Mumabot: Weaving Music, Mathematics and Educational Robotics in ECEC Settings

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Abstract: This contribution discusses a pilot course within the "INTEC - Developing an innovative in-service training model for ECEC staff" project (Erasmus+ KA2). The Mumabot (MUsic, MAthematics and educational roBOTics) training course presented an innovative methodology, based on a transdisciplinary and multimodal approach, focusing on the intertwining of the three disciplines through the use of Ozobot, the Rhythm Box and Lego bricks as mediators. The study aims to investigate the effect of the pilot course on the 39 trainees that were involved in the Italian and international versions. Our research questions are: Is this course effective in giving ECEC professionals the ability to plan Mumabot activities? What effect does it have on their ideas about children's learning in STEAM disciplines? Theoretical and empirical enquiries into STEAM disciplines highlighted the need for training and support for ECEC professionals, and the possibilities offered by a multimodal and transdisciplinary approach. Pre- and post-course questionnaires containing both multiple.choice and open-ended questions were administered to the participants. Thematic analysis was used to analyse the written responses. The findings suggest that while the course was effective in changing participants' perspectives on STEAM activities in ECEC, it was only partially effective in supporting professionals in planning Mumabot activities.

1 INTRODUCTION

STEAM activities in Early Childhood Education and Care (ECEC) can be used to develop critical thinking, problem-posing and problem-solving skills (Walshe et al., 2025) and can support the holistic development of the children by connecting artistic and scientific knowledge through play (Johnston et al., 2022), when designed as a multidimensional exploration in which each discipline is included in a meaningful way (Barry, 2008). Research shows that ECEC professionals often report difficulty in implementing this type of activity in their services, and a strong need for training and support in this area often considered very specialized (Jamil et al., 2018; Monkeviciene et al., 2020). In this paper a training course conducted on an innovative STEAM methodology that interweaves music, mathematics and educational robotics will be presented.

1.1 INTEC: Developing an Innovative In-Service Training Model for ECEC Staff

"INTEC - Developing an innovative in-service training model for ECEC staff" is a European Erasmus+ KA2 project created with the aim of developing an innovative approach to in-service training for professionals working in ECEC with a specific European dimension. Project partners include the Municipality of Vänersborg (Sweden), SERN - Sweden Emilia Romagna Network (Italy), the University of Vic (Spain), RTU Liepāja (Latvia), Fondazione Bambini Bicocca (Italy), and Erasmus Hogeschool Brussels (Belgium).

The project's primary focus was the development of the Transnational In-Service Training Curriculum (TITC), which aims to establish a European framework based on shared values and pedagogical

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approaches to support transnational learning experiences.

1.2 The Training Courses

The training proposal developed in the document includes five in-service training courses on topics selected based on the goals defined in the United Nations 2030 Agenda. These courses were designed and piloted by the project partners: internationalization (SERN); diversity and inclusion (Erasmus Hogeschool Brussels); social and environmental sustainability (RTU Liepāja); STEAM (Fondazione Bambini Bicocca); and family participation (University of Vic).

The design and implementation of the pilot courses followed a common framework based on key methodological principles and elements, which were then further refined based on the topic and implementation context. To evaluate the effectiveness of the training proposal, several shared tools were selected, with the option of using other tools described in the TITC, depending on the specific course characteristics. Each course was piloted in a national version, taught in the local language, and an intensive international version, conducted in English.

2 MUMABOT: EXPLORING THE INTERSECTIONS BETWEEN DISCIPLINES

The objective of this study is to evaluate the STEAM pilot course developed by Fondazione Bambini Bicocca, "Mumabot. Exploring the intersections between disciplines."

Mumabot (MUsic, MAthematics and educational roBOTics) is an innovative transdisciplinary and multimodal methodology that combines these three disciplines to make complex concepts in music, mathematics, and robotics accessible, deconstructing the concept of differentiated ways to learn and teach them. It involves a laboratory approach, where children can find multiple ways to understand the topic and express themselves, and the use of tools (the Ozobot robot, Rhythm Box cards, and Lego bricks) as educational mediators.

