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ΙΔΡΥΜΑ ΚΡΑΤΙΚΩΝ ΥΠΟΤΡΟΦΙΩΝ ΙΚΥ

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Contents

Executive Summary

In this report, the “FERTILE” consortium partners introduce the initial version of the Fertile Design Methodology (FDM), a comprehensive methodology aiming to support educators in designing blended learning projects that cultivate learners’ Computational Thinking (CT) skills through the seamless integration of Educational Robotics (ER) and Arts.

This report includes a section providing an up-to-date review of the FDM’s development process. This development process follows a Design-Based Research (DBR) approach structured in four phases. Notably, the first DBR phase is described in two reports (M1.1: A review on the current trends in ER and M1.2: Profiling of educators involved with ER) delivered by the consortium previously. To this end, this report focuses on the project work included in the second and third DBR phases towards culminating the initial version of the FDM methodology and its representational design format. Therefore, this section includes the theoretical underpinnings, and the interpretation of the literature review and the feedback provided by educators, towards aligning these findings with the FDM's objectives.

The section “Initial version of the FERTILE Design Methodology” includes the methodology. The partners elaborate on the FDM steps and the FDM activities incorporated in those steps. The last section of this report goes beyond delivering the initial FDM version to its evaluation. Specifically, the partners designed and implemented exemplar artful ER projects based on this methodology. Subsequently, evaluating the design and implementation process in educational settings allows determining the effectiveness of the FDM’s initial version. The promising findings regarding FDM’s comprehensibility and ease of adopting and adapting to particular educators’ contexts allows the consortium to move forward to the fourth DBR phase. In this last phase, the final FDM will be developed and evaluated to produce the project’s refined result “FERTILE Design Methodology”.

Acronyms

List of abbreviations

CCPS	Creative Computational Problem Solving
CT	Computational Thinking
ER	Educational Robotics
DBR	Design Based Research
FDM	Fertile Design Methodology
UniWA	University of West Attica, Greece (project coordinator)
URJC	Universidad Rey Juan Carlos, Spain (project partner)
CUB	Comenius University Bratislava, Slovakia (project partner)
CUP	Univerzita Karlova, Czech Republic (project partner)
UVa	Universidad de Valladolid, Spain (project partner)

1. Introduction

This report marks the achievement of the FERTILE project's third milestone "M1.3: An initial version of the FERTILE Design Methodology". This milestone is part of the project work involved in delivering the result: "The FERTILE Design Methodology," referred to as FDM.

Following the project's plan, researchers from all partners' teams conducted this report and its associated research. The partners distributed the workload according to the planned allocation degree. The URJC team, as the leading organisation in the associated result, and the UniWA team were involved to a higher degree. Notably, this report has undergone an internal review process before its publication. Specifically, two researchers from the participating organisations provided their feedback on internal review forms and as comments/suggestions on the report text towards its refinement.

After this introduction section, the second section: "Development process of the FDM" elaborates on the development process of the FDM using a Design-Based Research (DBR) approach. This approach follows four phases: (1) Problem identification and Needs analysis for the FDM, (2) The FDM conceptualisation, (3) Iterative cycles of formulating the FDM, and (4) Evaluation and refinement towards the final FDM. The first phase included the tasks T1.1 and T1.2 described in two reports (M1.1: A review on the current trends in ER and M1.2: Profiling of educators involved with ER) delivered by the consortium previously, while the fourth phase is forthcoming. Therefore, this report focuses on the second and third phases, describing:

- The theoretical underpinnings considered during the second DBR phase. As implied by the three core dimensions set by the FERTILE project: (i) blended learning, (ii) interdisciplinarity in Art and Educational Robotics (ER), and (iii) computational thinking (CT) cultivation, comprehending their essence was important towards developing FDM.
- The interpretation of the literature review and the feedback provided by educators during the first DBR phase towards aligning these findings with the FDM's objectives.

The third section focuses on the initial version of the FDM as it culminated through the iterative cycles of the DBR's third phase. The partners elaborate on the five FDM steps proposed and the FDM activities incorporated into those steps. A comprehensive presentation is provided, including explanatory visualisations.

In the fourth section, this report goes beyond delivering the initial FDM version to concluding the third DBR phase. Specifically, the partners designed and implemented pilot artful ER projects based on this methodology. This section includes these projects' scope, design description, and evaluation. Consequently, the partners gain valuable feedback on the effectiveness of the FDM's initial version towards moving forward to the fourth DBR phase. In this last phase, the final FDM will be developed and systematically evaluated to produce the project's refined result: "FERTILE Design Methodology".

2. Development Process of the FERTILE Design Methodology

As initially envisioned by the FERTILE consortium, the fundamental concept behind the FDM has been to promote CT by integrating Educational Robotics (ER) and Art while also effectively incorporating ER simulators into blended learning contexts. To this end, the FDM aims to empower educators to design and implement artful ER blended projects embracing interdisciplinary learning to cultivate CT.

The FDM development process presented in this report adopts a Design-Based Research (DBR) approach Amiel & Reeves (2008). Adopting this DBR approach provided several advantages. It facilitated interweaving practice with theory, thus ensuring the findings were grounded in real-world applications. Additionally, it triggered researchers' and practitioners' interaction, promoting collaboration and knowledge exchange throughout the research process. Figure 1 illustrates the four phases included in this DBR following the phases described by Amiel & Reeves (2008).

Regarding the first DBR phase, Amiel and Reeves (2008) propose to involve an *analysis of practical problems by researchers and practitioners in collaboration*. In this line, the consortium conducted a literature review (FERTILE project consortium, 2022a) and a needs analysis through educators' profiling (FERTILE project consortium, 2022b). Consequently, the practitioner's input promoted their active participation in defining research goals, formulating research questions, and identifying relevant issues for investigation.

Regarding the second DBR phase, *developing design solutions informed by existing design principles* was carried out by conceptualising the FDM's design principles. This conceptualisation is derived from synthesising previously tested design principles derived from theoretical underpinning and interpreting the previous phase's findings.

Regarding the third DBR phase, Amiel and Reeves (2008) propose conducting *Iterative cycles of testing and refining solutions in practice,* leading to a continuous cycle of design, assessment, reflection, and further design. In this line, the consortium conducted three iterative cycles to formulate, evaluate and reflect on three FDM versions. The first cycle involved a preliminary FDM, the second cycle a tentative FDM and the third cycle the initial FDM described in this report. As documented in the literature (Barab & Squire, 2004; Cobb et al., 2003), a development process following a research logic based on recursive cycles of action, analysis and reflection, has the potential to make unfamiliar situations more familiar while being empirical and data-based. As this approach is deemed essential for practical fields, such as education, aiming to answer questions that explore "what works" (Reigeluth & Frick, 1999), the consortium anticipates that the initial FDM constitutes a robust design methodology available for further exploration.

Regarding the fourth phase including *the reflection to produce design principles and enhance solution implementation,* the consortium plans to carry it out by formulating a final FDM version. Then, to evaluate the final FDM during pilot studies with educators towards refining and delivering it as the project's result "The FERTILE Design Methodology".

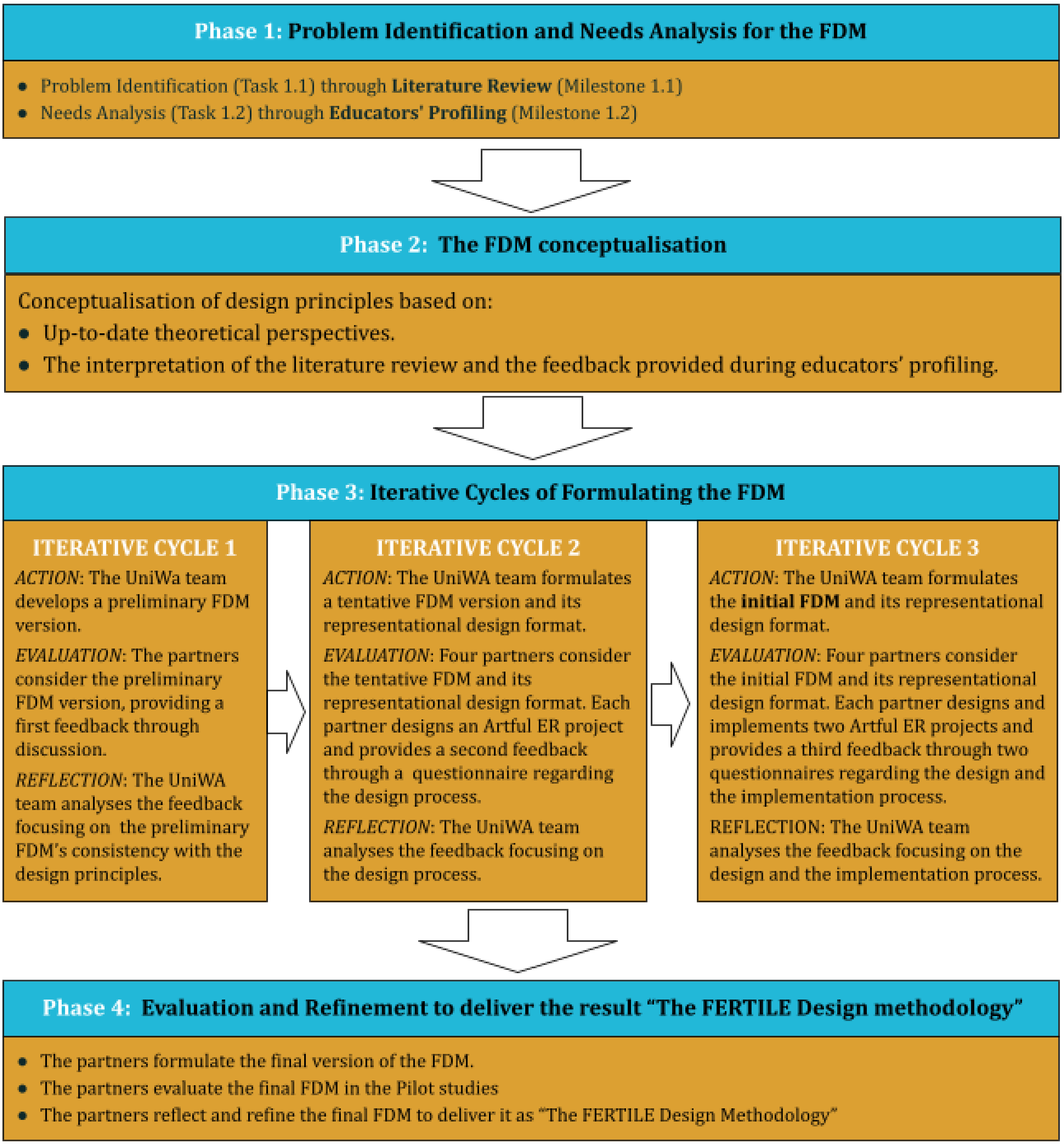

Figure 1: The FDM Development Process as a Design-Based Research (DBR) approach.

2.1 Phase 1: Problem Identification and Needs Analysis for the FERTILE Design Methodology

During this phase, the partners explored the challenges and practical problems to be solved by the FDM.

Specifically, the partners conducted a literature review to examine existing research on interdisciplinary projects combining Art and ER to promote CT. This review, designated as the FERTILE project‘s milestone M1.1: A review on the current trends in ER was the first step towards proposing a design methodology for Artful ER projects that cultivate CT skills. The review of available ER technologies, both physical robots and simulators, and the current state of curricula in the consortium partners' countries provided insights into current shortcomings and possible solutions to the issues that arise when applying ER in educational contexts.

In addition, the partners collected and analysed educators' profiles in the countries of the consortium This profiling, designated as the FERTILE project‘s milestone M1.2:: Profiling of educators involved with ER, aimed to gather as much information as possible from educators who teach ER or Arts, towards spotting the challenges they face and the kind of support they require to enhance their teaching practices. In this line, the educators' profiling included a needs analysis allowing the partners to gain insights into the educators' experiences and practices in implementing Artful ER projects towards identifying the gap between educators' current and intended practices based on the FDM

2.2 Phase 2: The FERTILE Design Methodology's conceptualisation

To conceptualise the FDM, the partners considered two data sources: (i) previously tested design principles derived from theoretical underpinnings and (ii) the educators' practical requirements derived from the previous phase's findings. In what follows, the partners synthesise these two data sources into the FDM's three core dimensions: blended learning, interdisciplinarity of Art and ER subjects, and CT cultivation.

2.2.1 Blended learning in the FERTILE Design Methodology

To develop an effective approach that promotes blended learning, within the project work, the partners conducted a literature review of (i) contemporary technologies' features employed to utilise physical robots and robot simulators, and (ii) educator's experience and suggestions for using simulators in everyday educational practice (FERTILE project consortium, 2022a).
Reviewing the literature, allowed the partners to found that, in recent years, various simulation environments have emerged that specifically cater to the educational requirements of students across different age groups. These simulated robots can be programmed using the same programming languages as their physical counterparts. This technological capability facilitates integrating remote activities using simulators with f2f activities involving their corresponding physical robots.
It is worth mentioning that while using simulated robots is expanding, it has not yet gained widespread adoption. This can also be seen from the educators profiling conducted within the project work (FERTILE project consortium, 2022b), where participating educators supported the potential of ER simulators for blended learning. Notably, the findings included educators experiencing difficulties in

using ER simulators mainly due to (i) challenges in achieving learners' engagement in online learning activities with ER simulators and (ii) limited students' participation. Therefore, the FERTILE consortium argues that these findings highlight the need for an appropriate design that engages learners in online activities.

To implement a blended learning approach, the consortium should acknowledge the educators' suggestions in addressing these difficulties. Educators primarily emphasised teaching strategies, including ideas pertaining to online learning, complementary online activities for students, and the flipped classroom model. These suggestions underscore the connection between face-to-face teaching and online learning, exploring various perspectives. Furthermore, acknowledging the practical issue of limited access to robotics technology, educators proposed the adoption of simulators as an alternative solution for the robotics course.

In terms of additional online activities, the educators suggested two approaches. Firstly, they proposed assigning simulator-based tasks as asynchronous homework for the students. Secondly, they proposed extra asynchronous activities for those who were interested. Regarding the flipped classroom approach, it was proposed that students could engage in programming tasks at home and subsequently apply them to the physical robot during class. Consequently, it is evident that teachers recognised the potential of simulators and primarily focused on incorporating online activities to expand the learning environment beyond the physical classroom.

However, implementing suitable online activities that support blended learning requires careful design, as highlighted by educators through their responses regarding the support needed. Hence, the blended learning model emphasises on employing online simulators for the practical application of newly acquired knowledge, as well as for experimentation with suggested ideas that can subsequently be validated using physical robots. Additionally, it incorporates the integration of WEB 2.0 tools to facilitate collaborative endeavours among students, as well as to establish effective communication and feedback between teachers and students. These activities serve as an extension of classroom work and their outcomes contribute to developing activities within the physical classroom. The alignment of these activities with classroom work, the engagement of teachers, and the promotion of student collaboration aim to foster active student participation.

2.2.2 Interdisciplinarity in Art and ER in the FERTILE Design Methodology

To develop an effective approach that promotes interdisciplinarity, the FERTILE consortium undertook an in-depth examination encompassing several key aspects. Firstly, the partners explored pedagogical approaches employed in Art subjects (see subsection 2.2.2.1).

Furthermore, the partners considered existing educational legislation across the countries represented by the consortium, specifically focusing on the intersection of ER and Arts subjects (see subsection 2.2.2.2). This encompassed a thorough investigation of the frameworks, policies, and guidelines shaping the implementation and integration of ER and Arts subjects in the respective educational systems.

Moreover, the educators' experience and valuable insights were sought to understand and gather their perspectives on the interdisciplinary activities of ER and Art (see subsection 2.2.2.3). Their expertise and suggestions were examined in detail to identify effective approaches and best practices to foster interdisciplinarity within the ER context.

2.2.2.1 Pedagogical approaches in Art

Robotics and the arts in education, beyond their co-existence in the modern terminology of STEM programs, in fact interact both pedagogically, interculturally and interdisciplinary. The modern philosophy of the arts in education puts the student at the center, is exploratory, provokes self-activity, cultivates a Vygotskian culture of team work and team-building, enhances creativity and imagination, motivates and opens up fields of multiple perspectives as to the solution of a problem or even as to the possible solution or change of strategy for a better problem-solving. The philosophy of ER has so many resemblances to the above described concept of arts education, even though at first hearing they seem to be concepts for different parts of the same mind. It may sound like a paradox, but it is true that interdisciplinarity, decomposition, synthesis, algorithmic thinking, creativity, problem solving and CT skills are building blocks of both robotics and arts in education.

In most forms of Arts education (of course with differences depending on the specific art and the specialization of the art teacher), arts teaching is based on three general stages, which are often extended to 4, based on the stage of conception, the stage of creation, the stage of presentation, the stage of evaluation-feedback. Surely, individual differentiations are a natural evolution of the autonomy of each art, such as music, visual arts, theatre, cinema, etc. According to Peter Abbs the four key stages in any significant art making are described as follows; «In making the students struggle to shape some impelling experience into form through a specific medium (through words, musical sounds, clay, bodily gesture, image, narrative or whatever). He or she seeks, but may not necessarily achieve, the creation of a symbolic form for this experience. When the symbolic realization is complete the creative process then moves to its second phase, the presentation of the work to an audience. [...] The presented work calls for immediate aesthetic response (third phase) and then considered evaluation (final phase) where judgments are made and justified and related not only to the individual work but the whole complex field of its forms (the aesthetic field) » (Abbs, 1994, pp. 96-97).

Although many art forms in education focus more on the process than on the result (product) and presentation, however, often in the educational process the presentation and dissemination of the art itself and the interaction with the audience is the goal of the action. In any case, an obvious division into phases of teaching and approaching the arts in: a. conception/creation, b. testing material-pre-design, c. presentation, d. feedback/evaluation, applies to a wide range of methods of teaching the arts in education, whether or not they also aim at presentation to an audience. Throughout this process, with greater or lesser exposure of students to the public, safety climate during work and improvisational (testing material) phases is a prerequisite. Then, exposure to the public and sharing to a larger or smaller audience is also a new goal that forms new creative skills in students and helps them to master more mechanical thinking in order to rationalize any fear of exposure. Their participation in public exposure through art, especially through the performing arts, reinforces their algorithmic and CT about the very process of mind and emotion, at the time of the exposition-presentation and the empathy of interactivity as well as physicality.

The paradigm of Devised Theatre Processes (Bicat & Baldwin, 2002) or Drama (Wagner, 1999; Fleming, 2003) which are forms of theatre/drama education strongly resemble algorithmic thinking, as participants are called to create something out of nothing or based on a given theme or subject or pretext [understand the problem], then they test their material by using improvisation or mixed forms of creating drama [propose ideas for solving it], choosing the material for the next stage according to the specific goals [formulate the desired behavior of the robot/program the robot], presenting or non presenting and discussing/pitching lab and evaluating. Simultaneously, different ways of making theatre/drama in education [presentational and non presentational forms] or of making performance for children and young audiences, re assumes key components of ER based on synthesis, abstraction, creativity, choice and decision or co-decision on the final solution, reflection and redesign and acceptance of assessment. Subsequently, this also happens in music education and, through another route, in the visual Arts.

In this creative dialogue of Arts and Robotics in education, the breaking of stereotypes is also interesting: in robotics children tend to focus on CT while developing life skills and creativity, and in art they focus on creativity and cultivating imagination, while actually learning important life and computational skills. It is particularly important in arts education, embedded, experiential learning that takes place; participants learn by doing, consequently they gain a new experience and they are led to a follow-up of this experience [critical thinking, reflection]. Experience and reflection are close friends throughout arts education's didactic processes, a fact which reinforces students' skills of creating, composing, decomposing, solving and re-solving. Embedding experience with the arts field gives students the chance to make experiments, to observe a specific environment or object with focus as it is in real life, and then to re-create it, depict, perform or document it though art.

Howard Gardner's Theory of Multiple Intelligences (Gardner, 1993) finds a fertile artistic and interdisciplinary field of highlighting skills that may be inherent in the same or different students and acquires new fields of application and investigation. Delving into characters and story analysis, robots come to life with the help of theatre/drama techniques, and theatre/drama techniques are enhanced by animating robots: an excellent synergy for creating interesting scenarios, artistic and educational. Robotics and the arts in education, in dialogue or embraced, synthetically redefine contemporary theories of learning through art and technology, and promise good practices for both teachers and students.

2.2.2.2 ER and Art in the curricula of the 4 consortium countries

The FDM aims to support teachers in real-life teaching situations, this is why the curricula of the consortium countries as they are reported in the milestone "M1.1: A review on the current trends in ER" (FERTILE project consortium, 2022a) is an important source of requirements for developing the methodology. Although data analysis from all countries showed plurality in terms ER and Art integration in schools, common points were identified contributing in developing the methodology and the pilot Artful ER projects that were designed and implemented to evaluate it.

At a formal level in Primary and Secondary Level, ER is not approached in any of the four countries as a separate subject except for some areas of Spain where it exists in Primary School as an elective course titled "Robotics and Technology". In all countries, it is applied for one or two hours per week as part of a module of an Informatics course or even a Technology course (Greece, Spain) or a skills Workshop course (Greece). As far as the Arts are concerned, Music and Art are found in all countries in both Primary and Secondary Education, with some variations in terms of teaching hours, there is more variation in teaching hours by level but if one wanted to generalise one would say that in all grades ART lessons take place from 2 to 3 hours per week. There is an exception in Greece where there are no

ART classes at all in the Upper Secondary Level, and there is one additional Art class of Drama in the first four grades of Primary School.

The analysis highlights that ER is not commonly approached as a separate subject in the four countries, but rather integrated into existing courses. Similarly, Arts subjects such as Music and Art are consistently present in all countries, with some variations in teaching hours. Recognizing these variations across different levels and countries, the FDM is designed to accommodate these differences. By offering flexibility in implementation, educators should be able to adapt the FDM to suit their specific time constraints and educational priorities.

2.2.2.3 Findings from the Educators' Profiling

The FDM aligns with the Artful ER projects' categories identified by the educators, as it suggests the same types of interdisciplinary activities that combine robotics and art. These categories, including 'Programming robots to create art', 'Programming robots to perform art', 'Creating artful robots', and 'Programming robots to respond to artful triggers', were identified by the educators during the profiling process reported in the milestone “M1.2: Profiling of educators involved with ER” (FERTILE project consortium, 2022b). Thus, the FDM provides a framework that resonates with the teachers' observations and allows designing interdisciplinary projects that integrate ER and artistic practices.

The analysis of educators' responses regarding cross-curricular ER and Art activities revealed three distinct themes: painting, literature, and performing Arts (music, dance, theatre) (FERTILE project consortium, 2022b). Similarly, the literature review identified Artful ER projects that integrated ER with painting, music, literature, and theatre (FERTILE project consortium, 2022a). Consequently, the FDM aims to integrate these artistic disciplines with robotics seamlessly.

The educators' attitude towards integrating ER and Art subjects through interdisciplinary activities has been highly positive. They recognise the potential of such activities to enhance learners engagement, facilitate authentic and meaningful learning experiences, and promote inclusivity. By adopting an interdisciplinary approach, the challenges encountered may be effectively addressed within the context of blended learning.

One of the major challenges highlighted by ER and Art educators is the limitation of teaching time, compounded by fragmented classroom schedules and varying timetables among teachers. In response to these challenges, the blended learning approach emerges as a promising solution. It establishes benchmarks for extending teaching time through online activities, enables the organization of digital classroom environments, and encourages the involvement of educators from diverse disciplines to provide online support for students.

To facilitate the integration of disciplines, the methodology suggests the development of a series of steps that aim to integrate both the art and robotics perspectives in order to create a comprehensive artefact. By strategically designing each step to attribute equal importance to both disciplines, the FDM ensures that both ER and art are integrated throughout the process. This approach promotes a holistic view of how these two fields may complement and enhance each other in the context of interdisciplinary activities.

The positive reception of interdisciplinarity by the educators highlights the value of this approach in promoting CT. By embracing an interdisciplinary framework, educators can effectively leverage the benefits of ER and art, creating a dynamic and enriched learning environment for learners.

2.2.3 Computational Thinking in the FERTILE Design Methodology

To incorporate a coherent CT approach within the FERTILE methodology, a literature review was conducted to analyse existing studies on the development of CT skills through robotics activities (FERTILE project consortium, 2022a). The primary aim was to investigate the various educational approaches employed in the design of these activities. Furthermore, an analysis was carried out to examine the educators' experiences and viewpoints concerning the cultivation of CT through ER, as part of their participation in the educators' profiling process (FERTILE project consortium, 2022b).

The literature review has shown that CT is approached in various ways and through diverse educational designs. Two primary trends were identified. The first is the conceptualization of CT as a problem-solving process (Chen et al., 2017; Wing, 2006; Leonard et al., 2016; Chevalier et al., 2020). In particular, Wing's (2006) definition characterizes CT as "the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent ". The second prevailing trend involves the analysis of CT into skills. The most commonly examined CT skills include abstraction, decomposition, algorithmic thinking (Atmatzidou & Demetriadis, 2016; Chen et al., 2017; Leonard et al., 2016), and evaluation (Chevalier et al., 2020).

