

# An empirical study of educational robotics as tools for group metacognition and collaborative knowledge construction

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**Abstract:** The affordances of Educational Robotics (ER) for advancing teaching and learning has become a widely researched topic. This study aims to identify the major components of collaborative knowledge construction in an ER learning environment and to investigate the mediating role of ER as mindtools to support group metacognition. Data analysis involved a micro-level examination of students' discourse, interaction with the technology, peers and the facilitator, using fine-grained analysis of video and audio recordings. The results made evident that metacognition, along with questioning and answering, were prevalent elements of collaborative knowledge construction around ER. We support that ER can be used as a learning tool and can be effective in supporting group metacognition through immediate feedback, openly accessible programmability and students' embodied interaction with the physical robot. Beyond the instrumental role of ER for supporting metacognitive processes, the study provides initial evidence for a relationship between collaborative and metacognitive talk in group problem-solving.

## Introduction

Educational robotics (ER) is constructible and programmable high tech devices which can be employed in education as constructivist learning tools to support teaching and learning through hands-on activities. The use of ER in educational contexts to support teaching and learning has become an extensively researched topic. ER too early earned an influential role as a research field, motivating the attention of many schools, and universities, both from an instructive and a research point of view. Jonassen (2000) first introduced the theoretical background and the motivation for the integration of robotic technologies as cognitive tools which can improve and enrich the educational process. According to Gaudiello and Zibetti (2013), two features of ER are linked to their high educational potential; "transparency" and "interactivity." "Transparency" refers to the openly accessible programmability of the robot whilst, "interactivity" refers to the immediacy of the feedback given by the robot when a student program and execute the commands (Gaudiello & Zibetti, 2013).

Many studies have focused on exploring the affordances of ER to promote several transversal skills such as problem-solving (e.g., Atmatzidou, Demetriadis & Nika, 2018), collaboration (e.g., Ardito, Mosley & Scollins, 2014), and computational thinking (e.g., Bers, Flannery, Kazakoff & Sullivan, 2014). Still, ER as metacognitive tools have been considered only recently (e.g., La Paglia, Caci, La Barbera & Cardaci, 2010; Gaudiello & Zibetti, 2013) but the research evidence is inconsistent. Further investigation in the area is needed to fully understand the potential of ER to support students' metacognitive processes and especially group and social mediated metacognitive processes.

We present an empirical investigation of ER, in a learning experience aiming at engaging students in collaboration and co-construction of shared understandings in the mathematics domain. In this work, the whole experience around using the robot is seen as a metacognitive experience that assists students to become more aware of their process of thinking and learning. We aim to unfold the elements of collaborative knowledge construction, identify details of the metacognitive processes during students' interaction with the robot and their peers, and document the educational potential of ER as tools for supporting group metacognition. Specifically, the research questions of this study are the following:

1. What are the elements of collaborative knowledge construction in an ER learning environment?
2. How does ER activate group metacognitive processes?
3. What is the relationship between collaborative and metacognitive talk?

In the following lines, we present the theoretical framework of the study, findings from previous empirical studies, methodology and findings from the present study along with discussion of the implications of this work.

## Theoretical Framing

## ER and CSCL

Many advanced learning approaches such as problem-based learning and computer-supported collaborative learning (CSCL) lay on the principles of social constructionism. Constructionism emphasizes on the importance of making things in learning and argues that knowledge construction happens most effectively when learners construct a meaningful artifact which then, enables them to reflect on their experience in solving problems (Harel & Papert, 1991). In this work, we consider ER as being fully compatible with the nature of collocated CSCL by providing a way to infuse real-world experiences to the CSCL setting, through the hands-on nature of collaborative activities.

## ER, metacognition and group metacognition

Over the past years, empirical studies have mainly confirmed that individual is an important factor in learning. Researchers agree that metacognition consists of two fundamental processes: knowledge of cognition (individual's awareness of cognition) and regulation of cognition (individual's actions or thoughts to control their own cognition) (Schraw & Moshman, 1995). Knowledge of cognition includes three subcomponents: declarative (knowing about things), procedural (knowing about strategies), and conditional (knowledge of why and when to use a strategy) knowledge. Regulation of cognition includes three types of control: planning, monitoring, and evaluating.

