What Emotions Do Pre-university Students Feel when Engaged in Computational Thinking Activities?

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Abstract

Emotions play a crucial role in knowledge acquisition and can significantly impact motivation when studying a new field. Unfortunately, young people, especially girls, are often not drawn to Computer Science. To address this issue, we conducted an analysis of emotions among 8-9-year-old and 12-13-year-old students engaged in Computational Thinking activities, considering educational level, gender, and type of intervention. Our study sought to understand the lack of interest by examining the emotions present in primary and secondary school students. Hour-long in-person classes were conducted, focusing on Computational Thinking activities. We used the Developmental Channels Questionnaire, which includes 13 emotions rated on a Likert scale from 0 to 10, to measure emotions. The results showed that the predominant emotions were mostly positive and ambiguous, with low-intensity negative emotions, particularly in primary education. Gender differences were observed only in secondary education, while in primary education, the differences were not significant. Girls demonstrated an emotional evolution when engaging in these activities, unlike boys. These findings provide valuable quantitative insights for primary and secondary school teachers. Understanding the emotions experienced can help guide effective teaching approaches. By addressing emotional factors, educators can enhance students' interest in computer science, thus fostering a more inclusive and engaging learning environment.

Keywords: Computational Thinking, Emotions, Primary Education, Secondary Education

1. Introduction

The use of Information and Computer Technology is routine at every level of schooling. Over decades, professional and scientific computing societies have taken leading roles in providing support for higher education in various ways, particularly in the formulation of curricular guidelines. The report of the last effort is called Computing Curricula 2020 (Force, 2020; Impagliazzo & Pears, 2018). It does not provide specific curricula for each computing discipline; instead, the report suggests and provides many opportunities. These include refreshing the paradigm of teaching and educating, moving from knowledge or outcomes to proficiencies, and engaging graduates to exploit the benefits of workplace competencies. The report does not address pre-baccalaureate education, although it occasionally mentions this area, specifying the extensive work done by the computing education community around the world to improve the availability and quality of computing-related courses in primary and secondary education, with a specific focus on improving the diversity of students who opt for careers in computing.

In pre-university education, some authors argue for the need to change the curricular guidelines of Computer Science by addressing the different key aspects on which they should focus, noting that all students should learn about them (Webb et al., 2017), or that the curricula should not be based on fashions and trends, but on contents and processes (Zendler et al., 2011). Moreover, Computer Science does not always pique the interest of young people since there is a lack of knowledge (Hubwieser et al., 2011) and there is the belief that it is complicated and beyond their reach (Giannakos et al., 2013). Also, recent studies show that popular stereotypes and identities of people who work with computers could potentially dissuade a pool of talents from contemplating computing careers as potential future pathways (Dou et al., 2020; Wong, 2016). Another consideration is the gender differences present in this field (Kim et al., 2021), with much fewer women than men in study fields that involve Computer Science (Strachan et al., 2018). One of the reasons for this lack of motivation is the stereotypes they have of computer scientists (Master et al., 2016).

Nowadays it is considered essential for anyone, in addition to having basic notions about computing, to also be knowledgeable of the operation of a programmable machine; that is, what can be automated and what cannot (Riesco et al., 2014). This could be addressed by working on Computational Thinking skills: the ability to solve problems, design systems, and understand human behavior through the use of essential concepts in Computer Science (Wing, 2006). It could also be described as those thought processes involved in formulating problems and representing their solutions, where said solutions can be executed by an information processing agent, be it a human, a computer, or a combination of the two. Some authors have also included in this definition a persistence in working with complicated problems or the ability to handle ambiguity (Barr & Stephenson, 2011). Others even go beyond computers, since it encompasses three areas, namely programming concepts (sequences, loops, events, etc.), certain practices that are developed through programming (improved problem-solving skills, repurposing, combining different projects, etc.) and perspectives from the world around us (expression, connecting with others, questioning ideas, etc.) (Brennan & Resnick, 2012). In addition, it has been shown that Computational Thinking is an effective way by which it is possible to approach and increase the interest of girls in Computer Science (Seneviratne, 2017).

