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Mapping Spontaneous Cooperation between Children in Automata Construction Workshops

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Abstract: This work analyzes spontaneous cooperation between children who participated in Automata for STEM, European Union funded Erasmus+ project workshops. Taking into account the characteristics of automata, that involve a narrative part and a mechanism, the project used them to implement contextualized and interdisciplinary STEM activities. The pedagogical method involved the presentation of automata, and children being challenged to plan and construct their own. Although no cooperative learning strategies were imposed during the workshops, this research aimed to identify types of spontaneous cooperation that could emerge among children. Data was gathered through participant observation and a questionnaire. Core dimensions of spontaneous cooperation were identified as well as specific dimensions, pointing to a divergent type, characterized by involvement between pairs of children in different projects, and to another type, convergent, involving work between pairs of children in the same project. Spontaneous cooperation also varied according to the children's age or the workshop structure. During workshops with children aged 6–7 years, the class teacher was present and provided guidance, the children were seated in pairs or in a presentation arrangement. During workshops for older children of 8–9 years of age, there was less guidance and the class teacher sometimes was not even in the room the children worked at round tables.

Keywords: automata construction; spontaneous cooperation; children; STEM

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1. Introduction

This work focuses on the analysis of spontaneous cooperation between children who participated in Automata for STEM European Union funded Erasmus+ project workshops. The project aims to explore automata construction as a strategy to plan and implement contextualized and interdisciplinary activities in Science, Technology, Engineering, and Mathematics (STEM) [1].

STEM competencies are of growing importance in a world where the pace of change and the need for technological advances have become critical to our survival. It is important then to promote appropriate STEM experiences in early childhood, as these can be starting points for supporting children's continued successes in STEM and other subjects at the primary, secondary, and post-secondary levels [2]. Although STEM is usually interchangeable with 'science' in several national and international reports, referring to the various domains of knowledge covered by the acronym, this can also be used to describe interdisciplinary approaches that make connections between some of the four disciplines. In this case, the meaning of STEM is usually expanded to refer to a rupture with 'traditional' teaching. An integrative STEM education usually implies multidisciplinary teaching and is directed at developing students' problem-framing and problem-solving skills, as well as their ability to contextualize scientific concepts to real-life situations. In this understanding, STEM education is not defined in terms of a break with traditional subjects, but rather a break from traditional instruction, in which lessons are strictly focused on the delivery of subject-specific content by the teacher and the acquisition of content knowledge by the students [3] (p. 6). However, a large-scale survey launched by Scientix in 2018, in 25 EU languages [4] about secondary school teachers teaching practices in STEM education shows that 'traditional teaching instruction, resources and materials still prevail in STEM classes' [4] (p. 43). In fact, although there was 'a diverse landscape, with STEM teachers trying their hand at new pedagogies and diversifying the resources and materials they use in their practice (...) these attempts are still in their early stages and need continuous support' [4] (p. 43). A review of empirical studies about STEM education in early childhood education developed by Wan, Jiang and Zhan points in the same direction, stating that 'early childhood teachers perceived the values of STEM education from the learning and social perspectives while they realized various practical constrains of time, support and resources, and worries about the teachers' capacity and subject knowledge, and considered students, developmental differences and safety. They were not confident to implement STEM lessons with their young students' [5] (p. 1).

The framework, aims and activities of the project AutoSTEM are in line with the interdisciplinary approach proposed by the STEM framework. A pedagogical approach to using automata construction in class can be based on toys, that combine narratives and mechanical movements and take into account that they consist of two fundamental parts: a figure, or a set of figures that can represent an idea or narrative; and a mechanism allowing the movement of the figure(s). These characteristics allow, in a playful approach, to implement activities related to the planning and construction of those automata and to enhance skills such as observation, problem-solving and cooperation. The narrative dimension can introduce elementary mathematics, geometry, engineering and physics, geology, and other science content while enhancing other abilities and attitudes with very affordable equipment made solely of recycled materials. Constructing automata allows the children not only to experience one or more areas of STEM but also to discover relationships and connections between the different disciplines and enhance soft skills.

