
Emotions and academic performance in bilingual learning of natural science

Emociones y rendimiento académico en el aprendizaje bilingüe de las ciencias de la naturaleza

在自然科学双语学习中的情感与学业成绩表现

Эмоции и академическая успеваемость в двуязычном обучении в области естественных наук

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Abstract

Language and education are two essential dimensions that go hand in hand when it comes to human beings. Neurobiologists and linguists share the idea that our ability to speak is innate and that we are pre-programmed from birth to learn any language almost unconsciously. However, in a school setting learning a foreign language requires substantial planning and methodology, involving an effort by the learner who is thereby affected by the process. This paper aims to determine the effects of bilingual teaching on students' emotions and academic performance during the learning process of the subject of Science. To this end, a study was carried out in the 5th and 6th grades of Elementary Education, focusing specifically on the teaching-learning process of the subjects of Ciencias Naturales (natural sciences taught in Spanish, CCNN) and Science (bilingual school, natural sciences taught in English). The participants in the study were 286 students from the city of Badajoz (Spain), of whom 123 studied Science (bilingual school) and 163 studied CCNN in Spanish. The design of the study was descriptive, with use of a questionnaire to collect the data. The conclusions of the statistical analysis indicate that language is clearly an influential factor, as shown both in the lower grades and more negative emotions experienced by the students studying science in English. Conversely, the students from the non-bilingual school obtained the best grades and experienced the most positive emotions.

Key words: science; bilingualism; emotions; Elementary Education; student performance.

Resumen

En el ser humano, el lenguaje y la educación son dos dimensiones esenciales que van de la mano. Neurobiólogos y lingüistas comparten la idea de que la capacidad del ser humano para hablar es innata y que desde el nacimiento estamos pre-programados para aprender cualquier idioma de manera casi inconsciente. Sin embargo, en el espacio escolar, el aprendizaje de una Lengua Extranjera (LE) requiere una planificación y un método, y conlleva un esfuerzo y unos efectos en el alumnado. Es por eso que el presente trabajo deriva de la necesidad de conocer los efectos de la enseñanza bilingüe en las emociones y en el rendimiento académico de los estudiantes durante el proceso de aprendizaje de la asignatura de Ciencias. Para ello se ha llevado a cabo un estudio en los cursos de 5^o y 6^o de Educación Primaria (EP) centrado en el proceso de enseñanza-aprendizaje de las asignaturas de Ciencias de la Naturaleza (CCNN) y Science (centro bilingüe, Ciencias de la Naturaleza en lengua inglesa). Se contó con la colaboración de 286 alumnos de la ciudad de Badajoz (España), de los cuales 123 estudian Science y 163 estudian CCNN. El diseño del estudio fue descriptivo, empleando un cuestionario como instrumento de recogida de datos. Tras el análisis estadístico las conclusiones obtenidas muestran que el idioma es un factor claramente influyente tanto en las calificaciones obtenidas como en las emociones experimentadas por el alumnado que cursa ciencias en inglés; obteniendo los alumnos del centro no bilingüe las mejores calificaciones y las emociones más positivas.

Palabras clave: Ciencias; bilingüismo; emociones; Educación Primaria; rendimiento académico.

摘要

在人类中, 语言和教育是相辅相成的两个基本方面。神经生物学家和语言学家的观点是, 人类的语言能力是天生的, 从出生开始, 我们就已经被预先编程为以几乎无意识的方式学习任何语言。但是, 在学校空间中, 学习外语 (FL) 需要计划和方法, 并与学生的努力及其他的因素相关。因此, 这项研究旨在了解双语教育在理科学习过程中对学生的情绪和学业成

绩影响。为此,我们在小学五年级和六年级进行了一项调查,重点研究自然科学课西语教学和在双语学校中该课程的英语教学的 教学过程。来自西班牙Badajoz市的286名学生参加了研究,其中123名用英语上科学课,163名用西语上科学课。我们采用了描述性研究设计,使用问卷作为数据收集工具。统计分析得出的结论表明,在用英语上科学课的学生中,语言对其学业成绩和情感经历都具有明显的影响力。在非双语学校的学生有着更好的学业表现和更积极的情绪。