Some authors have supported the idea of introducing Computational Thinking in pre-university studies as a way of improving students' notion of Computer Science (Funke et al., 2016; Herrero-Álvarez et al., 2023; Herrero-Álvarez et al., Jan 2021; Herrero-Álvarez et al., Oct 2021; Lye & Koh, 2014). Also, some experiments have confirmed that giving students a course in which they practice programming through a gaming environment using a robot increases the prospects of providing effective programming education to elementary students (Shim et al., 2017), or that the students' inadequate background knowledge of this field could be improved by teaching programming to children and teenagers at schools (Resnick et al., 2009), but for this to happen, it is necessary to foster the dialogue between the communities of primary and higher education (Medeiros et al., 2019), in addition to training the relevant teachers in pre-university education (Kalogiannakis & Papadakis, 2017).

Since the aforementioned misconception could considerably reduce the interest in this academic field (Henry & Dumas, 2018), in this paper we selected a set of extracurricular activities designed to disseminate and promote Computer Science through the development of Computational Thinking skills. The main aim is to provide a methodology to introduce concepts related to Computational Thinking, and therefore to Computer Science. The Computational Thinking training phase of said methodology consists of a set of both plugged and unplugged Computational Thinking activities, which have been designed and scheduled in five sessions lasting four hours each, involving primary (8-9 years old) and secondary (12-13 years old) education students.

However, it is important to consider that emotions affect how we acquire knowledge, that is, how we learn (Pekrun, 1992; Weiner, 1984). Preschool students, those younger than 6 years old, have mostly positive attitudes and emotions towards science-related activities, but this positive predisposition decreases with age, especially between 8 and 10 years old (Dávila-Acedo et al., 2021; Mellado Jiménez et al., 2014; Osborne et al., 2003). Specifically, in the area of Computer Science, better results have been obtained when learning to program using a platform with systems that recognize emotions and adapt the content accordingly, than by using the same platform with the recognition system disabled (Zatarain Cabada et al., 2018). Other authors have conducted measurements involving the emotions felt when carrying out activities related to Computer Science, reaching the conclusion that happiness affected positively, and anxiety negatively (Giannakos et al., 2014). Furthermore, some studies point to a loss in efficiency due to anxiety in people who use computers (Achim & Kassim, 2015), or show that it is possible, by lowering anxiety and anger through computers, to improve one's knowledge of computers (Kay, 2008).

The purpose of this paper is to analyze the emotions that are present in young people who engage in Computational Thinking activities. This study contributes to the existing literature by examining the emotions associated with Computational Thinking, which is a distinct aspect of Computer Science education and is not widely studied. By categorizing these emotions as negative, ambiguous, and positive, we can explore their impact on individuals' perception of Computer Science, considering factors such as age and gender.

The rest of this paper is organized as follows. A further description of the hypotheses and research goals is given in the next subsection. Section 2 presents the methodology used in this study, with a description of both the activity sessions conducted and the measurement instruments utilized. In section 3, the results of the study are presented and discussed. Finally, section 4 contains the findings of our work and future areas of research.

1.1 Hypothesis, Aims, and Objectives

The hypothesis considered in this paper is that the poor interest in Computer Science shown by young people is due to their misconception about the field. We would also like to determine why the number of girls enrolled in engineering degrees is low (Strachan et al., 2018). Bearing the above in mind, Computational Thinking training would also allow girls to become much more interested in Computer Science. At this point, we should note that, due to the low participation of women in engineering degrees, the questionnaires and activities designed were analyzed from a gender perspective.

We aim to show that no gender differences exist in the emotional state when providing training on Computational Thinking in primary education, but that they do exist in secondary education. Also, recent studies have shown that girls tend to align with stereotypes related to subjects of a more verbal nature, while boys excel in Mathematics and Science. This difference occurs mainly in adolescence (Kurtz-Costes et al., 2014; Plante et al., 2009). In the case of university studies, and specifically in Computer Science studies, there are women who avoid difficult technical tasks for fear of affecting the team's success, because of either their lack of experience or their lower self-efficacy in particular domains, influenced by gendered expectations of men's experience (Fowler & Su, 2018). Therefore, it is important to approach the work from a gender perspective and ascertain why differences in the perception of Computer Science between genders are not expected in primary education, but are expected in secondary education. Another important aspect that can affect the emotions felt by students is related to the methodology of the activity they perform, guided or discovery, as well as the order in which they perform them (Goo et al., 2006), or even a combination of both, guided-discovery (Honomichl & Chen, 2012).