The CCPS model (Chevalier et al., 2020) stood out as a comprehensive approach that encompassed both problem-based design and the development of CT skills although it does not explain in detail the cultivation of skills in the phases. The model consists of five main consequent phases. According to this model, learners are asked to i) understand the problem (Phase 1-Understanding the problem), ii) propose ideas for solving it (Phase 2- Generating Ideas), iii) formulate the desired behaviour of the robot that solves the problem (Phase 3 - Formulating the behaviour), iv) program the robot (Phase 4), and v) evaluate the solution (Phase 5).

Additionally, the CCPS model posits strengthening the preceding phases before programming to ensure that students can gradually advance through the problem-solving process, rather than rushing into robot programming. During the programming phase, it is suggested that students be given the opportunity to use the programming environment without directly testing their code on the robot. This approach aims to prevent them from engaging in a trial-and-error testing process.

The review of existing studies on CT skills through ER activities allows the methodology to draw from different educational approaches. By understanding the different ways in which CT is conceptualized as a problem-solving process and as specific CT skills (abstraction, decomposition, algorithmic thinking, pattern recognition and evaluation), the FDM gains a differentiated perspective on how CT can be effectively cultivated in educational settings. By aligning the FDM activities with these skills, educators can ensure that students develop a well-rounded set of CT skills. Specifically, the CCPS model, which encompasses problem-based design and the development of CT skills, provides a structured problem-solving framework. The FDM can utilize this framework to support educators to guide students through different phases of problem-solving, ensuring a systematic approach to CT development. Moreover, the CCPS model's emphasis on strengthening the preceding phases before programming aligns with research on effective CT development. By allowing students to progress gradually through problem-solving stages, the FDM can foster a deeper understanding of concepts and enhance students' ability to tackle more complex challenges as they advance.

2.2.4 Design principles of the FERTILE Design Methodology

The aforementioned analyses' results constituted the theoretical perspectives and practical requirements towards determining the key principles of a preliminary FDM version (see Figure A1 in Appendix A) . Consequently, the partners inferred the following design principles :

a) The FDM should cater to apply learning objectives both for ER and Art disciplines.

b) The FDM should follow a problem-based approach culminating in steps that interweave both disciplines.

c) Each FDM step should focus on developing CT skills.

c) The FDM steps should be flexible in terms of their modality.

d) An Artful ER project should conclude in producing a shared output - an artefact interweaving ER and Arts.

e) The FDM should apply to simulators' use.

2.3 Phase 3: Iterative cycles of formulating the FDM

In the third phase of the DBR approach, the partners organised three iterative cycles. Each cycle contributed to refining the research aims and contextual understanding. Also, it facilitated achieving the main research outcomes, i.e., refining design principles and improving the FDM and its representational format. The classic cycle of action, analysis, and evaluation occurred within each iterative cycle.

2.3.1 Iterative Cycle 1 - Preliminary FERTILE Design Methodology

The UNIWA team conceptualised a preliminary FDM (see Figures A2 and A3 in Appendix A) incorporating insights from (i) the educators profiling, and (ii) the pedagogical practices adopted in ER such as the Creative Computational Problem Solving (CCPS) model (Chevalier et al., 2020), and CT skills as suggested by Wing (2006).

To accomplish an in-depth understanding and consideration of the preliminary FDM, the UniWA team developed a design form, i.e., a representational design format for a project based on the FDM. This representational design format was developed in excel format (see Figures B1 and B2 in Appendix B) and contained two worksheets. The first worksheet in the Excel file outlines the five steps of the methodology and their descriptions, along with the five CT skills and instructions for cultivating them through activities. The second worksheet provides general project information, including cognitive objectives for both fields, the ER technology to be utilized, and the art form to be explored in the project. Subsequently, there are five separate worksheets, each dedicated to presenting one of the five steps, with detailed information about the activities involved in each step. Notably, the design form defines all the design information needed for describing an Artful ER design project and, therefore, the design decisions an educator should make.

To accomplish an in-depth understanding and consideration, the UniWA team developed the "Integrating the basic principles of animation with the robotic movement" project, an exemplar Artful ER project based on this FDM. An exemplar Artful ER project refers to a specific and well-designed project that showcases the integration of Arts and ER to cultivate CT. It serves as a practical demonstration of how the principles of FDM are applied in practice. The exemplar project can be used as a reference or inspiration for other educators interested in implementing similar projects, as it demonstrates best practices and effective approaches within the FDM. Based on the preliminary FDM, the exemplar project aimed to highlight the significance of collaboration between Art and ER teachers and the meaningful integration of learning objectives from both disciplines with CT. Furthermore, the exemplar project catered to support FDM in terms of its sound theoretic documentation and easiness of educators' adoption.

The UniWA team presented the preliminary FDM and its design form representing the exemplar project "Integrating the basic principles of animation with the robotic movement" during the transnational project meeting held in Prague in September 2022. The partners considered this presentation and collected feedback through discussion to reflect on and refine the FDM.

2.3.2 Iterative Cycle 2 - Tentative FERTILE Design Methodology

The UniWA team considered the feedback received during the 1st iterative cycle to synthesise a tentative FDM (see Figures A4, A5, A6, A7 and A8 in Appendix A) and its design form (see Figures B3 and B4 in Appendix B).

Afterwards, during an online meeting held in November 2022, the UniWA team presented the tentative FDM and the exemplar Artful ER project "ER and Abstract Expressionism". Also, the UniWA team informed the partners of its first attempt to enact such a project by showcasing an implementation with primary school students in an associated school.

Subsequently, four partners (UniWA, URJC, CUB, CUP) undertook the task of designing one pilot Artful ER project based on the tentative FDM. The partners organised an online meeting in December 2022 to present their pilot projects and discuss their experience. Furthermore, to collect comprehensive written feedback about the tentative FDM, the partners organised a questionnaire (https://forms.gle/wzeQVRSVwza2462x9), collecting their perceptions about designing these pilot projects towards reflecting on and refining the FDM.

2.3.3 Iterative Cycle 3 - Initial FERTILE Design Methodology

The UniWA team considered the feedback received during the 2nd iterative cycle to synthesise an updated FDM version. Subsequently, during the transnational project meeting held in February 2023 in Valladolid, the UniWA team presented this FDM version. A fruitful discussion between partners considering this FDM version with regards to their experience of designing Artful ER projects allowed determining that this version constitutes a robust methodology to be appointed as the initial FDM. This

FDM version constitutes the project's milestone "M1.3: An initial version of the FERTILE Design Methodology" and is presented in the 3rd chapter of this report.

Furthermore, the partners set as their forthcoming goal to evaluate the initial FDM version in real educational settings. They arranged that UniWA, URJC, CUB and CUP teams recruit Art and ER educators from the project's associated partners or any suitable acquaintances to design and implement two pilot Artful ER projects based on the initial FDM. As this task was within the timeframe of delivering this report, the partners complement the 4th chapter of this report with these pilot Artful ER projects .

Notably, the partners arranged to collect comprehensive feedback from participating educators through two online questionnaires. One regarding their perceptions of the design process (https://forms.gle/A48vz9fguuQLfFoj6) and another about their perceptions of the implementation process (https://forms.gle/Y7UVnbchu9zaPnGA9). This feedback allows the partners to gain valuable insights into educators' perspectives on utilising the initial FDM to design and implement Artful ER projects. In the 5th chapter of this report, the partners reflect on the feedback received from educators and provide brief conclusions.

2.4 Phase 4: Evaluation and Refinement to deliver the result "The FERTILE Design methodology"

The fourth phase of the DBR approach is scheduled after delivering this report. The partners intend to consider the feedback received during the 3rd iterative cycle regarding the initial FDM version towards synthesising the final FDM. Consequently, this FDM will reflect the outcome of the three iterative cycles organised during the DBR's third phase.

Also, in this last phase, the final FDM will be systematically evaluated during the pilot studies included in the project's work plan to produce the project's refined result: "The FERTILE Design Methodology".

3. The Initial FERTILE Design Methodology

Inspiration from the CCPS model, the FDM supports educators in designing structured problem-solving challenges using specific steps, embracing blended learning to integrate ER and art. In these scenarios, educators trigger students with a challenge that involves creating an artefact, requiring the seamless integration of ER and art elements.

3.1 The Computational Thinking incorporated in the FERTILE Design Methodology

The FDM addresses CT in two ways: firstly, as a problem-solving process characterised by specific steps, and secondly, as a collection of skills cultivated within each step of the methodology, aligned with the design of the instructional scenario.

The FDM aims to cultivate the CT skills: Abstraction, Decomposition, Pattern Recognition, Algorithmic Thinking and Evaluation. (Selby & Woollard, 2013)

Abstraction involves the process of identifying the key elements and concepts relevant to the problem at hand while ignoring unnecessary details. It helps students focus on the essential components of the challenge and develop a high-level understanding of its structure and requirements.

Pattern recognition involves identifying similarities, regularities, and recurring patterns within the problem domain. It enables students to recognize commonalities among different instances and discern underlying structures or relationships. By developing pattern recognition skills, students can make connections between different aspects of the challenge.

Decomposition involves breaking down complex problems or tasks into smaller, more manageable sub-problems or sub-tasks. By decomposing a challenge, students can identify its constituent parts and understand how they relate to each other.

Algorithmic Thinking is a fundamental CT skill that involves developing step-by-step instructions or a sequence of actions to solve a problem. It focuses on designing a logical and efficient solution that can be executed by a computer or followed by a human. Algorithmic thinking also promotes efficiency, as students strive to design solutions that are clear and concise.

Evaluation, as a CT skill, involves assessing and analyzing the effectiveness, efficiency, and overall quality of a solution or process. It focuses on critically examining the outcomes and determining whether they align with the intended objectives or criteria. Through evaluation, the students assess the performance, functionality, and impact of their Artful ER projects in relation to the challenge they were tasked to address.

3.2 The steps followed in the FERTILE Design Methodology

The FDM puts forward a series of interconnected steps that extend beyond the mere programming of the robot. Considering that CT can be developed across various disciplines through its application to real-world challenges, the FDM development has been carefully crafted to incorporate the art subject. Consequently, the proposed steps and their progressive implementation are also applicable in art courses, ensuring a comprehensive integration of CT and artistic exploration. The methodology promotes a gradual progression through each step, emphasizing the completion of the robot programming step before moving on to the implementation of the program on the physical robot.

To facilitate this process, the use of simulators during the programming step is of utmost importance. Using simulators eliminates the necessity of directly controlling or evaluating the program using a physical robot. Instead, students are encouraged to program while making assumptions about certain robot parameters. Similarly, the formulation of a comprehensive set of instructions for assembling the artefact prior to its final creation holds significant value. By following this approach, students will first conceptualize and formulate their solution before its practical implementation. During the solution formulation process, students will be encouraged to cultivate abstraction, reflect on abstract ideas, and document their solutions rather than resorting to immediate testing on the robot based on assumptions.

The FDM consists of five main steps ideally completed in sequence, and if needed they are repeated iteratively for maximum effectiveness: Understanding the Challenge (UND), Generating Ideas (GEN), Formulating the Solution (FORM), Creating the Solution (CRE) and Evaluating the Solution (EVA). The FDM empowers educators to design the learning context and the activities for each step, presenting a challenge to students. Through the design process fostered by the FDM, educators are supported to design educational interventions aiming to cultivate learners' CT by creating projects that require equal engagement with ER and Art elements.

- **Understanding the Challenge (UND)**: In this step, the educator presents the challenge and the students use abstraction, decomposition and/or pattern recognition to identify the given challenge's requirements. The input of this step is the given challenge situation (proposed by the teacher) and the output is the description of the challenge's requirements regarding ER and Art (to be carried out by students). The methodology suggests that during the "understanding the challenge" step, there is a focus on cultivating CT skills such as abstraction, pattern recognition, and decomposition.
- **Generating Ideas (GEN)**: In this step, students use abstraction, decomposition and/or pattern recognition, to generate one or more ideas that could fulfil the requirements set out in the challenge. Educators/designers encourage creative thinking and support students in brainstorming and developing ideas.
- **Formulating the Solution (FORM)**: In this step, the students transform the chosen idea into a formulated solution by taking into account the challenge requirements, and utilizing knowledge related to the characteristics of the robot and the artefact through decomposition and algorithmic thinking. Educators/designers guide students in the process of formulating a comprehensive plan for both the artefact and the robot's behavior. The output of this step regarding art is a full statement of the process to be followed and the materials to be used to

form the artefact, and regarding ER is a complete formulation of the robot's behaviour through construction and algorithms (natural language).

- **Creating the Solution (CRE)**: The step is successfully executed when the formulated Solution step is fully completed through the construction of the artefact and the programming of the robot. So the output of this step through decomposition and algorithmic thinking is the constructed artefact and the programmed behaviour in the robot's language and its execution. Educators/designers provide guidance and resources to support students in effectively implementing their ideas.
- **Evaluating the Solution (EVA)**: In this step, the students observe the completed artefact and the programmed robot, evaluating their correspondence to the requirements of the challenge and overall suitability. The progression between steps can either be terminated or continued through a feedback transition to one of the other steps. Educators/designers facilitate the evaluation process and provide constructive feedback to help students refine their designs.

Figure 2 shows the interconnection between the steps included in the FERTILE methodology and the CT skills.

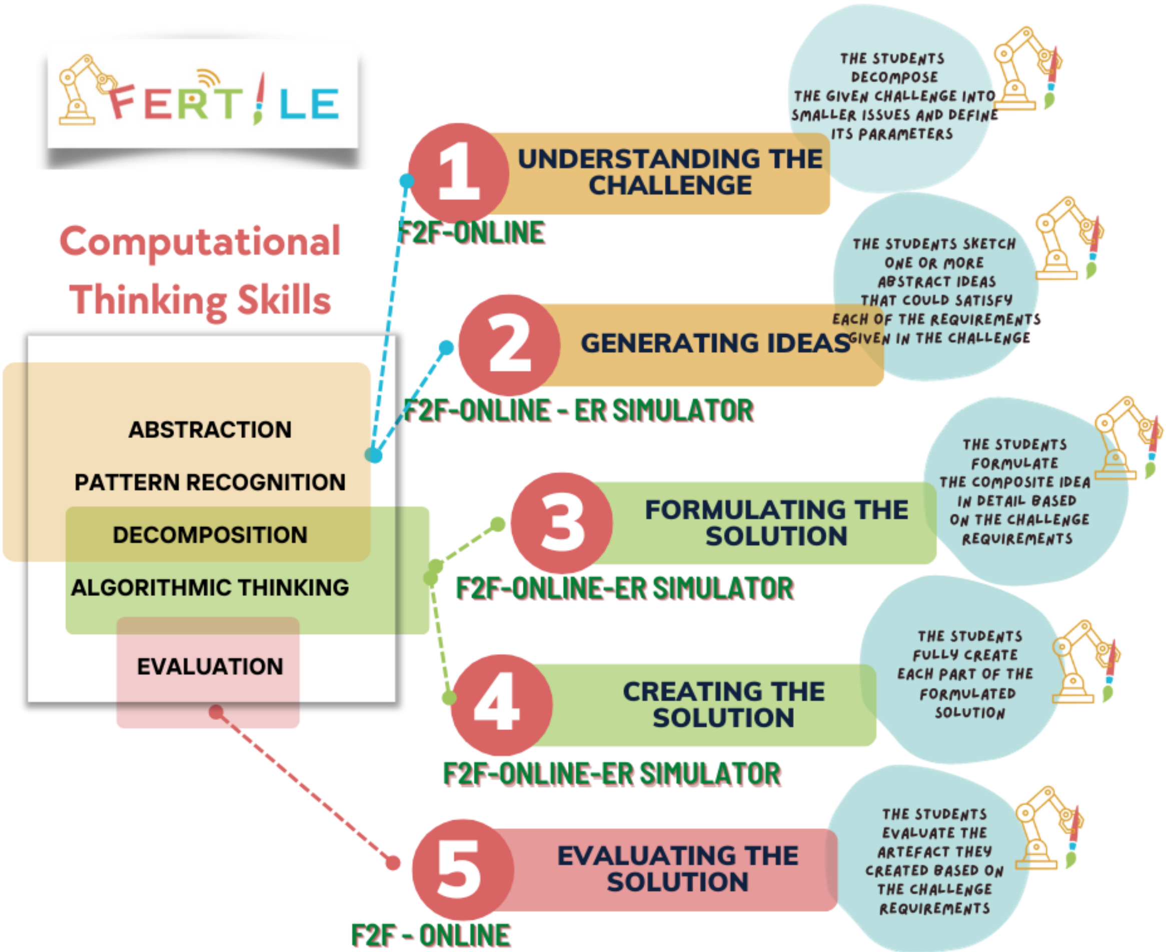

Figure 2. The steps included in the FERTILE methodology and CT skills

3.3 The characteristics of the activities incorporated in the FERTILE Design Methodology

Each step includes distinctive activities involving the ER subject, the Art subject, or a combination of both. Every activity is defined by its specific constituent characteristics. Below, the primary characteristics of each activity are outlined.

3.3.1 CT skills

In each step, specific CT skills are selectively emphasised and cultivated, while in other steps the development of these skills may not be prioritised to the same extent. Consequently, the activities within each step of the methodology have the potential to cultivate multiple CT skills, including abstraction, pattern recognition, decomposition, algorithmic thinking, and evaluation (see Table 1).

Table 1. The CT skills approach applied in the FDM methodology

CT skill	Indicative Instructions
Abstraction	1. Hide details of an idea, problem or solution that are not relevant, to focus on a manageable number of aspects. 2. Choose the right detail to hide so that the problem becomes easier, without losing anything important 3. Create a representation (idea) of what you are trying to solve 4. Choose a way to represent an artefact, to allow it to be manipulated in useful ways.
Decomposition	1. Break down a complex problem into smaller/simpler parts that are easier to manage. 2. Break down artefacts into constituent parts to make them easier to work with. 3. The parts can be understood, solved, developed and evaluated separately.
Pattern Recognition	1. Analyse the data and look for patterns that make sense of the data or problem. 2. Find the similarities or patterns among small, decomposed problems that can help you solve complex problems more efficiently. 3. Make predictions about what will happen next. 4. Transfer ideas and solutions from one problem area to another.
Algorithmic Thinking	1. Create step-by-step instructions for solving the problem or completing a task. 2. Explicitly state the algorithm steps. 3. Identify different effective algorithms for a given problem. 4. Find the most efficient algorithm
Evaluation	1. Assess a solution to a problem and use that information again on new problems. 2. See if the solution can be generalised via automation or extension to other kinds of problems and cover more possibilities/cases. 3. Assess whether an artefact does the right thing (functional correctness). 4. Design and run test plans and interpret the results (testing). 5. Use rigorous argument to check the usability or performance of an artefact (analytical evaluation). 6. Use methods involving observing an artefact in use to assess its usability (empirical evaluation).

3.3.2 Activity Types

The activities in each step are categorised into six types. These activity types are general categorisations of activities commonly used in educational settings to engage students in various tasks and promote learning. Although these types of activities are not bound by a specific framework or theory, they align with the collective expertise of the partners involved.

A. **Student engagement activities:** These activities aim to engage students in the educational process fostering their active participation, motivation, and interest. These activities often require students to actively participate, contribute ideas, critically analyze information, and work collaboratively with their peers. They provide opportunities for students to apply their knowledge, skills, and creativity in real-world contexts, making the learning experience more meaningful and relevant to their lives.
B. **New content activities:** New content activities are designed to introduce students to new concepts and facilitate the acquisition of knowledge relevant to the subject. These activities aim to expand students' understanding, broaden their perspectives, and provide them with the necessary foundation to explore and engage with the subject matter.
C. **Planning activities:** Plan activities involve students in the process of developing strategies, making predictions, and formulating questions based on the given challenge or problem. During plan activities, students are encouraged to think carefully and create a plan which may include goals, steps, and tasks to complete, as well as thinking ahead about potential problems and solutions.
D. **Programming activities:** In these activities, the students engage in the process of creating and specifying the precise instructions for the robots to execute, either in natural language or programming language. This involves developing a step-by-step sequence of commands or code that will enable the robots to perform desired actions and behaviours.
E. **Constructing activities:** During construct activities, students engage in hands-on building and construction tasks to create either the desired artistic work or the robot itself. They use various materials, tools, and components to assemble and construct the physical structure according to the given specifications or design requirements.
F. **Evaluating activities:** Evaluation activities provide students with opportunities to assess and reflect on their completed work, allowing them to gain insights into their progress, and identify strengths and areas for improvement.

3.3.3 Modality

In every step, activities can be conducted either face-to-face or online. However, it's important to note that "Constructing activities", which involve the physical presence of students and the use of materials for building robots or artwork, cannot be replicated online. Nevertheless, all other types of activities hold the potential to be conducted in an online setting.

Simulators can be employed during "Program activities", enabling students to practice algorithms that will be implemented on the robot. They can also be used during "New Content activities" aimed at acquiring new knowledge, particularly when it involves familiarising with the programming environment or knowledge related to programming.

Figure 3 depicts the process of an Artful ER project through the gradual completion of each step, achieved by accomplishing its corresponding activities. Specifically, the steps are performed in order as shown by the thin horizontal arrows. Each step consists of individual activities (boxes below each step) which are executed in order as indicated by their numbering. Each activity concerns either ER (e.g. Activity 4) or Art (e.g. Activity 1) or both subjects (e.g. Activity 10). The figure shows for each activity, the subject it applies, the computational thinking it targets, the type of activity as defined by FDM as well as the modality.

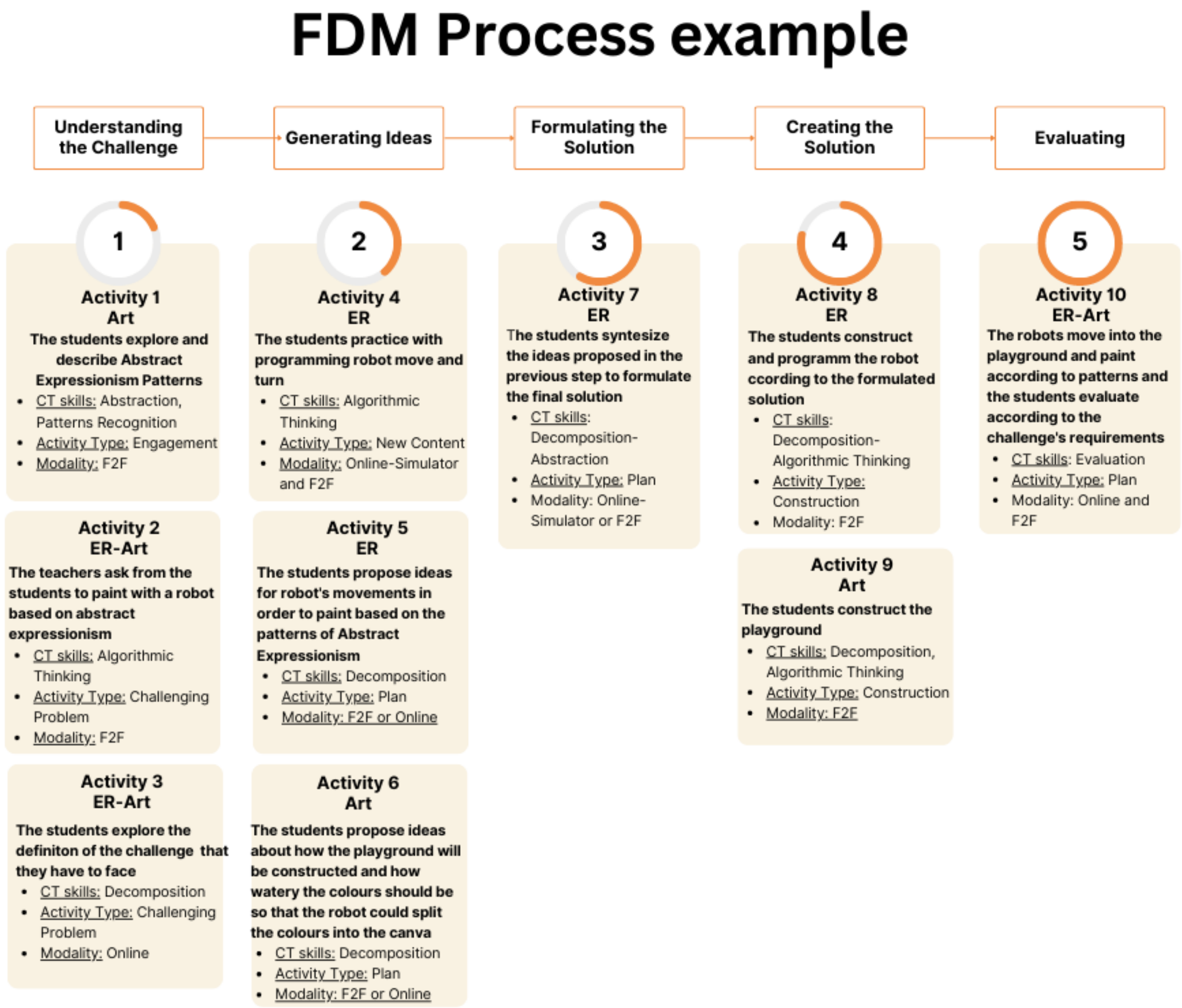

Figure 3. Artful ER Project's design representation based on the FDM

4. Artful ER projects

In this section, we showcase eight pilot Artful ER projects based on the initial FDM version. The partners organised designing and implementing them in real educational settings. Two/three educators/designers specialising either in ER or Art, or a single educator/designer with expertise in both fields were involved. These educators were either consortium members or in-service educators from the associated partners.