Automata construction also foster playful pedagogical approaches. In the scope of the AutoSTEM pedagogical framework [2], some concepts were considered as relational play-based pedagogy [6] within a dynamic learning concept [7]. According to Froebel [8] and Vygotsky [9], play is considered an opportunity for child development, exploring beyond their 'Zone of Proximal Development' (ZPD). 'In play, a child always behaves beyond his average age, above his daily behavior' [9] (p. 102). However, for this to happen, it is necessary that the play environment challenges the children to cross their Zone of Proximal Development [10]. The role of the teacher is then crucial to analyze how play can promote children's development [11–16]. In this scope, 'guided play', as a middle ground between direct instruction and free play, has been considered as a pathway to combine exploration and child autonomy with teacher guidance [12]. In 'guided play', teachers act as 'commentors, co-players, questioners, or demonstrators of new ways to interact with the materials involved' [11] (p. 275) in order to enhance the children's learning experiences while the 'children direct their own learning within the established play context' [11] (p. 275). According to research on the topic, guided play helps children achieve a better understanding of academic concepts compared to direct instruction [13,14] or free play alone [15,16].

In addition to aiming to promote STEM competences, the Automata for STEM project also aims to promote transversal competences. Since one of the transversal competences that is intended to be developed, within the activities of the project, consists of cooperation, we tried to observe how spontaneous cooperative forms emerge, even though cooperative learning strategies have not been introduced explicitly. Our aim was to explore how the emergence of cooperation is related to the dynamics of the activity proposed, the habitus, culture, classroom arrangement, the educator's attitude, and the children's age.

Cooperation is a form of interaction between two or more individuals. What distinguishes cooperation from other forms of interaction is the fact that it takes place according to an objective common to these two or more individuals. In this way, cooperation emerges as a way to achieve a goal that individually could not be achieved [17]. Indeed, cooperative learning is now advocated as a form of high-impact instruction [18], which refers to various strategies used in the classroom, designed to create active learning and involvement among students. These strategies are based on principles and procedures, which are different to ordinary group work, constituting an alternative to competitive and individualistic structures, contributing to better cognitive learning and the development of social skills. These strategies have different structures and syntaxes, which individualize them (jigsaw, cooperative scripting, learning together, group investigation and many more).

Hargreaves [19], a defender of these strategies, considers that they should be included in the repertoire of teachers. However, he recommends that they should be used with flexibility and discretion, recognizing that their introduction in schools and classrooms constitutes a safe simulation, artificial and bureaucratic, of the forms of collaboration that are more spontaneous and are possible among students, which have been somehow eradicated by the school and teachers, through discipline control and assessment practices. These forms of spontaneous cooperation are of great value and unpredictability as the locus of control of cooperation is in the student.

One of the components of cooperative learning consists of positive interdependence, which assumes several modalities, namely, the interdependence of purposes, when group members work towards a common purpose, of the task, when 'two hands are not enough', of resources, and the environment/space where the group works, which can become a unifying element [20]. It is in this sense that we consider that these forms of interdependence can be observed during the automata construction workshops, among others, without having been instructed for this type of learning [21]. These forms of cooperation can be named spontaneous cooperation and are characterized, by the positive interdependence between participants in order to develop the task, usually present in more structured cooperative strategies referred in the previous paragraph; and by the locus of control of cooperation to be with the students and not with the teachers. In this scope, there are no formal instructions nor rules about how to organize the cooperation as there are in teaching and learning cooperative strategies. These forms of spontaneous cooperation can take a divergent or convergent modality as explained in the next paragraph.

When analyzing cooperation among children, it is important to take into account findings from developmental psychology. It is known that cooperation between children only becomes possible when overcoming egocentrism. This one is characterized, in Piagetian terms, by the difficulty of the child to put themselves in the perspective of another, which prevents co-operation, which supposes the coordination of different perspectives [22]. However, research evidences that peer cooperation emerges at the end of the second year, children being able to cooperate with one another more systematically as well, recognizing and generating joint intentions and goals. Thus, children should become progressively more capable of taking their peer's goal-related activity into account in concert with their own, and to adjust their own behavior accordingly by monitoring, timing, and sequencing their behavior together with the peer to attain a shared goal year [23] (p.4). Additionally, Anderson [24] argues that the development of intersubjectivity leads to the use of playful activities that can be already observed in young children: a divergent play, in which children are still mainly centered on their own interests. Even if they are playing with other children, the most complex being a convergent engagement, which assumes a clear collaboration between peers. The interdependence between cognitive and social development will enable the observation of interactions between children in which reciprocity, solidarity and a sense of justice become present in the relationship between equals.