关键词: 科学; 双语; 情感; 小学教育; 学业表现。

Аннотация

В человеке язык и образование являются двумя основными аспектами, которые идут рука об руку. Нейробиологи и лингвисты разделяют идею о том, что человеческая способность говорить является врожденной и что с рождения мы заранее запрограммированы на изучение любого языка почти бессознательно. Однако в школьной среде изучение иностранного языка требует планирования и метода, а также требует усилий и воздействия на учащихся. Именно поэтому настоящая работа проистекает из необходимости знать влияние двуязычного обучения на эмоции и успеваемость учащихся в процессе изучения предмета «Естественные науки». С этой целью в 5-ом и 6-ом классах начальной школы было проведено исследование, посвященное процессу преподавания-обучения предметов Естественные науки и Science (Естественные науки на английском языке). С нами сотрудничали 286 учащихся из города Бадахос (Испания), из которых 123 изучали Science и 163 - Естественные науки. План исследования носил описательный характер, в нем в качестве средства сбора данных использовался вопросник. После статистического анализа полученные выводы показывают, что язык явно является влиятельным фактором как в полученных оценках, так и в эмоциях, испытываемых учениками, изучающими естественные науки на английском языке, при этом ученики из недвуязычных школ получают лучшие оценки и более позитивные эмоции.

Ключевые слова: Естественные науки; двуязычное образование; эмоции; начальное образование; успеваемость.

Introduction

Bilingual education has been a source of dispute and controversy in certain countries for many decades because of its effects on students' academic development (Bruton, 2011, 2015).

In 2002, the European Commission agreed that European citizens should learn at least two different languages other than their mother tongue (L1) (Barcelona European Council, 2002). In 2008, by virtue of a resolution of the European Council (2008) the member states agreed to promote social cohesion through multilingualism and strengthen language learning in order to promote linguistic diversity (Guadamillas & Alcaraz, 2017). In 2014, the European Commission published the document *Conclusions on multilingualism and the development of language competences*, which invited the member states to increase the measures aimed at enhancing the efficiency of early language learning and encouraged regional and European governments to make use of the various tools designed to promote language learning, such as the *Common European Framework of Reference for Languages (CEFR, 2002)*, the *Europass*, the *Erasmus+*

programs, the *European Language Portfolio* and the *European Language Label* (Council of the European Union, 2014).

In 1996, the Spanish Ministry of Education and the British Council signed a collaboration agreement to regulate Spanish-English bilingual education programs in publicly funded schools, with the aim of developing bilingual programs through an integrated Spanish-British curriculum. This agreement was implemented in 87 public pre-schools and elementary schools in ten Autonomous Communities. However, it must be taken into account that, alongside this agreement, the different Autonomous Communities have been drafting their own legislation to regulate bilingual education in monolingual communities (having a single official language) and trilingual education in bilingual communities (having co-official languages) (Guadamillas & Alcaraz, 2017; Martínez, 2019).

In the monolingual Autonomous Community of Extremadura, one of the main axes of the regional government's education policy is the prominence of foreign languages in the curriculum (Ministry of Education, 2004). Section 74(1) of Law 4/2011 on Education in Extremadura provides that "pre-schools and elementary schools to be created in the Autonomous Community shall be bilingual" (p.29). Meanwhile, the Decree of 20 April 2017 states that teachers must provide proof of a B2 level in the foreign language they teach, as well as their methodological competence in accordance with Decree 39/2014. With regard to the methodology, this same Decree mentions the need to work according to the CLIL methodological principles (Content and Language Integrated Learning). The CLIL approach requires collaboration and coordination between the teachers of foreign languages and those of non-linguistic subjects, thus increasing student motivation levels and reducing their inhibition to express themselves in a foreign language.

