An Overview of European Projects About Computational Thinking

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Abstract. Computational thinking is a 21st-century skill and an emerging global issue. Despite the great benefits for the educational context, there is little knowledge about the projects being carried out in the European context. Therefore, it was decided to re-conduct a systematic review of trends in projects addressing Computational Thinking at the pre-university level in Europe. The search was carried out in the CORDIS and Erasmus+ databases and several inclusion, exclusion and quality criteria were applied. The main results show most projects foster computational thinking across STEM subjects. Moreover, institutions in Spain and Italy tend to be more involved. Also, the projects provide digital didactic material for teachers to work within the classroom to foster students' computational thinking development. Furthermore, they propose action plans and activities be incorporated into the curricula of any institution.

Keywords: pre-university education · European projects · computational thinking · systematic research projects review · SRPR

1 Introduction

In the Information and Knowledge Society, individuals must develop computational thinking (CT) to cope with a changing and demanding labour market. According to Wing [1, 2], "Computational thinking is 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". For this reason, the European Union promotes the teaching-learning of programming in science, technology, engineering and mathematics (STEM) areas. Contributing to the above idea, [3] point out the need to promote CT from early childhood education or in the first years of primary education through the principle of activation. This principle consists of incorporating activities and resources into the curriculum.

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The development of computational thinking brings advantages to individuals, such as creativity, effective and safe use of technologies, supports for digital competence, and enhances problem-solving, among others [4, 5]. Despite this, no studies investigate computational thinking projects in pre-university stages in the European context.

Therefore, this study analyses European research projects related to Computational Thinking to understand the trends and their contributions to society. The paper is divided into six sections. Section 2 details the mapping process. Section 3 describes the data selection and extraction processes. Section 4 presents the results from the mapping questions. Finally, we summarised the main conclusions.

2 Methodology

The methodology used to obtain a coherent, detailed, selective and critical study was the systematic research projects review (SRPR) [6]. This approach is an adaptation of systematic literature reviews proposed [7–9] and Petersen's proposal to carry out systematic mapping studies [10, 11]. It allows reviewing the compendium of resources, documents, and information, which form a research project. This analysis is rigorous, structured, reproducible and uniform, aiming to synthesise information qualitatively and quantitatively.

The main difficulty of conducting a review of research projects is identifying the documentation associated with the project to make decisions. If a project is not included in the final selection of the SRPR does not mean that the project is not valid, it means that there is not enough information available to know more details about the project aims, activities and results.

2.1 Mapping Questions

The research aims to find out the trends of projects dealing with computational thinking in pre-university education in the European context. The following questions (MQ) were considered:

- MQ1: What are European research trends regarding computational thinking at pre-university level?
- MQ2: In which countries were the projects implemented?
- MQ3: Which calls for proposals fund this type of research project?
- MQ4: What years do the projects cover?
- MQ5: How much money has been invested in these projects?
- MQ6: In what context were the projects carried out?
- MQ7: What actions have been developed in the projects?

The study also used the PICOC method [12] to review the scope of the project:

- Population (P): European research projects.
- Intervention (I): European research projects that develop studies related to computational thinking at pre-university level (preschool, primary, secondary, vocational, high school).
- Comparison (C): no comparison.
- Outputs (O): to know the trends in computational thinking studies at pre-university stages.
- Context (C): pre-university education.

2.2 Inclusion, Exclusion and Quality Criteria

The project selection process involved several phases in which the projects were analysed. In the first phase, inclusion and exclusion criteria were applied. The inclusion criteria (IC) are:

- IC1: The project addresses issues of computational thinking in pre-university education AND
- IC2: The project is available in the most relevant databases supported by the European Union AND
- IC3: Information on the project is available in English or Spanish.

In contrast, the exclusion criteria are the opposite of the inclusion criteria, so we discarded projects that are not related to computational thinking or are focused on higher education, projects that are not accessible in the European databases, or projects that are not available in English or Spanish.

The inclusion and exclusion criteria do not ensure the results' quality, making it difficult to answer the proposed research questions. Therefore, in the second phase, filtering is carried out by applying criteria, ensuring quality. The quality criteria applied are based on those described by the SRPR guidelines [6]:

- The project website is available.
- The project results are available.
- There is more information in English or Spanish about the project than in the project summary.
- The project focuses on computational thinking.
- The project was carried out in different countries.
- The project has some kind of evaluation process focusing on computational thinking.
- The project provides a proposal for introducing computational thinking into the curriculum.
- The project activity continues after the funding period.