Additionally, assuming that the ability to cooperate can be more or less stimulated by the educational environment, the present work focuses on the analysis of spontaneous cooperation between children who participated in the AutoSTEM project workshops. The research aims to characterize spontaneous cooperation that emerges during the workshops and to explore how it can vary taking into account the task, the resources used, as well as the habitus, culture, classroom arrangement, the children's age or the teacher's attitudes.

2. Materials and Methods

According to the objectives of this study and the research questions, a qualitative study was carried out, based on grounded theory [25], using participant observation and activity reports.

2.1. Corpus, Data Gathering and Analysis

The corpus considered included data gathered during four AutoSTEM workshops. Data was gathered through participant observation, registering notes, photos and videos and a questionnaire. This data was gathered in the scope of the workshop's evaluation process. Templates can be found at https://www.autostem.info/wp-content/uploads/2019/11/IO-I-B2Template-to-collect-piloting-children2019-10-20-1.pdf (accessed on 2 January 2021).

The observation guide included general dimensions to be considered, related to the structure of the workshop, as well as engagement, satisfaction, and automata developed, in order to analyze learning and creativity. During the workshop, the trainers talked with the children about their ideas and took notes. Additionally, photos were taken in order to illustrate the work developed by each child, the different steps and the final products.

At the end of the workshop, each child completed a short questionnaire about satisfaction and perception of learning. The questionnaire included statements and open questions about motivation, following Deci and Ryan indicators for intrinsic motivation [26], perception of learning, experienced difficulties, and suggestions for improvement.

A report for each workshop was developed including data gathered.

Participant observation notes and photos were analyzed through content analysis according to Charmaz [25]. The analysis involved coding data in an iterative process, aiming to identify categories related with spontaneous cooperation during the workshops. Questions were based on the categories proposed by the results;'How do children cooperate when constructing automata? Where? When?', 'How? and for what purpose did the children cooperate?', as well as comparisons such as 'Which characteristics were common to Workshops 1, 2, and 3 and different to Workshop 4?'

Answers to the questionnaire were also coded to identify the main topics about perception of learning.

2.2. Pedagogical Approach

The pedagogical general method followed in all the workshops involved the presentation of prepared automata to the participants and the children being challenged to plan and construct their own. The starting point is the observation and analysis of the automata. The children observe the movement of the automata and explore the mechanisms in order to discover and understand how they work. Before the children can construct their own automata, they must decide on the one they want to build. Next the children must design the mechanisms, plan the construction process construct it, reflect, and then play with it.

However, there were some differences in the workshops. A short description of each workshop is presented.

Workshop 1: involved 22 children of the 2nd grade of a primary school, who were 7 years old. The session lasted two hours and took place in class in the presence of the class teacher and four educators collaborating in the AutoSTEM project. In this session, a friction drive mechanism was presented with different narrative examples. The specific theme of this session included the environment, so it was expected that the children would work around that theme and develop some understanding of the topic. To introduce the theme, a poem was read on the topic of saving the blue planet. After reading the poem, children were challenged to plan and construct their own automata. Some instructions were given about how to construct the mechanism, but the children could develop their own ideas and narratives for the automata. Although all the prototypes had the friction drive mechanism, there were different narratives, e.g. a dancing doll, a carrousel, and the Earth.

Workshop 2; involved 22 children of the 2nd grade of a primary school, who were 7 years old. As in Workshop 1, the session lasted two hours and took place in class in the presence of the class teacher and four educators collaborating in the AutoSTEM project. In this session, the friction drive mechanism was presented. The structure of the workshop was also very similar to Workshop 1. The specific theme of this session was the environment, so it was expected that the children would work around that theme and develop some understanding of the topic. To introduce the theme, a poem was read on the topic of saving the blue planet. Children followed the instructions, planned and developed their own projects.