There are already some studies examining the use of ER to promote metacognition at an individual level. For example, A study by Keren and Fridin (2014), examined how ER can assist the teaching of geometric thinking and promote children's metacognitive development. Findings of the study showed that students' performance on geometric thinking and metacognitive tasks were improved. Also, in an effort to investigate the process of constructing and programming ER as a metacognitive tool, La Paglia et al. (2010) found that ER activities may be conceptualized as a novel metacognitive setting that motivates learners to monitor and control their own learning actions. Gaudiello and Zibetti (2013) tried to identify and classify the heuristics that are applied by elementary school students interacting with and controlling robotic technologies. The results demonstrated three main types of heuristic: (a) procedural-oriented, (b) declarative-oriented, and (c) metacognitive-oriented. Atmatzidou, Demetriadis, and Nika (2018) investigated the development of students' metacognitive skills in ER activities performing different levels of guidance (low and high) in different age groups. The results suggested that strong guidance had a positive impact on students' metacognitive skills independently of their age and gender.

Research on metacognition in group situations is not well developed, despite group learning being commonplace in schools and other learning environments (Smith & Mancy, 2018). Despite the limited research on group metacognition, there are some findings suggesting that metacognition is mediated and socially shared among group members in collaborative activities (Goos, Gailbraith & Renshaw, 2002) and that group metacognition can be considered as an extension of individual metacognition into group interactions. Also researchers agree on that metacognition in group situations consist of students' monitoring, reflecting and control of one another's knowledge or actions. In CSCL research the potential role of CSCL tools for supporting metacognition has been virtually ignored (Järvelä & Hadwin, 2013). In this work, we see ER as CSCL tools that can promote students' metacognitive thinking. Most of ER activities are collaborative activities, however, there are no studies in the literature that have examined the impact of ER on the development of metacognition as an essential part of group work. Methods

## Participants

The participants were 14 students (6 male and 8 female) in Grades 4, 5 and 6 (aged 9-11 years old) in a public primary school. ). The students worked in 4 groups of 3-4 students each. Each group was formed with different genders and abilities (i.e, mathematical, technological and problem-solving abilities) to allow different discourses and problem-solving approaches to develop. The participants had no previous experience in robotics.

## Procedures

There were two weeks of introductory activities to help students get familiar with the EV3 kit. These activities were followed by three 80-minutes sessions of STEM problem-solving tasks. Students should program a robot using a tablet which was connected to the robot via Bluetooth to download the software program. Each group was assigned with the following programming tasks.

- Program a robot to move from its starting position, through a maze, to the finish position;
- Program a robot to move along the outside of the flags without touching them;
- Program a robot to draw a hexagon

In these activities, students could adopt any approaches they wanted to come to a solution. The teacher acted as a facilitator assisting the whole procedure; assessing progress, examining understandings, monitoring group work and connections among concepts, and suggesting attention to data. When the groups completed their tasks, a debriefing phase took place; groups demonstrated their approach in addressing the problem and answered questions asked by the facilitator and the students of other groups.

## Data collection and analysis

Verbal contributions were recorded via four audio recorders next to each group. A camera was also placed in the room to record the whole procedure of student interaction and technology use. To answer RQ1, the audio data were transcribed verbatim and analyzed using a fine-grained analysis, coded on a turn-by-turn basis. A new turn was considered to start when the speaker changed. When the speaker shifted the theme of the discussion or when a different kind of discourse appeared, these were parsed into extra coded units. Generally, a conversational turn had more than one coding units. For instance, when a pupil asked a question and at the same turn added one or more statements, this was coded as two or more different codings. Two independent raters coded 35% of the data to verify coding reliability. Reliability was high (agreement 75%), and consequently, the first researcher completed coding the whole dataset. We used the coding scheme reported in Hmelo-Silver (2003), which conceptualizes the thinking processes and the general cognitive, metacognitive and social characteristics involved in collaborative knowledge construction.

