Evaluation of the Socio-Affective Competence with Unplugged Activities to Develop Computational Thinking in Mathematics Education

Gregorio Arjona-Aranda[1 2], Cristina Sánchez-Cruzado[1], Antonio Ruano-Cano[3], Álvaro Raya-Fernández[1]

University of Málaga, Spain[1]
University of Córdoba, Spain[2]
University of Almería, Spain[3]

Abstract

The Spanish education law has included the socio-affective competence in the mathematics curriculum. It is important to establish resources that not only show them what the subject can offer to them in an instrumental, functional and formative way [15] but also help them develop emotionally, both personally and socially. We aim to evaluate this competence through a series of unplugged activities that also develop computational thinking skills. To do so, we create a rubric which includes different topics concerning the control of emotions, learning from mistakes, working in groups, communicating ideas and letting others communicate theirs and others [1]. All these topics come from criteria inspired by experts in the field of emotional intelligence. This is part of a broader investigation in which we try to promote computational thinking through unplugged tasks in mathematics education and improve the development of socio-affective competence in students.

Keywords: *socio-affective competence, computational thinking, emotional intelligence, evaluation*

1. Introduction. Theoretical Framework

Mathematics is a subject often neglected or feared by students, left as a difficult part of education with no apparent way of softening up. In Spain, its Education Law has included a “socio-affective” sense (SS) in the mathematics curriculum [25] to help teachers focus on those emotional aspects that they need to work with their students.
The SS has been divided into two main psychological aspects:

1. Beliefs, attitudes and proper emotions: students must learn to regulate their emotions by themselves and adapt or change their resolution strategy when necessary, seeing mistakes as another learning opportunity.
2. Teamwork, inclusion, respect, and diversity: They must be able to apply simple teamwork techniques and learn strategies to manage conflicts, considering that everyone must be included in this experience and their ideas must be respected.

Mathematics must be contemplated throughout this process. It has been established that emotions play a significant role in learning, especially in mathematics education [1] [2].

1.1 Emotional intelligence

Although SS feels like a new term that needs to be further studied, a branch of thought has developed these points of view in a more general sense: emotional intelligence.
Emotional intelligence as a term was first used in the texts of Beldoch [7] and Leuner [22]. There were attempts to model emotional intelligence back in 1989, either by Greenspan, Salovey or Mayer [26]. But Goleman and Bar-On are thought to be the first to conceptualize it and apply it in the workplace and social situations. Bar-On defines emotional intelligence as a set of emotional and personality features that constantly interact with the individual so they can adapt to the surroundings [4]. The proposal aims to find the relevant aspects of social and emotional interactions further to develop a better psychological well-being [5].
Goleman states that emotional intelligence is an ability that determines the degree of skill we can achieve in controlling our other faculties. He outlines five different elements that determine its development: emotional conscience, self-control or emotion management, motivation, empathy and social abilities. The first three features are strongly related to oneself, since you must know how you

are feeling, you must control your mood and achieve some form of motivation. On the contrary, empathy and social skills refer to how you behave around others, how you interact with them and how you understand their viewpoints [14].

It is safe to assume that emotional intelligence can be formed by two complementary sides: intrapersonal and interpersonal intelligence. These two terms were coined by Gardner [13] in his theory of multiple intelligences, as two of the eight possible intelligences to be manifested by a person. According to him, interpersonal intelligence lets us connect and work efficiently with others, show empathy as well as compassion and understand motivations and goals. Intrapersonal intelligence is the ability to self-analyze, reflect, contemplate and silently evaluate actions and profound feelings to know yourself.
No matter the name, this has been studied extensively in many disciplines, such as education and sanity [27]. There have been several studies in the context of mathematics as well [1] [2], which means that SS has already a lot of work behind it. We just named it differently.

1.2 Game-Based Learning

However, it can be challenging to evaluate emotional intelligence in school in terms of intrapersonal and interpersonal intelligence if the way of teaching is closed and unidirectional [13], like in a traditional methodology. Therefore, investing time to develop interactive activities that form students with competencies in mind is crucial. Active methodologies show increased students' capacity to learn, motivation and overall participation in an activity. They also provide experiences that can be achieved in groups, so students can work together to finish a task or create a project to present in class [33].
One of many active methodologies that work exceptionally well is Game-Based Learning (GBL), which, in short, uses games for an educational purpose and learning outcomes [11]. The term "game" is used in its broadest meaning, ranging from board games to computer games and videogames [31].
As Schrader and McCreery suggest [28] [29], game studies often explore a diverse array of outcomes, behaviors, and variables, partly due to researchers embracing different paradigms regarding the role of games in their studies. This influences everything from formulating hypotheses and study design to the conclusions derived from the findings. Hence, games can be seen through three different paradigms:

1. Games as interventions: This viewpoint shows that we learn *from* technology, understanding this term as a tool that can either be a digital or physical game. Here, the game is thought to be a delivery mechanism from which a result occurs [6]. We could hypothesize that change occurs as a direct consequence of an experience *from* a game.
2. Games as interactive tools: Unlike before, we work *with* technology in a way that students can interact with each other. In this case, there exists a link between the tool and the learner, which enables goals that go beyond those attainable by one or the other alone and promotes meaningful learning [19].
3. Games as immersive tools: As opposed to the first point of view, we do not work *for* technology; we work *with* it (like previously) and *in* it, implying an interaction in addition to knowledge gains and a level of presence that cannot be achieved without it [19].

It is relevant to differentiate between these ways of thinking because it allows us to dedicate time to design experiments with games as tools.
GBL has been established as a competent active methodology to teach mathematics when dealing with the students' affective domain [32]. Therefore, it is an interesting option to take into consideration.

1.3 Computational Thinking

Another key component added to the mathematics curriculum in K-12 education is Computational Thinking (CT). Over the last few years, CT has been included in curriculums across the European Union [9], including Spain [25]. Therefore, it is essential to understand what it means and how to implement it in class appropriately.
There is no consensus when defining the term. Still, the most accepted definition says that CT is the thought process 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 [18]. This agent can either be a computer, or any tool that can carry an action, whether digital or analog. Studies

have shown that experiences without computers, tablets or any electronic device (also known as *unplugged experiences*) can be done before any activities with said electronic devices because they require almost no cognitive demand and technical knowledge, avoiding a possible learning barrier [20]. These activities also promote cooperation and collaboration [30], if they are embedded in rich open problem-solving stories that give rich scenarios within which CT is applied.
Even if there is no consensus among experts to define this thought process, most agree that CT relies on a set of skills that can be worked on at any level: decomposition, algorithmic thinking, abstraction, automation, debugging, and generalization [8]. With them, students take complex problems and reduce them to smaller but easier to solve, reducing the unnecessary details to get the basic ideas. They create solutions through a clear definition of steps and instruct the information-processing agent to execute repetitive tasks quickly and efficiently compared to the processing power of a human. During that creation process, they identify patterns, similarities and connections to exploit in that solution or others. Ultimately, they evaluate the solution by predicting what the outcome does, applying it directly to the agent, and fixing possible mistakes [12] [21].
Nowadays, there are initiatives that create repositories of resources that teachers can use in class to develop CT, like *Bebras* and *CS Unplugged*, amongst others. Its research within the mathematical context has been recent, but we see more experiences over time, either plugged or unplugged [23].

2. Method

This investigation is part of a bigger project to promote CT through unplugged tasks and develop socio-affective skills in the mathematical curriculum of K-12 education. The focus of this study is qualitative, and we realize an observational investigation [17] over a pilot study, in which we try to check whether the tools chosen for the evaluation are pertinent in the designed protocol [3]. The objective of the communication is to analyze how six students of around 9 to 10 years old behave in pairs while solving unplugged tasks that develop CT.

2.1 Context

These six participants were chosen as an intentional sample, according to availability, with an agreement signed by their parents. For anonymity, fake names will be used: Alma, Mía, Eva, Ana, Sara and María. Every student shared the same class in the same school and agreed to participate with optimism. Only one of the girls (Alma) knew the game beforehand, and even then, her knowledge was limited. Another student (Mía) knew some basics about programming, but the rest had no experience with CT or programming.
The game used for the experiment is called *Turing Tumble*. As we said earlier, it is a board educative game that simulates a Turing machine with a set of pieces (ramps, crossovers, bits and interceptors; see Figure 1) located in a board which guide a set of marbles to go down the board, to hit one of two levers below.

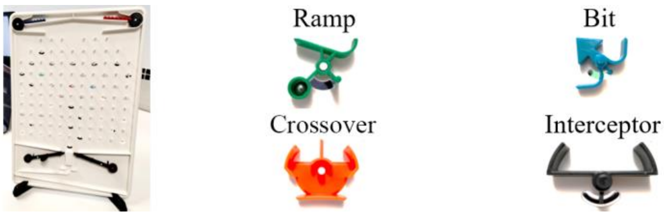

Fig.1. *Turing Tumble*: board and pieces.