Workshop 3 was a two-hour session that took place in a classroom, involving 22 children from the first grade, between the ages of 6 and 7 years. The class teacher was present as well as four educators from the AutoSTEM project. The session began with the presentation of some examples of automata with a linkage mechanism. After this presentation, some direct instructions were given about how to build the mechanism. The teacher made this decision based on the children's young age. After the assembling their automata, the children had total freedom to decorate their own toys and create a narrative about them. In the second part of the session, some lever automata were presented and the children were given some instructions about how to build them. Again, the children had total freedom in terms of how to decorate.

Workshop 4 consisted of two sessions, lasted a total of three hours, and involved 21 children in the first session and 19 children in the second session. These children were between 9 and 10 years old. The workshop took place in the school library in the presence of the librarian teacher and four educators collaborating in the AutoSTEM project. The class teacher was not present. In this workshop, children were presented with different automata, with a friction drive mechanism and one with a lever and linkages. The activity started with a short presentation about the project and some examples of automata. After that, a story about the environment was read in order to inspire the children regarding the theme. Afterwards, the children were free to create their own automata based on the mechanisms that had been shown to them. The theme of this session was related to the school network project and the sciences and citizenship curriculums. In order to develop their project, children first observed some examples, but were then free to innovate and could make adaptations through experiences and tests.

To sum up, although workshops had a similar general structure, there were some differences: in three of the workshops, a poem about the Earth was presented, and in one of the workshops took place in the library, while the others took place in class with children seating in pairs or large classroom arrangements. There were different class arrangements: in pairs, at round tables, in a presentation format. Teachers and educators scaffolded the process. In the library workshop (workshop 4) there were minimum instructions by the adults, while in the classroom workshops, some instructions were given. The class teacher was not present in the library workshop.

It is important to highlight that there were no formal instructions or rules for cooperative work, methodology or other techniques in any of the workshops.

3. Findings

Workshop reports, including observation field notes and photos were analyzed following methodological procedures proposed in the framework of grounded theory [25].

3.1. Dimensions

Behaviors or expressions of cooperation were identified, constituting units of analysis, when answering the question 'How did children cooperate when constructing automata?' These are presented in Table 1 and included in a category named dimensions of spontaneous cooperation.

Table 1. Core and specific dimensions of spontaneous cooperation.

How Did Children Cooperate When Constructing Automata?	Workshop	
Informal distribution of tasks	1, 2, 3, and 4	Core dimensions
Sharing materials	1, 2, 3, and 4	
Observing each others work	1, 2, 3, and 4	
Helping with construction	1, 2, 3, and 4	
Interdependence of purposes	4	Specific dimensions
Coordinating actions	4	
Shared tasks	4	
All ideas are considered and included in the automaton	4	
To imitate and being inspired by a colleagues' work	1, 2, and 3	
Selfless willingness to help a colleague	1, 2, and 3	

Then the question was 'Where did the dimensions of spontaneous cooperation take place?'. Some behaviors and non-verbal expressions of spontaneous cooperation were identified in all four workshops, while others were only identified in some of the workshops.

Based on this observation, a distinction was suggested between core dimensions of spontaneous cooperation and specific dimensions (Table 1).

3.2. Working Modality

The distribution of the spontaneous cooperation dimension between the workshops led to the questioning of the specificity of the cooperation developed in Workshop 4 and Workshops 1, 2, and 3. How and why did the children cooperate in Workshop 4 and in Workshops 1, 2, and 3? This questioning allowed the emergence of a category focusing on the modality of children's work. The category 'Working modality of spontaneous cooperation' points to different ways of organizing this cooperation and includes two concepts: one, where there is a decision to construct a unique automaton for the whole group; second, where each child constructs its own automaton but develops strategies of cooperation (Table 2).

Table 2. Working modality of spontaneous cooperation during AutoSTEM workshops.