Transdisciplinary refers to working in the areas of intersection between different disciplines, identifying concepts that can be explored through the lenses and tools of each discipline to generate new arenas of knowledge (Areljung, 2023). Multimodality refers to including multiple sensory channels of access in the design and implementation of activities, using culturally relevant tools, artifacts, and symbolic systems (Ludovico et al., 2017; Tomlinson, 2013).

Our research questions are:

Is the course effective in providing teachers and educators with the ability to design STEAM activities using Mumabot within their services?

Have there been any changes in their ideas about children's learning in STEAM?

3 THEORETICAL FRAMEWORK

The INTEC work group conducted a literature review of scientific publications from the previous five years on the topic of continuing professional development in the ECEC sector, examined European guidelines for continuing professional development, and compared official national references for in-service training in the research partner countries.

This analysis highlighted several key aspects regarding the design and evaluation of in-service training.

3.1 Design and Methodological Elements

The main characteristics identified for effective in-service training are the constant intertwining of theoretical elements and practical activities (Gealy et al., 2022), the creation of learning communities (Jensen & Iannone, 2018), collaborative learning and reflection (Gealy et al., 2022; Jensen & Iannone, 2018), situated learning (Peleman et al., 2018) and the flexible use of different learning strategies (Jackson, 2023; Jensen & Iannone, 2018).

3.2 STEAM in ECEC

Within this methodological framework, for the Mumabot course the topic of STEAM was explored in the literature, highlighting a perceived difficulty for ECEC professionals to implement this type of activity in their services and the need for training and support (Jamil et al., 2018; Johnston et al., 2022; Monkeviciene et al., 2020); it also presented the possibilities offered by a multimodal (Tomlinson, 2013; Ludovico et al. 2017) and transdisciplinary (Areljung, 2023) approach to give better access to knowledge, by allowing children multiple channels of entry to the themes explored.

4 METHODOLOGY

4.1 Structure of the Pilot Course

4.1.1 The Local Version

The local version of the "Mumabot. Exploring disciplinary intersections" course took place in Milan, Italy from February 8 to May 17, 2025.

It was structured in two five-hour face-to-face training sessions in February, twelve hours of on-the-job implementation from early March to mid-May, and a final three-hour online session. The course was led by three trainers, each specialized in one of the disciplines involved. Thirty-four trainees, all women, participated: 13 infant-toddler centre educators, 12 preschool teachers, 2 primary school teachers, 5 music specialists working with the 0-3, 3-6, or 6-11 age groups, and 2 pedagogical coordinators (one from an infant-toddler centre and one from a preschool). Each group of participants coming from the same service or organization received a Mumabot kit on loan, containing three Ozobot Bits and three Rhythm Boxes, to use with the children during the implementation phase.

During the two face-to-face meetings, the trainees experienced Mumabot activities firsthand, working in small groups that were diverse in terms of their professional roles and the services they worked in. These experiential activities were accompanied by an introductory session on the theoretical foundations of the approach, and several large-group sessions for sharing and reflecting on what happened during the small group activities. The final part of the second meeting focused on the use of the design and documentation sheet provided to the trainees to use in the implementation phase in the services and included a group session during which the trainees began planning how they would introduce the activities to the children.

A Microsoft Team was created to serve as a repository for the materials shared by the trainers and as a platform for the trainees to share written and multimedia documentation (photographs, videos, audio recordings) with the trainers and other participants.

The final online meeting provided an opportunity for the trainers to give an overview of the common themes that emerged from the documentation shared by the participants, and to create a space for discussion on these topics between trainees and trainers.

4.1.2 The International Version

The international version of the course took place in Milan from May 20 to 22, 2025, and consisted of three intensive, in-person days.