Six tasks were designed around the toy machine and solved in two days. The activities were hugely based on the ones proposed by their creators, Boswell and Boswell [10]. The challenges were chosen to work within a connected path so that the activities would include something new to the previous one, intending to escalate their difficulty. The activities have been defined in a previous work, so we refer to it [3]. Boswell and Boswell suggest that *Turing Tumble* can be enjoyed by you or in pairs, so we chose to group the students in pairs. This way, it is possible to analyze both their management of emotions (intrapersonal intelligence) and their teamwork skills (interpersonal intelligence). The pairs are Alma and Mía, Eva and Ana, Sara and María. It is important to know these pairings to understand possible behaviors occurring during the experiment.

2.2 Data analysis

These six participants were recorded in video format and transcribed to gather information. Like in the previous work [3], we make a microgenetic analysis of the students' activity, allowing us to study an ability, concept or strategy in a short period of time. It especially helps detect behavior variability over the same task [34].
Unlike CT, emotional intelligence has been widely studied and has multiple tools to evaluate it, depending on how we base this idea. Sadly, there is no consensus on the most appropriate tool to test [27]. In this communication, we choose a set of items to analyze according to tests like the *Emotional Quotient Inventory - Youth Version (EQ-i:YV)* [5], which is specially designed for children and adolescents, and the *Trait Emotional Intelligence Questionnaire (TEIQue)* [24] or the *Emotional Regulation Questionnaire (ERQ)* [16], which are focused on adults.
In Table 1, we discuss the five different sets of abilities chosen to be analyzed, all divided into two parts. Table 1 also showcases whether the skill is linked with intrapersonal intelligence (individual) or interpersonal intelligence (group).

Table 1. Items used to study SS in the pilot tasks.

Section	Items	Subitems	Code
INDIVIDUAL	Initiative	They feel inclined to **start** an activity.	STA
		They show initiative **during** the challenges.	DUR
	Autonomy	They make their own **decisions**, without overrelying on others.	DEC
		They ask for **help**, when necessary, especially in mental blocks.	HEL
	Emotional management	They manage **frustrations** within themselves.	FRU
GROUP		They control **emotions**; they are sensitive and respectful.	EMO
	Teamwork	They actively **work** in group to solve tasks.	WOR
		They **distribute** tasks accordingly, assuming responsibilities.	DIS
	Communication	They **communicate** appropriately without imposing ideas, respecting the diversity around them.	COM
		They **listen** to the rest of the group.	LIS

Source: Prepared by the authors

Even if the students were put in pairs, the evaluation would be done individually.
To analyze each ability, we rank them according to four degrees of how often they are shown in each student: (1) rarely, (2) sometimes, (3) often, (4) usually. It was designed with four levels in mind because if any skill falls into the middle category, we can check whether they have acted towards an ability.

3. Results

Before commenting on the results of the analysis, it is crucial to inform on the results of the previous work, which focused on measuring CT skills while evaluating the efficacy (whether the algorithm worked or not) and efficiency (how “well” an algorithm has been created) of the algorithms created on the game.
Every group could finish every single task on time, with most solutions being very efficient (i.e., they took a small number of pieces to build, and the function processing was fast). The pair that struggled the most was Sara and María, but even then, the algorithm’s efficiency was mild, far from low. These results show that these students are skilled in CT and capable of organizing and analyzing data, designing algorithms, testing and debugging, and generalizing [3].

3.1 Alma and Mía

It is important to remember that Alma had the most experience with the game, while Mía knew some basics of programming. They both had a lot of initiative, showing interest in creating different algorithms before starting and during the activities. Alma started imposing herself as she knew more than her colleague, either in her communication, in the process of building the road, or listening to her. But, as Mía kept learning how to use the pieces, she was more cooperative, and Mía would have more moments to shine.
Alma would be more autonomous than any of the other girls, and she would only ask questions out of curiosity. In contrast, Mía asked more questions at the beginning to understand the new environment (the pieces, marbles and the levers of the game). They would rarely become frustrated and were respectful towards each other.
In the end, however, Mia would take a more receptive approach, while Alma would know all the answers, showing a lack of teamwork right at the end. Mía seemed to lose interest in the more difficult tasks at the end, and they would not distribute their work equally. However, they liked the overall experience and felt like the activities were easy at the end.
In this pair, we find two girls with strong intrapersonal intelligence who need to learn to work better with others. Mía was more receptive, so she worked better around others but sacrificed her self-worth for it (see Table 2 for scores).