How and What for Did Children Cooperate?	
Each child developed its own automata while cooperating in an informal way with colleagues	Divergent
Children spontaneously decided to cooperate and build a group automata	Convergent

The analysis of the results also evidences that when children spontaneously decided to cooperate and build a group automaton, there was a type of cooperation with a common goal and task, a convergent involvement between pairs. Another type of cooperation was also observed, were each child developed their own prototype while cooperating in an informal way with colleagues. In this case, there were no shared goals or tasks, so the cooperation that emerged can be considered as a divergent or non-convergent cooperation.

3.3. Influencing Factors

Following, a more detailed analysis of the workshops' characteristics with different modalities of spontaneous cooperation, the following units emerged: the children's age, guidance, presence of the class teacher and seating arrangement. These processes allowed a deeper understanding of the spontaneous cooperation modality (Table 3).

Table 3. Influencing factors.

Workshop	Which Characteristics Were Common to Workshops 1, 2, and 3 and Different in Workshop 4?	
Workshops 1, 2, and 3 Workshop 4	6–7 years old 8–9 years old	Children's age
Workshops 1, 2, and 3 Workshop 4	More guidance Less guidance	Guidance
Workshops 1, 2, and 3 Workshop 4	Class teacher is present Class teacher is not present	Class teacher
Workshops 1, 2, and 3 Workshop 4	Pairs or presentation Round tables	Seating arrangement

An analysis of Table 3 shows that the characteristics of the workshop are associated with the characteristics of the spontaneous cooperation that emerged, in particular divergent and convergent cooperation. Children who developed their own project were 6–7 years old, the workshop took place in the presence of the class teacher and the seating arrangement followed the previous arrangement in class, so children were seated in pairs or in a presentation mode.

When working on the same project, children were 9 years old and the workshop took place in the library. Although there were teachers guiding the workshop, the class teacher was not present and the children were free to choose the automata they wanted. Children were seated around tables.

3.4. Outcomes

Finally a question about the outcomes of the workshops and different modalities of spontaneous cooperation was formulated (Table 4).

Table 4. Outcomes.

What Were the Main Outcomes?	How Were the Automata Produced?	Workshop	
Automata produced	Automata similar to the one presented Automata 'in pairs' Predominance of a narrative/idea	Workshops 1, 2, and 3	Similar to examples
	When working on the same project, the automata produced included differences from the automata initially presented	Workshop 4	More creative
Perception of learning	Learning to construct a mechanism Learning about the narrative Learning to cooperate and solve problems	Workshops 1, 2, 3, and 4 Workshops 1, 2, 3, and 4	Transversal learning
Emotions	Happiness, joy Being proud	Workshops 1, 2, 3, and 4	Transversal emotions

In all the workshops analyzed, some of the automata were very similar to the ones presented. However, children also produced automata similar to the ones produced by a colleague seated at the same table, although each child worked on their own construction. This was interpreted as a normal class working routine, a way of working that has happened previously and children often develop. When children decided to work on the same automata, the automata produced included differences from the automata initially presented. This was interpreted as evidence of creativity.

Based on the answers to the question 'What did you learn in this workshop?', there is evidence that most of the children learned how to construct a simple mechanism, how to construct a moving toy and also about the topic of the narrative initially presented, related to protection of the Earth. Children also referred to other competences in order to cooperate or solve problems.

Several emotions were also registered. In general, children expressed joy and satisfaction for the work they developed, some expressed being proud of their work. This was observed when a child developed their own automata and when they developed a 'shared automaton.'

These findings are in line with children's answers to the intrinsic motivation questions [26] included in the questionnaire. Children expressed high levels of agreement on questions expressing satisfaction, autonomy, perceptions of usefulness or self-efficacy during the automata construction. The scale levels varied between 1 and 4, with 4 representing high agreement (Table 5).

Table 5. Intrinsic motivation.

Item	Workshop 1	Workshop 2	Workshop 3	Workshop 4
I have enjoyed this activity very much	3.7	3.8	4	3.9
This activity was done using my ideas	3.4	3.7	3.9	3.8
The activity is useful to learn about mechanisms and toys that move	3.7	3.8	3.8	3.8
I did this activity quite well	3.2	3.5	3.9	3.6

While most children answered to having had no difficulties during the workshops, three of them said that they had some difficulties in cutting, painting and in assembling the mechanism.