To promote pre-university education in the field of Science, Technology, Engineering, and Mathematics (STEM), it is necessary to train the relevant teachers, who must possess knowledge in this domain. However, they did not receive sufficient pre-service or in-service training, and lacked an adequate understanding of planning, implementing, and assessing activities (Gözüm et al., 2022).

Considering the aforementioned context, one of the main goals of this initiative is to make Computer Science much more appealing to young people through specific training on Computational Thinking. The main goal of this work is to analyze the emotional state of pre-university students as they engage in Computational Thinking activities, identifying what emotions are present during these sessions and their intensity and determine if there are differences in the emotions depending on the age, gender, and session model. The specific hypothesis are as follows:

H1: *Girls will feel fewer positive emotions than boys, especially in secondary school*.

H2: *Negative emotions will be higher in secondary school than in primary school*.

H3: *The session model does not significantly affect the emotions felt*.

2. Method

To develop Computational Thinking skills in young individuals, a course was conducted wherein primary and secondary students participated in a series of activities focused on exploring these concepts.

2.1 Activities

The students took a course with five lessons, two-hour classroom sessions, and a further 10 hours of homework. To train the students, a combination of both plugged and unplugged activities (that is, activities that rely on using a computer or mobile device, paper and pencil or any electronic device) and tools was used. It has been demonstrated that this type of activity effectively enhances interest in Computer Science among pre-university students (Herrero-Álvarez et al., 2023).

The activities were divided into two types, depending on the learning methodology. One was guided, where the basic concepts and principles of Computational Thinking were presented using a problem and analyzing the algorithm required to solve it. And the other involved discovery, where the student was taught the tools needed to implement some of the examples involved in Computational Thinking. The course employed two models: one began with two guided sessions and ended with three discovery sessions, guided-discovery (GD) model; in the other, the sessions were reversed, discovery-guided (DG) model.

These activities are described in Table 1 for both the primary and secondary levels. The activities for the DG model are the same but in different order, since the discovery activities are presented first, followed by the guided activities.

Table 1. Description of activities in the GD model

PRIMARY		
Guided		Discovery
Session 1	Session 2	Sessions 3, 4 & 5
Code&Go Mouse. Program a robot that travels in a maze[1].	Course at Code.org. Course 2[2].	Exercise on Scratch (Resnick et al., 2009). Fruit basket. The students program a basket in which they must place fruits without going over a specified calorie limit. Using the Makey Makey board[3], they cut out fruits from construction paper and line it with aluminum paper.
SECONDARY		
Guided		Discovery
Session 1	Sessions 2 & 3	Sessions 4 & 5
Course at Code.org. 20-hour course[4].	Exercise on Scratch. Matrioskas challenge. Arrange 5 dolls in size from smallest to largest. Discovery work continues in session 3	Robot mBot[5]. A self-steering robot with multiple sensors is programmed to travel in a circuit.

2.2 Participants

All the students participating in the project also participated in the study described in this work. This project was carried out with students in different schools on the island of Tenerife, Canary Islands, Spain, in 3rd grade, 8-9 years old, and 7th grade, 12-13 years old. Both girls and boys participated in the study. The teaching staff responsible for them authorized their participation. No payment was made to the participants. All the data were collected in the schools that participated in the project, which was affected by the COVID-19 pandemic, meaning the expected sample size was reduced, as schools closed from March to June, especially the secondary education schools, which were scheduled for those months. In previous editions, the project was carried out with more than 250 students; however, in the school year that is the subject of this study (2019/2020), the total sample was 102 students. Table 2 lists all the students who took part in the project, grouped by grade and gender.