To answer RQ2 and RQ3 a group was selected for further examination with a chronological investigation of within-group interaction; we plotted students' talk and activity on chronological visuals to examine the impact of group metacognition in collaborative knowledge construction. We used the CORDTRA technique, initially suggested by Hmelo-Silver, Jordan, Liu, and Chernobilsky (2011) in combination with example excerpts of students' discourse to identify details of metacognitive and collaborative processes and the role of the technology.

## Findings

### What are the elements of collaborative knowledge construction? (RQ1)

#### Knowledge

Student groups rarely referred to prior conceptual knowledge or experience of knowledge overall (5.2%). Not surprisingly, they more often made comparisons and links referring to observations of previous actions in the same task (3.6%).

#### Metacognition

As presented in Table 1, groups used a high amount of metacognitive utterances (24.1%). The majority of metacognitive reports were monitoring statements (13.3%). Planning component of metacognition accounted the second largest percentage of metacognitive statements (6.7%). The nature of planning contributions was almost always in response to the data that derive from the results of previous trials (5.9%). Students do not mediate their planning with, prior knowledge, experience, or existing theories (0.4%). Reflective statements accounted 3.4% of the total statements. Reflection statements were significant in reconsidering and adjusting their plan using outputs from previous trials to modify the current plan.

#### Interpretation

Students dedicated a good amount of effort interpreting data derives from the robot or the tablet display (6.8%). Interpreting data coming from screen display was an excellent opportunity to reconsider, test and refine their solutions. However, they rarely made interpretations at a higher level (1.3%) and were staying more often at the lowest level of literal interpretations (5.5%).

#### Collaboration

Collaboration category included three subcategories: conflict, questioning and facilitator's input. Conflicts within a group were few (4.8%) and were appeared mostly at early stages of the whole procedure. When conflicts appeared were more often related to the robot's failure to perform the expected outcomes (4.1%) and rarely over a concept (0.6%). Student groups generated many questions (22.7%), most of which referred to teammates rather than to the facilitator. The majority of these questions (7.9%) were plan-related questions. Software- and robot use- related questions appeared fairly often (4%). Facilitator questioning (4.1%) was mainly concerned with the software and robot use.

Responses by the students (24.3%) were meaningful because they revealed the degree of consensus among the group members. As shown by the great number of statements related to agreement with peers (12.8%), students involved in a great deal of consensus-seeking. Students also constructed simple explanations (2.9%) and brief answers (4.3%) more often than elaborated explanations (0.7%). The main operation of the facilitator’s input was coded as monitoring (7.4%).

Table 1: Major categories and subcategories frequencies

<b>Coding categories</b>	<b>N (%)</b>	<b>Coding categories</b>	<b>N (%)</b>
<b><i>Knowledge</i></b>	<b>29 (5.2%)</b>	<b><i>Collaboration</i></b>	<b>355 (63.9%)</b>
Conceptual knowledge	5 (0.9%)	Conflict	26 (4.8%)
Prior experiences	4 (0.7%)	Conceptual	3 (0.6%)
Analogies	20 (3.6%)	Task-specific	23 (4.1%)
<b><i>Metacognition</i></b>	<b>134 (24.1%)</b>	Questioning	126 (22.7%)
Monitoring	74 (13.3%)	Clarifications	30 (5.4%)
Evaluation	4 (0.7%)	Plan-related	44 (7.9%)
Reflection	19 (3.4%)	Software-related	22 (4%)
Total planning	37 (6.7%)	Self-answered	5 (0.9%)
Theory-driven Planning	2 (0.4%)	General	2 (0.4%)
Data-driven Planning	33 (5.9%)	Facilitator	23 (4.1%)
Unjustified	2 (0.4%)	Responses	135 (24.3%)
<b><i>Interpretation</i></b>	<b>38 (6.8%)</b>	Agreement with facilitator	20 (3.6%)
High-level	7 (1.3%)	Agreement with partner	71 (12.8)
Low-level	31 (5.5%)	Brief answers	24 (4.3%)
		Simple explanations	16 (2.9%)
		Elaborate explanations	4 (0.7%)
		Facilitator’s input	68 (12.1%)
		Monitoring	41 (7.4%)
		Explaining concepts	3 (0.4%)
		Explaining Software	24 (4.3%)