The course was led by the same trainers as the national version. 5 trainees, all women, participated: 1 coordinator and 1 teacher from a Swedish service for children aged one to six; 2 teachers from a Latvian service for children aged one and a half to six; and 1 Belgian facilitator who organizes activities with children and youth aged four to sixteen.

During the first two days, the trainees were involved in similar activities as the ones used in the national course, although given the small group size, each activity was carried out as a whole group and with the three trainers present at the same time. The final day was dedicated entirely to co-designing educational activities for the children, given the lack of a design and implementation phase supervised by the trainers.

4.1.3 The Implementation Phase of the Local Course: A Training-Action-Research

The implementation phase of the local course was structured as Recherche-Action-Formation (RAF), or training-action-research, a type of training-research (Zecca, 2018). RAF is a recursive research model with three main objectives: contributing to pedagogical knowledge; bringing about change in practice; and generating transformation in the individuals participating in the process. The teachers and educators involved acted as co-researchers, not merely participants.

Trainees' updates to the documentation tools were monitored weekly by the trainers, who provided feedback using two types of intervention: informative (the trainer provides factual information or corrects a misconception/error) and activating/stimulating (the trainer asks questions or invites reflection or questioning of something written). These two types of interventions are aimed not at directly guiding the professional's action, but rather at supporting their reflexivity.

4.1.4 Evaluation and Assessment Tools

The tools selected for ongoing and final assessment and evaluation are: pre-course and post-course self-assessment questionnaires (which were used in all the INTEC pilot courses, and were translated into Italian for the local version of the course); the design and

documentation sheet and the multimedia file repository, used only in the local version of the course.

The pre-course questionnaire includes a first section on the professional's profile, three open-ended questions on expectations and motivation for attending the course, and five numerically scored questions on the perceived applicability of the course, the importance of experiential learning, the importance of continuing professional development, the level of commitment to improving one's practice, and the need for a European ECEC curriculum.

The post-course self-assessment questionnaire contains nine thematic blocks: *general satisfaction*, *teaching action*, *content and objectives*, *learning proposals*, *participation and involvement*, *learning resources*, *collaboration between colleagues*, *assessment system*, *learning outcomes*, and *applicability in the educational service*. Each of these fields is structured with one or more positively worded statements, asking respondents to indicate their level of agreement with the statement on a Likert scale of one to five, and an open-ended question explaining the numerical rating. These are followed by two additional open-ended fields to indicate positive aspects of the course and any suggestions.

The post-course questionnaire was administered anonymously through the use of Google Forms.

4.2 Data Analysis

In this paper, aiming to evaluate both the local and international courses, the pre- and post-course questionnaires administered in both editions were analysed.

The responses to the open-ended questions were analysed using thematic analysis (Braun & Clarke, 2012). After a first phase of data familiarization, an initial list of codes was generated using an inductive approach, identifying elements present in the data relevant to the research questions. Starting from the initial list of codes, some potential themes were identified, which were then reviewed and refined through direct comparison with the coded data.

5 DISCUSSION

5.1 Pre-Course Questionnaires

33 Out of 39 participants completed the pre-course questionnaire.

The numerical evaluations show that the course proposal is perceived as innovative and transferable to daily practice. Participants are motivated and ready to share their learnings in their own services.

Regarding expectations, the trainees hope to learn how to integrate different disciplines into STEAM activities, how to foster the development of transversal skills in children, and how to effectively use the specific tools presented in the course. They believe the course will improve the educational quality of their services, helping to implement more inclusive and engaging strategies.

5.2 Post-Course Self-Assessment Questionnaires: The Numerical Evaluations

30 Out of 39 participants completed the post-course questionnaire.

A number between 1 to 5 was assigned to each possible level of agreement, with 1 corresponding to “Completely disagree” and 5 to “Completely Agree”, to analyse the data.

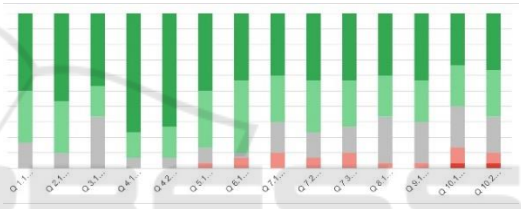

Figure 1: Level of agreement for each thematic block.