Table 2. Quantitative description of the sample

PRIMARY		SECONDARY	
74 students		28 students	
39 girls	35 boys	10 girls	18 boys

2.3 Data Collection

At the end of the first session, at the end of the first session after the methodology change, session 3 in the GD model and session 4 in the DG model, and in the last session, the participants completed the *Developmental Channels Questionnaire* - DCQ (Mosston & Ashworth, 2002), which was used to record their emotions. This questionnaire was available online and was completed by the students autonomously on the device they had used

[1] https://www.learningresources.com/code-gor-robot-mouse-activity-set
[2] https://studio.code.org/s/course2
[3] https://makeymakey.com/
[4] https://studio.code.org/s/20-hour
[5] https://www.makeblock.com/mbot/

to carry out the different exercises of the project, which could be a computer or a tablet. This data collection method represents an affordable option with greater data completeness compared to data collection by paper (Ebert et al., 2018). This questionnaire also included a question about the student's gender (girl/boy).

Gathering data at the conclusion of each stage facilitates the examination of potential disparities that arise when implementing either methodology.

2.4 Instrumentation

The different methods of learning show the relationship between pedagogical elements by creating conditions for diverse experiences (Mosston & Ashworth, 2002), becoming a tool that teachers can use to express their creativity and individuality (Goldberger et al., 2012). The choice of teaching method is an important decision for instructors, since it affects their relationship with the various elements of the teaching activity (Tsolakidis & Anagnostou, 2011).

The DCQ includes scales described using opposing pairs of adjectives, such as minimum-maximum, hard-easy, strong-weak, bad-good, useful-useless, and pleasant-unpleasant, which provide an excellent gauge of an individual's thoughts. Specifically, it was used to ask about their happiness, compassion, surprise, joy, sadness, fear, humor, anxiety, love, anger, rejection, shame, and hope, using a Likert scale from 0 to 10.

The students were given this questionnaire three times: at the end of the first session, at the end of the first session after the methodology change (session 3 in the GD model and session 4 in the DG model), and in the last session.

2.5 Data Analysis

After gathering the data from the questionnaires, the theoretical variables were calculated and classified into positive (happiness, joy, humor and love), negative (sadness, fear, anxiety, anger, rejection and shame), and ambiguous (compassion, surprise, hope), as per Lazarus (Lazarus, 1991) and Bisquerra (Bisquerra Alzina, 2003), based on the average score for each group of emotions. In Section 3 on the results, graphs are provided in a bar diagram format for each of group of emotions, separating them by gender and educational level, and by gender and type of session.

The data were analyzed using version 2.0 of the SPSS statistics program for Windows. The Kolmogorov-Smirnov normality tests show that the distributions of the theoretical variables do not follow a normal distribution, which translates into a lower reliability of the mean as a measure of central tendency. It is therefore possible that some of the trends observed as not significant are, nonetheless, sufficient to be considered important.

We then conducted a *Chi-square Automatic Interaction Detector* - CHAID - analysis (Kass, 1980), which yielded a representation of the data in decision trees for the Gender (girls or boys), Level (primary or secondary) and Session Type (GD or DG model) variables.

The data show an interrelation between the variables different from that suggested by Lazarus (Lazarus, 1991) and Bisquerra (Bisquerra Alzina, 2003). Preliminary tests using exploratory factor analysis demonstrate a two-factor result, positive + ambiguous and negative, instead of three. In future work, the results could gain in strength by considering only these two factors.

3. Results

In this section, the results of the *DCQ* questionnaire are presented, analyzing them first according to gender and educational level, then according to gender and session model, and finally the decision trees are included according to the *CHAID* analysis (Kass, 1980) for each classification of emotions: positive, negative and ambiguous.

3.1 Emotions, gender and educational level

This section specifies the positive, ambiguous and negative emotions obtained depending on the students' educational level. Figure 1 shows the positive, ambiguous and negative emotions by gender and educational level, reflecting the median for each classification of emotions on a scale from 0 to 10.

As we can see, there are no apparent differences between boys and girls at the primary level; however, the girls in secondary school express fewer positive emotions, with a difference of more than one point.

As regards the ambiguous emotions by gender and level of education, there are differences between boys and girls in both educational levels, although both girls and boys feel fewer ambiguous emotions in secondary school. Both tendencies, boys and girls, seem to be present in equal measure, but as with the positive emotions, the difference is greater in secondary school, where girls feel somewhat less ambiguous emotions, with a difference of up to one point on average.