### How does ER activate group metacognitive processes? (RQ2)

To answer RQ2, we examined in depth an integrated view of an episode. In Fig. 1, the numbers on the x-axis represent the order and as a result, the time of each contribution and the numbers along the y-axis represent the coded categories. The records 1 to 5 on the y-axis of the visual refers to speakers and records 6 to 29 to cases of discourse which were coded in the categories. The phase of the activity presented here is when two groups were trying to solve the “Draw a hexagon” challenge. The CORDTRA diagram reveals the relation of the discourse among time, but alone it cannot help us to identify the nature of student’s talk, the relation of the technology and metacognitive talk, and the use of ER as a tool for promoting metacognition. Combining CORDTRA diagram with discussion excerpts can help us to understand and describe better student’s interaction. We zoomed in on an episode in which students were trying to solve the “draw a hexagon” challenge (lines 90-190).

#### ER activating group metacognitive processes through embodied interaction

In this activity, students should combine knowledge, experience, and programming skills to link their existing knowledge of mathematics in real-world conditions. At first, students started to discuss how they could solve the problem without having many ideas. A student stated that they should use the gyro sensor while one other added that they should place a pen holder. A fairly detailed discussion about where they could set the pen holder took place in lines 91-99. Here, questioning discourse appeared as an essential aspect of collaborative knowledge construction. Students’ questioning about where they should put the gyro sensor and the kind of turns, opened up the dialogue and guided its direction. This triggered the next step as students started to research the question using the robot as a mean for experimentation by adjusting the pen holder in different places of the robot. Students seemed to recognize the significance of where they should adjust the pen holder. This was important because this experimentation of where they should place the pen holder moved students’ thinking forward. This experimentation involved their bodies as students held the robot in their hands and were trying to simulate possible movements of the robot and thinking of possible footprints of the pen on the paper. Students involved their bodies in understanding the difference between swing and point turn (lines 100-114). Students’ embodied interaction with the physical robot allowed students’ mobility, and natural interaction with the robot triggered social interaction and stimulated group metacognitive processes. The physical and embodied interaction with the robot gave students the opportunity to test and modify

their new synthesis against existing cognitive knowledge, personal experiences, and data. Thus, robotic technology here, through embodied interaction, serves as a tool for experimentation that activates group metacognitive processes and endorses collaborative knowledge construction.

- Student 1 We have to draw a hexagon (*laughing*). Any ideas?  
Student 3 We must use the gyro sensor to turn exactly as degrees as we program it (*for accurate angle measure*).  
Student 2 Yes, the robot must turn exactly as degrees as we program it.  
Student 4 We also need to adjust a marker to draw the hexagon as the robot moves and turns.  
Student 2 What kind of turns?  
Student 3 Turns.  
Student 1 Pivot turns. The robot must turn very sharp and make pivot turns to draw an angle.  
Student 1 Ok! Where can we apply the marker?  
Student 2 If we put it here (*holds marker and robot and try to make turns to draw a random angle*).

*These tests continued until students managed to draw angles formed by two rays rather than curved lines. Students placed the marker on different parts of the robot and tried to draw random angles. They tried to put the marker in different places (between the wheels, next to the right wheel and on the back of the robot) to understand where it would be more efficient to place the marker.*