2.3 Sources and Search String

In Europe, different bodies fund national, regional, and international research projects. This study considers the last two levels. It excludes projects at the national and regional levels because they are not English or Spanish-speaking, as this is an established exclusion criterion. Therefore, the chosen databases meet the requirements defined by [6]:

- It is a reference database in the European context.
- It is a relevant database in the research area of this study.
- It allows searching and downloading results in an accessible format.
- It is a database available through the authors' institution or authors' membership in an association.

In this study, we searched four European databases: CORDIS (Community Research and Development Information Service) (https://cordis.europa.eu/); the Erasmus+ Project results database (https://ec.europa.eu/programmes/erasmus-plus/projects/); the KEEP database, Knowledge and Expertise in European Programs (https://keep.eu/); and the database of the European Investment Bank (IEB) (https://www.eib.org/en/projects/).

The search terms were "computational thinking" and "education". We combine them to create the search string: ("computational thinking" AND "education").

3 Data Extraction

The data extraction process was carried out in different stages. The process is represented in the PRISMA 2020 flow diagram (Fig. 1). In the first stage, the search strategy was applied in each database to collect projects on computational thinking in pre-university education. However, no information on the topic was found in two of the four databases chosen. The Cordis results were extracted in text format and the Erasmus+ results were extracted in a Microsoft Excel file. The results were combined in a Google Sheets document to be shared openly. (https://bit.ly/3v2S1aF). No duplicates were found.

In the second stage, inclusion and exclusion criteria were applied to all projects to determine whether or not it was relevant candidate. A detailed reading of each project's title, abstract and keywords was carried out to determine the selection. The selected projects are related to computational thinking at pre-university level. The quality criteria were applied to ensure that the above choice was correct. However, before applying these criteria, each project's website or related documents were identified because the databases only provide basic information on the projects. For this reason, a search was conducted on Google and Google Scholar using the project name or reference number.

Each quality criterion is related to a score: 1 (Yes), 0 (No) and 0.5 (Partially). Projects with non-deductible answers were given a dash, which means no value. Only projects that achieved an average of 4.5 out of 9 points passed to the next stage, the final analysis (https://bit.ly/3aRI897).

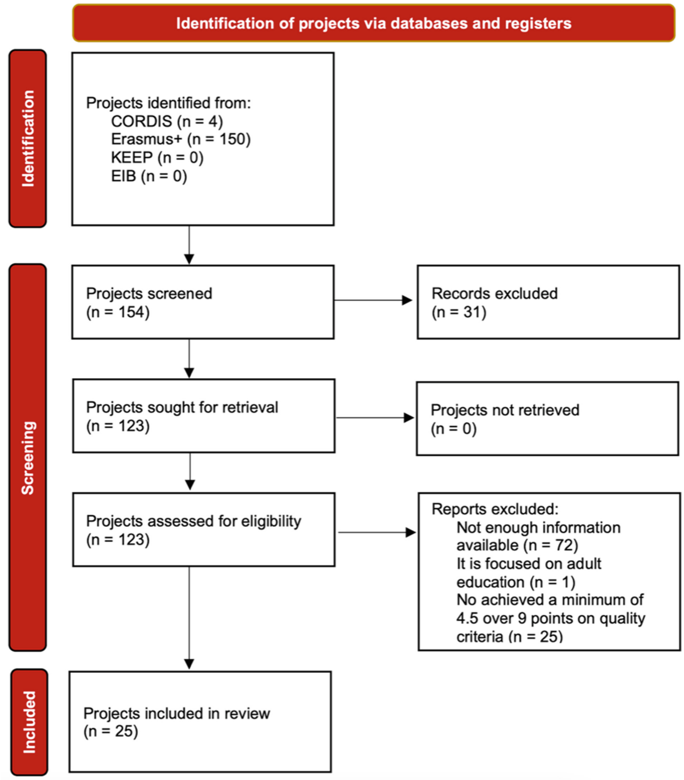

Fig. 1. Identification process adapted from PRISMA 2020 flow diagram [13]

4 Results

4.1 What are European Research Trends Regarding Computational Thinking at Pre-university Level?

Most of the projects focus on fostering and embedding computational thinking in STEM subjects; they consider the use of robotics, the Internet of Things, different programming environments, digital services and the use and creation of open resources. They also promote computational modelling and coding and incorporate unplugged approaches. Table 1 summarizes the main objectives.