Each pilot Artful ER project is showcased through the following subsection structure:

- The project scope, elaborating on its objectives regarding ER and Arts (e.g. Section 4.1.1).
- The project design following the initial version of the FDM's representational format (e.g. Section 4.1.2). This tabular representational format includes:

  i) The project overview, e.g. Table 2.

  ii) The project activities involved in each step, e.g. Tables 3, 4, 5, 6 and 7. Every activity is accompanied by a short title, a brief description, the targeted CT skills, the activity type, the modality of implementation, the class orchestration and the activity's duration in minutes. The colours used in the tables distinguish activities focusing on Art (yellow), ER (blue), or both subjects (green).

- The evaluation of the project's design process, e.g. Section 4.1.3 (Tables 8 and 9), by its designers.
- The evaluation of the project's implementation process, e.g. Section 4.1.4 (Tables 10 and 11) by the educators who implemented it.
- The insights and observations of the project evaluation to draw brief conclusions of the FDM's effectiveness.

4.1 "The Art of Anticipation" an Artful ER project by UniWA

4.1.1 The scope of "The Art of Anticipation" project

"The Art of Anticipation" is a fundamental principle in animation that involves creating a sense of anticipation in a character's actions or movements to enhance the impact and realism of the animation. By building up tension or expectation before a significant action, the audience becomes more engaged and emotionally invested in the scene.

In the realm of ER, incorporating the principle of anticipation can greatly enhance the learning experience for students. By integrating the FDM phases (Understanding, Generating, Formulating, Creating, Evaluating), students can explore the concept of anticipation, apply it to their robotics projects, and refine their ideas through feedback and evaluation.

To initiate the learning process, the teacher prompts the students to actively engage in storytelling activities centered around a robot character. They learn about Blender software, specifically focusing on enhancing the robot's movements with anticipation as a key element. During this step, students gain a clear understanding of the challenge they face, which involves incorporating anticipation into the robot's movement when reenacting the story they have created (Understanding the Challenge, CT: Abstraction, Pattern Recognition).

As a challenge, students are asked to reenact their original story using the robot and its anticipation-based movements. They choose and construct a robot-hero based on its characteristics, generating ideas for their storytelling project. Students enhance their programming skills and apply anticipation techniques through hands-on practice and simulations. They break down their story, analyse it, and propose effective solutions to meet the challenge requirements (Generating Ideas, CT: Decomposition).

Afterwards, the students formulate the robot's behaviour and identify suitable materials and objects for constructing the story scene (Formulating the Solution, CT: Algorithmic Thinking, Decomposition).

Then, the students put their programmed instructions into action by applying them to the physical robot. Additionally, they prepare the scene using the selected materials, aligning them with the decisions they made earlier in the project (Creating the Solution, CT: Algorithmic Thinking).

Students apply their programmed instructions to the physical robot, making necessary adjustments along the way. They set up the scene using the chosen materials. Finally, they present their stories, showcasing the robot's movements, and engage in a guessing game with their classmates' stories. Through discussions and evaluations, they assess their work, make corrections if needed, and reflect on ways to improve the anticipation in their robot movements (Evaluating the Solution, CT: Evaluation).

By applying the Art of Anticipation in ER, students not only gain a deeper understanding of animation principles but also develop CT.

4.1.2 The design representation of “The Art of Anticipation” project

Table 2. Project Overview

Project Category:		Programming Robot to perform Art
Educational Level:		Upper Primary
Total Duration:		7 hours
Art form(s):	Category:	Visual
	Subcategory:	Animation
Learning Outcomes - Art:		speed, movement and pause as basic elements of anticipation
Learning Outcomes - ER:	Construction:	robot axis with one or two motors
	Programming:	direction and speed
Technical requirements for the robot:		
Technology Used:	Robotic Kit:	NEZHA Inventor’s kit for micro:bit
	Programming Environment:	Makecode for microbit
	Simulator:	Makecode for microbit
Construction Elements:	Actuators:	two motors and one servo
	Sensors:	no sensor
Minimum requirements for the expected behaviour of the robot:	one motor	
Material Needed:	various objects of 5-10 cm in size so that the robot can pick them up and move them	
Extension Ideas:		

Table 3. Breaking Down Step 1: Understanding the Challenge

STEP 1: "Understanding the Challenge" in the project "The Art of Anticipation"			
SCOPE: The students engage in storytelling activities with a robot as the central character. They are introduced to the Blender software for animation and learn techniques to enhance the realism of the robot's movements, with a focus on incorporating anticipation as a key element. Afterwards, as a challenge, they are asked to reenact the story they created using the robot and its anticipation-based movements.			
Activity 1-ART: Creating the robot-hero The teacher presents a scenario to the students involving a robot situated in a room containing different objects, such as a significant amount of rubbish. Then he/she asks the students to imagine and describe the robot in the story by answering to specific questions: who, what, when, where, and why. CT skills: Decomposition, Abstraction Activity Type: Engagement Modality: F2F Class orchestration: Teamwork Duration:20'	**Activity 2-ART: Creating the story** Each student group is tasked by the teacher to conceive and describe a situation in which their robot hero has been involved. They are encouraged to use their imagination and narrate the unique circumstances of their robot's story. CT skills: Abstraction Activity Type: Engagement Modality: F2F Class orchestration: Teamwork Duration: 20	**Activity 3-ART: Animation through the Blender software** Blender is a versatile 3D computer graphics software used for creating animated films, visual effects, interactive 3D applications, and more. The teacher familiarizes the students with the blender environment and demonstrates how animation can be utilized to narrate the story of a mobile robot. During the demonstration, the students engage in a discussion about enhancing the realism of the robot's movements, particularly through the implementation of the anticipation technique. The teacher incorporates the students' suggestions into the modelling of the robot's movements, highlighting the importance of incorporating variations in time, speed, and direction to achieve a more natural and lifelike portrayal of the robot's motion. CT skills: Pattern Recognition, Decomposition Activity Type: New Content Modality: F2F Class orchestration: Plenary Duration: 35'	**Activity 4-ER & Art : Presenting the challenging problem** The teacher asks the students to use all they have learned in the previous activities, to construct and program a robot, enabling it to embody the hero they have designed in their story and effectively portray its character. The emphasis is placed on ensuring that the hero moves with a sense of anticipation. CT skills: Abstraction, Decomposition, Pattern Recognition Activity Type: Challenging problem Modality: F2F Class orchestration: teamwork Duration: 15'

Table 4. Breaking Down Step 2: Generating Ideas

STEP 2: "Generating Ideas" in the project "The Art of Anticipation"				
SCOPE: The students choose and construct their robot-hero based on its characteristics.Through hands-on practice and simulation, they enhance their programming skills and apply anticipation in stop-motion animations. This enables them to analyze the story, decompose it into robot behavior, and propose effective solutions to meet the challenge requirements.				
Activity 5-ER: Choosing the robot and identifying the components Every group selects the construction for their robot-hero based on the capabilities and the character of the hero. Building upon the three anticipation techniques, students try to identify and articulate the mechanisms (motors) that may be required to bring each robot to life. CT skills: Decomposition, Abstraction Activity Type:Plan Modality: F2F Class orchestration: teamwork Duration: 15'	**Activity 6-ER: Exploring Actuators and Programming Motor Speed: Hands-on Practice** Through hands-on practice and experimentation, students learn about the concept of speed and how to program the motor. CT skills: Abstraction, Decomposition Activity Type: New Content Modality: F2F Class orchestration: teamwork Duration: 90	**Activity 7-ER: Exploring Actuators and Programming Motor Speed: Online Practice** Students engage in practical activities using simulators to enhance their programming skills specifically focused on controlling motors. CT skills: Abstraction, Decomposition Activity Type: Plan Modality: Online Class orchestration: plenary Duration:	**Activity 8-Art: Stopmotion ideas** The teacher introduces the students to the stop-motion environment, where they put the constructed robot to act according to their story, employing anticipation techniques. This approach allows them to precisely perceive the robot's subsequent movements and understand how to decompose the story into robot's behavior and movements in order to solve the challenge effectively. CT skills: Pattern Recognition Activity Type: Plan Modality: F2F Class orchestration: teamwork Duration: 30'	**Activity 9-ER: Unleashing Creativity through Stop Motion Activities.** Inspired by the activities with stop motion, students propose solutions to meet the requirements of the challenge. CT skills: Pattern Recognition Activity Type: Plan Modality: F2F Class orchestration: teamwork Duration: 30'

Table 5. Breaking Down Step 3: Formulating the solution

STEP 3: "Formulating the solution" in the project "The Art of Anticipation"	
SCOPE: The students describe the movements and instructions for their robot-hero, as well as any decoration plans. They then proceed to program the robot's behavior in a simulator. Additionally, they identify suitable materials and objects for constructing the story scene and provide clear instructions for the robot's actions within that environment.	
Activity 10-ER: Developing the algorithm for robot's movements The students provide a verbal description of a) the chosen movements that the robot will perform and the corresponding sequence of instructions in natural language, and b) the decoration plans for the robot (if applicable). After that they program the robot's behaviour in the simulator. CT skills: Algorithmic thinking, Decomposition Activity Type: Plan Modality: F2F Class orchestration: Teamwork Duration: 15	**Activity 11-ART: Selecting the material and formulating the instructions for the robot** The students describe which materials are suitable for constructing the scene of the story, identify objects that are of appropriate shape and size for the robot to interact with, and formulate clear instructions for the robot's actions. CT skills: Algorithmic thinking, Decomposition Activity Type: Plan Modality: Online Class orchestration: plenary Duration: 45'

Table 6. Breaking Down Step 4: Creating the solution

STEP 4: “Creating the solution” in the project “The Art of Anticipation”	
SCOPE: The students apply their programmed instructions to the physical robot, making necessary adjustments along the way. They also set up the scene using materials according to their previous decisions.	
Activity 12-ER: Programming the robots The students implement the program they have created and apply it to the robot, following the instructions they have formulated both verbally and through simulation and make various accommodations. CT skills: Algorithmic thinking Activity Type: Program Modality: F2F Class orchestration: teamwork Duration: 45’	**Activity 13-ER: Setting the scene** Students use various materials to set up the scene as they decided in a previous activity. CT skills: Algorithmic thinking Activity Type: Construct Modality: F2F Class orchestration: teamwork Duration: 15

Table 7. Breaking Down Step 5: Evaluating the solution

STEP 5: “Evaluating the solution” in the project “The Art of Anticipation”	
SCOPE: The students present their stories with the robot's movements and guess their classmates' stories. They discuss and evaluate their work, making corrections if needed.	
Activity 13-ER & Art: Presenting the final story Students present their final story with the robot's movements based on the anticipation, and in turn, try to guess their classmates' story according to the robot's behaviour. CT skills: Evaluation Activity Type: Evaluate Modality: F2F Class orchestration: plenary Duration: 20’	**Activity 14-ER-Art: Reflecting on the process** The students discuss on the process and evaluate their work and the work of others. Depending on the final result, they return to a previous phase to make appropriate corrections. CT skills: Evaluation Activity Type: Evaluation Modality: F2F Class orchestration: plenary Duration: 20’

4.1.3 The evaluation of “The Art of Anticipation” project’s Design Process

Table 8. Educators evaluation of “The Art of Anticipation” project’s design process through closed -ended questions (five-point Likert scale).

Question	ER Educator’s rate	Art Educator’s rate (1)	Art Educator’s rate (2)
FDM Steps			
I found the sequence of the steps helpful to design the project (usefulness of the sequence of steps)	5	5	4
I found the scope of every step helpful towards designing the project gradually (usefulness of the various steps)	5	5	4
FDM Activities			
Breaking down each step into individual activities was helpful for designing students' involvement in the project	5	5	5
The features describing each activity (Activity Type, Duration, Modality, Class Orchestration, CT skills, etc.) were helpful in promoting ideas generation on both disciplines (Arts, ER)	4	5	5
The features describing each activity (Activity Type, Duration, Modality, Class Orchestration, CT skills, etc) were helpful in representing and communicating ideas among the disciplines (Arts, ER)	5	5	4
FDM Key Components			
The FDM supported me to collaborate with the teacher - co-designer in order to set goals from both disciplines.	5	5	4
Designing together activities for cultivating particular CT skills promoted mutual understanding of the disciplines involved.	5	5	5
The FDM supported me to decide which activities will be better implemented f2f in the classroom or remotely from home (blended learning).	5	5	4
The FDM supported me in understanding how to cultivate CT skills through the project.	5	5	4

Table 9. Evaluation of "The Art of Anticipation" project's design process by ER and Art Educators through open-ended questions.

FDM Steps			
Question	*What difficulties did you face in a) following the steps' sequencing, b) understanding the scope of each step?*		
ER Educator's Answer:	There were no difficulties either on following the steps' sequencing or understanding the scope of each step		
Art Educator's Answer (1):	the form complexity	Art Educator's Answer (2):	the time to complete the schedule
Question	*How did you find useful designing the project by a) following the particular steps' sequencing, and b) designing activities for each step?*		
ER Educator's Answer:	This method has proven useful because it allows for a structured approach that incorporates both my subject and the animation course. By sequencing the steps and designing activities that align with the ER aspect of the project, I was able to stay focused and avoid engaging in unrelated activities of ER that do not contribute to the project's overall purpose.		
Art Educator's Answer (1):	very helpful	Art Educator's Answer (2):	(a) and (b)
FDM Activities			
Question	*What difficulties have you faced, regarding a) breaking down the steps into individual activities and b) the features describing each activity?*		
ER Educator's Answer:	Breaking down the steps into individual activities proved to be a complex task, as there were interdependencies and overlapping aspects between the steps, making it difficult to delineate clear boundaries for each activity. For instance, it was difficult to decide whether the task of building the robots should precede or follow the story planning process, which serves as the basis for students to define the movements and behavior of the robot hero. However, I realized that the methodology allows flexibility in making such decisions, as they can be adjusted based on the class level and the specific focus chosen by the teachers for the project.		
Art Educator's Answer (1):	the layout of the form	Art Educator's Answer (2):	taking more time
Question	*How did you find useful designing the project by a) breaking down the steps into individual activities and b) setting the features of each activity?*		
ER Educator's Answer:	a) Breaking down the steps into individual activities required careful analysis and thoughtful consideration, but by clearly defining and separating each activity, I was able to establish a well-organized and logical project plan. b) By thoroughly detailing the specific characteristics and attributes of each activity, I ensured a comprehensive understanding of the project requirements. This clarity facilitated greatly planning and implementing the steps, enabling me to effectively communicate and delegate responsibilities to team members involved in the project.		
Art Educator's Answer (1):	it was very helpful regarding the creation process of animation as the same steps are used for professional animation production	Art Educator's Answer (2):	it was very appealing to the students
FDM Overview			

Question	*Since the FDM aims to cultivate CT through the interdisciplinarity of Art and ER in a blended learning context, suggest changes/improvements in this direction.*
ER Educator's Answer:	It would be useful to establish connections between the activity types and computational thinking (CT) skills, while providing concrete examples of how each activity type can foster the development of CT skills.
Art Educator's Answer (1):	the FDM helped me to find the connection between animation creative process and computer thinking principles
Art Educator's Answer (2):	the FDM supported me in understanding the criteria of both robotics and art

4.1.4 The evaluation of "The Art of Anticipation" project's Implementation Process

Table 10. Evaluation of the implementation process of the Artful ER pilot project "The Art of Anticipation" by the ER and Art Educators through closed -ended questions (five-point Likert scale).

Question	ER Educator's rate	Art Educator's rate (1)
Evaluation of the Project's implementation in relation to its original design		
1. I implemented the FDM steps in the sequence they were originally designed	4	4
2. I implemented all the FDM steps without skipping any of those originally designed.	5	4
3. I found all the activities well integrated within each step.	4	3
4. The activities lasted as long as originally designed.	4	3
5. Splitting teaching hours between the disciplines was implemented as originally designed.	5	4
6. I collaborated effectively with the teacher - co-designer in applying every step.	4	4
7. The combination of ER and Arts activities was implemented as originally designed.	4	4
8. The combination of classroom (f2f) and remote activities was implemented as originally designed.	4	4
Evaluation of the Project's implementation according to the FDM instructions for each step		
9. In the "Understanding the challenge" step, the students managed to clarify the concepts required to understand the challenge they had to face.	5	5
10. In the "Generating ideas" step, the students suggested one or more ideas that potentially satisfied the conditions given in the challenge.	5	5
11. Regarding the ER discipline, in the "Formulating the solution" step, the students managed to formulate an algorithm for the robot behaviour (in natural language), considering the requirements of the challenge, before proceeding to program the robot at the next step "Creating the Solution".	4	5
12. Regarding the Art discipline, in the "Formulating the solution" step, the students managed to formulate the art part of the solution, considering the requirements of the challenge, before proceeding to its construction at the next step "Creating the Solution".	4	4

13. The students' final artefact created at the "Creating the solution" step met the challenge's requirements set at the "Understanding the challenge" step.	5	5
14. In the "Evaluating the solution" step, the students managed to evaluate the artefact's adequacy and its correspondence to the requirements of the challenge given in the "Understanding the challenge" step.	5	4

Table 11. Evaluation of "The Art of Anticipation" project's implementation process by the ER and Art Educators through open-ended questions.

Evaluation of the "The Art of Anticipation" Project's implementation	
Question	*What changes have you applied to the original Artful ER project designed during its implementation for the students to manage completing the project?*
ER Educator's Answer:	In response to the students' familiarity, the programming activities that were held online through the simulator, were modified to focus more on programming back-and-forth movements of the robots rather than emphasizing motor speed control. Additionally, the process of formulating the final solution, implementing it, and evaluating the results was conducted in cycles, repeating twice before achieving the desired outcome. As a result, this cyclic approach extended the project timeline beyond the initial expectations.
Art Educator's Answer (1):	The method of Animation was enriched with demonstration of 3D Animation Software
Question	*What would you change in the Arful ER project design after the implementation experience?*
ER Educator's Answer:	To effectively assess students' progress in developing CT skills within both Art and ER, it is essential to implement regular assessments and provide feedback. These assessments should encompass various formative evaluation methods, including peer evaluations and teacher assessments. However, due to the lack of common hours in the school program for ER and Art teachers, I suggest conducting these assessments online within a blended learning context. Through online feedback, we can ensure flexibility and accessibility for both teachers and students. This approach allows for evaluation of CT skills, considering the interdisciplinary nature of Art and ER. Moreover, it creates an opportunity to foster computational creativity which leads to the final step of the methodology, the evaluation step.
Art Educator's Answer (1):	I would try to make the forms that we have to complete more friendly to the user . As far as the content concerns I would put more common educational terms according to the up -to-date learning theories of student centred learning.

4.1.5 Insights and observations on the project "The Art of Anticipation"

The educators acknowledged the value of the design process despite its time-consuming and complex nature. They found it to be ultimately beneficial for effectively organizing the project. The division of steps into separate activities was seen as a useful approach. The art educators stated that the methodology supported their design process based on CT, while the robotics educator recommended integrating CT skills into the specific activities. Additionally, the educators proposed making adjustments in the project implementation to better cater to the students' level and emphasized the importance of ongoing support through informative assessment.

4.2 “RoboTerrorizing the playground” an Artful ER project by UniWA

4.2.1 The scope of the “RoboTerrorizing the playground” project

This project combines ER and Theatre, and is implemented with Lower Secondary students. More specifically, the Arts and Robotics teacher assign students to develop and subsequently present a 10-minute theatre play. During the project students conceptualise a play that robots may perform Arts, build, program and decorate robots and go on scene together with the robots re-enacting in the play scenes simultaneously.

Initially, students participate in various drama-pedagogy-based activities aimed at fostering trust and communication between them (Abstraction, Decomposition). Divided into groups, they choose some character robots that will inspire them to gradually write the play text of their performance. Concerning ER, they make the first attempts to identify and experiment with the mechanisms that their construction should involve and suggest possible sounds they will use (Abstraction, Decomposition).

In the next phase, students focus on expressing through their bodies the robots' movements as well as recording the possible views and feelings of each robot. At the same time, they propose ideas for the initial constructions and programming (Pattern Recognition). Through all these ideas and experimentation, the students come up with their final design regarding the robotic constructions as well as the final performance. They edit the scenes, build and program the robots and make decisions about the conditions of the performance (Algorithmic Thinking).

Finally, they go live on stage in a 10-minute performance titled "RoboTerrorizing the playground". The story is about a Bigfoot who invades a schoolyard during a break, destroys its basketball hoop and escapes. The Bigfoot's motives and enactment are presented in the play through students and robots acting as incident’s witnesses or objects, and Bigfoot’s former acquaintances. These testimonies reveal that he was bullied during his school years. The story concludes with Bigfoot’s arrest where he is interrogated about the incident but not revealing his motives. Finally, the audience gets to decide through a live poll whether to forgive or punish Bigfoot.

After the performance, the students evaluate the presentation, the way of collaboration, and finally their feelings about their experience (Evaluation).