Even though the negative emotions in both levels are very low -close to zero-, we see significant differences between the levels, these differences being much starker in the girls than in the boys. The girls in secondary school stand out, where the greatest number of negative emotions was evident when carrying out the activities, near three points out of 10. These differences are much more significant in the girls than in the boys, which reaffirms hypothesis **H1**. In general, negative emotions are more present in secondary school than in primary school, so hypothesis **H2** is accepted.

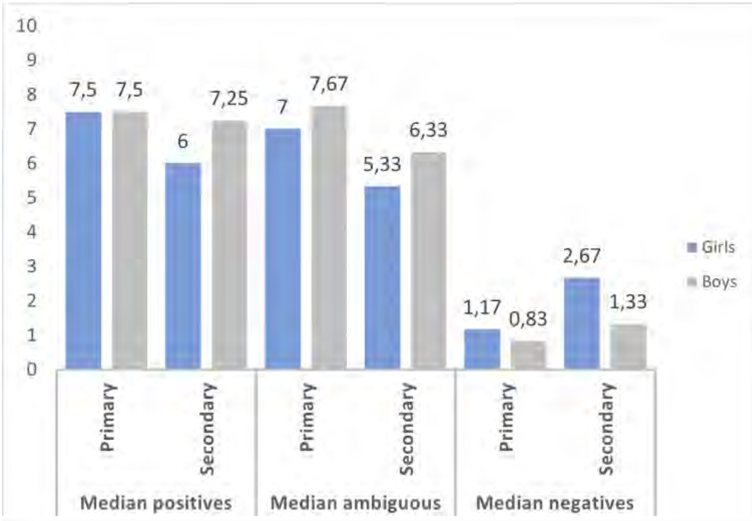

Figure 1. Emotions by gender and educational level

3.2 Emotions, gender and session model

This section presents the median of the positive, neutral and negative emotions obtained based on the session model employed. Figure 2 shows the positive, neutral and negative emotions based on the gender and session model employed.

We see differences between the boys and girls in the Discovery-Guided sessions, but there seem to be no differences between them in the Guided-Discovery sessions. Moreover, the Discovery-Guided sessions seem to provoke a lower number of positive emotions in the girls, of one point out of 10. We see no large differences between the boys and girls regarding ambiguous emotions; however, there is a slight change in the boys during the Discovery-Guided sessions, since there is a difference of about one point higher with respect to the girls.

As for the negative emotions by gender and session model, there are no apparent significant differences between the two models. What is more, we see an inverse relationship in the differences between the boys and the girls, such that the girls seem to develop more negative emotions during the Guided-Discovery sessions, whereas the boys develop more negative emotions during the Discovery-Guided sessions. Despite the differences observed, these are not significant, so hypothesis **H3** is accepted.

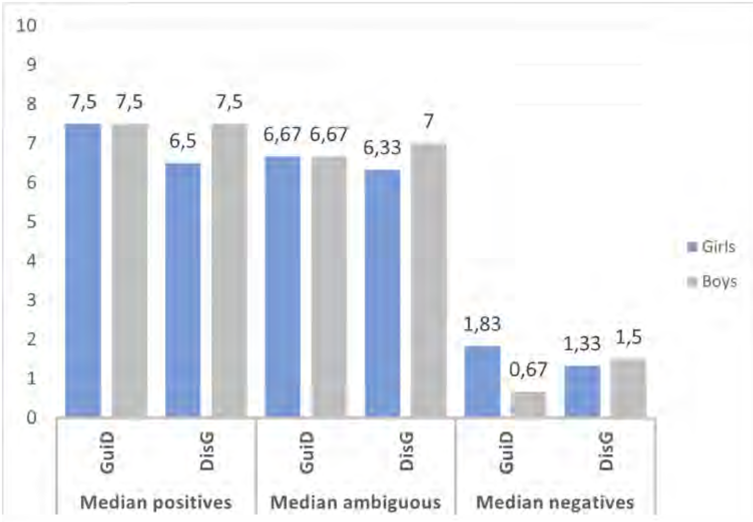

Figure 2. Emotions by gender and session model

3.3 Emotions, gender and educational level model trees

This section presents the classification trees for the positive, ambiguous and negative emotions obtained depending on educational level and gender, as shown in the next three figures.