3.2 Eva and Ana

They were both interested in beginning the challenge but wanted to go gradually, neglecting future activities beforehand. Their initiative during the activities was alright, but it started to decrease over time, likely due to the difficulty of the task. Eva slowly learnt how to use the toy machine and regained interest, but Ana became more receptive.
Eva lacked autonomy throughout the activities; she overrelied on the person in charge of the investigation. Ana depended solely on Eva, so her autonomy depended on Eva's autonomy. However, Eva was more assertive than Ana, showing more interest in more activities when Ana was more hesitant to continue.
They had fun all the time, so they did not take their mistakes as seriously as other groups, and they were respectful towards each other, with the usual quip to joke with each other. Even if Ana lacked interest, in the end, the overall experience was collaborative. They would take turns placing the pieces on the board, respect each other's decisions, and improvise ideas without fearing failure. However, they would stall when receiving a new task out of the thought of it being more complex.
This pair struggled at first to be assertive, but they slowly improved on it. They still depended on the comments of the people in charge of the investigation to know that they did a good job. However, they excel in teamwork; they respect each other quite well and are part of a group rather than two girls sharing a board. Their lack of knowledge of the game caused them to have fewer expectations towards themselves, meaning they would manage their emotions well (see Table 2 for scores).

3.3 Sara and María

This pair also started with a lot of interest in what was to come and kept that initiative when facing the tasks. The first day was complicated for them; Sara would often go over María and rarely listened to or respected her decisions, making María quite frustrated. Some of the correct solutions were discarded initially because Sara was more assertive than María, which made María take the receptive approach and complain whenever an answer was wrong.
The second day was better for them. Although their positions were still there to a lesser extent, they started working together. María would be more assertive this time and allow herself to at least comment on options and solutions to Sara. They were also calmer and more patient towards each other, allowing for a much better experience overall.
Sadly, there were multiple pauses during both days because they would get stuck with a wrong answer. There was no intention of asking the people in charge for help, so the group of investigation sometimes gave clues for them to continue. They still finished every single task and enjoyed them as much as the other pairs.
Sara had strong intrapersonal intelligence but struggled with teamwork and respecting her colleagues. María had better interpersonal intelligence but had problems imposing her ideas and managing her emotions at first (see Table 2 for scores).
Table 2 reflects the scores given to each kid in each item, according to how prominent each was in the videos and how positive or negative the experiences were.

Table 2. Scores given to each kid over every item discussed in Table 1.

E.I.	Code	Alma	Mía	Eva	Ana	Sara	María
INDIVIDUAL	STA	4	4	4	4	4	4
	DUR	4	3	3	2	4	3
	DEC	4	3	2	2	4	2
	HEL	4	4	3	3	1	1
	FRU	4	4	4	4	3	2
GROUP	EMO	3	3	4	4	2	3
	WOR	2	2	4	4	2	3
	DIS	2	3	4	4	3	3
	COM	2	3	4	4	2	3
	LIS	2	3	4	4	2	3

Source: Prepared by the authors

4. Discussion and Conclusions

All in all, we captured three different experiences in each pair. Even if they all had interest before the activity, their curiosity would differ depending on the output they were giving and the respect they were given. Being accustomed to the work environment was also important to notice since they were surer of themselves the more they learned about the game's rules. But we can see how, even if they all finished every single task and did it efficiently, they lacked some elements of self-assurance, self-respect, teamwork, and communication.
In this study, we find out that the students can excel in one of the emotional intelligence subdivisions established earlier (intrapersonal intelligence or interpersonal intelligence). Even then, they showed some skills in their non-predominant type of intelligence. Alma, Mía and Sara are good at managing emotions, being autonomous and having the initiative to work. In contrast, Eva, Ana and María had more skills surrounding teamwork, allowing them to communicate accordingly and listen to their coworkers, treating them with respect and sensibility [13].
If we look at the results obtained in the previous study [3], we observe that the group with the best results was the second one (Eva and Ana), obtaining a high-efficiency level in each algorithm. As we can see above, this group has strong interpersonal intelligence. The first pair (Alma and Mía) had similar results but struggled slightly with one task, showing that, with strong intrapersonal intelligence, the group can efficiently work on tasks, although with improvable results. The third pair (Sara and María) had less efficient algorithms and spent much more effort solving the tasks. They had a clash, since one was strong in the individual aspect, whereas the other was strong in the group aspect.

4.1 Further Research

This pilot experiment was helpful because of the complexity of evaluating emotions within students. Our sample had a strong level in some aspects of emotional intelligence, although they lacked in either one of the two intelligences outlined by Goleman [14]. But it was not too significant as to notice many differences.
In future investigations, we expect to improve and validate the item, seeking to compare the results of this analysis tool with other tools commonly used when investigating emotional intelligence, adapting them to our research context. In addition, work is already underway with larger samples, so future data will include more diverse responses to reach more general conclusions. One thing is sure: teaching is essential for our students to become competent while maintaining their mental health and social skills.

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