The numerical ratings show a strong predominance of 4s and 5s (light green and green in the graph), indicators of a high level of satisfaction with the training and the learning process. (see also Table 1).

Items 1.1 through 9.1 all have a mean above 4, while items 10.1 and 10.2 (relating to the transferability of the knowledge in the work setting) have a mean of 3.7 and 3.9 respectively.

The mode of all items except one is 5; item 6.1 (relating to the learning resources) has a mode of 4.

Subsequently, the ratings of items belonging to the same thematic block were averaged and a top-two, neutral and bottom-two scale was created in order to identify the areas that presented the highest and lowest level of agreement with the items.

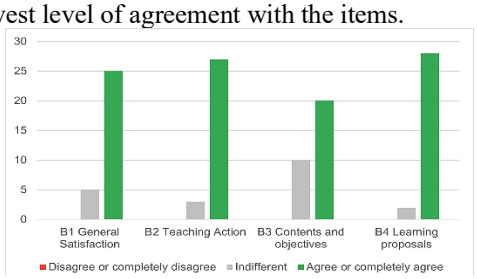

Figure 2: Top-two and bottom-two box scoring for areas with highest level of agreement.

Table 1: Frequency distribution of answers to each item expressed in percentages.

Item	Completely disagree	Disagree	Neutral	Agree	Completely agree
1.1. Overall, the course has met my initial expectations	0%	0%	17%	33%	50%
2.1. The general satisfaction with the teaching action is high	0%	0%	10%	33%	57%
3.1. The contents and objectives are appropriate for the development of the assigned skills (expected or planned for the course)	0%	0%	33%	20%	47%
4.1. The learning activities have been useful and interesting for my learning	0%	0%	7%	17%	77%
4.2. The methodology for carrying out the learning proposals has been very appropriate (readings, case analyses, group work, simulations, etc.)	0%	0%	7%	20%	73%
5.1. Satisfaction with my level of active participation and commitment to the course is high	0%	3%	10%	37%	50%
6.1. Overall high satisfaction with learning resources (videos, articles, etc.)	0%	7%	3%	47%	43%
7.1. My satisfaction with the collaboration with colleagues is high	0%	7%	20%	30%	43%
7.2. The assessment of good practice exchange between colleagues/s is high	0%	7%	17%	33%	43%
7.3. The value of establishing a support network between course partners is high	0%	10%	17%	30%	43%
8.1. My overall satisfaction with the competency assessment system is high	0%	3%	30%	27%	40%
9.1. My overall satisfaction with the learning process itself and the results obtained is high	0%	3%	27%	27%	43%
10.1. The general assessment of the degree of transfer of the knowledge learned at my educational centre is high	3%	10%	27%	27%	33%
10.2. The general assessment of the degree of transfer of knowledge learned in my classroom is high	3%	7%	23%	30%	37%

The statements that show the highest level of agreement, with no participant indicating partial or complete disagreement, belonging to the thematic blocks general satisfaction (83% agreement), teaching action (90% agreement)methods, content and objectives (67% agreement), and learning proposals (93% agreement) show the highest level of agreement, with no participant indicating partial or complete disagreement, and are therefore These are therefore the areas most positively evaluated by the trainees.

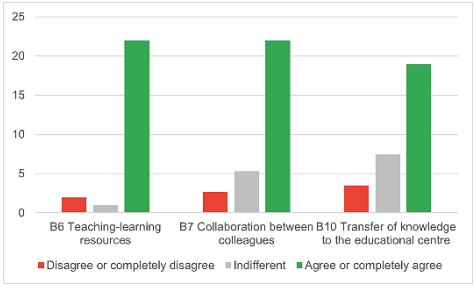

Figure 3: Top-two and bottom-two scoring for areas with highest level of disagreement.