4.2.2 The design representation of the "RoboTerrorizing the playground" project

Table 12. Project Overview

Project Category:		Program Robot to perform Art
Educational Level:		Lower Secondary
Total Duration:		12h
Art form(s):	Category:	PERFORMING ARTS
	Subcategory:	Theatre
Learning Outcomes - Art:		To familiarize students with the techniques of Theatre and Drama in Education and create a short performance.
Learning Outcomes - ER:	**Construction:**	Moving mechanisms, connecting sonar:bit
	Programming:	Sequences, selections, programming motors and sonar:bit
Technical requirements for the robot:		
Technology Used:	**Robotic Kit:**	Wonderbuilding kit with micro:bit
	Programming Environment:	makecode
	Simulator:	makecode
Construction Elements:	**Actuators:**	Motor, servo
	Sensors:	Sonar:bit
Minimum requirements for the expected behaviour of the robot:	The robots must be capable of moving (using one or two motors), play sounds and if necessary, avoid objects.	
Material Needed:	Wonderbuilding kit, micro:bit, simple materials for art and crafts, chairs, music	
Extension Ideas:	The project could be implemented in Upper Secondary but regarding ER the constructions could deal with more difficult mechanisms	

Table 13. Breaking Down Step 1: Understanding the Challenge

STEP 1: “Understanding the Challenge” in the project “RoboTerrorizing the playground”		
SCOPE: The students understand the challenge they have been given. In particular, they should be able to get to know the members of the group better, understand how to represent the robots through body expressions and become familiar with the robotic kit, the program environment, and the mechanisms that they are going to use for their constructions.		
Activity 1-ART- ER: Give the challenge to be accomplished Students are assigned to create a stage action (maximum duration of 10 minutes) through which they will find ways to interact with robots they have built and programmed themselves. CT skills: Abstraction Activity Type: Challenging problem Modality: F2F Class orchestration: Plenary/teamwork Duration:10	**Activity 2-ART: Introductory Exercises/Games** Students participate in plenary or individual group activities, which aim at getting to know the members of the group better, their physical activation, communication, cooperation, the development of trust, etc., through familiarisation exercises, movement in space, observation, improvisation, etc. (the facilitator can choose any exercise - game he/she wishes and believes that it can help to achieve the above objectives). CT skills: Decomposition, Pattern Recognition Activity Type: Engagement Modality: F2F Class orchestration: Plenary/teamwork Duration: 55’	**Activity 3-ART: Improvisations** Students are randomly divided into groups of 4-5 members. The members of the groups discuss among themselves how they use technology in their daily lives and distinguish which uses have positive effects on their lives and which negative ones. After the discussion they should prepare two non-verbal actions, each lasting a maximum of 2 minutes. The groups present their actions. When each group's action is completed, the facilitator asks the student-spectators what they think they saw, and at the end the group that presented their action talks about it. CT skills: Abstraction, Pattern Recognition Activity Type: Engagement Modality: F2F Class orchestration: Plenary/teamwork Duration: 35’
Activity 4-ER: Choosing the robot and identifying the components Each team chooses the robots they wish to build and creates a story with them. Based on the 4 choices they made, students try to identify and describe the mechanisms (motors, sensors) that might be needed to build each of them. CT skills: Abstraction, Decomposition, Pattern Recognition Activity Type: Challenging problem Modality: F2F Class orchestration: teamwork Duration: 15’	**Activity 5-ER: Explaining the components** The students identify in the robot kit the mechanisms of the previous activity and make predictions about their functionality on a given worksheet. CT skills: Abstraction Activity Type: New content Modality: F2F Class orchestration: teamwork Duration: 15’	**Activity 6-ER: Simulating a servo** The students experiment by writing the first lines of code for running a servo in the makecode simulator. CT skills: Decomposition Activity Type: Program Modality: Online, simulator Class orchestration: individual Duration: 15’

Table 14. Breaking Down Step 2: Generating ideas

<table>
<tr><td colspan="5">STEP 2: “Generating ideas” in the project “RoboTerrorizing the playground”</td></tr>
<tr><td colspan="5">SCOPE: The students familiarise themselves with the robots and through the techniques of Theatre and Drama in Education, create stories and content from which the final performance will be composed. They will also experiment and suggest ideas for the construction and programming parts.</td></tr>
<tr>
<td>Activity 7-ART: Improvisation & Talking Freeze
The students are divided into groups and each group, inspired by the 4 robots, has to create an improvised action. During the presentation of the actions, the facilitator "pauses" the action (of each group presenting) and asks questions to the students in rotation, focusing on specific characters in the story
<u>CT skills:</u> Abstraction
<u>Activity Type:</u> New content
<u>Modality:</u> F2F
<u>Class orchestration:</u> Plenary/teamwork
<u>Duration:</u> 35’</td>
<td colspan="2">Activity 8-ART: Writing monologues/dialogues
The students are divided into groups and each group, inspired by the 4 robots, has to create an improvised action. During the presentation of the actions, the facilitator "pauses" the action (of each group presenting) and asks questions to the students in rotation, focusing on specific characters in the story.
<u>CT skills:</u> Abstraction
<u>Activity Type:</u> New content
<u>Modality:</u> F2F
<u>Class orchestration:</u> Individual
<u>Duration:</u> 10’</td>
<td colspan="2">Activity 9-Art: Improvisation & Reflection
The students are divided into groups and create improvised actions focusing on each robot individually (based on the general story they created in the previous session). When each group completes the presentation of each action, there is a plenary discussion about what was presented.
<u>CT skills:</u> Abstraction
<u>Activity Type:</u> New content
<u>Modality:</u> F2F
<u>Class orchestration:</u> teamwork
<u>Duration:</u> 75’</td>
</tr>
<tr>
<td>Activity 10-Art: Role on the wall
The students, on measure papers, where the outlines of the 4 robots are drawn, write inside the outlines the thoughts and feelings that the robots themselves have (based on their position in the improvised actions and the monologues/dialogues they created), while outside the outlines, they write the thoughts and feelings that others involved in the stories they created have about them.
<u>CT skills</u>: Decomposition
<u>Activity Type:</u> New content
<u>Modality:</u> F2F
<u>Class orchestration:</u> teamwork
<u>Duration:</u> 75’</td>
<td>Activity 11-ER: Construction ideas
The students experiment and suggest possible ways of building the robot. They add the necessary extensions to the programming environment
<u>CT skills:</u> Pattern Recognition
<u>Activity Type:</u> Plan
<u>Modality:</u> F2F
<u>Class orchestration:</u> teamwork
<u>Duration:</u> 15’</td>
<td colspan="2">Activity 12-ER: Robots’ voices
The students experiment in makecode with activities involving audio inserting and creating sounds that may be needed for their constructions.
<u>CT skills:</u> Pattern Recognition
<u>Activity Type:</u> Program
<u>Modality:</u> F2F
<u>Class orchestration</u>: teamwork
<u>Duration:</u> 15</td>
<td>Activity 13-ER: Robots’ faces
The students create in the makecode with LEDs the "face" of their construction and possible emotions it may have
<u>CT skills:</u> Pattern Recognition
<u>Activity Type:</u> Program
<u>Modality:</u> Online, Simulator
<u>Class orchestration:</u> individual
<u>Duration:</u> 15’</td>
</tr>
</table>

Table 15. Breaking Down Step 4: Formulating the solution

<table>
<tr><td colspan="2">STEP 3: “Formulating the solution” in the project “RoboTerrorizing the playground”</td></tr>
<tr><td colspan="2">SCOPE: The students formulate and articulate the final solution clearly according to robots’ construction and programming and composition of the performance.</td></tr>
<tr>
<td>Activity 14-ER: Creating the algorithm for robot's movements
The students present in natural language a) how the robot will represent the movements they chose, the sequence of instructions (natural language) for the robots’ reactions, b) how the robot will be constructed and decorated (if needed). They also articulate and reflect upon the final behavior of the robot, considering factors such as speed, pauses, and direction of movement that they have selected.
<u>CT skills:</u> Decomposition, Algorithmic thinking
<u>Activity Type:</u> Plan / <u>Modality:</u> F2F
<u>Class orchestration:</u> Teamworkm / <u>Duration:</u> 20’</td>
<td>Activity 15-ART: Creation of the final performance
From the content offered by the students, through the activities they have taken part in and the improvised actions they have presented, the performance to be presented is composed.
CT skills: Algorithmic thinking
<u>Activity Type:</u> Construct
<u>Modality:</u> Online
<u>Class orchestration:</u> plenary / <u>Duration:</u> 45’</td>
</tr>
</table>

Table 16. Breaking Down Step 3: Creating the solution

STEP 4: "Creating the solution" in the project "RoboTerrorizing the playground"		
SCOPE: The students complete the construction of the performance (rehearsals) and the construction and programming of the robots. All the modifications take place in this phase.		
Activity 14-ER: Creating the algorithm for robot's movements The students present in natural language a) how the robot will represent the movements they chose, the sequence of instructions (natural language) for the robots' reactions, b) how the robot will be constructed and decorated (if needed). They also articulate and reflect upon the final behavior of the robot, considering factors such as speed, pauses, and direction of movement that they have selected. CT skills: Decomposition, Algorithmic thinking Activity Type: Plan Modality: F2F Class orchestration: Teamwork Duration: 20	**Activity 15-ART: Creation of the final performance** From the content offered by the students, through the activities they have taken part in and the improvised actions they have presented, the performance to be presented is composed. CT skills: Algorithmic thinking Activity Type: Construct Modality: Online Class orchestration: plenary Duration: 45	**Activity 16-ER: Look and fix** The students bring close the robots that will interact and make the necessary modifications to the construction and the program. CT skills: Evaluation, Algorithmic thinking Activity Type: Evaluate Modality: F2F Class orchestration: teamwork Duration: 20'
Activity 17-ART-ER: What happens in the end Students make decisions about which robots can stand live on scene and which is appropriate to be recorded in video CT skills: Evaluation Activity Type: Evaluate Modality: F2F Class orchestration: plenary Duration: 5	**Activity 18-ART-ER: Video editing** Students take pictures and short videos to create a new video. CT skills: Decomposition, Algorithmic Thinking Activity Type: Construct Modality: F2F Class orchestration: teamwork Duration: 40'	**Activity 19-ART: Role distribution** Each team member takes on a role. Since the final event consists of several group actions, some roles are played by a group of students. CT skills: Decomposition Activity Type: Construct Modality: F2F Class orchestration: individual Duration: 5'
Activity 20-ART: Rehearsals Division of the performance into scenes and rehearsals for each scene separately. The students studied their roles and experimented on how to perform them (in the roles represented by groups of students, the members of each group consulted and decided on how to perform them). CT skills: Abstraction, Decomposition Activity Type: Construct Modality: F2F Class orchestration: teamwork Duration: 175'	**Activity 20-ART: Rehearsals with the robots and their decoration** The students, having decided in which scenes the robots will appear "live" on stage and will interact with them, start rehearsals at the corresponding points and at the same time, adjust parameters such as: how they will enter the stage, what movement they will make, what sound etc.). Finally, they decorate the robots, according to the needs of the "role" they are going to play (e.g. ears on the dog, configuration of the car as a patrol car...) CT skills: Abstraction Activity Type: Construct Modality: F2F, Class orchestration:. Duration: 45'	**Activity 21-ART: What happens in the end** The students decide 2 different endings to the story, giving the audience the opportunity to vote and decide which ending they want, via QR Code. CT skills: Decomposition Activity Type: Construct Modality: Online Asynchronously Class orchestration: plenary Duration: 20'

Table 17. Breaking Down Step 5: Evaluating the solution

STEP 5: “Evaluating the solution” in the project “RoboTerrorizing the playground”	
SCOPE: The students present and evaluate their performance and robots’ performance.	
Activity 22-ER: The presentation The students present live on scene the 10 minute play CT skills: Evaluation Activity Type: Evaluate Modality: F2F Class orchestration: plenary Duration: 15	Activity 23-ER-ART: The review of the play The students discuss about the performance (specific criteria about their performance and robots’ functionalities) CT skills: Evaluation Activity Type: Evaluate Modality: F2F Class orchestration: plenary Duration: 25’

4.2.3 The evaluation of the "RoboTerrorizing the playground" project's Design Process

Table 18. Educators evaluation of "RoboTerrorizing the playground" project's design process through closed -ended questions (five-point Likert scale).

Question	ER Educator's rate	Art Educator's rate
FDM Steps		
I found the sequence of the steps helpful to design the project (usefulness of the sequence of steps	4	5
I found the scope of every step helpful towards designing the project gradually (usefulness of the various steps	4	5
FDM Activities		
Breaking down each step into individual activities was helpful for designing students' involvement in the project	4	5
The features describing each activity (Activity Type, Duration, Modality, Class Orchestration, CT skills, etc.) were helpful in promoting ideas generation on both disciplines (Arts, ER)	4	5
The features describing each activity (Activity Type, Duration, Modality, Class Orchestration, CT skills, etc) were helpful in representing and communicating ideas among the disciplines (Arts, ER)	4	5
FDM Key Components		
The FDM supported me to collaborate with the teacher - co-designer in order to set goals from both disciplines.	5	5
Designing together activities for cultivating particular CT skills promoted mutual understanding of the disciplines involved.	5	5
The FDM supported me to decide which activities will be better implemented f2f in the classroom or remotely from home (blended learning).	3	4
The FDM supported me in understanding how to cultivate CT skills through the project.	5	5

Table 19. Evaluation of the "RoboTerrorizing the playground" project's design process by ER and Art Educators through open-ended questions.

FDM Steps	
Question	*What difficulties did you face in a) following the steps' sequencing, b) understanding the scope of each step?*
ER Educator's Answer:	a) No particular difficulties. b1) Sometimes it was difficult to choose either the CT skill that was cultivated or the type of activity. (In many activities were more than one option)
Art Educator's Answer:	a) There was a slight difficulty in matching the activities to the skills of the CT. b) It was difficult to briefly describe each activity and define exactly what it aims at and what is produced by it. This weakness, I think, probably led to generalisations, which may not be very helpful (such as rehearsals, which take up 4 teaching hours and are described in 5 lines). At the same time, there were extra objectives for each activity, which could not be mentioned.
Question	*How did you find useful designing the project by a) following the particular steps' sequencing, and b) designing activities for each step?*
ER Educator's Answer:	a) I find that following the steps helped me to better organize the lesson and understand the way CT is cultivated through different types of activities. It is also a good way to identify the solution of a problem through the steps of FDM and go back to any step if necessary. b) Regarding the activities, it helped me to connect the cognitive objectives of the lesson in an easier way and to organise activities for some steps where students probably find it more difficult.
Art Educator's Answer:	a) It helped me to organise the activities and to understand the methodology. b) It helped me more in understanding the steps and distinguishing between activities involving theatre, robotics or a combination of both.
FDM Activities	
Question	*What difficulties have you faced, regarding a) breaking down the steps into individual activities and b) the features describing each activity?*
ER Educator's Answer:	a) No particular difficulties. b1) Sometimes it was difficult to choose either the CT skill that was cultivated or the type of activity. (In many activities were more than one option)
Art Educator's Answer:	a) There was a slight difficulty in matching the activities to the skills of the CT. b) It was difficult to briefly describe each activity and define exactly what it aims at and what is produced by it. This weakness, I think, probably led to generalisations, which may not be very helpful (such as rehearsals, which take up 4 teaching hours and are described in 5 lines). At the same time, there were extra objectives for each activity, which could not be mentioned.
Question	*How did you find useful designing the project by a) breaking down the steps into individual activities and b) setting the features of each activity?*
ER Educator's Answer:	a)Decomposing each step organises the activities in such a way that the implementation process will be easier. b) The categorisation of the activities. The types and the CT skill linked was very helpful
Art Educator's Answer:	a) It helped me to plan activities more relevant to the step they are going to take part in. b) It helped me to organise my activities, to notice which activity does not have the expected results or is not completed in the expected time and so on, depending on the response and participation of the students.

FDM Overview	
Question	*Since the FDM aims to cultivate CT through the interdisciplinarity of art and ER in a blended learning context, suggest changes/improvements in this direction.*
ER Educator's Answer:	I can't think of any...maybe just more types of activities.
Art Educator's Answer:	As far as the combination of theatre education and ER is concerned, I do not think that it is necessary for the design to aim at a final performance, as the whole process, through which various issues are explored and theatre and robotics are combined, is sufficient to achieve the expected goals. Besides, in our case, the final performance was an integral part of the preceding meetings, from which its content emerged. If the necessity to create a performance is removed as an issue, then more attention and more time can be given to the process, where the results can be better.

4.2.4 The evaluation of the "RoboTerrorizing the playground" project's Implementation Process

Table 20. Evaluation of the "RoboTerrorizing the playground" project's implementation process by ER and Art Educators through closed -ended questions (five-point Likert scale).

Question	ER Educator's rate	Art Educator's rate
Evaluation of the Project's implementation in relation to its original design		
1. I implemented the FDM steps in the sequence they were originally designed	4	4
2. I implemented all the FDM steps without skipping any of those originally designed.	5	5
3. I found all the activities well integrated within each step.	4	5
4. The activities lasted as long as originally designed.	4	4
5. Splitting teaching hours between the disciplines was implemented as originally designed.	4	5
6. I collaborated effectively with the teacher - co-designer in applying every step.	5	5
7. The combination of ER and Arts activities was implemented as originally designed.	5	5
8. The combination of classroom (f2f) and remote activities was implemented as originally designed.	4	5
Evaluation of the Project's implementation according to the FDM instructions for each step		
9. In the "Understanding the challenge" step, the students managed to clarify the concepts required to understand the challenge they had to face.	4	5
10. In the "Generating ideas" step, the students suggested one or more ideas that potentially satisfied the conditions given in the challenge.	5	5
11. Regarding the ER discipline, in the "Formulating the solution" step, the students managed to formulate an algorithm for the robot behaviour (in natural language), considering the requirements of the challenge, before proceeding to program the robot at the next step "Creating the Solution".	5	5

12. Regarding the Art discipline, in the "Formulating the solution" step, the students managed to formulate the art part of the solution, considering the requirements of the challenge, before proceeding to its construction at the next step "Creating the Solution".	5	5
13. The students' final artefact created at the "Creating the solution" step met the challenge's requirements set at the "Understanding the challenge" step.	5	5
14. In the "Evaluating the solution" step, the students managed to evaluate the artefact's adequacy and its correspondence to the requirements of the challenge given in the "Understanding the challenge" step.	4	5

Table 21. Evaluation of the "RoboTerrorizing the playground" project's implementation process by ER and Art Educators through open-ended questions.

Evaluation of the Project's implementation	
Question	*What changes have you applied to the original Artful ER project designed during its implementation for the students to manage completing the project?*
ER Educator's Answer:	The fact that the topic was quite based on the students' choices sometimes changed the application of the activity and the next steps had to be adjusted based on the changes.
Art Educator's Answer:	Sometimes I had to forward the performance text and provide solutions based on the views and ideas presented by the students, synthesizing them.
Question	*What would you change in the Arful ER project design after the implementation experience?*
ER Educator's Answer:	This project was very creative and the students were fully engaged. From the ER part, for the next implementation, I would suggest the students make different theatre performances but with the same basic robotic construction.
Art Educator's Answer:	I would change the teaching hours needed for the introductory activities from 2 to 1 so that there is an extra hour to be used in the basic process.

4.2.5 Insights and observations on the Project "RoboTerrorizing the playground"

As the teachers report, the project was implemented without major deviations from the initial planning and this is evident from the fact that during the implementation they did not skip any of the activities they had planned.

The initial design was mainly based on the students' original ideas and their implementation and this on the one hand, as planned, increased the degree of creativity of the students but at the same time led to modifications on the part of the teachers.

Although from different points of view, both of them mentioned that the fact that the presentation of the activity was done in front of an audience increased to some extent their difficulty and demands.

The teachers suggest appropriate activities to achieve their objectives and also add two minor modifications that teachers wishing to implement this scenario could take into account.

From the theatre education perspective, it is preferable that the 10-minute activity is not carried out in front of a large audience, while from the robotics perspective the groups could rely on the same construction.

4.3 “Languages of Children” an Artful ER project by URJC

4.3.1 The scope of the “Languages of Children” project

When thinking about art, one may think about paintings that we may find in a museum. However, painting can also be found in other types of scenarios, such as urban art. One variation of this type of art is known as pixel art which is a form of digital art in which images are created pixel by pixel. Through pixel art students can also practise the technical language that is used in this field. By using Microbit, the students can design their own art using pixels while they learn about the most relevant concepts involved in art. In this project, the students will use pixel art to represent emojis, learning to express emotions. Therefore, by combining robotics and arts through the FERTILE methodology (Understanding, Generating, Formulating the idea, Creating and Evaluating) students will be able to understand emotions through their representation with pixel art in a Microbit board.

This project is focused on the design of emojis that will be shown in the Microbit board. To do so, the teacher will start by shadow playing with emojis in the projector. Meanwhile, songs will be played, allowing the students to identify the emotions present in the song through the creation of emojis. Afterwards the students were given emojis of different sizes representing different emotions so they can also associate the emotions that the emoji is representing.

In the second phase, the students will choose the emoji they want to put in the projector, swapping the activity afterwards to a more analogical device such as tables and bottles, where students will need to create the emojis by using leds, which will act as pixels.

Before starting to work with robotics, the teacher will teach the students the basic vocabulary of the robotic kit they will use. Concepts such as board, led, matrix, button, batteries or cables are studied so the students familiarise with them.

Once the students learn the robotic concepts they will use the Microbit simulator to create emojis. Then they will program the created emojis in a physical Microbit. After finishing their designs, the evaluation process will take place. The students will discuss the emotion that represents the emojis each student has designed, assessing each student’s success in successfully portraying the given emotion.

4.3.2 The design representation of the “Language of the children” project

Table 22. Project overview

Project Category:		Program robot to perform art
Educational Level:		Childhood education (0-3)
Total Duration:		5h 10 min
Art form(s):	Category:	Visual
	Subcategory:	Painting
Learning Outcomes - Art:		
Learning Outcomes - ER:	Construction:	-
	Programming:	Being able to represent digital images through code
Technical requirements for the robot:		
Technology Used:	Robotic Kit:	Microbit
	Programming Environment:	Other
	Simulator:	Makecode for Microbit
Construction Elements:	Actuators:	-
	Sensors:	-
Minimum requirements for the expected behaviour of the robot:	The Microbit board must be able to represent an emotion through an emoji that other students should be able to identify.	
Material Needed:	Microbit, overhead projector, light table, materials to design the physical emojis.	
Extension Ideas:	The project has been developed and tested in a public nursery school with 40 children (0-3 years olds). It can be extended to higher education levels by using more complex robotics kits and changing the type of pixel art the students need to design.	

Table 23. Breaking Down Step 1: Understanding the Challenge

STEP 1: "Understanding the Challenge" in the project "Language of the children"		
SCOPE: The students understand the challenge they have been given. In particular, they should be able to get to know the members of the group better, understand how sounds work and how they can be implemented with robotic kits.		
Activity 1- ART: Shadow play with emojis The teacher plays songs using an overhead project to shadow play with emojis. Students try to identify the emotion the emoji represents. CT skills: Abstraction Activity Type: Engagement Modality: F2F Class orchestration: Plenary Duration: 15'	**Activity 2-ART: Physical emojis** The teacher gives the students different sized emojis which represent different emotions. The students put the emojis in their faces and other students need to identify those emotions. CT skills: N/A Activity Type: Engagement Modality: F2F Class orchestration: Plenary Duration: 15	**Activity 3-ART: Definition of the problem (Emojis and pixel art)** The students explore and participate in defining the problem they have to face: a)how are they going to represent emojis,, b) What emotion the emoji is going to represent. CT skills: Decomposition Activity Type: Challenging problem Modality: F2F Class orchestration: Plenary Duration: 15'

Table 24. Breaking Down Step 2: Generating ideas

STEP 2: "Generating ideas" in the project "Language of the children"		
SCOPE: The students familiarise themselves with the robotic software they will use in order to fabricate the playground and code the robot.		
Activity 5-ART: Choosing the emoji The students will decide what emoji they are going to display in the overhead projector. They will paint the emoji in acetate paper in order to be able to put it in the projector. CT skills: Abstraction Activity Type: Construct Modality: Online asynchronously Class orchestration: Individual Duration: 15'	**Activity 6-ART: Emojis in a light table** The students will design the chosen emoji in a light table. They can use the pre-design emojis, but in this step they can also start thinking about their own emojis CT skills: N/A Activity Type: New content Modality: Online asynchronously Class orchestration: Plenary Duration: 15'	**Activity 7-ART: Mirrors, light bottles and lanterns** The students will use leds, mirrors, light bottles and torches to represent the emojis. CT skills: Abstraction Activity Type: Plan Modality: F2F Class orchestration: Plenary Duration: 15'

Table 25. Breaking Down Step 3: Formulating the solution

STEP 3: "Formulating the solution" in the project "Language of the children"	
SCOPE: The students will formulate the solution to the proposed problem.	
Activity 9-ART: Creating emojis with school pegs The students will synthesize the ideas proposed in the previous step and they will construct the playground for the robots in order to face each step of the problem: a) the dimensions, shape and borders of the playground,, b) the main parts and materials they will need and, c) the music for the robot to play CT skills: Decomposition / Activity Type: Plan Modality: F2F / Class orchestration: Teamwork Duration: 20'	**Activity 10-ER: Robotic vocabulary** The students will be taught the basic robotic vocabulary so they understand the tools they are going to use in the next step to design their own emoji in a Microbit board. CT skills: N/A Activity Type: New content Modality: F2F / Class orchestration: Plenary Duration: 30

Table 26. Breaking Down Step 4: Creating the solution

STEP 4: "Creating thesolution" in the project "Language of the children"	
SCOPE: The students will construct and code the robot based on the ideas formulated in the previous step.	
Activity 12-ART-ER: Emojis in the simulator The students will design their emojis using the Microbit Simulator CT skills: Pattern recognition Activity Type: Program Modality: Online-Asynchronous Class orchestration: Individual Duration: 45'	**Activity 13-ART-ER: Emojis in the Microbit board** The students will design the emojis in a physical Microbit board. CT skills: Pattern recognition Activity Type: Program Modality: F2F Class orchestration: Teamwork Duration: 45'

Table 27. Breaking Down Step 5: Evaluating the idea

STEP 5: "Evaluating the solution" in the project "Language of the children"	
SCOPE: The students will observe the realised artefact and the programmed robot and evaluate their correspondence to the conditions of the problems and their adequacy in general	
Activity 16-ER: Evaluation of the robot The students will discuss in groups on the evaluation criteria of the robotic constructing, its code and the final design. They will present and compare their approaches taking into account the issues they had to face. CT skills: Evaluation Activity Type: Evaluate Modality: F2F Class orchestration: Teamwork Duration: 40'	**Activity 17-ART: Evaluation of the playground** The students discuss the evaluation criteria for the playground construction and the music score. CT skills: Evaluation Activity Type: Evaluate Modality: F2F Class orchestration: Teamwork Duration: 40'

4.3.3 The evaluation of the "Languages of the children" project's Design Process

Since educators in Spain usually have a mixed set of abilities and they teach in different areas of expertise, especially in Primary and Childhood education, the evaluation was carried out by the Art teacher, who is also involved in ER in her school.

Table 28. Evaluation of the "Languages of the Children" project's design process by the ER/Art Educator by the ER and Art Educators through closed -ended questions (five-point Likert scale).

Question	ER / Art Educator's rate
FDM Steps	
I found the sequence of the steps helpful to design the project (usefulness of the sequence of steps)	4
I found the scope of every step helpful towards designing the project gradually (usefulness of the various steps)	4
FDM Activities	
Breaking down each step into individual activities was helpful for designing students' involvement in the project	5
The features describing each activity (Activity Type, Duration, Modality, Class Orchestration, CT skills, etc.) were helpful in promoting ideas generation on both disciplines (Arts, ER)	5
The features describing each activity (Activity Type, Duration, Modality, Class Orchestration, CT skills, etc) were helpful in representing and communicating ideas among the disciplines (Arts, ER)	5
FDM Key Components	
The FDM supported me to collaborate with the teacher - co-designer in order to set goals from both disciplines.	5
Designing together activities for cultivating particular CT skills promoted mutual understanding of the disciplines involved.	5
The FDM supported me to decide which activities will be better implemented f2f in the classroom or remotely from home (blended learning).	1
The FDM supported me in understanding how to cultivate CT skills through the project.	5

Table 29. Evaluation of "Languages of the Children" project's design process by the ER/Art Educator through open-ended questions.