4.2 In Which Countries Were the Projects Implemented?

A total of 108 institutions are involved in the 25 selected projects. There are institutions from 28 countries (Table 2). The number of participating institutions from Italy (15), Spain (12) and Poland (8) stands out.

Table 1. Main objectives of the selected projects

Title	Objectives
Active Media Education for Disabled Youth (AMEDY) 2018-3-DE04-KA205-017101	Train children and young people with disabilities in digital literacy (basic ICT skills, information literacy, media literacy and computational thinking), digital devices and services. To offer online training to professionals working with them
Code to Create new knowledge using programming in primary school (Code to create) 2016-1-SE01-KA219-022112	Support the exchange of good practice, and create methods for teaching programming in Mathematics, Technology and Crafts. Create an open and innovative resource for teachers
CODING in a cultural Europe 2018-1-ES01-KA229-051065	Create a vertical computational thinking curriculum for students aged 3–13 years. Train teachers in these subjects
Coding the future 2018-1-IT02-KA101-047650	Train secondary school teachers on coding and computational thinking through learning mobility
COmputational thinking and Digital skills in European education for all (Code4all) 2017-1-IT02-KA219-036645	Develop computational thinking so that they can understand how to use technology and become future digital citizens
Computational Thinking Learning Environment for Teachers in Europe (COLETTE) 2020-1-DE03-KA201-077363	Developing a learning environment for teaching and learning computational thinking
Creative Opinions Differentiate Education in Maths (C.O.D.E in Maths) 2018-1-TR01-KA229-059796	Encourage students toward computational thinking and mathematics through robotics and coding to train teachers in robotics, cooperation and leadership
Developing make spaces to promote creativity around STEM in schools (STEMJAM) 2016-1-ES01-KA201-025470	Improve STEM skills (including Computational Thinking) in secondary school students
Developing Teaching Materials for Preschool Teaching Undergraduates on Computational Thinking and Introduction to Coding (EarlyCode) 2018-1-TR01-KA203-058832	Encourage and develop computational and algorithmic thinking in the early years
Development of computational and algorithmic thinking in basic education (PIAF) 2018-1-BE01-KA201-038611	Develop various types of computational thinking activities to support teachers

(*continued*)

Table 1. (*continued*)

Title	Objectives
Gifted European mathematician (GEM) 2017-1-RO01-KA201-037470	Literacy in mathematics and English, use computational thinking, and use mathematical procedures and tools to solve challenges, situations and games
Integrating STEAM and Computational Thinking development by using robotics and physical devices (RoboSTEAM) 2018-1-ES01-KA201-050939	Define a knowledge base to facilitate integrating STEAM and computational thinking using robots. This is done by developing pilot programs, gathering good practices and tools, and defining learning actions and educational resources for teachers [14, 15]
It's Logical, dear Math! 2017-1-PT01-KA219-035766	Develop mathematical and logical thinking using innovative activities and gamification strategies to link mathematical thinking with logical and computational thinking
Modeling at School 2018-1-AT01-KA201-039268	To put the educational pyramid scheme and computer modelling (including the development of computational thinking, creativity, and problem-solving) into school practice for teachers and students
No One Left Behind H2020-ICT-2014-1	Create a programming environment (dynamics, assets and analysis in the SME game) in mobile media for children [16]
Not one less (Non uno di meno) 2018-1-IT02-KA229-048416	Apply Tinkering methodology in infant school, introduce Coding and Robotics activities (including the application of computational thinking) in primary school and experiment with CLIL methodology in STEM subjects
Reviving hands on educational play for learning skills of tomorrow (Play2Learn) 2019-1-UK01-KA201-061466	Support teachers to encourage children to engage with computational thinking and programming and to develop STEM-related skills and competences
roBOTics and STEM education for children and primary schools (BotSTEAM) 2017-1-ES01-KA201-038204	Provide early childhood and primary school teachers with a new didactic model and integrated STEM activities based on research and tested with robotics