The most problematic aspects of training, as highlighted by the responses, concern learning resources (7% disagreement), collaboration between colleagues (7% disagreement) and the applicability of what has been learned in one's own service or in one's own section/class (10% disagreement). While these percentages are quite low, they point to aspects of the course that might benefit from restructuring in the future.

One interesting aspect to highlight is that in the questionnaires filled out by the trainees who participated in the international, intensive version of the course there was no disagreement present in response to any of the items. This might point to higher levels of satisfaction with learning in a smaller group with the simultaneous presence of the three trainers, but could also depend on the active engagement of the participants during the implementation phase, which might have led them to identify with greater precision the areas in which they would have needed more support.

5.3 Post-Course Self-Evaluation Questionnaires: The Open-Ended Questions

Through thematic analysis, five themes were identified in the trainees' responses:

- Transdisciplinarity and multimodality, which encompasses all references to the intertwining of Mumabot disciplines and languages, as well as the difficulties reported by participants with specific aspects of individual disciplines;
- Effects on the trainee, the elements of professional growth, satisfaction, and difficulties highlighted by the participants;
- General evaluation, which highlights the strengths and weaknesses regarding the overall organization of the course, the coherence between the training phases, and the role of the trainers;
- Evaluation of the initial training, aspects related to the content, structure, and methodologies used in the in-person meetings reported by the participants;
- Evaluation of the implementation phase, aspects related to the materials provided, the documentation required, the evolution of the training program, and the relationship with the relevant service.

5.3.1 Is the Course Effective in Providing Teachers and Educators with the Ability to Design STEAM Activities Using Mumabot within Their Services?

Regarding our first research question, the teachers' responses reveal that designing and implementing these types of activities proved challenging yet stimulating. One participant wrote, "I tried to combine the languages (especially music and educational robotics), and although I was sceptical about the outcome of the proposals, the children surprised me." The trainees reported that the methodologies employed in the initial phase fostered their learning, particularly active involvement, the alternation of theoretical and practical phases, and the small group activities.

The main difficulty encountered was integrating all three disciplines into a single activity. This was probably at least partly due to the fact that they had learned in a strongly sectorised way during their previous education history, and often found themselves designing activities where one discipline was the main topic and the other(s) merely supportive, one of the scenarios described by Areljung (2003) as distinct from real transdisciplinarity; Another issue present in the responses of some trainees concerns a lack of familiarity with the disciplines involved and the feeling of not having acquired sufficient knowledge to best plan and manage the activity with the children. These aspects are often connected in their responses to the duration of the training, which is described as too short both in the initial training and in the implementation phase, but also seems to relate to a perceived difficulty encountered in their previous schooling on mathematics and music, combined with a feeling of inadequacy in operating in scientific and technological fields in general; Johnston et al. (2022) indicate that a more holistic and integrated approach to STEM professional training can be supportive in circumventing these predispositions, but in this case it only had a mitigating effect on a part of the participants.

Another aspect that proved to have a significant impact on the confidence of professionals in planning and implementing Mumabot activities was the collaborative dimension, which some participants found (and rated highly) within their services, but which was found lacking at the training group level. Some participants reported that they would have found intermediate meetings with the trainers and other trainees more helpful than exclusively sharing their process on the Teams platform.

Many participants who work in services for the 0-3 age group report difficulty tailoring the activities to their age group. Some of them comment how it might be useful to have more practical examples of possible activities with children in their age group in the materials provided. This aspect is also connected to the previous point, since many trainees found the Teams platform rather difficult to navigate, and therefore probably missed some of the successful activities carried out and documented by their peers working with children in that age group which might have helped them in re-designing their proposals.

Finally, some participants report difficulty integrating the proposal into their own service organization, citing a lack of resources, time, adequate space, and the large number of children in their classes.

In connection to the higher levels of agreement reported in the questionnaire by the international trainees, these difficulties and problematic aspects were present only in the written answers of the participants to the local course, which included the implementation phase conducted as RAF. It is likely that the opportunity of designing and conducting the

activities with the children, combined with the use of tools to support reflection and ongoing feedback given by tutors, made the participants more aware of the elements that could help or hinder this kind of proposal.