FDM Steps	
Question	*What difficulties did you face in a) following the steps' sequencing, b) understanding the scope of each step?*
ER/Art Educator's Answer:	For this level more time is needed to be able to better implement the methodology. More and better activities could have been done if there had been more time. It has been a challenge to do it in such a short time.
Question	*How did you find useful designing the project by a) following the particular steps' sequencing, and b) designing activities for each step?*
ER/Art Educator's Answer:	A teacher from level 1-2 who was not going to carry out the project participates in the meeting of step 1 (Understanding the challenge) and proposes it in her level meeting and it is carried out in classroom 1-2 (years). Participates in the design of the activities for this step, considering that the children are capable of doing it (self-fulfilment prophecy). The project is a joint project between all the teachers, all of them have designed the activities and have been supported. The previous reflections favoured by the methodology have given support to the teachers. The support of the university in undertaking the project has been useful. The climate of respect prior to the design to propose ideas and activities is fundamental to generate the activities. There is no brake on error.
FDM Activities	
Question	*What difficulties have you faced, regarding a) breaking down the steps into individual activities and b) the features describing each activity?*
ER/Art Educator's Answer:	For co-design it is important that there is time for team coordination and a good climate of involvement of the teachers participating in the project.
Question	*How did you find useful designing the project by a) breaking down the steps into individual activities and b) setting the features of each activity?*
ER/Art Educator's Answer:	It is fundamental to be able to design successful activities. Collective participation is important. The breakdown gives assurance to the more novice teachers. It has also been useful to improve the activities by doing it previously with other groups. Learning from execution to improve. Level 2-3. As the first activities went well, the teachers' confidence improved as time went by. From activity to activity and within the activity. As the design was well thought out, the execution of the project was successful and the teachers, in spite of the technical and other difficulties in the execution, felt comfortable and were able to solve the situations.
FDM Overview	
Question	Since the FDM aims to cultivate CT through the interdisciplinarity of art and ER in a blended learning context, suggest changes/improvements in this direction.
ER/Art Educator's Answer:	Multidisciplinary teams are fundamental. In addition, the support of the university (also multidisciplinary) is considered to have been a key interdisciplinary factor. The methodology has given us guidance for the sequencing of activities and an approach that

	we would have originally done differently. It is important for the design to be able to collect previous data on the realities and previous experiences of the children.

4.3.4 The evaluation of the "Language of the Children " project's Implementation Process

Table 30. Evaluation of the "Languages of the Children" project's implementation process by the ER/Art Educator through closed -ended questions (five-point Likert scale).

Question	ER/Art Educator's rate
Evaluation of the Project's implementation in relation to its original design.	
1. I implemented the FDM steps in the sequence they were originally designed	5
2. I implemented all the FDM steps without skipping any of those originally designed.	4
3. I found all the activities well integrated within each step.	5
4. The activities lasted as long as originally designed.	3
5. Splitting teaching hours between the disciplines was implemented as originally designed.	5
6. I collaborated effectively with the teacher - co-designer in applying every step.	5
7. The combination of ER and Arts activities was implemented as originally designed.	5
8. The combination of classroom (f2f) and remote activities was implemented as originally designed.	1
Evaluation of the Project's implementation according to the FDM instructions for each step	
9. In the "Understanding the challenge" step, the students managed to clarify the concepts required to understand the challenge they had to face.	5
10. In the "Generating ideas" step, the students suggested one or more ideas that potentially satisfied the conditions given in the challenge.	5
11. Regarding the ER discipline, in the "Formulating the solution" step, the students managed to formulate an algorithm for the robot behaviour (in natural language), considering the requirements of the challenge, before proceeding to program the robot at the next step "Creating the Solution".	5
12. Regarding the Art discipline, in the "Formulating the solution" step, the students managed to formulate the art part of the solution, considering the requirements of the challenge, before proceeding to its construction at the next step "Creating the Solution".	5
13. The students' final artefact created at the "Creating the solution" step met the challenge's requirements set at the "Understanding the challenge" step.	5
14. In the "Evaluating the solution" step, the students managed to evaluate the artefact's adequacy and its correspondence to the requirements of the challenge given in the "Understanding the challenge" step.	5

Table 31. Evaluation of the “Languages of the Children” project’s implementation process by the ER/Art Educator through open-ended questions.

Evaluation of the Project's implementation	
Question	*What changes have you applied to the original Artful ER project designed during its implementation for the students to manage completing the project?*
ER/Art Educator’s Answer:	None
Question	*What would you change in the Arful ER project design after the implementation experience?*
ER/Art Educator’s Answer:	More time. Materials and budget: operational wifi, better tablets and budget to implement. Minimal practical training of teachers in technology. Training that is fun and like that of children. The robotics courses that are planned are a drag. In order to do it well, it is essential to have fun. Bigger materials for small children. It is very complicated to manipulate so small. It's good to see the "guts" of electronics.

4.3.5 Insights and observations on the project “Language of the Children”

The completion form (Excel spreadsheet format) proves to be less intuitive for early childhood educators (in fact, we needed to transfer the information to a Word document for them). Given this, they have opted for conducting numerous short activities centered around the project, encompassing various aspects such as emotional development, language skills, and fostering autonomy. By doing so, they strive to create a holistic learning experience that addresses the multifaceted needs of young learners.

Understanding the unique requirements of early childhood education, the decision to move away from the Excel table format to a Word document reflects a thoughtful approach. The educators recognize that young children thrive in an environment that promotes exploration, hands-on experiences, and meaningful interactions. These activities, carefully designed to engage multiple dimensions of development, foster emotional intelligence, language acquisition, and the nurturing of autonomy. Through this approach, educators aim to provide a rich and comprehensive educational experience that supports the growth and development of each child in their care. By valuing flexibility and adaptability, they can tailor activities to meet the specific needs and interests of their young students, ensuring a more engaging and effective learning process.

4.4 "Project smartwatch" an Artful ER project by URJC

4.4.1 The scope of the "Project smartwatch"

When thinking about robotics, it is usual to imagine artefacts of considerable size that emulate some form of human activity. However, robotics also include small artefacts with specific functionality that need to be designed thoroughly in order to be usable by humans in our daily life. In this scenario, wearables such as smartwatches have become handy in many situations and their popularity is increasing as their prices go down with the years. A smartwatch is an electronic device that is placed in the wrist that has more computational functionalities than a conventional watch. Thanks to having a processor and a small motherboard, many sensors, such as an accelerometer, gyroscope or compass, with many different goals can be attached to it.

In the area of ER, constructing a smartwatch not only teaches how to incorporate sensors and functionalities that need to be coded, but the design of the smartwatch is also an important factor that needs to be taken into account. Therefore, by creating a small artefact and integrating the FERTILE methodology phases (Understanding, Generating, Formulation, Creating, Evaluating), students will be able to explore and understand both robotics concepts, through adding and coding sensors; and art concepts, through the design of the smartwatch.

To initiate the process, the teacher shows the students different types of smartwatches in combination with the different sensors and functionalities they include. Not all the smartwatches have the same functionalities, let alone the same design. Students will use this first approach to look at the different available possibilities, using the teacher examples as inspiration.

Then, students will think about what functionalities and sensors they want to include in their smartwatch. In addition, the teacher will explain the usage of the MakeCode block environment so the students have a first idea about how they will code the alarms and functions for their smartwatch.

Afterwards, the students will plan how they are going to build the watch band, thinking about whether they want to print 3D pieces for it or not and the design of those pieces. Then, they will plan the structure of their code, thinking about the triggers that will call the coded functions once they wear the smartwatch.

In the next step, the students will use the Micro:bit board simulator in order to test the functionalities they programmed in the previous step. Once they are sure that everything works appropriately, they will build the smartwatch and incorporate the code into it. Then, the students will evaluate their smartwatch, and through discussions and evaluations they will assess the aesthetics and comfort of the watch band design and if their code works.

4.4.2 The design representation of the "Project smartwatch"

Table 32. Overview of the Exemplar Artful ER Project

Project Category:		Design a smartwatch through robotics
Educational Level:		Secondary education
Total Duration:		7h 50min
Art form(s):	Category:	Visual
	Subcategory:	Arts and crafts
Learning Outcomes - Art:		Design of a comfortable wristband for the smartwatch
Learning Outcomes - ER:	Construction:	Design of a smartwatch
	Programming:	Clock with event detection
Technical requirements for the robot:		
Technology Used:	Robotic Kit:	Microbit
	Programming Environment:	Other
	Simulator:	Makecode for Microbit
Construction Elements:	Actuators:	-
	Sensors:	-
Minimum requirements for the expected behaviour of the robot:	The smartwatch must be comfortable enough to be worn. The clock needs to provide at least basic functionality such as the time and the detection of events.	
Material Needed:	Microbit, 3D printer (optional), materials to draw (flowcharts)	
Extension Ideas:	This project was carried out by 25 students from secondary education (12-16 years old). It can be extended to higher education by incorporating complex sensors to provide extra functionality to the smartwatch.	

Table 33. Breaking Down Step 1: Understanding the Challenge

STEP 1: "Understanding the Challenge" in the project "Project smartwatch"		
SCOPE: The students. understand the challenge they have been given. In particular, they should be able to get to know the members of the group better, understand how smartwatches work and how they are designed. In this phase, students will get a first idea about what they will need to construct.		
Activity 1- ART-ER: Give the challenge to be accomplished Students have to research smartwatches. They need to discover the different functionalities they provide. CT skills: Abstraction Activity Type: Engagement Modality: F2F Class orchestration: Plenary/teamwork Duration:15'	**Activity 2-ER: Introduction to sensors.** Once the students get to know the functionalities that a smartwatch can provide, the next step is to research how those functionalities work at a basic level. They research about each individual sensor that may be involved in each functionality, how the data is sent and how the data is processed. CT skills: Decomposition, Pattern Recognition Activity Type: Pattern recognition Modality: F2F Class orchestration: Plenary/teamwork Duration: 15'	**Activity 3-ART: Design of a smartwatch** Smartwatches are usually small and they have designs that allow people to wear them on their wrists as if they were regular watches. Designs may be different, but they always try to have an attractive design. In this activity, the students need to research how smartwatches are designed. CT skills: Abstraction, Pattern Recognition Activity Type: Engagement Modality: F2F Class orchestration: Plenary/teamwork Duration: 15'

Table 34. Breaking Down Step 2: Generating ideas

STEP 2: "Generating ideas" in the project "Project smartwatch"		
SCOPE: The students familiarise themselves with the robotic software they will use in order to fabricate and code their smartwatch.		
Activity 4-ER: Software decisions Each student will think about the functionalities their own smartwatch will have. Therefore, each student will make a list with the programmes their smartwatch will include CT skills: Abstraction Activity Type: Plan Modality: F2F Class orchestration: Individual Duration: 20'	**Activity 5-ER: Flowchart** Each student will create a flowchart of the programme, thinking about how to create the alarms and functions that will run in their smartwatch. CT skills: Algorithmic thinking Activity Type: Plan Modality: F2F Class orchestration: Individual Duration: 110'	**Activity 6-ER: Understanding functions** The teacher will explain how functions work. Both teachers and students will start coding examples of software and functions in the MakeCode block environment for Micro:bit CT skills: Abstraction Activity Type: New content Modality: F2F Class orchestration: teamwork Duration: 15'

Table 35. Breaking Down Step 3: Formulating the solution

STEP 3: "Formulating the solution" in the project "Project smartwatch"	
SCOPE: The students formulate and articulate the final solution clearly according to smartwatch construction and programming and composition of its functionalities	
Activity 7-ART: Smartwatch materials The students will plan how they are going to build the smartwatch. They will think about whether they want to make it with the 3D printer or not. Therefore, they will think about the materials they will use to build their smartwatch. CT skills: Algorithmic thinking Activity Type: Plan Modality: F2F Class orchestration: Teamwork Duration: 20'	**Activity 8-ER: How to code the functionalities** The students will plan how they are going to code the functionalities that will be integrated into their smartwatches. Moreover, they will need to code when those functionalities are going to be triggered, according to alarms and according to the sensors they integrated in their smartwatches. CT skills: Algorithmic thinking Activity Type: Plan Modality: F2F Class orchestration: teamwork Duration: 55'

Table 36. Breaking Down Step 4: Creating the solution

STEP 4: "Creating the solution" in the project "Project smartwatch"		
SCOPE: The students complete the construction of the smartwatch, integrating the functionalities they planned in the previous steps.		
Activity 9-ART: Construct the smartwatch The students build the wristband of the smartwatch according to what they decided in the previous step. CT skills: N/A Activity Type: Construct Modality: F2F Class orchestration: teamwork Duration: 55'	**Activity 10-ER: Program the clock** The students program the clock using the Micro:bit board simulator CT skills: Algorithmic thinking Activity Type: Program Modality: Online Asynchronously Class orchestration: individual Duration: 55'	**Activity 11-ER: Integrating the software** The students transfer the program they coded online to a physical Micro:bit board. CT skills: Algorithmic thinking Activity Type: Program Modality: F2F Class orchestration: teamwork Duration: 55'

Table 37. Breaking Down Step 5: Evaluating the solution

STEP 5: "Evaluating the solution" in the project "Project smartwatch"	
SCOPE: The students present and evaluate their performance and robots' performance.	
Activity 12-ER: Evaluating the clock The students present their clocks in order to check if they work correctly CT skills: Evaluation Activity Type: Evaluate Modality: F2F Class orchestration: plenary Duration: 20'	Activity 13-ER-ART: Evaluating the design The students evaluate the aesthetics and comfort of the design of their clock CT skills: Evaluation Activity Type: Evaluate Modality: F2F Class orchestration: plenary Duration: 20'

4.4.3 The evaluation of the "Project smartwatch" Design process

Since educators in Spain usually have a mixed set of abilities and they teach in different areas of expertise, especially in Primary and Childhood education, the evaluation was carried out by the Art teacher, who is also involved in ER in her school.

Table 38. Evaluation of the "Project smartwatches" project's design process by the ER/Art Educator through through closed -ended questions (five-point Likert scale).

Question	Art Educator's rate
FDM Steps	
I found the sequence of the steps helpful to design the project (usefulness of the sequence of steps)	4
I found the scope of every step helpful towards designing the project gradually (usefulness of the various steps)	5
FDM Activities	
Breaking down each step into individual activities was helpful for designing students' involvement in the project.	5
The features describing each activity (Activity Type, Duration, Modality, Class Orchestration, CT skills, etc.) were helpful in promoting ideas generation on both disciplines (Arts, ER)	4
The features describing each activity (Activity Type, Duration, Modality, Class Orchestration, CT skills, etc) were helpful in representing and communicating ideas among the disciplines (Arts, ER)	4
FDM Key Components	
The FDM supported me to collaborate with the teacher - co-designer in order to set goals from both disciplines.	4
Designing together activities for cultivating particular CT skills promoted mutual understanding of the disciplines involved.	4
The FDM supported me to decide which activities will be better implemented f2f in the classroom or remotely from home (blended learning).	4
The FDM supported me in understanding how to cultivate CT skills through the project.	4

Table 39. Evaluation of the "Project smartwatches" project's design process by the ER/Art Educator through open-ended questions.

FDM Steps	
Question	*What difficulties did you face in a) following the steps' sequencing, b) understanding the scope of each step?*
ER/Art Educator's Answer:	I have not encountered any difficulties. The steps have been very gradual and I have made the pupils see how the project was progressing little by little.
Question	*How did you find useful designing the project by a) following the particular steps' sequencing, and b) designing activities for each step?*
ER/Art Educator's Answer:	Yes
FDM Activities	
Question	*What difficulties have you faced, regarding a) breaking down the steps into individual activities and b) the features describing each activity?*
ER/Art Educator's Answer:	None
Question	*How did you find useful designing the project by a) breaking down the steps into individual activities and b) setting the features of each activity?*
ER/Art Educator's Answer:	Very useful. Everything was much clearer and a progression could be seen.
FDM Overview	
Question	*Since the FDM aims to cultivate CT through the interdisciplinarity of art and ER in a blended learning context, suggest changes/improvements in this direction.*
ER/Art Educator's Answer:	I can not think of any improvements

4.4.4 The evaluation of the "Project smartwatch" Implementation process

Table 40. Evaluation of "Project smartwatches" project's implementation process by the ER/Art Educator through through closed -ended questions (five-point Likert scale).

Question	Educator's rate
Evaluation of the Project's implementation in relation to its original design.	
1. I implemented the FDM steps in the sequence they were originally designed	5
2. I implemented all the FDM steps without skipping any of those originally designed.	5
3. I found all the activities well integrated within each step.	4
4. The activities lasted as long as originally designed.	3
5. Splitting teaching hours between the disciplines was implemented as originally designed.	5
6. I collaborated effectively with the teacher - co-designer in applying every step.	5
7. The combination of ER and Arts activities was implemented as originally designed.	5
8. The combination of classroom (f2f) and remote activities was implemented as originally designed.	5
Evaluation of the Project's implementation according to the FDM instructions for each step	
9. In the "Understanding the challenge" step, the students managed to clarify the concepts required to understand the challenge they had to face.	4
10. In the "Generating ideas" step, the students suggested one or more ideas that potentially satisfied the conditions given in the challenge.	4
11. Regarding the ER discipline, in the "Formulating the solution" step, the students managed to formulate an algorithm for the robot behaviour (in natural language), considering the requirements of the challenge, before proceeding to program the robot at the next step "Creating the Solution".	4
12. Regarding the Art discipline, in the "Formulating the solution" step, the students managed to formulate the art part of the solution, considering the requirements of the challenge, before proceeding to its construction at the next step "Creating the Solution".	3
13. The students' final artefact created at the "Creating the solution" step met the challenge's requirements set at the "Understanding the challenge" step.	4
14. In the "Evaluating the solution" step, the students managed to evaluate the artefact's adequacy and its correspondence to the requirements of the challenge given in the "Understanding the challenge" step.	4

Table 41. Evaluation of the "Project smartwatches" implementation process by the ER/Art Educator through open-ended questions.

Evaluation of the Pilot Artful ER Project's implementation	
Question	*What changes have you applied to the original Artful ER project designed during its implementation for the students to manage completing the project?*
ER/Art Educator's Answer:	I have not applied changes to the original design.
Question	*What would you change in the Arful ER project design after the implementation experience?*

ER/Art Educator's Answer:	The steps they have followed have been very clear and coherent. It has helped them to know where they were at each moment and they have gone step by step in the process. I would only change the step from thinking about the design of the watch to stage 1.

4.4.5 Insights and observations on the "Project smartwatch"

The methodology has been followed with all the steps and designed activities, ensuring a structured and comprehensive approach to the learning process. Each stage of the plan has been meticulously addressed, from introducing fundamental concepts to the practical application of acquired knowledge. Teachers have deployed their expertise and pedagogical skills to guide students throughout this educational journey, fostering their active engagement and motivation.

As a result, the students have been highly involved in various aspects of the project. They have demonstrated a high level of commitment, showing interest and enthusiasm in every proposed activity. Their active participation has contributed to a dynamic and enriching learning environment, where they have been able to interact with each other, exchanging ideas and engaging in debates about the topics discussed. This involvement has generated a greater sense of ownership and responsibility towards their own learning process, thereby promoting more meaningful and long-lasting learning. In summary, the applied methodology has proven effective in comprehensively involving students, enhancing their learning and academic development.

The whole process seems centered on the teachers but it would be interesting to establish a structured feedback mechanism where students can express their opinions and suggestions regarding the learning process. Therefore, teachers would be able to act on this feedback to continuously improve the learning environment based on their needs.

4.5 "One-stroke-drawing" an Artful ER project by CUP

4.5.1 The Scope of the "One-stroke Drawing" project

The project "One-stroke Drawing" is aimed at training drawing in art education in combination with the creation of a relevant algorithm. In the context of linking ER and art education, students are guided to create a robotic vehicle that is equipped with a drawing tool and can draw a shape according to a suitably designed algorithm. Pupils work with the Lego Spike kit and common drawing tools. From the point of view of ER, the project aims mainly at developing skills in the field of construction and algorithmization. The project is aimed at pupils of the 2nd grade of primary school, rather for higher grades (13 - 15 years old pupils).

At the beginning, the teacher introduces the pupils to one-stroke drawing, discussing the broader contexts in art and engineering disciplines. The aim here is to induce thinking about the practical application of one stroke drawing and the transfer of this to everyday practice. They will also explore together the different types of patterns, both lighter and more complex, that are typical of one-stroke drawing.

Then the pupils first create patterns and drawings using the one-stroke drawing method, considering two ways of drawing at once. Pupils will first create the patterns by hand without the use of technical equipment. They will then create the crepe using the Lego Spike robotic set. In both cases, pupils will need to plan their activity appropriately, i.e. to create a suitable workflow plan (algorithm) leading to the achievement of the set goal.

In the next stage, pupils will then compare the workflows, on several levels: hand drawing vs. drawing with robotic equipment, chosen hand drawing vs. other hand drawing method, chosen drawing method with robotic equipment vs. other robotic methods. On the basis of these comparisons, students should come to a generalisation and then, in the context of sharing their conclusions together, also evaluate and select the optimal solution.

In the last stage, evaluation and further generalisation should occur, leading to the selection of the optimal procedure for creating drawings, sketches and diagrams.

4.5.2 The design representation of the "One-stroke Drawing" project

Table 42. Project Overview

Project Category:		Program robot to perform Art
Educational Level:		Lower Secondary education
Total Duration:		3 lessons (3 x 45min)
Art form(s):	Category:	Visual
	Subcategory:	Painting
Learning Outcomes - Art:		
Learning Outcomes - ER:	Construction:	Construction of vehicle with drawing tool
	Programming:	Creating an algorithm for vehicle movement with a drawing tool
Technical requirements for the robot:		
Technology Used:	Robotic Kit:	*Lego Spike*
	Programming Environment:	Lego Spike App
	Simulator:	
Construction Elements:	Actuators:	motors, wheels
	Sensors:	touch or optical (proximity) sensor
Minimum requirements for the expected behaviour of the robot:	mobility (engine, wheels); modifiability (possibility of own design, construction and modification, including drawing tool attachment)	
Material Needed:	drawing tools (pencil, pen, etc.)	
Extension Ideas:	the possibility of connecting / activating sensors (e.g. optical, tactile or ultrasonic to detect the edges of the work surface or obstacles)	

Table 43. Breaking Down Step 1: Understanding the Challenge

STEP 1: "Understanding the Challenge" in the project "One-stroke Drawing"
SCOPE:
Activity 1- ART-ER: Motivation Pupils are briefly introduced to the topic of drawing with one stroke (creating figures with one stroke). They are asked if you know any examples of creating shapes in one stroke. The issue is included in a wider context CT skills: N/A Activity Type: Engagement Modality: F2F Class orchestration: Plenary Duration: 5

Table 44. Breaking Down Step 2: Generating ideas

STEP 2: "Generating ideas" in the project "One-stroke Drawing"		
SCOPE:		
Activity 2-ART-ER: Task Pupils are given the task of creating a picture in one stroke - it is a classic basic model picture of a house. Pupils have to create this figure by hand in an analog way and also with the use of robotic sets. For both sub-problems, they will have to design a correct solution procedure including a balance sheet, a solution plan and an algorithm. CT skills: N/A Activity Type: Challenging problem Modality: F2F Class orchestration: Plenary Duration: 10'	**Activity 3-ART: Solving Art - part 1** Pupils in groups look for the optimal procedure for solving the task (ART area). CT skills: Abstraction Activity Type: Plan Modality: F2F Class orchestration: Teamwork Duration: 10'	**Activity 4-ER: Solving ER - part 1** Pupils in groups look for the optimal procedure for solving the given task (ER area), using the results from the ART part. CT skills: Abstraction Activity Type: Plan Modality: F2F Class orchestration: Teamwork Duration: 10'

Table 45. Breaking Down Step 3: Formulating the solution

STEP 3: "Formulating the solution" in the project "One-stroke Drawing"	
SCOPE:	
Activity 5-ART: Solving ART - part 2 Pupils solve the assigned task (ART area) - partial stage of searching for the correct solution strategy CT skills: Decomposition Activity Type: Program Modality: F2F Class orchestration: Teamwork Duration: 5'	**Activity 6-ER: Solving ER - part 2** Pupils solve the assigned task (ER area) - partial stage of searching for the correct solution strategy CT skills: Decomposition Activity Type: Program Modality: F2F Class orchestration: Teamwork Duration: 5

Table 46. Breaking Down Step 3: Creating the solution

STEP 4: "Creating the solution" in the project "One-stroke Drawing"	
SCOPE:	
Activity 7-ART: Solving ART - part 3 Pupils solve the assigned task (ART area) - partial stage - drawing a figure CT skills: Algorithmic thinking Activity Type: Program Modality: F2F Class orchestration: Teamwork Duration: 5'	**Activity 8-ER: Solving ER - part 3** Pupils construct a robotic vehicle incl. grip on the drawing tool. They verify functionality, fix bugs, etc. CT skills: N/A Activity Type: Construct Modality: F2F Class orchestration: Teamwork Duration: 20'
Activity 9-ER: Solving ER - part 4 Pupils solve the assigned task (ER area) - partial stage - compile an algorithm, program a robotic vehicle, verify and debug the program. CT skills: Algorithmic thinking Activity Type: Program Modality: F2F Class orchestration: Teamwork Duration: 20'	**Activity 10-ER: Solving ER - part 5** Pupils solve the assigned task (ER area) - partial stage - drawing a figure, possibly if necessary, modification and tuning of the program, modification of the structure. CT skills: N/A Activity Type: Program Modality: F2F Class orchestration: Teamwork Duration: 15'

Table 47. Breaking Down Step 5: Evaluating the solution

STEP 5: "Evaluating the solution" in the project "One-stroke Drawing"		
SCOPE: The students evaluate their solutions based on mutual sharing. They first focus on ART and ER components separately, then compare their solutions comprehensively and evaluate their procedures.		
Activity 11-ART: Sharing, presentation, evaluation Pupils present, share and evaluate the results of the work and the solution procedure(s). CT skills: Evaluation Activity Type: Evaluate Modality: F2F Class orchestration: Plenary Duration: 10'	**Activity 12-ER: Sharing, presentation, evaluation** Pupils present, share and evaluate the results of the work and the solution procedure(s). CT skills: Evaluation Activity Type: Evaluate Modality: F2F Class orchestration: Plenary Duration: 10'	**Activity 13-ART-ER: Final evaluation** Overall evaluation of the solution based on the presented outputs and partial evaluations for both areas (ART and ER) CT skills: Evaluation Activity Type: Evaluate Modality: F2F Class orchestration: Plenary Duration: 10'

4.5.3 The evaluation of the "One-stroke Drawing" project's Design Process

Table 48. Evaluation of "One-Stroke Drawing" project's design process by the ER and the Art Educator through closed -ended questions (five-point Likert scale).