#### ER activating students' group metacognitive processes through interactivity and transparency

Here, in lines 160-176, on the CORDRA diagram students went through an exploration in which they used their conceptual knowledge of mathematics and programming in a real-world situation. Students were concerned about how many degrees their robot should turn and with teacher's assistance they managed to connect their knowledge in mathematics and programming with a particular real-world condition. A student influenced by previous robotics lessons used intellectually a flowchart describing the required moves of the robot to draw a hexagon (line 168). Then they decided to program the robot to turn  $120^\circ$ , as much as the internal angle and observed their robot turning much more than they expected. Immediate feedback from the robot's moves (observing the robot turn more than they expected) made students think and monitor their thoughts (line 169). Robot's failure to produce the expected outcome here looks to act as a tool that activated students' group metacognitive thinking. Thinking of what they were doing wrong, checking various aspects (lines 169-172) and constructing one on each other's words they excluded various possibilities and proposed a solution to the problem. After that, Student 4 contributes a more advanced thinking to the discussion, suggesting that they should put a smaller value for the turning angle because with  $120^\circ$  the robot was turning too much. Student 4 proposed to represent the problem on a paper to calculate the turning angle. Students acknowledge this more advanced comment and began to model the problem on a paper. By representing the problem on paper students managed to find the correct value for the turning angle. Then, Student 1 made his individual thinking visible showing on the paper the correct angle (line 174) and Student 2 built on him proposing the solution of the problem (line 175). The process of socially shared metacognition emerged in this group when Student 4 provided a metacognitive regulation statement and contributed to the discussion. The other group members acknowledged this contribution and developed a solution to the problem.

Transparency features of ER helped students to think, apply and check their ideas to overcome the problem. Easy changes to the software and hardware without any cost helped students to avoid frustration, and through the open and accessible programmability of the robot, they managed to overcome the obstacles. Robot's programming, the expected results and the actual results of its actions served as a metacognitive tool, as a referent that pupils could use towards and negotiate as they were developing their solution. Students identified knowledge problems and collectively discussed, elaborated, and improved their ideas to find a solution. Regulatory statements that were produced due to the interactivity and transparency features of the robot, and were focused mainly on collaboration, promoted group metacognitive processes and facilitated knowledge construction.

- Student 3 Now, we will program the robot to move forward, then make a turn for some degrees then again forward and then turn, etc.  
Student 2 Ok, we have to think about how many turns and how many degrees.  
Student 1 Six turns and six forward. I do not know how many degrees.  
Teacher What do we know about the total internal angles of polygons?  
Student 4 It depends on how many different triangles are formed into the hexagon that does not overlap each other.

Student 2 How many different triangles does a hexagon have?  
 Student 3 I will draw a hexagon to find how many triangles are formed.  
 Student 3 4 different triangles. So, multiplies by  $180^\circ$  each equal  $720^\circ$   
 Student 1 Divide by 6 angles of a hexagon (*thinking*). Equals  $120^\circ$ . So, we will program the robot to move forward and then turn  $120^\circ$  for 6 times.  
 (*The team programmed the robot and is going to test the program*).  
 Student 2 No, it's turning too much. Perhaps we calculate wrong the angles. Let's check it.  
 Student 3 Or the sensor is not working  
 Student 2 Gyro sensor looks ok!  
 Student 1 (*They are doing the calculations*) The angle is correct  $120^\circ$ . Must be something else.  
 Student 4 Yeah, but I think we just have to take a smaller angle.  $120^\circ$  are all the internal angles of the hexagon. The robot moves on one of the sides of the hexagon. If the robot turn  $120^\circ$  left it will get into the hexagon. Let's draw the hexagon on a paper to find the angle.  
 (*They draw a hexagon with a robot, representing it with a dot, on one of its angle*)  
 Student 1 The robot is this dot and must turn here (*showing with his finger*). So the turning angle is this one, we must find this one (*showing on the paper*).  
 Student 2 This angle is the supplementary of the internal angle. So its  $180-120 = 60$ .  
 Student 4 Yes, that is. The robot must turn as much as the supplementary of the internal angle, only  $60^\circ$  not  $120^\circ$ .