(*continued*)

Table 1. (*continued*)

Title	Objectives
Robotics through sign language: ensuring access and engagement of students with disabilities (deaf or with hearing impairment) to the digital world of coding and robotics (ROBOTICS4DEAF) 2019-1-PL01-KA201-065123	To train teachers working with deaf students. And develop an educational training package, a digital platform and a mobile application to promote coding and robotics skills (including computational thinking) among students with deafness or hearing impairment in formal or non-formal settings
Science, Technology, Engineering, ARTS and Mathematics - Computational Thinking (STEAM-CT) 2019-1-BE02-KA201-060222	Strengthen the teaching and learning of computational thinking skills
STEM Learning Activities & Methods (SLAM) 2018-1-HR01-KA229-047465	Create and develop devices, and exchange practices and learning materials in the STEM area through computational thinking
Step into Future 2017-1-HR01-KA101-035279	Train 8 teachers in technological competences, learning assessment and language teaching through computational thinking, coding and tablets
TACCLE3 – Coding 2015-1-BE02-KA201-012307	Encourage and support teachers to introduce coding, programming and/or computational thinking in the curriculum. To develop digital skills and improve their professional competence, and act as an exchange space for curricula, ideas and practices [17]
We grow digitally 2018-1-IT02-KA229-048037	Develop digital competences (including computational thinking) for students and teachers through activities
Working together: Education through new bridges 2019-1-ES01-KA229-065886	Improve digital competence and attention to diversity through computational and critical thinking

Among the institutions involved, six institutions have participated in two projects. These institutions are Ita-Suomen Yliopisto (Finland), Universidad de Salamanca (Spain), Universitat Linz (Austria), A & A Emphasys Interactive Solutions Ltd. (Cyprus) and Karlsruher Institut Fuer Technologie (Germany).

In terms of project coordination (Fig. 2), Spain is the country that coordinates the most projects on computational thinking (24%), followed by Italy (16%) and Belgium (12%).

Table 2. Number of partners per country

Country	Partners (N = 108)	%
Italy	15	13.89
Spain	12	11.11
Poland	8	7.41
Portugal	7	6.48
Turkey, Germany	6	5.56
United Kingdom, Greece, Finland	5	4.63
Romania, Belgium, Sweden, Cyprus	4	3.70
Austria, Croatia, Slovakia, Lithuania	3	2.78
France, Estonia, Latvia	2	1.85
Luxembourg, Ireland, Bulgaria, The Netherlands, Hungary	1	0.93

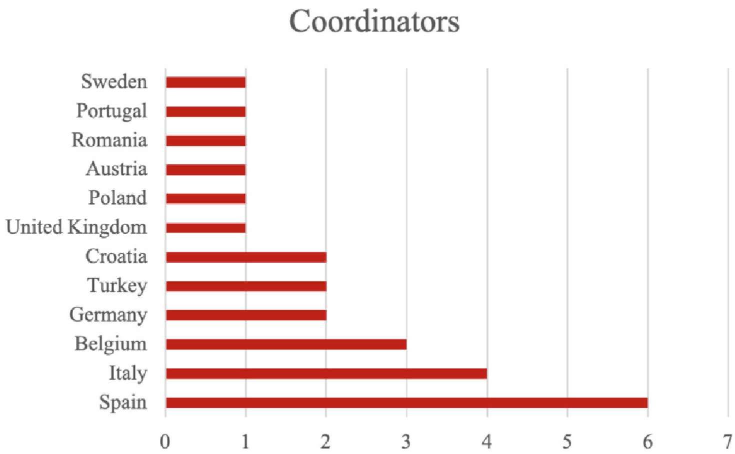

Fig. 2. Country in which the coordinating institution is located

4.3 Which Calls for Proposals Fund this Type of Research Project?

The selected projects and calls are only from the Erasmus+ and CORDIS databases. In particular, the Erasmus+ projects are from the key actions Cooperation for innovation and the exchange of good practices and Learning Mobility of Individuals. Regarding CORDIS, there is only one project from Horizon 2020 (H2020). Specifically, 96% are Erasmus+ funded projects and 4% are CORDIS H2020 funded projects.