These decision trees contain different nodes showing the number of sample data for that node '*n*', the mean score '*mean*', the standard deviation '*Std. Dev.*', and the percentage of the total sample that this node represents '*%*', as per the CHAID analysis method (Kass, 1980). The *n* in the trees indicates the total number of tests collected, considering that this was completed by each student three times for each session and that data cleaning was not performed for this analysis.

Each level of the decision trees contains the statistical analysis performed, such that the next nodes of the next level are those where the greatest differences are evident, where the p-value < 0.05.

3.3.1 Tree of positive emotions

The decision tree for positive emotions, see Figure 3, shows that the most significant difference is found between secondary school students, with boys feeling more positive emotions than girls, so hypothesis **H1** is accepted. The values obtained were p-value $= 0.017$; $\mathrm{F} = 5.839$. There are also differences between the educational level, with the younger students feeling these kinds of emotions more than the secondary students.

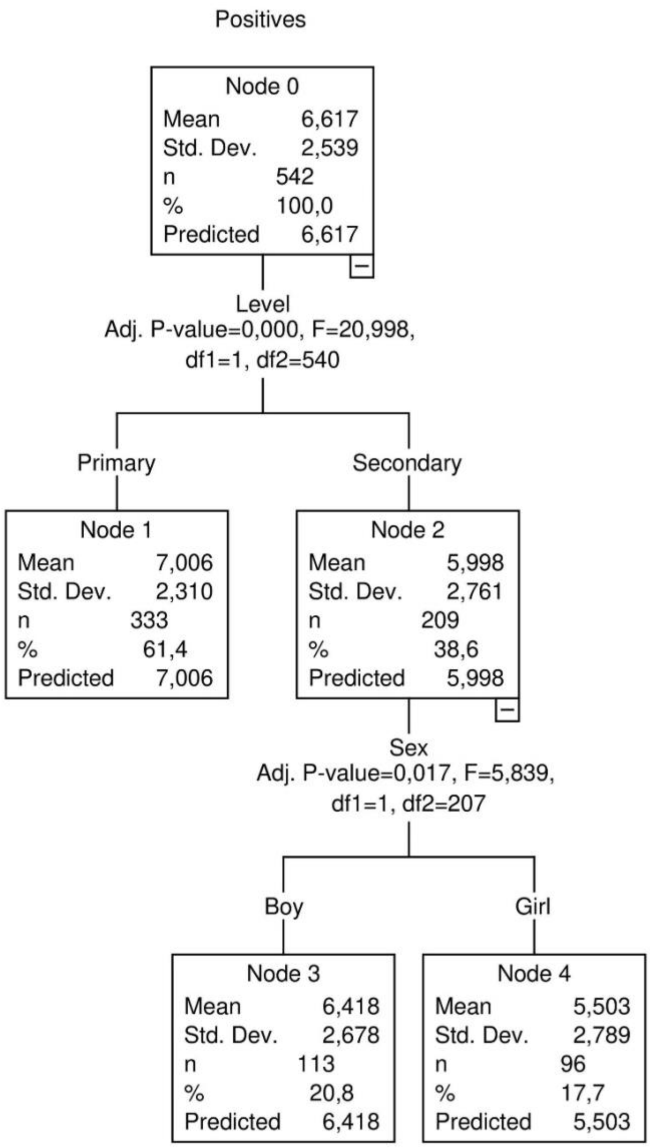

Figure 3. Tree of positive emotions

3.3.2 Tree of ambiguous emotions

Again, in the decision tree of ambiguous emotions, see Figure 4, we see that the most significant difference is found between the older boys and girls, since the latter feel these types of emotions to a lesser extent. The values obtained were p-value $= 0.014$; $F = 6{,}188$. Regarding the educational level, differences also appear, since in the case of primary school, these types of emotions are greater than in secondary school, with a difference of more than 1.5 points.

