues.
- Keep in mind that you will have to manage the duration of the activities to be synchronised in both subjects.
- Also, you must specify in which class the activity will take place and what materials/resources you need for the joint activity.

Step 5: Evaluating the solution

Reflect and improve! Help your students evaluate their work and think about what they learned and how to improve.

CT skills to focus on Step 5: Evaluation

Step 5: Evaluating the solution in the project "Travel to Mars"

Using specific criteria, the students evaluate their performance as crew members and the robots' performance as engines. They also reflect on the mission's strengths and weaknesses.

How do students evaluate the solution, cultivating at the same time

Evaluation?

- evaluate the compliance of the evidence found with the mission.
- reflect on the experience through an interview with the art teacher acting as a journalist

- assess whether the robots acted adequately during the mission.
- evaluate programming, synchronisation with the other engines, and synchronisation with students' movements

Arts Activity Example

Activity Title: Discussion on the findings
Description: The students evaluate the compliance of the evidence found with the mission.
Duration: 15'
Type of activity: Evaluating
Subject: Arts
CT Skill: Evaluation
Modality: Face-to-face
Class Orchestration: Plenary

Design the 5th step: "Evaluating the solution" of your project on this page

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How do students evaluate the solution, cultivating at the same time **Evaluation?**

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Tips for CT skills cultivation

Evaluation

1. Assess a solution and see if it can be generalized via automation or extension.
2. Assess whether an artefact does the right thing (functional correctness).
3. Design and run test plans and interpret the results (testing).
4. Use rigorous argument to check the usability or performance of an artefact (analytical evaluation).
5. Use methods involving observing an artefact in use to assess its usability (empirical evaluation).

Tips for setting the evaluation criteria

- Remember that the evaluation criteria that students will use to assess the artefact in each subject should be associated with the initial requirements you have defined in the challenge.
- If the artefact does not fulfil the requirements, students should be able to identify at which step they have made a misunderstanding and suggest ways of resolving it.

For more information, visit
https://fertile-project.eu/

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