5.3.2 Have There Been any Changes in Their Ideas about Children's Learning in STEAM?

Many participants indicated that the proposed experience allowed them to try something new, opening their eyes to previously unconsidered aspects and methods, and encouraging them to embrace new learning. One participant wrote: "I found the transdisciplinary approach interesting, and I will bring it into my teaching. It's like starting with something children are familiar with (Lego) and developing something less familiar (musical notes) to encourage progression in a subject and delve deeper into another."

When describing the implementation phase with the children, many reported great engagement during the activity and observed the children working collaboratively and creatively, achieving a good understanding of the topics through these experiences. In the trainees' words: "The children are able to bring out all their creativity; even the shyest ones find their space and express themselves; the liveliest ones remain calm and respect Ozobot; the things learned with Mumabot remain in their memory." "The project has certainly created new bonds and opened up avenues of research among children who don't usually interact with each other."

6 CONCLUSIONS

Post-course self-assessment questionnaires revealed that the training was partially effective in providing participants with the tools to design Mumabot activities within their services, especially regarding the simultaneous use of all disciplines. Infant-toddler centre's educators encountered particular difficulties, reporting greater uncertainty about how to translate the course content into their own context. The introduction of more varied supplemental material in the online repository, including multiple examples of activities tailored to different age groups, might mitigate this difficulty. Another possible strategy to support 0-3 professionals could be a stronger focus during the initial training on how to tailor STEAM learning objectives in that age range, for example focusing on language development and problem posing skills, and more structured guidance on how to observe what the children are doing during the activity, since something that emerged from reviewing the documentation provided during the implementation phase in the local course was a lack of noticing and interpreting in this framework some of the children's actions.

Regarding STEAM learning, many trainees reported a shift in perspective on the possibility of exploring this field even with younger children, although not all of them felt sufficiently competent to do so effectively.

During the initial training phase, the interweaving of theory and hands-on activities and the close collaboration with other participants during small-group work were highlighted as beneficial in approaching complex topics which trainees didn't feel particularly confident in. During the implementation phase, the methodologies chosen to maintain contact did not appear to be able to support the creation of an educational community, and this had a strong impact on the participants that weren't able to find support inside their own services in developing their activities for the children. Adding some synchronous online meetings during the implementation phase might be a solution for supporting collaboration and exchange between trainees.

The feeling of poor mastery of the disciplines involved reported by some of the participants, for whom the initial training proved insufficient, is consistent with the findings of Johnston et al. (2022) in their scoping review of STEM and STEAM in early childhood services, namely that many professionals working in these fields feel the need for more in-depth support in these areas of knowledge that are considered outside their knowledge base. It is possible that a longer initial training focused on supporting the acquisition of the individual core disciplinary concepts might have sustained the trainee's learning better, though considering the difficulties reported by the participants in adopting the transdisciplinary approach in their services this change might exacerbate the existing disciplinary divide in their conception of knowledge. Another possible route would be revising the hands-on activities presented during the initial training to be each more focused on a singular shared concept, while maintaining throughout the connections between the three disciplines and the presence of multiple semiotic mediators.

Regarding the difficulty reported by many participants in integrating Mumabot activities inside their services due to structural constraints, one

possible improvement would be conducting the training at the service level, involving multiple professionals and the pedagogical coordinator to co-design ways in which the service organization could work with - instead of against - the introduction of this kind of activity, laying the foundations for a continued practice.

The two different versions of the course presented peculiarities that influenced the way the course was experienced by the trainees. On one hand, the longer timeframe and the presence of the RAF in the local course gave the Italian participants a chance to reflect in action and describe more in-depth strengths and weaknesses of their training. On the other, the reduced number of participants and the intensive schedule of the international course allowed the trainees to better discuss the theoretical concepts behind the hands-on activities.

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