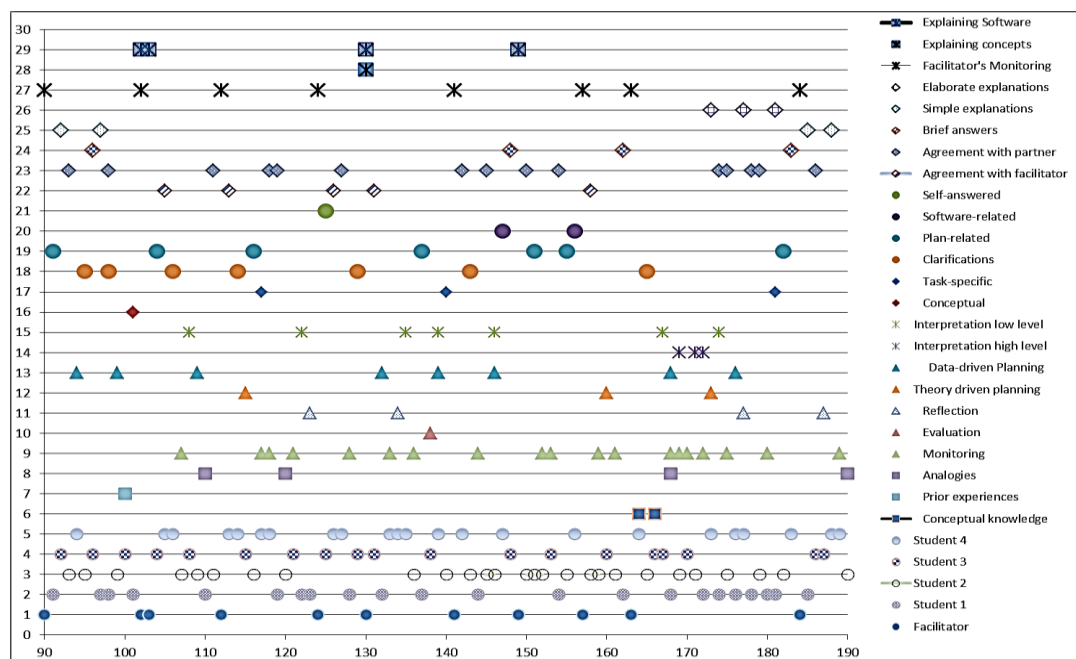


Figure 1. CORDTRA diagram of students' contributions.

### Is there any relationship between collaborative and metacognitive talk? (RQ3)

Both in the previous excerpt and this one, students made their metacognitive thinking visible mainly in mutual interaction with their teammates. Student 1 tried to explain their failure to solve the challenge proposing that the flags were small so the sensor could not detect them. This contribution monitored Student's 3 thinking, leading him to suggest a new idea, proposing the use of two ultrasonic sensors instead of one. Student 1 pointed his disagreement over the proposed idea and documented his position using the experience of a previous failed effort outside the current activity. Then Student 1 contributed a metacognitive statement to justify his position proposing that they do not know well how to handle an ultrasonic sensor and so, he proposed a trial and error plan. Student 3 ignored Student's 1 plan highlighting that with two sensors, would be easier for the robot to detect the flags. Student 3 seems to understand that the proposed plan was a trial and error strategy and probably he wanted to avoid it, so Student 3 proposed to use this plan as an alternative. When they failed, Student 3 accepted to use the alternative plan proposing first, to measure the distances among the flags so that they did not use a trial and error plan completely. In this excerpt, students compared their thinking with peers' thinking and this involved the use of collaborative in combination with metacognitive talk. Also, as shown in CORDRA diagram, collaborative and metacognitive talk seems to mediate each other. For example, contributions that were coded as collaborative were usually followed by one or more metacognitive

contributions and metacognitive contributions were often followed by collaborative contributions. There was a switching among metacognitive and collaborative talk.

- Student 2 We will use the ultrasonic sensor to avoid the flags.  
Student 3 Ok then. Put the ultrasonic sensor. (*They executed their plan, but they failed*).  
Student 1 The flags are small, so the sensor cannot detect them.  
Student 3 We can use two ultrasonic sensors. What do you think?  
Student 1 No, we tried to use the ultrasonic sensor once, and we failed. We do not know how to handle it. Let's program the robot to move, and then we can adjust the values.  
Student 3 If we put two sensors, it will be easier for the robot to detect the flags.  
Student 2 Ok! Let's try with two sensors.  
Student 1 Ok then. (*They executed their plan using two sensors, but they failed*).  
Student 1 I told you, we do not need the sensors.  
Student 3 One more trial with two sensors and then, if we fail, we can move with your plan. (*They changed the position of the two sensors and tried again, but they failed*).  
Student 3 Ok. Let's do what you said, but first, we can measure the distance between the flags to calculate the value of rotations.