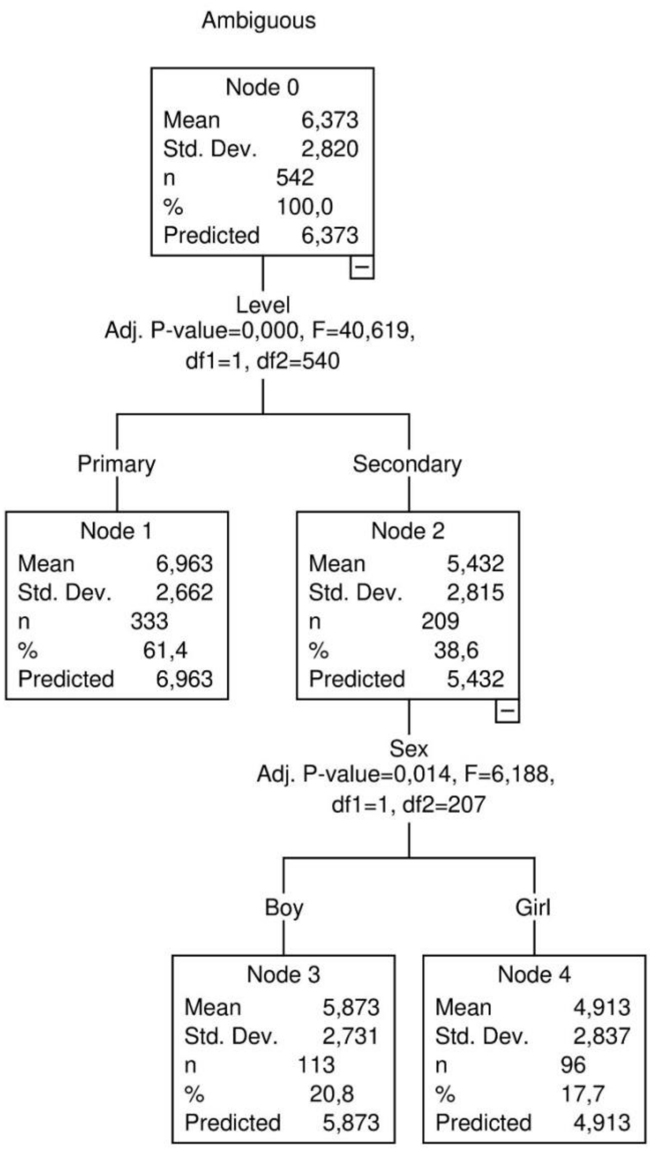

Figure 4. Tree of ambiguous emotions

3.3.3 Tree of negative emotions

In the case of the decision tree of negative emotions, see Figure 5, the most significant differences are again apparent in secondary school between girls and boys, with girls being the ones who feel the most negative emotions when engaged in activities involving Computational Thinking. The values obtained were p-value $= 0.014$; $F = 6{,}207$. The primary school students feel fewer negative emotions than the secondary school students, since the former do not reach two points, while the latter exceed 2.5 points out of 10, so hypothesis **H2** is accepted.