Question	ER Educator's rate	Art Educator's rate
FDM Steps		
I found the sequence of the steps helpful to design the project (usefulness of the sequence of steps)	4	4
I found the scope of every step helpful towards designing the project gradually (usefulness of the various steps)	3	4
FDM Activities		
Breaking down each step into individual activities was helpful for designing students' involvement in the project	3	4
The features describing each activity (Activity Type, Duration, Modality, Class Orchestration, CT skills, etc.) were helpful in promoting ideas generation on both disciplines (Arts, ER)	5	5
The features describing each activity (Activity Type, Duration, Modality, Class Orchestration, CT skills, etc) were helpful in representing and communicating ideas among the disciplines (Arts, ER)	5	5
FDM Key Components		
The FDM supported me to collaborate with the teacher - co-designer in order to set goals from both disciplines.	4	4
Designing together activities for cultivating particular CT skills promoted mutual understanding of the disciplines involved.	5	4
The FDM supported me to decide which activities will be better implemented f2f in the classroom or remotely from home (blended learning).	3	3
The FDM supported me in understanding how to cultivate CT skills through the project.	5	5

Table 49. Evaluation of the "One-Stroke Drawing" project's design process by the ER and the Art Educator through open -ended questions.

FDM Steps	
Question	*What difficulties did you face in a) following the steps' sequencing, b) understanding the scope of each step?*
ER Educator's Answer:	a) the prepared table for creating a project activity scenario was very useful and helpful for planning the steps, b) the very characteristics and description of the individual steps (the project sheet) seemed quite confusing and rather complicated the planning (from the point of view of activity planning, the chronological structure of successive steps is much more useful , as they follow each other)
Art Educator's Answer:	a) the sequence of individual steps helped me a lot, but the very characteristics of those individual steps were sometimes unclear and incomprehensible b) it was the content and scope of the individual steps that were confusing
Question	*How did you find useful designing the project by a) following the particular steps' sequencing, and b) designing activities for each step?*
ER Educator's Answer:	For both a) and b): The description on the "main steps" sheet was useful, understandable and beneficial. It enabled the subsequent creation of an activity scenario.
Art Educator's Answer:	a) the methodology was definitely beneficial, manageable and helpful, the same applies to question b
FDM Activities	
Question	*What difficulties have you faced, regarding a) breaking down the steps into individual activities and b) the features describing each activity?*
ER Educator's Answer:	Transfer of starting points / instructions / contents between descriptive non-chronological capture and chronological scenario of the project.
Art Educator's Answer:	I did not notice any major difficulties when transforming the main steps or during individual activities.
Question	*How did you find useful designing the project by a) breaking down the steps into individual activities and b) setting the features of each activity?*
ER Educator's Answer:	The preset choices in the activity description table were very useful and beneficial. I would appreciate the possibility to add my own text directly in the sheet of the table.
Art Educator's Answer:	Designing options was good, I had something to follow so that the overall result of the work was successful.
FDM Overview	
Question	*Since the FDM aims to cultivate CT through the interdisciplinarity of art and ER in a blended learning context, suggest changes/improvements in this direction.*

ER Educator's Answer:	-	Art Educator's Answer:	-

4.5.4 The evaluation of the “One-stroke Drawing” project’s Implementation process

Table 50. Evaluation of the “One-Stroke Drawing” project’s implementation proxess by the ER and the Art Educator through closed questions (five-point Likert scale).

Question	ER Educator’s rate	Art Educator’s rate
Evaluation of the Project's implementation in relation to its original design.		
1. I implemented the FDM steps in the sequence they were originally designed	5	5
2. I implemented all the FDM steps without skipping any of those originally designed.	4	4
3. I found all the activities well integrated within each step.	2	2
4. The activities lasted as long as originally designed.	2	2
5. Splitting teaching hours between the disciplines was implemented as originally designed.	4	4
6. I collaborated effectively with the teacher - co-designer in applying every step.	5	5
7. The combination of ER and Arts activities was implemented as originally designed.	3	3
8. The combination of classroom (f2f) and remote activities was implemented as originally designed.	3	3
Evaluation of the Project's implementation according to the FDM instructions for each step		
9. In the "Understanding the challenge" step, the students managed to clarify the concepts required to understand the challenge they had to face.	5	5
10. In the "Generating ideas" step, the students suggested one or more ideas that potentially satisfied the conditions given in the challenge.	5	5
11. Regarding the ER discipline, in the "Formulating the solution" step, the students managed to formulate an algorithm for the robot behaviour (in natural language), considering the requirements of the challenge, before proceeding to program the robot at the next step "Creating the Solution".	4	4
12. Regarding the Art discipline, in the "Formulating the solution" step, the students managed to formulate the art part of the solution, considering the requirements of the challenge, before proceeding to its construction at the next step "Creating the Solution".	4	4
13. The students' final artefact created at the "Creating the solution" step met the challenge's requirements set at the "Understanding the challenge" step.	4	4
14. In the "Evaluating the solution" step, the students managed to evaluate the artefact's adequacy and its correspondence to the requirements of the challenge given in the "Understanding the challenge" step.	5	5

Table 51. Evaluation of the "One-Stroke Drawing" project's implementation process by the ER and Art Educator through open-ended questions.

Evaluation of the Project's implementation	
Question	*What changes have you applied to the original Artful ER project designed during its implementation for the students to manage completing the project?*
ER Educator's Answer:	Shortening and actually almost omitting the use of LEGO sets by pupils during the implementation of the project (only an exemplary teacher's model was used), shortening the project and using (slightly in "substitute" mode) OzoBot sets instead of LEGO sets.
Art Educator's Answer:	We missed one step regarding the use of LEGO sets by students in the implementation of the project. This shortened it.
Question	*What would you change in the Arful ER project design after the implementation experience?*
ER Educator's Answer:	Greater time allowance for the entire project as well as partial steps, spread over several teaching units.
Art Educator's Answer:	After experience with the project, I would dedicate more time to it, so that there would be more time for the entire project, as well as for the individual steps.

4.5.5 Insights and observations on the project "One-stroke Drawing"

Although the concept of project design through the main steps of the methodology helped the teachers to be more aware of some important aspects related to the connection of ER and ART, they rather welcome the chronological ordering of activities and their assignment to individual steps/phases. Within this project, teachers avoided blended-learning activities. The reason was mainly the small time allowance for the given project, including within the implementation.

As part of designing individual activities, they generally perceived the pre-preparedness of the offers as beneficial, however, in some cases they lacked the possibility to replace the choice with their own text.

As part of the implementation itself, for organizational reasons, the intended Lego Spike kits were replaced by Ozobot robots. The reason was a smaller time allowance, so there was a reduction in activities mainly in the area of construction. However, even this change showed that the activities, or the whole project can be implemented meaningfully, more or less with the original goals even in such a reduced form.

4.6 "Folk Songs" an Artful ER project by CUP

4.6.1 The scope of the "Folk Songs" project

The project Folk Songs targets 4th grade students and combines knowledge from music education with skills from creating an algorithm. The main focus is on notes and working with them, awareness of repetition, repeats, in folk songs.

Pupils first worked on a specific song to review the notes, their length and naming, and optionally could use a piano with named keys to discover the types of notes. They could also use colour codes to do this. They then had the task of figuring out a simplification of the song in question, specifically "Sheepdogs, Squares", which they knew intimately. They could simplify it using colour codes.

In the next step, they had to teach the song to the Codey Rockey robot and they had to compare the original notation and their simplified notation and write them both down. At the same time they compared the simplified notations with each other. The moment the notation met the teacher's criteria, the students worked as a group to figure out the next song and had to figure out the simplest way to write the notation in the notation chart and then in the mBlock program. The output was a song played by the robot with the algorithm efficiently created according to the notation modification.

4.6.2 The design representation of the "Folk Songs" project

Table 52. Project overview

Project Category:		Robot performing music
Educational Level:		primary
Total Duration:		5 lessons
Art form(s):	Category:	performing
	Subcategory:	music
Learning Outcomes - Art:		
Learning Outcomes - ER:	Construction:	no construction
	Programming:	block programming
Technical requirements for the robot:		
Technology Used:	Robotic Kit:	Codey Rockey
	Programming Environment:	mBlock
	Simulator:	mBlock
Construction Elements:	Actuators:	nothing necessary
	Sensors:	sound sensor
Minimum requirements for the expected behaviour of the robot:	to play sounds, especially notes and melodies	
Material Needed:	paper, stationery, prepared melodies (in this case, Czech folk songs)	
Extension Ideas:	the ability of the robot to move to the given melody; the opportunity to work with specific artists and reproduce their works	

Table 53. Breaking Down Step 1: Understanding the Challenge

STEP 1: "Understanding the Challenge" in the project "Folk songs"		
SCOPE: The students understand the theme Folk songs, discuss about features of folk songs and discover, that the robot is able to play as well melody as piano or violin.		
Activity 1-ART: Folk songs discussion about the place of folk songs in our country CT skills: N/A Activity Type: engagement Modality: F2F Class orchestration: Plenary Duration: 10	**Activity 2-ART: Song books** looking for the folk songs in song books. CT skills: Decomposition, abstraction Activity Type: engagement Modality: online asynchronously Class orchestration: teamwork Duration: 25	**Activity 3-ART: Authors of folk songs** talking about authors of folk songs CT skills: N/A Activity Type: engagement Modality: F2F Class orchestration: Plenary Duration: 10
Activity 4-ART: Music instruments who can sing the melody and how CT skills: abstraction Activity Type: engagement Modality: F2F Class orchestration: Plenary Duration: 10	**Activity 5-ER: Robot and melody** how to do a specific melody with Codey Rockey CT skills: algorithmic thinking Activity Type: new content Modality: F2F Class orchestration: individual Duration: 30	

Table 54. Breaking Down Step 2: Generating ideas

STEP 2: "Generating ideas" in the project "Folk songs"		
SCOPE: The students think about musical notation and better program entry		
Activity 6-ART: Musical notation how to make easier the notation CT skills: decomposition Activity Type: challenging problem Modality: F2F Class orchestration: Teamwork Duration: 10’	**Activity 7-ER: Program entry** how to make easier the program entry CT skills: algorithmic thinking Activity Type: Plan Modality: Online Synchronously Class orchestration: Teamwork Duration: 10’	**Activity 8-ER-ART: Possibilities of solutions** discussion about solutions CT skills: evaluation Activity Type: evaluate Modality: F2F Class orchestration: plenary Duration: 15’

Table 55. Breaking Down Step 3: Formulating the solution

STEP 3: "Formulating the solution" in the project "Folk songs"		
SCOPE: The students find the song to edit, transform to easy way for note transcription and effective algorithm		
Activity 9-ART: find a song looking for the folk song to transform CT skills: Generalisation Pattern Activity Type: Plan Modality: Online Synchronously Class orchestration: Teamwork Duration: 10’	**Activity 10-ART: Musical notation** transform the musical notation (look for repetition, rests) CT skills: Decomposition, Algorithmic Thinking Activity Type: Challenging problem Modality: F2F Class orchestration: Teamwork Duration: 10’	**Activity 11-ER: preparation of effective program transformation** find the loops, prepare the effective program entry CT skills: generalisation pattern Activity Type: plan Modality: Online Synchronously Class orchestration: Teamwork Duration: 15’

Table 56. Breaking Down Step 4: Creating the solution

STEP 4: "Creating the solution" in the project "Folk songs"	
SCOPE: The students program the robot and test the melody of folk songs	
Activity 12-ER: testing the program preparing the solution with mBlock, testing with robot CT skills: Algorithmic Thinking Activity Type: Construct Modality: F2F Class orchestration: Plenary Duration: 20'	**Activity 13-ER-ART: testing the melody** Polishing the robot so that the result fits into the whole CT skills: evaluate, algorithm thinking Activity Type: evaluation Modality: F2F Class orchestration: Teamwork Duration: 15'

Table 57. Breaking Down Step 5: Evaluating the solution

STEP 5: "Evaluating the solution" in the project "Folk songs"		
SCOPE: The students present and evaluate their performance and evaluate each performance		
Activity 14-ER: The presentation The students present live the folk song CT skills: Evaluation Activity Type: Evaluate Modality: F2F Class orchestration: plenary Duration: 5 minutes for each group	**Activity 15-ART: Evaluation of melody** Self-assessment (points) CT skills: Evaluation Activity Type: Evaluate Modality: F2F Class orchestration: Individual Duration: 10'	**Activity 16-ER-ART: Feedback** Feedback on the whole activity. Perception of the connection between robotics and art. CT skills: Evaluation Activity Type: Evaluate Modality: F2F Class orchestration: Plenary Duration: 15'

4.6.3 The evaluation of the “Folk Songs” project’s Design process

Table 58. Evaluation of the “Folk Songs” project’s design process by the ER and the Art Educator through closed questions (five-point Likert scale).

Question	ER Educators’ rate	Art Educator’s rate
FDM Steps		
I found the sequence of the steps helpful to design the project (usefulness of the sequence of steps)	5	3
I found the scope of every step helpful towards designing the project gradually (usefulness of the various steps)	4	2
FDM Activities		
Breaking down each step into individual activities was helpful for designing students' involvement in the project	3	4
The features describing each activity (Activity Type, Duration, Modality, Class Orchestration, CT skills, etc.) were helpful in promoting ideas generation on both disciplines (Arts, ER)	4	4
The features describing each activity (Activity Type, Duration, Modality, Class Orchestration, CT skills, etc) were helpful in representing and communicating ideas among the disciplines (Arts, ER)	3	4
FDM Key Components		
The FDM supported me to collaborate with the teacher - co-designer in order to set goals from both disciplines.	5	5
Designing together activities for cultivating particular CT skills promoted mutual understanding of the disciplines involved.	2	5
The FDM supported me to decide which activities will be better implemented f2f in the classroom or remotely from home (blended learning).	3	5
The FDM supported me in understanding how to cultivate CT skills through the project.	3	3

Table 59. Evaluation of the design process of the Artful ER pilot project: "..." by the ER and by the Art Educator through open questions.

FDM Steps	
Question	*What difficulties did you face in a) following the steps' sequencing, b) understanding the scope of each step?*
ER Educator's Answer:	mainly to understand the general point of this procedure, it seems to me to be a bit lengthy
Art Educator's Answer:	A succession of steps that seemed to me too dissected, too detailed for the first degree; in the end, my colleague and I had quite a fight with it, Petra (the tutor) helped us with it, but if I were to do it myself, I wouldn't have gone through with it.
Question	*How did you find useful designing the project by a) following the particular steps' sequencing, and b) designing activities for each step?*
ER Educator's Answer:	Probably because of a change in thinking about music and certainly because of the connection with informatics. I probably wouldn't choose such a detailed procedure next time, something else probably suits me better. But I liked the structure.
Art Educator's Answer:	I realized what I should pay attention to and what I should specifically develop, but I don't think that I always want to complete or complete all the steps.
FDM Activities	
Question	*What difficulties have you faced, regarding a) breaking down the steps into individual activities and b) the features describing each activity?*
ER Educator's Answer:	b) Maybe a logical infographic would help me more than a table. a. it took me a long time to get my bearings, and above all, I really wouldn't have done it without help.
Art Educator's Answer:	a) I had to do my own procedure first and only then think about it in this proposal b) I can't think of anything, maybe my colleague and I were in a different mood and we had to explain it to each other
Question	*How did you find useful designing the project by a) breaking down the steps into individual activities and b) setting the features of each activity?*
ER Educator's Answer:	a) really a lot, this kind of logical thinking, when everything has to logically follow each other, goes against my beliefs about creativity in music b) too long and at the end I got quite lost, we had to print out the steps separately on paper.
Art Educator's Answer:	Actually, probably the fact that we could talk about it together and clarify everything, because I'm not used to such a broad concept of teaching.
FDM Overview	
Question	*Since the FDM aims to cultivate CT through the interdisciplinarity of art and ER in a blended learning context, suggest changes/improvements in this direction.*
ER Educator's Answer:	somehow shorten it, or at least give a reasonable manual, like a video
Art Educator's Answer:	I didn't really like multiple sheets in Excel, I would like to see everything under me and together, it seemed to me that it should be separate and yet together.

4.6.4 The evaluation of the "Folk Songs" project's Implementation Process

Table 60. Evaluation of the "Folk Songs" project's implementation by the ER and by the Art Educator through closed questions (five-point Likert scale).

Question	ER Educator's rate	Art Educator's rate
Evaluation of the Project's implementation in relation to its original design.		
1. I implemented the FDM steps in the sequence they were originally designed	5	2
2. I implemented all the FDM steps without skipping any of those originally designed.	4	2
3. I found all the activities well integrated within each step.	4	3
4. The activities lasted as long as originally designed.	4	4
5. Splitting teaching hours between the disciplines was implemented as originally designed.	5	4
6. I collaborated effectively with the teacher - co-designer in applying every step.	5	5
7. The combination of ER and Arts activities was implemented as originally designed.	4	5
8. The combination of classroom (f2f) and remote activities was implemented as originally designed.	4	3
Evaluation of the Project's implementation according to the FDM instructions for each step		
9. In the "Understanding the challenge" step, the students managed to clarify the concepts required to understand the challenge they had to face.	2	4
10. In the "Generating ideas" step, the students suggested one or more ideas that potentially satisfied the conditions given in the challenge.	4	4
11. Regarding the ER discipline, in the "Formulating the solution" step, the students managed to formulate an algorithm for the robot behaviour (in natural language), considering the requirements of the challenge, before proceeding to program the robot at the next step "Creating the Solution".	5	3
12. Regarding the Art discipline, in the "Formulating the solution" step, the students managed to formulate the art part of the solution, considering the requirements of the challenge, before proceeding to its construction at the next step "Creating the Solution".	4	5
13. The students' final artefact created at the "Creating the solution" step met the challenge's requirements set at the "Understanding the challenge" step.	5	5
14. In the "Evaluating the solution" step, the students managed to evaluate the artefact's adequacy and its correspondence to the requirements of the challenge given in the "Understanding the challenge" step.	5	5

Table 61. Evaluation of the "Folk Songs" project's Implementation process by the ER and Art Educator through open questions.

Evaluation of the Pilot Artful ER Project's implementation	
Question	*What changes have you applied to the original Artful ER project designed during its implementation for the students to manage completing the project?*
ER Educator's Answer:	well, I didn't know fourths had such problems with the notes, we had to change it a bit in that first stage, but then it pretty much worked until the end.
Art Educator's Answer:	I would probably need to be able to give the activity in a regular class as well, not only in the computer room, but I know it would be possible, I would devote more time to the sheet music, because we had to change our plans a little and finish one more part there
Question	*What would you change in the Arful ER project design after the implementation experience?*
ER Educator's Answer:	I would probably find out more about what children discuss in music. In this particular class, it was quite a problem, but somehow we solved it verbally and we put children in each group who knew the notes to sort of balance it out. So, thanks to a change of groups at the beginning, we finally managed to make it to the end. But now I know that it would be much better if Petra or Marie (like some kind of IT/Teacher of Informatics) were there all the time, if something happens to us, she can solve it and we can solve the teaching and nothing is delayed.
Art Educator's Answer:	I would probably leave it as it is, I would just think more about the connection of robots and music with movement, folk songs made my head spin, so maybe a little more distance from the individual lessons

4.6.5 Insights and observations on the project "Folk Songs"

The educators were more aware of the connection between robotics and music education and were generally very enthusiastic about the project, as were the pupils. On the other hand, the reflection also revealed that the methodology is divided into several sheets and it is possible to get lost in this non-linear solution.

The educators liked the cooperation between themselves (a teacher from the primary and a teacher from the lower secondary), however, they would appreciate more involvement of technical assistance from the IT metodic. During the oral reflection with the teachers, it was also heard that at first they were bothered by the loud noise in the classroom, but when they saw that this noise was productive and the students were working on the project, they became detached from it. What bothered them the most was the time they didn't have enough to perform the next song, as the students would have liked. The whole activity would also be best F2F, but they admit that some parts can also be done online, but with larger students.
It should be noted that, in general, teachers can use any robot that can play notes and create melodies.

4.7 “Charlie and the Chocolate Factory” an Artful ER project by CUB

4.7.1 The scope of “Charlie and the Chocolate Factory” project

In films, but also in theatre performances, various requisites are increasingly used to make the performance more attractive. Props also include various modern, technical devices that need to be controlled or programmed. This was the inspiration for a project that was carried out in an after-school club with pupils from several grades of lower secondary school. The pupils attended a drama club and in addition to their teacher, a teacher from the robotics club was also involved in the project.

Project combined theatre performance and robotics. The theme of the drama performance was the story of Charlie and the Chocolate Factory, featuring the little goblins "Oompa Loompas".

At the beginning, the students had to identify what roles the robots would play and when they would perform. (Generating, CT skill: Decomposition). They were supposed to suggest how they would adapt the robots and the scenario so that the robots could be programmed. (Understanding, Formulating)

In parallel, students rehearsed their roles in drama classes and programmed the robots' behaviours in robotics classes, modifying and improving them (Algorithmic Thinking). They had two types of robots. There were multiple robots performing simultaneously in the sketch, so they also tried to apply parallel performance, in which they had to determine a behaviour where the least inaccuracies would be visible (Pattern recognition). Finally, they tested the correct timing so that the performance would be smooth.

The outcome of the whole project was a final performance, presented to parents and friends, in which both students and robots had their roles. Afterward, the students evaluated the performance and the project with each other and the teachers. (Evaluation).