Only three children offered suggestions for improvement, all came from children in Workshops 2 and 3 and were 'Build something together' and 'Build in group because it is easier'. Although the children developed spontaneous cooperation, this was mainly divergent, the responses indicate that they would like to develop convergent cooperation.

Summing up, our results suggest that despite strategies of cooperative work not being formally established, spontaneous cooperation between children emerged, appearing to respond to the challenges experienced by children both individually and in groups. The answer to the question about the forms of cooperation during the workshops made it possible to identify characteristics, including informal distribution of tasks, sharing materials, observing each other's work, and helping with the construction. These cooperations occurred in all the workshops. In addition, other manifestations of spontaneous cooperation were registered in Workshops 1, 2, and 3, while in Workshop 4, there was interdependence of purposes, coordinating actions, and shared tasks, usually considered as characteristic dimensions of cooperative learning that arise from explicit strategies aimed at their implementation. Consideration of the different workshops was important for a more detailed understanding of spontaneous cooperation. The spontaneous cooperation displayed different features and two different modalities emerged, based on the working modality. A type of cooperation emerged where each child is centered on their own construction, but at the same time may cooperate in an informal way with colleagues, being inspired by colleague's work or expressing selfless willingness to help a colleague. This cooperation is in line with divergent engagement proposed by Andersen [21]. The other type of spontaneous cooperation is centered around the construction of a unique automaton, and involves dimensions that are similar to the ones that characterize cooperative learning, namely sharing goals, interdependence of purposes, and coordinating actions. Following previous research [21] (p. 142), this can be named 'convergent cooperation'. Thus, it is then possible to associate Workshops 1, 2, and 3 to a divergent spontaneous cooperation modality and Workshop 4 to a convergent modality.

Spontaneous cooperation also varied according to the children's age, the context, structure, and organization of the workshop, e.g., the seating arrangement and the presence of the class teacher.

A summary of the results and emergent types of spontaneous cooperation is presented in Table 6.

Table 6. Summary of the results and emergent types of spontaneous cooperation.

Spontaneous Cooperation		
Core dimensions		Dimensions
Informal distribution of tasks		
Sharing materials		
Observing each other work		
Helping with the construction		
Specific dimensions		
Workshops 1, 2, and 3	Workshop 4	
To imitate and being inspired by a colleagues' work	Interdependence of purposes Coordinating actions	
Selfless willingness to help a colleague	Shared tasks	
Divergent Each child develops his or her own prototype	Convergent Children spontaneously decided to cooperate and build a group automaton	Modality
Children age		Influencing factors
6–7 years old	8–9 years old	
Guidance		
More guidance	Less guidance	
Class teacher		
The class teacher is present	The class teacher is not present	
Seating arrangement		
Presentation and pairs	Seated around a table	
Automata produced		Outcomes
Automata in pairs A dominant idea/narrative	Automata produced have different elements than the ones presented	
Perception of learning		
Learning to construct a mechanism		
Learning about the narrative		
Learning to cooperate and solve problems		
Emotions		
Happiness, joy		
Being proud		

4. Discussion

Within the scope of the workshops held for the AutoSTEM project, we could observe the emergence of spontaneous cooperation. The activities developed by the project are not explicitly directed towards group work, assuming a free character, and the implementation of playful pedagogical approaches, based on playful pedagogy, is developed. The play pedagogy broadened the tasks and the structure of the workshops, as children were challenged to observe automata previously constructed, to explore how and why they move, to plan and implement their own prototype, following their own ideas, and to play with it. However, although based on a child's autonomy, the role of the teacher guiding children's play was also considered crucial and so teachers could present an automaton or some ideas supporting the construction process and highlight the STEM content involved. Although the scaffolding process differed between the workshops, taking into account the setting where it took place or the children's age, findings converge to show that a guided play approach may enhance play potential in order to promote children' learning, as referred to in previous research [15,16], and various forms of cooperation. Our findings point to children's engagement in the task, as all the children managed to successfully construct an automaton, perceived efficacy to construct their own plans and develop their ideas and expressed positive emotions, with different types of cooperation emerging. This cooperation can be categorized as spontaneous, since the educators organizing the workshop never asked the children to work together. This contributed to the success of the task with a peer scaffolding process emerging in some cases and/or an altruistic attitudes to help the others to solve problems encountered in the construction of their automaton, which we named spontaneous cooperation.