4.4 What Years do the Projects Cover?

Of the 25 selected projects, 56% had a duration of 2 years, 32% had a duration of 3 years and 12% had a duration of one year. Regarding the year of funding, most selected projects were in 2018. Figure 3 shows a summary of the projects funded for each corresponding year.

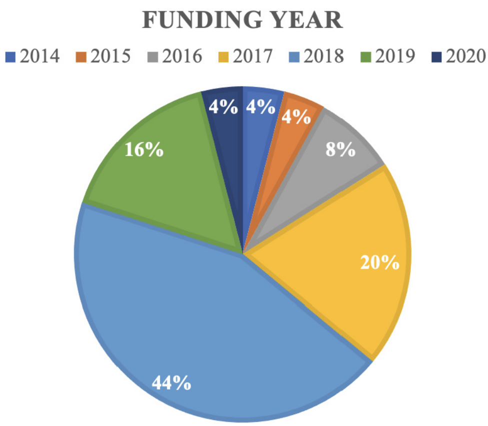

Fig. 3. Number of projects per funding year

4.5 How Much Money Has Been Invested in These Projects?

The projects available in the CORDIS database, specifically the H2020 projects, have a larger budget than the Erasmus+ projects. Table 3 shows that H2020 project funding represents almost 50% of the sum of the 22 "Cooperation for innovation and the exchange of good practices" projects. The year with the highest investment for projects focused on computational thinking at pre-university stage was 2014 (Table 4), which corresponds to the CORDIS project. In total, the European Commission, from 2014 to 2020, has invested 6 938 284.66 euros in projects related to computational thinking.

Table 3. Investment per programme

Database	Programme	Investment €	Projects (N = 25)
Erasmus+	Cooperation for innovation and the exchange of good practices	4 208 456.66	22
	Learning Mobility of Individuals	41 903.00	2
CORDIS	H2020	2 687 925.00	1

Table 4. Investment per funded year.

Funding year	Investment €	Projects (N = 25)
2014	3 082 741.25	1
2015	277 856.84	1
2016	150 705.00	2
2017	774 302.00	5
2018	1 678 397.82	11
2019	971 438.00	4
2020	397 660.00	1

4.6 In What Context Were the Projects Carried Out?

The majority of the 25 projects selected focus on secondary and primary education levels. In addition, 15 projects address two or more educational levels, such as childhood and primary and/or secondary education (4), childhood and higher education (1), primary and secondary education (7), and secondary and higher education (3) (Fig. 4). Although higher education is not the focus of this study, the selected projects include future teachers as the target group, so there are actions and resources for training them during their university studies.

On the other hand, regarding target groups, all projects consider students from different educational levels. Moreover, most projects focus on service teachers and/or future teachers (92%). Highlight that we have identified 4 projects (16%) that consider parents or families and 5 projects that involve teacher trainers (20%).

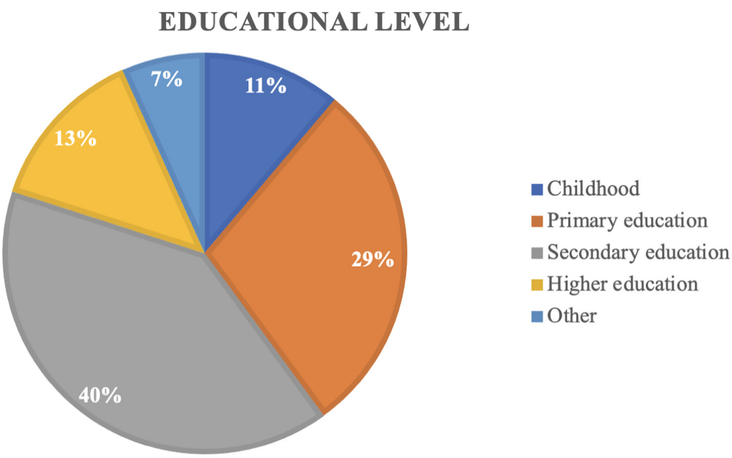

Fig. 4. Educational levels addressed in the projects

4.7 What Actions Have Been Developed in the Projects?

The main results of the selected projects refer to the creation of digital teaching materials to support teachers in developing computational thinking in students (Table 5). In addition, 10 projects have created and proposed guides, modules or action plans to guide the educational community in introducing computational thinking in any area, not only STEM. On the contrary, few results point to the creation of assessment rubrics and an improvement in the educational offer of the participating institutions (Table 5).