## Discussion

The study shows evidence that CSCL activities using ER can engage students in collaborative knowledge construction with prevalent elements of metacognitive processes, questioning, and answering. Indeed, students' discourse demonstrated logical reasoning coupled with metacognitive statements enabling students to predict and to plan the flow of actions required to solve the problem. Monitoring elements of metacognition seem to be activated in an ER learning environment; it appears encourages procedural knowledge rather than declarative knowledge and therefore engages students in the process of exploration for the acquisition of knowledge.

During the CSCL ER activity, intensive collaboration was enacted in the form of questioning and answering while metacognition was enacted in the form of monitoring and planning. Many researchers have identified questioning (e.g., Hmelo-Silver & Barrows, 2008) and reflective thinking (i.e., metacognition) (e.g., Baker & Lund, 1997) as important kinds of discourse in knowledge building situations. Contributions of knowledge were limited, although this might not be replicated in a setting where learners have prior experiences with ER. Our findings seem to confirm previous evidence about ER promoting collaborative knowledge construction (Chambers, Carbonaro, Rex & Grove, 2007). Our work contributes in that it presents a fine-grained analysis of the phenomenon to strengthen the scientific evidence in the area. Although previous studies rely heavily on the individual level of metacognition using self-reported data to describe the respective variable (e.g., Atmatzidou et al., 2018), this study documents metacognition as a result of group work, while it occurred in-situ.

Metacognitive elements, coded as monitoring, evaluation, reflection, and planning, are activated in ER activities through embodied interaction with the physical robot. Indeed, when robot is being used in the CSCL activity, the process can take place in students' natural environment, and therefore allows for students' mobility and physical interaction. Such activities can encourage expression and personal involvement in the learning process whilst supporting teamwork which is important for metacognitive processes. Moreover, the transparent software design of the interface and the direct interactivity (feedback) coming from the robot's moves in response to students programming algorithms and design factors assisted in scaffolding students' metacognitive processes. In fact, when the robot failed to perform the expected outcomes, monitoring and planning (i.e., elements of metacognition) were documented on our chronological diagrams. Metacognition was necessary for students to understand how tasks were performed and be able to identify problems, negotiate modifications and operating changes to solve the problems. Embodied interaction with the physical robot, combined with feedback coming from the robot acted as an extension of students' mind, scaffolding knowledge construction by re-evaluating and re-thinking their solutions. From this perspective ER can be considered as "scaffolding embedded technological tools" (Chambers et al., 2007).

Our research has provided some initial evidences for a relationship between collaborative and metacognitive talk in a problem-solving CSCL environment. Metacognitive and collaborative talk seemed to mediate each other. We understand that these evidence is not clear yet; further research is needed for a better understanding of this relationship in CSCL settings. Developing our understanding of this relationship should help us develop strategies to fully maximize the effectiveness of ER as metacognitive tools in group problem-solving CSCL tasks.

## Conclusions

Coding and plotting student's discourse around an ER CSCL experience can shed light on the elements of collaborative knowledge construction. In this work, fine-grained analysis of student's discourse made evident that metacognition, along with questioning and answering, were prevalent elements of collaborative knowledge construction around ER. What's more the role of the technology was instrumental; namely, the embodied interaction, direct feedback and openly accessible programmability allowed by the robot were tightly coupled with group MC processing and overall collaborative knowledge construction. In conclusion, this work extends the evidence on the value of ER integration in learning environments, partially CSCL settings. The study contributes in that it presents a fine-grained analysis of the phenomenon to strengthen the scientific evidence in the area. Future work should extend on the nature of the problem, the teacher's scaffolding, the students' roles and the characteristics of the technology which might further endorse collaborative knowledge construction, especially the development of metacognitive skills.

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