We assume then, that the pedagogical approach used in AutoSTEM workshops allowed the emergence of different dimensions of spontaneous cooperation, due to the workshop settings, structure and dynamics. The accomplishment of the task, namely the construction of automata, involves the sharing of materials, which involves one of the forms of interdependence found. There was also spontaneous cooperation in sharing ideas and materials that led to group work on a single automaton or to build their own individual automata. These core dimensions of spontaneous cooperation could be observed in all the workshops, and were associated with the results concerning perceptions of learning and positive emotions.

It was possible to identify cooperation in the sense of convergent involvement in carrying out a group task, with the same purpose, but also other forms of cooperation that led to the realization of individual projects, which can be named as non-convergent or divergent cooperation. Although similar cooperative behavior was involved in both dimensions, there were also specific behaviors in each dimension, pointing to a more complex cooperative interaction in convergent cooperation. It was also possible to identify factors that are associated with these different types of cooperation. In fact, convergent cooperation was found in older children, arranged in groups, in a less formal learning environment, which corroborates the findings of studies that highlight the existence of these differences according to age levels but also highlights other variables that may have influenced the emergence of this type of cooperation. If convergent cooperation can occur at earlier ages [21,23], it was found, however, that at older ages, as is the case with children who participated in the workshops, the emergence of convergent cooperation is associated with contextual factors, such as the disposition of groups, habitus, culture and the environment of the class. In this regard, it is suggested that what emerges even before entering school, the convergent cooperation, may disappear in a schooling process, which eradicates, in different ways, this spontaneous conduct, separating play from learning. The representation of the task by the children, of individual or group accomplishment, is regulated by academic and social factors.

4.1. Limitations and Suggestions for Further Research

This study was complex and involved many factors, automata construction, play-based pedagogy, different influencing factors, as well as the development of STEM knowledge and transversal skills. As such, determining the results of the project was challenging. One of the findings concerns cooperation, which, being one of the competences targeted, emerged spontaneously and was not imposed by rules or cooperative learning strategies, with advantages, revealing the most in-depth understanding of the dynamics involved and the mapping of this spontaneous cooperation, which was our goal. In this sense, we can distinguish cooperative learning, regulated by the teacher, from spontaneous cooperation regulated by children, which was the object of the analysis in the present study. Being of a qualitative nature, it would be interesting to complement this type of approach with an extended study, using another methodological design, involving a sample of children accomplishing the same type of tasks, considering the variables that have been revealed to be associated with the different forms and types of spontaneous cooperation. It could be interesting to determine whether the same types of spontaneous cooperation emerge in other situations. Within the scope of the project, it is important to deepen the impact of the STEM content and automata construction on the one hand and the impact of the workshop setting and play-based pedagogy on the other hand. Future studies could explore these relationships in greater depth.

4.2. Conclusion and Implications

In characterizing cooperation that emerged spontaneously during the AutoSTEM project workshops, our findings contribute to defining spontaneous cooperation and determining how to optimize its educational potential. Our findings also highlight that developmental as well as contextual issues must be considered when implementing cooperation in learning contexts, taking into account that the age of the children and teacher guidance are associated with different types of cooperation. Finally, the data suggest that the types of spontaneous cooperation among children that emerged during AutoSTEM workshops are related to the dynamics, workshops settings and structure/arrangement of these workshops. This study supports [19] using cooperation with flexibility and discretion to promote more spontaneous forms of collaboration, which proved to be particularly enriching in the indicators of motivation and perception of learning in the evaluation carried out in this study. Given the importance of cooperation as an objective in the OECD's 2030 agenda [27], it is pertinent to pursue this goal and develop studies that account for its implementation and achievement.

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Informed Consent Statement: AutoSTEM workshops were integrated in the school pedagogical plan with parents' permission for children participation in these type of activities.

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