Table 5. Main projects actions

Title/Acronym	Activities and results
AMEDY	Seminars, multiplier events. Creation of support materials and online training for professionals
Code to create	Lessons in mathematics, technology and handicrafts in schools for use in the classroom. Workshops, online courses
CODING in a cultural Europe	Online and offline coding activities, using programming platforms such as Scratch Junior and Scratch to develop games and digital storytelling
Coding the future	A course on using and integrating web platforms, applications and mobile apps in educational contexts
Code4all	Meetings, events, teacher mobility and product creation
COLETTE	Creation and implementation of a handbook, web portal and mobile app, training of teachers based on the short-term curriculum, conference on the project and its results
C.O.D.E in Maths	Mobilities that include workshops, field work, excursions, socialisation events, competitions, games and meetings with experts on related topics
STEMJAM	Workspaces for coding and computational thinking
EarlyCode	Training Materials Manual, Training Manual on Computational Thinking and Introduction to Coding
PIAF	Ten seminars and symposia. Creating meaningful activities (experiences, lesson plans and design of educational resources) and assessment tools

(*continued*)

Table 5. (*continued*)

Title/Acronym	Activities and results
GEM	Two courses (Maths and Coding; MATHISH MASTERS), and a GAMING itinerary based on didactic units and outdoor events
RoboSTEAM	Systematic mapping, test contexts, design of open hardware kits, design and implementation of RoboSTEM Environment
Step into Future	Advanced training and internships. Study plans in subjects and curriculum, creation of digital educational material
It's Logical, dear Math!	A gamified contest, mixing the PISA assessment and the national curriculum of each country
Modeling at School	Workshops and a congress for teachers and students. Generic curriculum, modelling and assessment tools. Online collection of units and teaching materials
No One Left Behind	Co-creation of games or projects for the curriculum. Creation of lesson plans for 3 curricular areas. And three pilots in UK, Austria, and Spain with 600 children/students from schools and academies
Not one less (Non uno di meno)	Training course about Coding in CLIL. The activities were carried out through the methodology "learning by doing and learning by playing" to address the topic of robotics and coding
Play2Learn	Play2Learn hands-on game kit, development of animated videos about the hands-on game, educational modules, transcription of the contents into interactive multimedia resources. Planning of learning units to experiment in schools
BotSTEAM	Online events, webinars, workshops, assessment rubrics, toolkit and boSTEAM game
ROBOTICS4DEAF	Training on an e-learning platform. Workshops with Scratch, Gears, Catapult, Lego Mindstorm. Comparative report on the education system, disability law and inclusion of deaf students in partner countries. Creating an Inclusive Ecosystem for teaching, learning and assessment of coding and robotics through digital badges. Guidance for establishing Robotics4Deaf clubs

(*continued*)

Table 5. (*continued*)

Title/Acronym	Activities and results
STEAM-CT	Online course and a didactic model “Educating children to become creative problem solvers”
SLAM	Workshops, webinars, presentations and meetings. Participation in Science Days, visits science festivals, preparation of speeches by scientists. Field experiments and research
TACCLE3	Creation of a website of activities and ideas for teaching coding and programming. And creation of resource kits
We grow digitally	Workshops, discussions and labs on Scratch
Working together: Education through new bridges	Programming and robotics workshops and activities (Scratch JR. - Scratch 3.0) and CLIL with ICT. Creation of a repository of contents and activities

5 Conclusions

The study analyses the projects on computational thinking in pre-university stages, funded by the European Commission in the different calls for proposals since 2014. This topic is on the rise and is one of the priorities of education systems, governmental and non-governmental organisations and universities. The countries that are promoting computational thinking the most are Spain and Italy.

The projects promote computational thinking through STEM subjects to educate the citizens of the future. In addition, most of them focus on students and teachers at secondary level and therefore propose curricula, activities, modules, games and activities that can be used and implemented in institutions, with and without using technologies. Finally, it should be noted that few projects continue after their funding period.

All research has a percentage of bias, which could affect validity. In this study, all authors were involved throughout the review process. In addition, several quality criteria were established to analyse the project information. The information comes from the abstract, web pages, scientific publications, papers, and videos, among others.

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