4.7.2 The design representation of the “Charlie and the Chocolate Factory” project

Table 62. Project Overview

Project Category:		Program Robot to perform Art
Educational Level:		Lower Secondary
Total Duration:		12h
Art form(s):	Category:	PERFORMING ARTS
	Subcategory:	Theatre
Learning Outcomes - Art:		To familiarize students with the techniques of Theatre and Drama in Education and create a short performance.
Learning Outcomes - ER:	Construction:	Moving mechanisms, connecting sonar:bit
	Programming:	Sequences, selections, programming motors and sonar:bit
Technical requirements for the robot:		
Technology Used:	Robotic Kit:	Wonderbuilding kit with micro:bit
	Programming Environment:	makecode
	Simulator:	makecode
Construction Elements:	Actuators:	Motor, servo
	Sensors:	Sonar:bit
Minimum requirements for the expected behaviour of the robot:	The robots must be capable of moving (using one or two motors), play sounds and if necessary, avoid objects.	
Material Needed:	Wonderbuilding kit, micro:bit, simple materials for art and crafts, chairs, music	
Extension Ideas:	The project could be implemented in Upper Secondary but regarding ER the constructions could deal with more difficult mechanisms	

Table 63. Breaking Down Step 1: Understanding the Challenge

STEP 1: "Understanding the Challenge" in the project "Charlie and the Chocolate Factory"		
SCOPE: The students understand the challenge they have been given. In particular, they should be able to get to know the members of the group better, understand how to represent the robots through body expressions and become familiar with the robotic kit, the program environment, and the mechanisms that they are going to use for their constructions.		
Activity 1-ART: Getting acquainted with the story Script reading, performance preparation CT skills: N/A Activity Type: New content Modality: F2F Class orchestration: Plenary Duration: long term	**Activity 2-ART: Assignment of roles to actors** Dividing the story into parts, dividing roles of actors. CT skills: Decomposition Activity Type: Plan Modality: F2F Class orchestration: Plenary Duration: long term	**Activity 3-ER-ART: Role of robots** Choosing a suitable scene to engage robots CT skills: Abstraction Activity Type: Plan Modality: F2F Class orchestration: Plenary Duration: 30'

Table 64. Breaking Down Step 2: Generating ideas

STEP 2: "Generating ideas" in the project "Charlie and the Chocolate Factory"	
SCOPE: The students familiarise themselves with the robots and through the techniques of Theatre and Drama in Education, create stories and content from which the final performance will be composed. They will also experiment and suggest ideas for the construction and programming parts.	
Activity 4-ER: Familiarising with robots Getting to know the robots following the worksheet. CT skills: Abstraction Activity Type: Engagement Modality: F2F Class orchestration: Teamwork Duration: 30'	**Activity 5-ER-ART: Suggesting robot behaviour** Thinking about what robots can do and how they can be incorporated into a scenario, testing whether a robot has the needed function, whether it is possible to find such a command. CT skills: Abstraction Activity Type: Plan Modality: F2F Class orchestration: Plenary Duration: 15'

Table 65. Breaking Down Step 3: Formulating the solution

STEP 3: "Formulating the solution" in the project "Charlie and the Chocolate Factory"		
SCOPE: The students formulate and articulate the final solution clearly according to robots' construction and programming and composition of the performance.		
Activity 6-ER-ART: Distribution of work with robots Dividing up the work, which robot has what to do, how to behave in the scene CT skills: Decomposition Activity Type: Plan Modality: F2F Class orchestration: Plenary Duration: 20'	**Activity 7-ER: Programming robots' behaviour** Programming robots CT skills: Algorithmic thinking Activity Type: Program Modality: F2F Class orchestration: Teamwork Duration: 30'	**Activity 8-ER-ART: Testing by parts** Testing and rehearsing with the scenario CT skills: N/A Activity Type: Challenging Problem Modality: F2F Class orchestration: Teamwork Duration: 20'

Table 66. Breaking Down Step 4: Creating the solution

<table>
<tr><td colspan="4">STEP 4: “Creating the solution” in the project “Charlie and the Chocolate Factory”</td></tr>
<tr><td colspan="4">SCOPE: The students program the robot and test the melody of folk songs</td></tr>
<tr>
<td>Activity 9-ER-ART: Testing the whole sketch
Testing the robots and the scenario of the sketch as a whole
<u>CT skills:</u> N/A
<u>Activity Type:</u> Challenging Problem
<u>Modality:</u> F2F
<u>Class orchestration:</u> Plenary
<u>Duration:</u> 20’</td>
<td>Activity 10-ER: Fine-tuning robot behaviour
Polishing the robot so that the result fits into the whole
<u>CT skills:</u> Algorithmic thinking
<u>Activity Type:</u> Program
<u>Modality:</u> F2F
<u>Class orchestration:</u> Teamwork
<u>Duration:</u> 20’</td>
<td>Activity 11-ART: Fine-tuning the acting
Adjusting the scene, fine-tuning the acting part and decorating the robots
<u>CT skills:</u> Evaluation, Algorithmic thinking
<u>Activity Type:</u> Construct
<u>Modality:</u> F2F
<u>Class orchestration:</u> Plenary
<u>Duration:</u> 20’</td>
<td>Activity 12-ER-ART: The presentation
<u>CT skills:</u> N/A
<u>Activity Type:</u> Construct
<u>Modality:</u> F2F
<u>Class orchestration:</u> Plenary
<u>Duration:</u> 15’</td>
</tr>
</table>

Table 67. Breaking Down Step 5: Evaluating the solution

<table>
<tr><td colspan="3">STEP 5: “Evaluating the solution” in the project “Charlie and the Chocolate Factory”</td></tr>
<tr><td colspan="3">SCOPE: The students present and evaluate their performance and evaluate each performance</td></tr>
<tr>
<td>Activity 13-ER: Self-asessment (“Everyone says themselves, but all together”)
Evaluating your work in programming. Whether the robot did what we wanted, opinions, feedback
<u>CT skills:</u> Evaluation
<u>Activity Type:</u> Evaluate
<u>Modality:</u> F2F
<u>Class orchestration:</u> Individual
<u>Duration:</u> 10</td>
<td>Activity 14-ART: Self-asessment (“Everyone says themselves, but all together”)
Self-assessment
<u>CT skills:</u> Evaluation
<u>Activity Type:</u> Evaluate
<u>Modality:</u> F2F
<u>Class orchestration:</u> Individual
<u>Duration:</u> 10’</td>
<td>Activity 15-ER-ART: Feedback
Feedback on the whole activity. Perception of the connection between robotics and art.
<u>CT skills:</u> Evaluation
<u>Activity Type:</u> Evaluate
<u>Modality:</u> F2F
<u>Class orchestration:</u> Plenary
<u>Duration:</u> 15’</td>
</tr>
</table>

4.7.3 The evaluation of the "Charlie and the Chocolate Factory" project's Design Process

Table 68. Evaluation of the Artful ER pilot project's "Charlie and the Chocolate Factory" design process by the ER and the Art Educator through closed questions (five-point Likert scale).

Question	ER Educator's rate	Art Educator's rate
FDM Steps		
I found the sequence of the steps helpful to design the project (usefulness of the sequence of steps)	4	5
I found the scope of every step helpful towards designing the project gradually (usefulness of the various steps)	4	5
FDM Activities		
Breaking down each step into individual activities was helpful for designing students' involvement in the project	4	5
The features describing each activity (Activity Type, Duration, Modality, Class Orchestration, CT skills, etc.) were helpful in promoting ideas generation on both disciplines (Arts, ER)	4	5
The features describing each activity (Activity Type, Duration, Modality, Class Orchestration, CT skills, etc) were helpful in representing and communicating ideas among the disciplines (Arts, ER)	5	5
FDM Key Components		
The FDM supported me to collaborate with the teacher - co-designer in order to set goals from both disciplines.	5	5
Designing together activities for cultivating particular CT skills promoted mutual understanding of the disciplines involved.	3	5
The FDM supported me to decide which activities will be better implemented f2f in the classroom or remotely from home (blended learning).	3	3
The FDM supported me in understanding how to cultivate CT skills through the project.	4	3

Table 69. Evaluation of the design process of the Artful ER pilot project: "Charlie and the Chocolate Factory" by the ER and by the Art Educator through open questions.

FDM Steps	
Question	*What difficulties did you face in a) following the steps' sequencing, b) understanding the scope of each step?*
ER Educator's Answer:	Time in a sequence of steps - how we've scheduled it. In reality, something took much less time in the end, and something else took much more.
Art Educator's Answer:	We tried to follow exactly the proposed steps, but we were given little time for the project.
Question	*How did you find useful designing the project by a) following the particular steps' sequencing, and b) designing activities for each step?*
ER Educator's Answer:	It was a good idea to write it all down in advance and go over how we want to proceed. But sometimes it was a bit more detailed written down, we do those points in real life, but sometimes two at the same time, not separately.
Art Educator's Answer:	The preparation of the project, the time, the sequence of steps and the setting of the goal, is very important, it has proven itself, we have tried to adhere to it.
FDM Activities	
Question	*What difficulties have you faced, regarding a) breaking down the steps into individual activities and b) the features describing each activity?*
ER Educator's Answer:	Time. Some activities we wanted to do in one day, but we had to work on them the next day as well. Some things took much longer than we had planned, others were shorter.
Art Educator's Answer:	Breaking down the steps was not that difficult, but it was more difficult to estimate how long a given step would take.
Question	*How did you find useful designing the project by a) breaking down the steps into individual activities and b) setting the features of each activity?*
ER Educator's Answer:	It's good to have predetermined goals, sequences of steps, but I probably wouldn't go to the point of completely dividing one bigger step into smaller ones. Rather, just in general terms, what needs to be done in a given step, and the approximate time together.
Art Educator's Answer:	It was helpful for the project, but in a normal lesson we don't go into such detailed steps.
FDM Overview	
Question	*Since the FDM aims to cultivate CT through the interdisciplinarity of art and ER in a blended learning context, suggest changes/improvements in this direction.*
ER Educator's Answer:	Robotics and a theatre sketch - it was challenging... If I were to do it again, we would probably use different robots, I would also schedule it as an activity for a few months, not a few hours. So that the kids explore in depth what the programming possibilities are for that robot, understand the concepts, and sufficiently connect that to the theatre sketch.
Art Educator's Answer:	I can't fully evaluate how the project helped to develop CT, as I work in the field of art. However, the pupils enjoyed it and some had no problem with it, and those who don't do much with computers got involved as well and at least tried it out.

4.7.4 The evaluation of the “Charlie and the Chocolate Factory” project’s Implementation Process

Table 70. Evaluation of the implementation process of the Artful ER pilot project: “Charlie and the Chocolate Factory” by the ER and by the Art Educator through closed questions (five-point Likert scale).

Question	ER Educator’s rate	Art Educator’s rate
Evaluation of the Pilot Artful ER Project's implementation in relation to its original design.		
1. I implemented the FDM steps in the sequence they were originally designed	5	5
2. I implemented all the FDM steps without skipping any of those originally designed.	5	5
3. I found all the activities well integrated within each step.	4	4
4. The activities lasted as long as originally designed.	2	2
5. Splitting teaching hours between the disciplines was implemented as originally designed.	3	5
6. I collaborated effectively with the teacher - co-designer in applying every step.	5	5
7. The combination of ER and Arts activities was implemented as originally designed.	5	5
8. The combination of classroom (f2f) and remote activities was implemented as originally designed.	5	3
Evaluation of the Pilot Artful ER Project's implementation according to the FDM instructions for each step		
9. In the "Understanding the challenge" step, the students managed to clarify the concepts required to understand the challenge they had to face.	4	5
10. In the "Generating ideas" step, the students suggested one or more ideas that potentially satisfied the conditions given in the challenge.	4	5
11. Regarding the ER discipline, in the "Formulating the solution" step, the students managed to formulate an algorithm for the robot behaviour (in natural language), considering the requirements of the challenge, before proceeding to program the robot at the next step "Creating the Solution".	4	3
12. Regarding the Art discipline, in the "Formulating the solution" step, the students managed to formulate the art part of the solution, considering the requirements of the challenge, before proceeding to its construction at the next step "Creating the Solution".	4	5
13. The students' final artefact created at the "Creating the solution" step met the challenge's requirements set at the "Understanding the challenge" step.	5	5
14. In the "Evaluating the solution" step, the students managed to evaluate the artefact's adequacy and its correspondence to the requirements of the challenge given in the "Understanding the challenge" step.	5	5

Table 71. Evaluation of the implementation process of the Artful ER pilot project: "Charlie and the Chocolate Factory" by the ER Educator through open questions.

Evaluation of the Pilot Artful ER Project's implementation	
Question	*What changes have you applied to the original Artful ER project designed during its implementation for the students to manage completing the project?*
ER Educator's Answer:	Other robots, more time, more detailed exploration of the programming environment and robot behaviour.
Art Educator's Answer:	Especially more time.
Question	*What would you change in the Arful ER project design after the implementation experience?*
ER Educator's Answer:	Maybe connect it a bit more, so that the robotics is present throughout the whole theatre, not just in one part, so that it is "more alive" also from the robots' side.
Art Educator's Answer:	These robots were not able to go to the rhythm, they were not always reliable, it would require much more time, more depth in rehearsing the theatrical part and the programming of the robots.

4.7.5 Insights and observations on the project "Charlie and the Chocolate Factory"

According to the teachers designing this project, the methodology has proved to be successful in the preparation of the project. They found it less difficult to divide the activities into steps than to estimate how long a given step would take. They tried to follow a sequence of steps, but some seemed too detailed and they performed two at a time when carrying out the project. They expressed that this was helpful during the project, but in a regular lesson they do not plan activities in such detailed steps.

They also rated the implementation of the project quite highly. The problem they had was the lack of time for the project, so pupils who had not worked with robots before did not have enough time to get to know the programming environment and the behaviour of the robots in detail.

4.8 "Little Red Riding Hood" an Artful ER project by CUB

4.8.1 The scope of "Little Red Riding Hood" project

The project was implemented at the primary school level (1st and 2nd grade). At this age, students develop not only cognitive knowledge but also fine motor skills and other skills to a great extent. Therefore, the project was connected with storytelling, in which students were not only storytellers but also creators of the story environment. The story was a well-known fairy tale about Little Red Riding Hood, which carries a moral lesson.

In the first step, students, together with the teacher, reviewed the story to clarify the basic characters in the story, using a digital tool for introductory mind maps. (Understanding, CT: Abstraction) Then the students were divided into groups, where they familiarized themselves with the Ozobot robot and its behavior. They focused on programming the robot's behavior using color codes and pairing these codes to its actions. (Generating ideas, CT: Pattern recognition) This step also involved evaluating the robot's behavior, its functionality, and limitations (Evaluating solution, CT: Evaluation). Subsequently, the students created the stage/scene, the path, and the actual program for the individual characters in the well-known story (Formulating and Creating solution, CT: Decomposition).

Creating the program for the Ozobot was the most significant part of the project, where students planned and programmed the path for the characters in the story using pre-selected codes, providing reasons for their choices in the story (CT: algorithmic thinking). Together with the teacher, they evaluated the created plan and the behavior of the robots. If necessary, they corrected poorly functioning designs (CT: Evaluation). The final products were short films.

4.8.2 The design representation of the “Little Red Riding Hood” project

Table 72. Project Overview

<table>
<tr><td colspan="2">Project Category:</td><td>Program Robot to perform Art</td></tr>
<tr><td colspan="2">Educational Level:</td><td>Primary, 1st and 2nd grade</td></tr>
<tr><td colspan="2">Total Duration:</td><td>5 lessons (5x45 min)</td></tr>
<tr><td rowspan="2">Art form(s):</td><td>Category:</td><td>PERFORMING ARTS</td></tr>
<tr><td>Subcategory:</td><td>Theatre</td></tr>
<tr><td colspan="2">Learning Outcomes - Art:</td><td>"theatrical" interpretation of a well-known fairy tale for children</td></tr>
<tr><td rowspan="2">Learning Outcomes - ER:</td><td>Construction:</td><td>Ozobots do not need to be constructed</td></tr>
<tr><td>Programming:</td><td>Programming is based on the construction of a path for ozobots - pupils learn some basic commands to control the movement of the ozobot along the path</td></tr>
<tr><td colspan="2">Technical requirements for the robot:</td><td></td></tr>
<tr><td rowspan="3">Technology Used:</td><td>Robotic Kit:</td><td>Ozobot</td></tr>
<tr><td>Programming Environment:</td><td>–</td></tr>
<tr><td>Simulator:</td><td>–</td></tr>
<tr><td rowspan="2">Construction Elements:</td><td>Actuators:</td><td>Motor</td></tr>
<tr><td>Sensors:</td><td>optical sensor (color sensor)</td></tr>
<tr><td>Minimum requirements for the expected behaviour of the robot:</td><td colspan="2">The robots should move in all directions and respond to the code being read (different sequence of 2-4 coloured rings in a maximum of 4 colours).</td></tr>
<tr><td>Material Needed:</td><td colspan="2">Robot, paper, markers, tape</td></tr>
<tr><td>Extension Ideas:</td><td colspan="2"></td></tr>
</table>

Table 73. Breaking Down Step 1: Understanding the Challenge

STEP 1: "Understanding the Challenge" in the project "Little Red Riding Hood"			
SCOPE: The students understand the challenge they have been given. In particular, they should be able to get to know the members of the group better, understand how to represent the robots through body expressions and become familiar with the robotic kit, the program environment, and the mechanisms that they are going to use for their constructions.			
Activity 1-ART: Recalling the story Retelling the story, drawing attention to the main character and, the setting in which the story takes place. CT skills: Abstraction Activity Type: Engagement Modality: F2F Class orchestration: Plenary Duration: 5'	**Activity 2-ER: Getting to know robots** Getting acquainted with the robots, demonstration of their movement along a pre-prepared route. CT skills: Abstraction Activity Type: Engagement Modality: F2F Class orchestration: Plenary Duration: 10'	**Activity 3-ER: First work with robots** Division into teams (3 pupils in one team), testing different movements of the Ozobot after reading different parts of the code drawn by the pupils on the paper. CT skills: Pattern recognition Activity Type: New content Modality: F2F Class orchestration: Teamwork Duration: 25'	**Activity 4-ER: Robot control evaluation** Evaluation of the (dis)functionality of the commands in the ozoboto movement CT skills: Evaluation Activity Type: Evaluation Modality: F2F Class orchestration: Plenary Duration: 5'

Table 74. Breaking Down Step 2: Generating ideas

STEP 2: "Generating ideas" in the project "Little Red Riding Hood"	
SCOPE: The students familiarise themselves with the robots and through the techniques of Theatre and Drama in Education, create stories and content from which the final performance will be composed. They will also experiment and suggest ideas for the construction and programming parts..	
Activity 5-ART: Creating scenery parts The teacher printed out the text of the fairy tale, which she cut out section by section, at the same time she prepared a route on paper, in which she left free spaces to write the colour codes determining the movement of the ozobots. Pupils create the scenery for the project (trees, house, mushrooms, etc.) CT skills: N/A Activity Type: Challenging problem Modality: F2F Class orchestration: Teamwork Duration: 70'	**Activity 6-ART: Putting scenery together** In this step, the pupils have to arrange the scenery and correctly place the parts of the story in the route (prepared by the teacher) according to the chronological sequence. Activity Type: Plan Modality: F2F Class orchestration: Teamwork Duration: 20'

Table 75. Breaking Down Step 3: Formulating the solution

STEP 3: "Formulating the solution" in the project "Little Red Riding Hood"
SCOPE: The students formulate and articulate the final solution clearly according to robots' construction and programming and composition of the performance.
Activity 7-ER: Preparing color codes to program a robot The route contains blanks in whichcolour codes need to be placed to make the ozobot behave in the expected way. Pupils write colour codes from a predetermined set of codes, according to which Ozobot will move with respect to the story. In several cases there are several correct solutions and it is up to the pupils to decide which one to choose. However, they will have to justify their choice. CT skills: Algorithmic thinking Activity Type: Challenging problem Modality: F2F Class orchestration: Teamwork Duration: 45'

Table 76. Breaking Down Step 4: Creating the solution

STEP 4: "Creating the solution" in the project "Little Red Riding Hood"		
SCOPE: The students complete the construction of the performance (rehearsals) and the construction and programming of the robots. All the modifications take place in this phase.		
Activity 8-ER: Verifying the color codes Pupils verify the correctness and appropriateness of the choice of colour codes already with the help of ozobots (so far they have been working without them). Comment: It is likely that some pre-selected robot movements will have to be substituted by pupils due to the technological limitations of ozobots (e.g. acceleration before a turn is likely to cause the robot to be off-track, etc.). It is therefore likely that they will have to correct their originally proposed solution. CT skills: Pattern recognition Activity Type: Construct Modality: F2F Class orchestration: Teamwork Duration: 20''	**Activity 9-ART: Adjusting the scenery** Pupils adjust the arrangement of scenery according to the current needs of Ozobots. Comment: We expect that the pupils will have to change the placement of the scenery parts on their routes, as it is possible that the original placement will not be suitable for the movement of the Ozobots. CT skills: N/A Activity Type: Construct Modality: F2F Class orchestration: Teamwork Duration: 10	**Activity 10-ART: Recording the sketch with robots** The pupils, with the teacher's help, will record short films in which their Ozobots will perform according to their prepared rout. CT skills: N/A Activity Type: Construct Modality: F2F Class orchestration: Teamwork Duration: 15'

Table 77. Breaking Down Step 5: Evaluating the solution

STEP 5: "Evaluating the solution" in the project "Little Red Riding Hood"	
SCOPE: The students present and evaluate their performance and evaluate each performance	
Activity 11-ER: Reflection I The pupils, together with the teacher, reflect on what all needs to be corrected compared to their original plan in order for the Ozobots to work properly (moving the scenery, increasing the space for transition in the house, etc.). CT skills: Evaluation Activity Type: Evaluate Modality: F2F Class orchestration: Plenary Duration: 5'	**Activity 12-ER: Reflection II** Pupils describe situations in which an ozobot behaved differently than they expected, and also describe ways in which they corrected the behaviour of the ozobot (a situation in which two ozobots were close to each other and stopped moving; a colour code written in reverse, etc.) CT skills: Evaluation Activity Type: Evaluate Modality: F2F Class orchestration: Plenary Duration: 5'

4.8.3 The evaluation of the "Little Red Riding Hood" project's Design Process

Table 78. Evaluation of the design process of the Artful ER pilot project: "Little Red Riding Hood" by the ER and by the Art Educator through closed questions (five-point Likert scale).

Question	ER Educator's rate	Art Educator's rate
FDM Steps		
I found the sequence of the steps helpful to design the project (usefulness of the sequence of steps)	4	5
I found the scope of every step helpful towards designing the project gradually (usefulness of the various steps)	5	5
FDM Activities		
Breaking down each step into individual activities was helpful for designing students' involvement in the project	4	5
The features describing each activity (Activity Type, Duration, Modality, Class Orchestration, CT skills, etc.) were helpful in promoting ideas generation on both disciplines (Arts, ER)	5	5
The features describing each activity (Activity Type, Duration, Modality, Class Orchestration, CT skills, etc) were helpful in representing and communicating ideas among the disciplines (Arts, ER)	5	5
FDM Key Components		
The FDM supported me to collaborate with the teacher - co-designer in order to set goals from both disciplines.	4	5
Designing together activities for cultivating particular CT skills promoted mutual understanding of the disciplines involved.	4	5
The FDM supported me to decide which activities will be better implemented f2f in the classroom or remotely from home (blended learning).	5	3
The FDM supported me in understanding how to cultivate CT skills through the project.	5	5

Table 79. Evaluation of the design process of the Artful ER pilot project: "Little Red Riding Hood" by the ER and by the Art Educator through open questions.

FDM Steps	
Question	*What difficulties did you face in a) following the steps' sequencing, b) understanding the scope of each step?*
ER Educator's Answer:	a) the sequence of steps - the steps followed a logical sequence, it was nice to be able to "backtrack" in case of confusion ; b) the steps were clearly and distinctly formulated, the scope of the steps was fine, but I would have welcomed a simpler formulation.
Art Educator's Answer:	I don't rate anything as challenging, as we dealt with the artistic side of the project and the trajectory of the ozobots themselves. The appropriate setting and scenery completed the project.
Question	*How did you find useful designing the project by a) following the particular steps' sequencing, and b) designing activities for each step?*
ER Educator's Answer:	a) the steps were fine for me, the steps helped us to classify thoughts and ideas ;-) b) the activities in a given step were beneficial for us, thanks to the proposal we were able to look at the activity in a systemic way and give the activity a "head and heel".
Art Educator's Answer:	In cooperation with my colleagues, we had clearly defined sub-tasks and followed predefined steps.
FDM Activities	
Question	*What difficulties have you faced, regarding a) breaking down the steps into individual activities and b) the features describing each activity?*
ER Educator's Answer:	a) individual activities - we didn't know what to add in the "name" column; in some steps we were unsure of the assignment of the activity to the CT skill or the "activity type" because we found more than one type applicable when there were several. (b) The features were worded well; we did not encounter any difficulties.
Art Educator's Answer:	From the pupils' point of view, I can say that they were interested in how to create the most believable environment referring to the fairy tale of Little Red Riding Hood.
Question	*How did you find useful designing the project by a) breaking down the steps into individual activities and b) setting the features of each activity?*
ER Educator's Answer:	a), b) very well, it helped us to better design the activity, to think through and specify the individual sub-activities and it also guided us in the objectives we set for our activity.
Art Educator's Answer:	The answer to this question does not cover the content of my art class.
FDM Overview	
Question	*Since the FDM aims to cultivate CT through the interdisciplinarity of art and ER in a blended learning context, suggest changes/improvements in this direction.*
ER Educator's Answer:	Simplify the formulation of the methodology itself, a teacher of a subject other than informatics has a lot to do ;-). The rest was thought-provoking and excellently handled. Anyway, thank you for this opportunity, it was a completely new but beneficial experience for me.

Art Educator's Answer:	Interdisciplinarity between any subject is always an asset for teaching and a methodological challenge for the teacher. But it also creates beautiful projects.

4.8.4 The evaluation of the "Little Red Riding Hood" project's Implementation Process

Table 79. Evaluation of the implementation process of the Artful ER pilot project: "Little Red Riding Hood" by the ER and by the Art Educator through closed questions (five-point Likert scale).