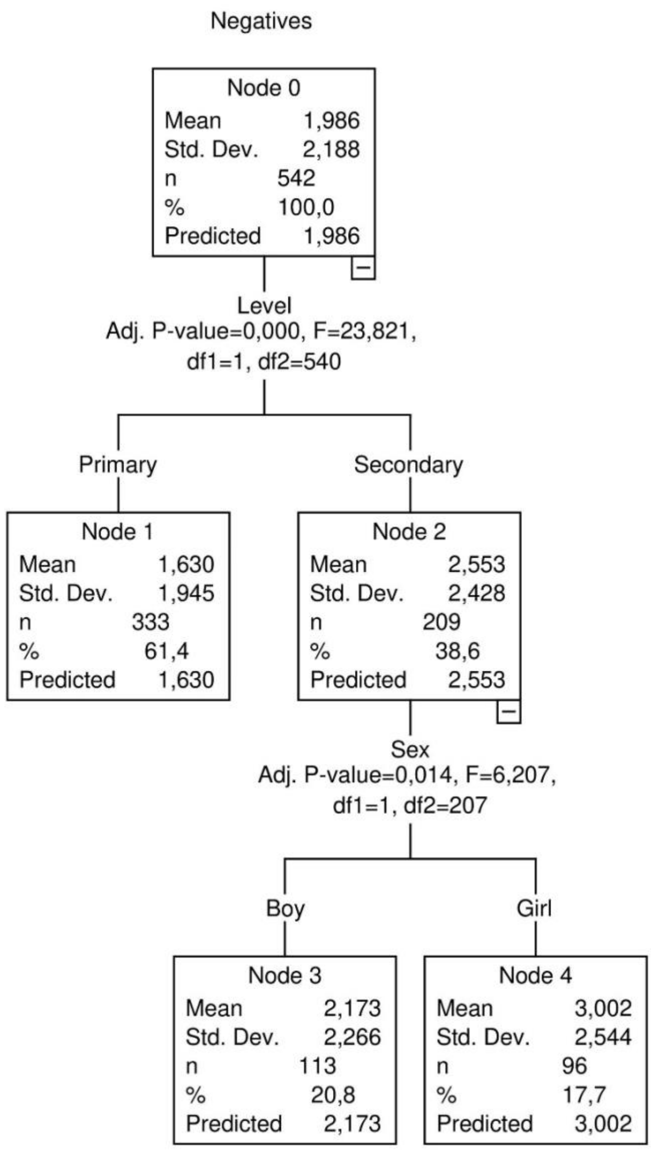

Figure 5. Tree of negative emotions

4. Conclusions and discussion

The main conclusions of this study have been established based on the objectives and hypotheses proposed for its development. Regarding the objective of identifying the emotions that are produced, as well as their intensity, we conclude that positive and ambiguous emotions are mainly produced in this type of session with intensity values of 6.62 and 6.37 on average, respectively. Although the students show negative emotions with low intensity, with an average of 1.99 over 10.0, it is in secondary education where they mostly appear.

In addition, regarding the study of the possible differences between the emotions felt depending on the session model, Guided-Discovery or Discovery-Guided, we conclude that at the primary and secondary educational level, it follows that, with the data collected, similar positive, negative, and ambiguous emotions can be found between boys and girls without finding significant differences between the two genders in any of them, but there is an inverse relationship in the differences between the boys and girls, since the girls seem to develop more negative emotions during the Guided-Discovery sessions, but the boys develop more negative emotions during the Discovery-Guided sessions.

However, regarding the educational level, primary or secondary, it is necessary to note that in secondary, there are differences between boys and girls in all of them. We see that the girls exhibit more important changes in this type of session, whereas the boys hardly evolve emotionally in this aspect. Thus, the girls seem to show a lower intensity of positive and ambiguous emotions, and a slight increase of negative ones.

Our results show that the hypotheses considered at the beginning of the work are accepted. In addition, they are consistent with what other authors have confirmed regarding the change that occurs in emotions with age, where positive emotions decrease, and regarding how in the case of girls, there is a more noticeable difference with respect to the boys as they grow up.

The implications of this work, which observes the emotions felt by the students when carrying out these activities, mean that by knowing what the students feel, it is possible to adapt the activities proposed so that they are more appealing to the students, improving their learning process, guiding them to those that produce the greatest number of positive emotions, or eliminating those that produce negative ones. In this work, we have observed that the positive emotions in primary school are greater, changing completely when reaching secondary education, so it would be interesting to adapt the activities before reaching this educational stage. It is thus essential to work on maintaining positive emotions as the students grow up in order to keep their interest, especially in girls, since many of the studies focus on the emotions experienced by students regarding Computer Science, either through computer usage or by engaging in specific activities, without addressing the training of Computational Thinking skills. This work offers a review that can assist pre-university teachers with guiding various exercises aimed at enhancing students' emotional response.

The results show that the highest number of negative emotions is observed among female students in secondary education. Therefore, a special effort should be made to conduct activities that foster interest at these ages. One of the future objectives is to conduct a detailed study of the emotional response to each activity, specifically regarding programming concepts, regardless of whether they were taught through guided or discovery-based approaches.

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