Question	ER Educator's rate	Art Educator's rate
Evaluation of the Pilot Artful ER Project's implementation in relation to its original design.		
1. I implemented the FDM steps in the sequence they were originally designed	5	5
2. I implemented all the FDM steps without skipping any of those originally designed.	5	5
3. I found all the activities well integrated within each step.	5	5
4. The activities lasted as long as originally designed.	4	5
5. Splitting teaching hours between the disciplines was implemented as originally designed.	4	5
6. I collaborated effectively with the teacher - co-designer in applying every step.	5	3
7. The combination of ER and Arts activities was implemented as originally designed.	5	5
8. The combination of classroom (f2f) and remote activities was implemented as originally designed.	5	5
Evaluation of the Pilot Artful ER Project's implementation according to the FDM instructions for each step		
9. In the "Understanding the challenge" step, the students managed to clarify the concepts required to understand the challenge they had to face.	5	5
10. In the "Generating ideas" step, the students suggested one or more ideas that potentially satisfied the conditions given in the challenge.	5	5
11. Regarding the ER discipline, in the "Formulating the solution" step, the students managed to formulate an algorithm for the robot behaviour (in natural language), considering the requirements of the challenge, before proceeding to program the robot at the next step "Creating the Solution".	4	5
12. Regarding the Art discipline, in the "Formulating the solution" step, the students managed to formulate the art part of the solution, considering the requirements of the challenge, before proceeding to its construction at the next step "Creating the Solution".	4	5
13. The students' final artefact created at the "Creating the solution" step met the challenge's requirements set at the "Understanding the challenge" step.	5	5
14. In the "Evaluating the solution" step, the students managed to evaluate the artefact's adequacy and its correspondence to the requirements of the challenge given in the "Understanding the challenge" step.	5	5

Table 80. Evaluation of the implementation process of the pilot project: "Little Red Riding Hood" by the ER Educator through open questions.

Evaluation of the Pilot Artful ER Project's implementation	
Question	*What changes have you applied to the original Artful ER project designed during its implementation for the students to manage completing the project?*
ER Educator's Answer:	Just a change in time - some parts of the activity took pupils longer than we expected.
Art Educator's Answer:	–
Question	*What would you change in the Arful ER project design after the implementation experience?*
ER Educator's Answer:	Time allocation.
Art Educator's Answer:	–

4.8.5 Insights and observations on the "Little Red Riding Hood" Project

The teachers expressed that thanks to the different steps of the methodology, they were able to sort their thoughts and ideas and proceed systematically in the design of the activity. The steps were, in their opinion, clearly and distinctly formulated, the scope of the steps was fine, but they would have appreciated simpler wording. They were unsure about some of the steps, e.g. in matching the activity to the skill or identifying the type of activity. Overall, they found the methodology to be beneficial for project design as it helped them to specify the sub-activities and guided them in their stated objectives.

They also rated the implementation process of the proposed project very high, with the only comment regarding the incorrectly estimated duration of some activities.

5. Conclusions

The evaluation of designing and implementing multiple pilot Artful ER projects based on the initial FDM indicates its potential. Educators acknowledge its value in organising and structuring learning experiences effectively (The Art of Anticipation, Project smartwatch, One-stroke Drawing, Charlie and the Chocolate Factory, Folk Songs, Little Red Riding Hood). However, some educators raised concerns about the complexity of the methodology, suggesting potential areas for improvement or simplification (Charlie and the Chocolate Factory, Languages of Children).

Several implementations reported high levels of learner involvement and enthusiasm, indicating the effectiveness of the initial FDM in fostering active engagement and interest in the learning process (RoboTerrorizing the playground, Project smartwatch). Educators highlighted the significance of incorporating student feedback and preferences to create a more student-centered and meaningful learning intervention (Project smartwatch).

The integration of CT skills is deemed beneficial, supporting the design process and enhancing students' learning experiences (The Art of Anticipation). One of the notable advantages reported for the initial FDM is its adaptability, allowing educators to adapt the activities based on the time constraints (Folk Songs, One-stroke Drawing) or other practical considerations (Charlie and the Chocolate Factory, Little Red Riding Hood), while still striving to achieve the intended learning goals.

The initial FDM also seem to support educators in their collaboration with each other and the interdisciplinary dimension of the projects designed (One-stroke Drawing, Folk Songs).

All in all, the partners deem that the FDM development process following a DBR approach allowed delivering a robust initial FDM. It facilitated interweaving practice with theory, and triggered researchers' and practitioners' interaction to ground FDM in real-world educational settings.

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Appendix A

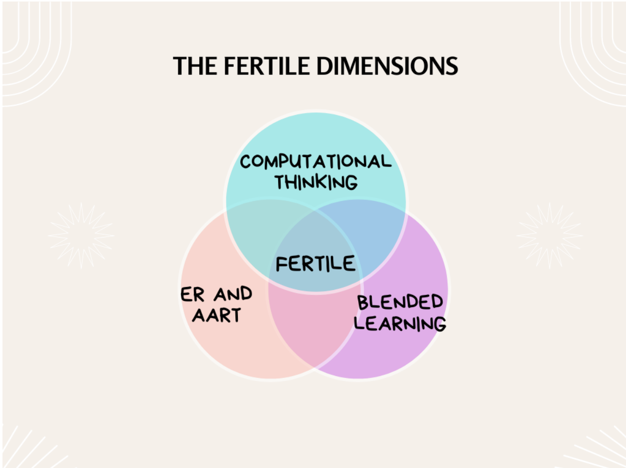

Figure A1. Draft graph visualising the relationship among the FERTILE Dimensions

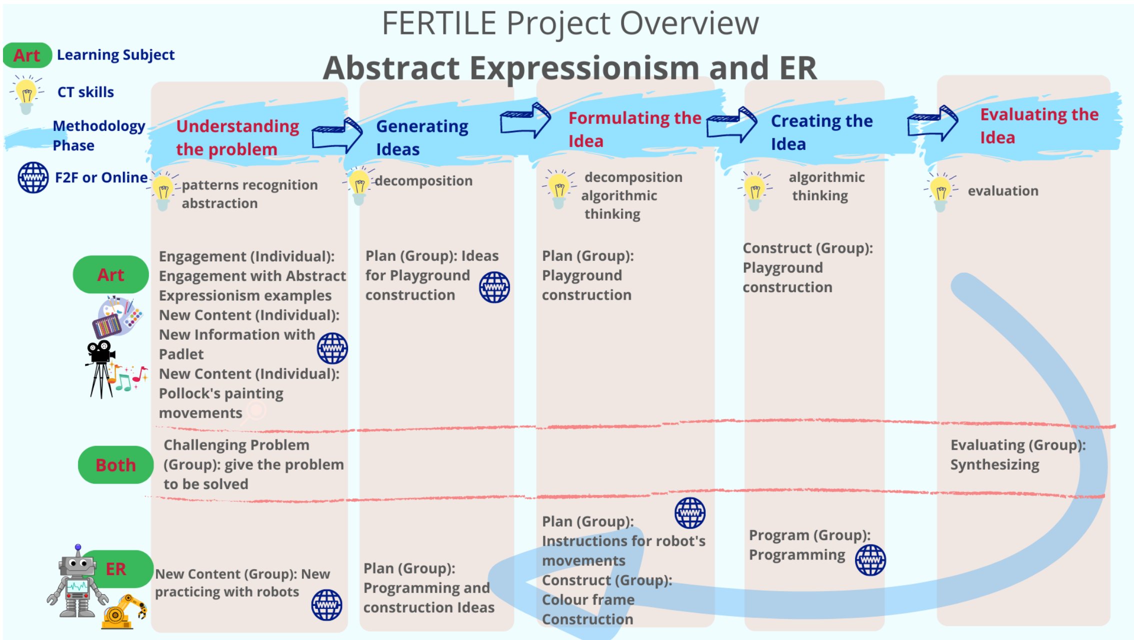

Figure A2. First draft graph illustrating the FERTILE steps and the structure of the preliminary FDM version based on interdisciplinarity

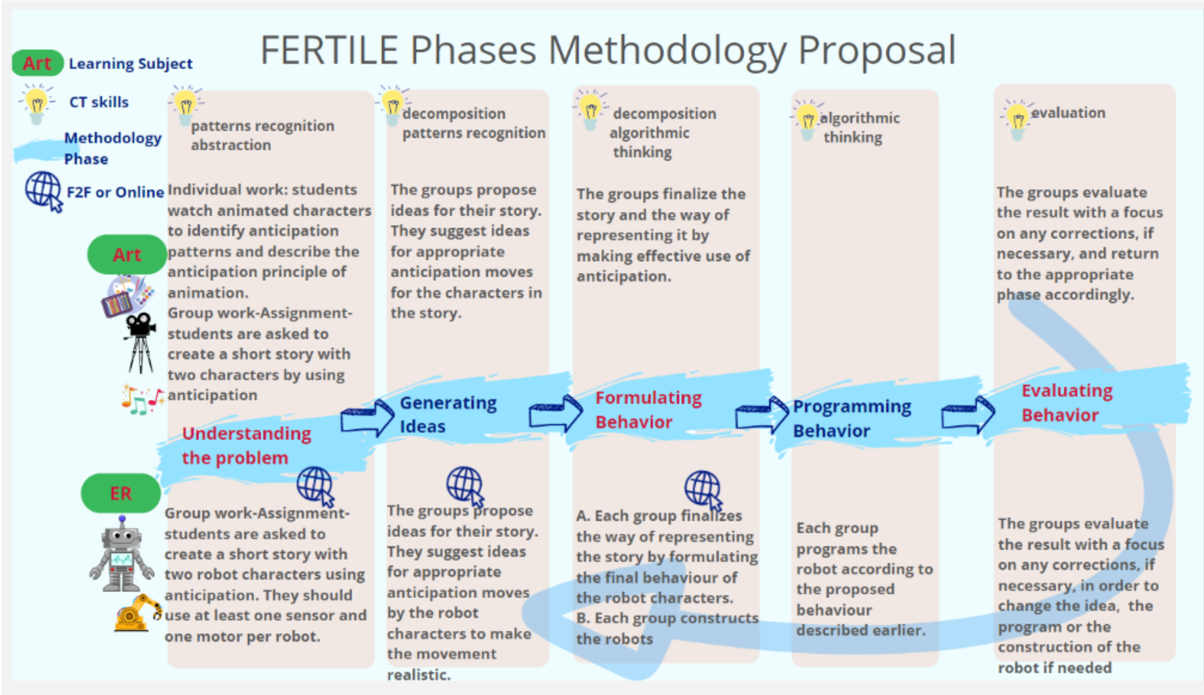

Figure A3. Second draft graph illustrating the steps included in the FERTILE methodology and the structure of the preliminary FDM version based on interdisciplinarity

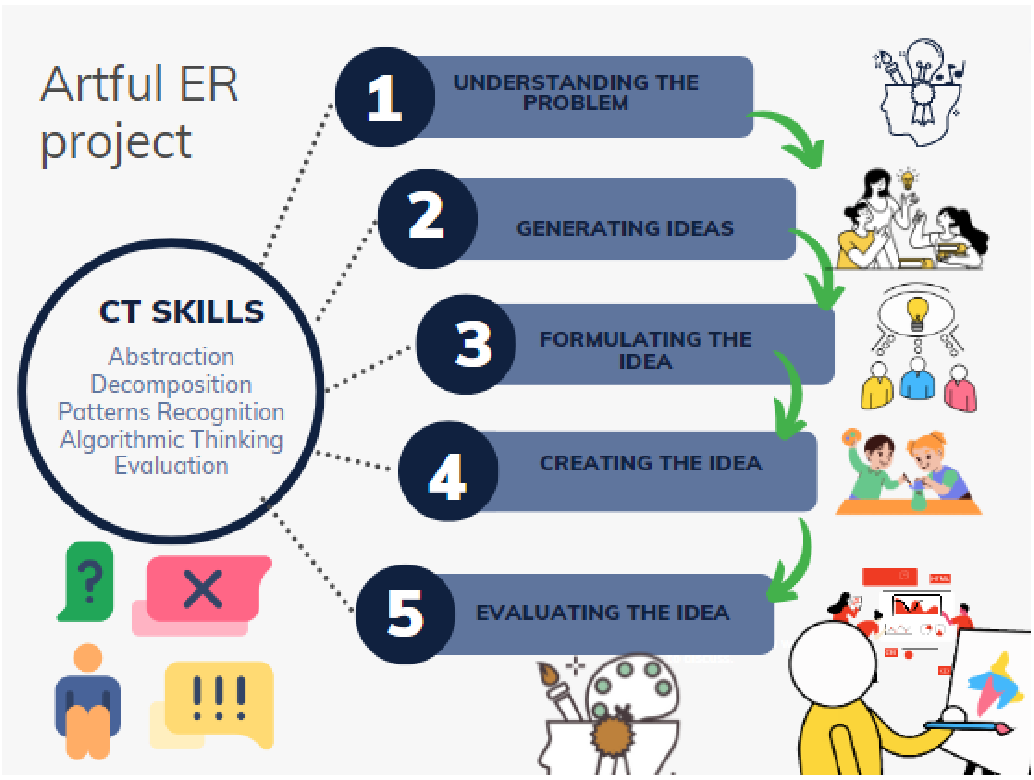

Figure A4. Draft graph illustrating the connection of the CT skills to the steps included in the FERTILE methodology

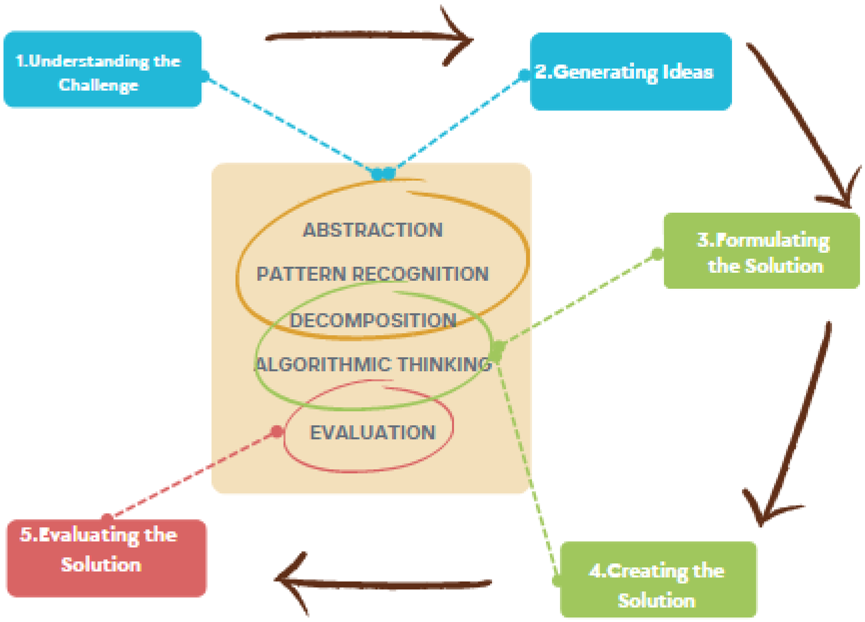

Figure A5. First draft graph illustrating the connection of the CT skills to each step included in the FERTILE methodology

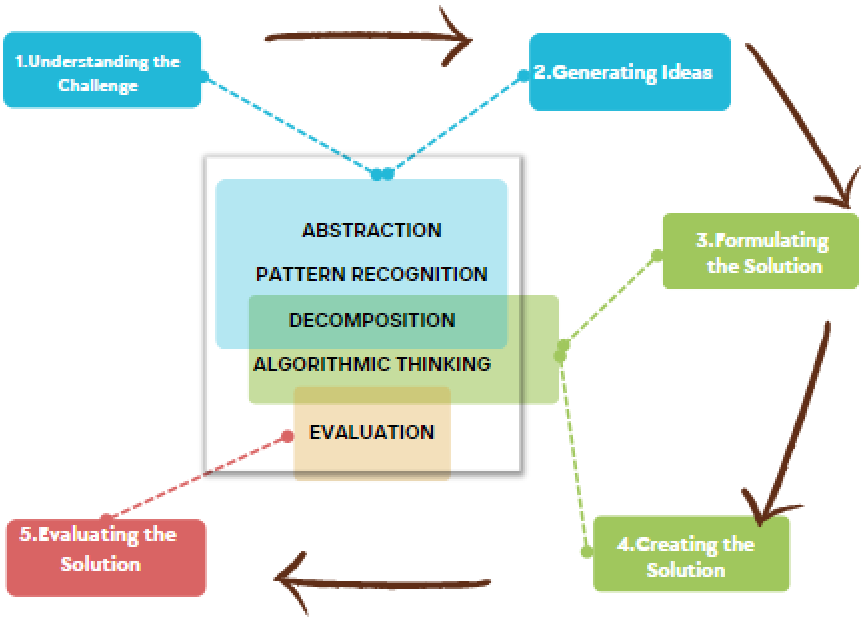

Figure A6. Second draft graph illustrating the connection of the CT skills to step included in the FERTILE methodology

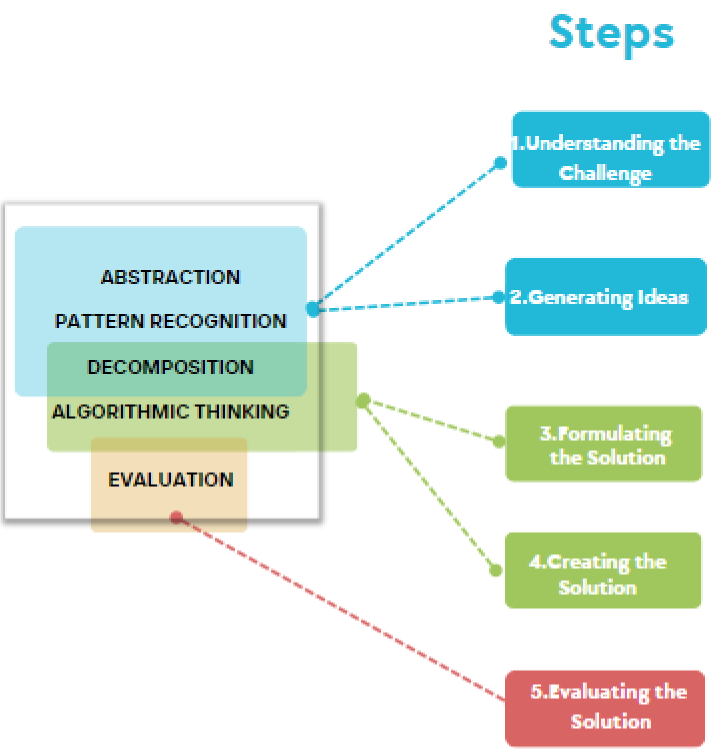

Figure A7. Third draft graph illustrating the connection of the CT skills to each step included in the FERTILE methodology

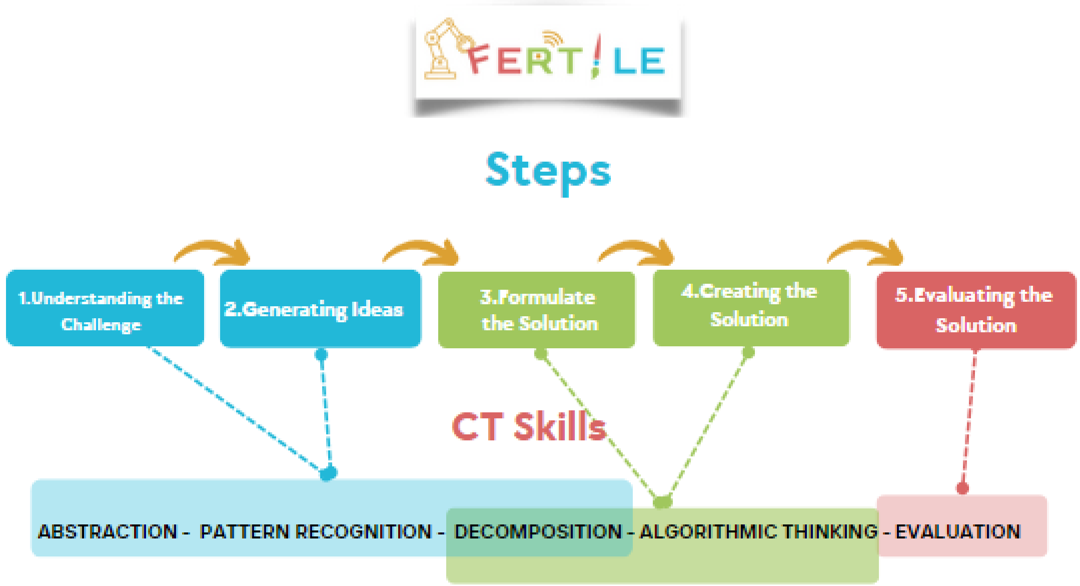

Figure A8. Fourth draft graph illustrating the connection of the CT skills to each step included in the FERTILE methodology

APPENDIX B

Project Title	Project Description

Learning Objective - Art:	
Learning Objective - ER:	

Art form(s):	**LITERACY**	**VISUAL**
	poetry	**painting**

Technical requirements for the robot:		
Technology Used:	**Robotic Kit:**	
	Programming Environment:	
	Simulator:	

Educational Level	
Extension ideas	

Figure B1. Design form of an Artful ER project overview based on the preliminary FDM version (1st iterative DBR cycle)

Sequence	Type of Activity	Subject	CT Skill	Blended Learning	Activity Description	Title	Duration (Minutes)	Materials	Group Organization
1	Engagement	Art	Pattern Recognition	F2F	the teacher gives examples to introduce students to the concept of abstract expressionism and its specific characteristics.	Engagement with Abstract Expressionism examples	15		Individual
2	New Content	Art	Abstraction	Online Asynchronously	the teacher asks from the students to find information about painters and abstract expressionism (Padlet)	New Information with Padlet	15		Individual
3	New Content	Art	Pattern Recognition	F2F	the teacher shows to the students the movements of Pollock (pattern recognition)	Pollock's painting movements	25		Individual
4	Challenging Problem	Both	N/A	F2F	Challenging problem (assignement): the teacher asks from the students to paint with a robot based on abstract expressionism	Give the problem to be solved	15		Individual
1	New Content	ER	N/A	Simulator	the students practice with programming robot move and turn	New practicing with robots	60		Group

Figure B2. Design form of an Artful ER project illustrating the characteristics of the first step's activities based on the preliminary FDM version (1st iterative DBR cycle)

Project Title	Project Description
Anticipation through Educational Robotics	*the students will recreate story characters that move according to the principle of anticipation through programming and constructing robots*

Authors	Maria Tzelepi
Project Category	Program Robot to perform Art

Learning Objective - Art:			
Learning Objective - ER:	**Construction:**	*robot axis with one motor*	
	Programming:	*sequence, variables*	
Art form(s):	**Category:**	*VISUAL*	*PERFORMING*
	Subcategory:	*animation*	*theatre*
Technical requirements for the robot:			
Technology Used:	**Robotic Kit:**	*Lego WEDO*	
	Programming Environment:	*N/A*	
	Simulator:	*OpenRoberta*	
Construction Elements:	**Actuators:**	*one motor*	
	Sensors:	*distance or accelerometer*	
Description:	*be able to move forward and turn according to the obstacle encountered or the position of the robot*		
Educational Level	*Lower Primary*		
Extension ideas			

Figure B3. Design form of an Artful ER project overview based on the tentative FDM version (2nd iterative DBR cycle)

FERTILE Methodology Step	Description	Output
Understanding the challenge	the students identifiy the given challenge	Art: a description of the requirements concerning the artistic part ER: a description of the technical requirements regarding educational robotics

Sequence	Type of Activity	Subject	CT Skill	Modality	Activity Description	Title	Duration (Minutes)	Materials	Class Orchestration
3	Challenging Problem	Both	N/A	F2F	Challenging problem (assignement):Art: the teacher asks the students to re-enact the story using the robots they have already built; they should modify the robots to express a role in the story. ER: They should use at least one sensor and one motor per robot.	Give the challenge to be solved	10		plenary
4	Plan	Art	Decomposition, Abstraction	F2F	the students explore and analyze the requirements of the challenge that they have to face, regarding Art: a)what decorating materials they will need for the robots, b) how the robots will move with anticipation, c) what should be the main behaviour that would distinguish a robot playing a particular character, how the environment of the scene will be formed	The students decompose the challenge trying to identify its main requirements (brainstorming) regarding Art	5		plenary
4	Plan	ER	Abstraction, Decomposition	F2F	the students explore and analyze the requirements of the challenge that they have to face: a) what constructing materials they will need for the robots, b) what will be the movement of the robots, c) how the robots will represent the anticipation etc	The students decompose the challenge trying to identify its main requirements (brainstorming) regarding ER	5		plenary

Figure B4. Design form of an Artful ER project illustrating the characteristics of the first step's activities based on the tentative FDM version (2nd iterative DBR cycle)