According to Lorenzo (2015) and Salaberri (2009), this approach has triggered the need to create a meaningful teaching-learning process and to search for the greatest possible number of interdisciplinary connections between the different areas (Travé, 2016). However, in relation to the importance of language learning, authors such as Pavón (2009) argue that "if the linguistic objective prevails over the academic one, there will inevitably be an impoverishment in the acquisition of academic content" (p.71).

Meanwhile, authors such as Coste (2001) and Duverger and Maillard (1996) argue that this bilingual education model provides linguistic, cognitive and cultural benefits to students given that despite the need for the mother tongue in the acquisition of knowledge, the use of a foreign language has a positive influence on the processes of abstraction and construction of knowledge. Likewise, numerous studies outlined in Vásquez (2009) claim that students with access to bilingual programs will have greater chances of academic success due to the fact that they have higher levels of self-control and ability to manipulate language, although they also emphasize the importance of balanced bilingualism (a similar level of linguistic competence in both languages).

Focusing on the subject of science, Archila (2013) argues that a good cognitive-linguistic level facilitates students' learning of science since "progress by students in the field of scientific knowledge is linked to the acquisition of vocabulary and expressions that allow them to assimilate, develop and communicate new ideas without ambiguity" (p.157). In addition, Lemke (1997) found certain similarities between the process of learning the language of science and the learning of a foreign language:

Learning science involves learning to speak the language of science. It also involves using this special conceptual language when reading and writing, when reasoning and solving problems, during practice in the laboratory, and in everyday life. It involves learning to communicate in this language and being an active member of the community of people using it. (p.17)

It should also be noted that the learning process is the result of the interaction between cognitive and emotional causes (García 2012; Koballa & Glynn, 2017). Thus, despite the fact that the current educational model tends to suppress or minimize the aspect of emotions, thanks to the impact of Gardner's theory of multiple intelligences (1998) and the emergence of the constructivist model, emotions are increasingly being considered as one of the fundamental aspects of a comprehensive education. For Bisquerra (2014), the need for emotional education is evident given that emotions are "an essential part of life" (p.1) and he defines them as "a complex state of the organism characterized by an excitement or disturbance that predisposes action" (p.2).

From the standpoint of the didactics of science, more and more authors question the idea of independence between the rational and the emotional, considering the relationship between both domains to be evident (Frijda, 2000; Gómez, Lucas, Bermejo, & Rabazo, 2018; Koballa & Glyn, 2000; Martínez, 2009). Currently, emotions are assuming increasing importance in our society and it has been clearly demonstrated that there is a need to include the emotional dimension in both research on education and the teaching-learning process itself (Arslan, 2017; Mellado, Blanco, Borrachero, & Cárdenas, 2013).

Despite the importance of science and mathematics in our society, many students still fail to see the utility of these subjects because they perceive them as boring, excessively theoretical, irrelevant, impractical and disconnected from their daily life (Lyons, 2006; Solbes, 2011; Vázquez & Manassero, 2008). This has created a strong degree of rejection and a high failure rate at various educational levels (Pino, 2013; Gómez-Chacón, 2000), since this perception affects academic performance (Monje, Pérez-Tyteca, & Castro, 2012). Authors such as Romero-Ariza (2017) point out that "since the second half of the 20th century, specialists have urged that the teaching of science should be more relevant for students, in order to allow them to understand and deal with everyday phenomena and issues in life" (p.286).

Fortunately, several studies (García-Ruiz & Orozco, 2008; Mellado et al., 2014; Mora, 2013) maintain that students' emotions can be transformed from negative to positive, provided that teachers make them understand the usefulness of the knowledge in question. It is also important that teachers use innovative methodologies in the classroom, and above all, they need to be aware of the social context in which they are working in order to build meaningful teaching-learning processes. Various authors point out that trainee teachers should receive a thorough and adequate emotional education, since they are the ones who will help students to handle their emotions in the future (Chen, 2018; Del Rosal, Moreno-Manso, & Bermejo, 2018; García-Carmona & Cruz-Guzmán, 2016; Ramos & Espinet, 2013).

Lemkow-Tovias et al. (2016) highlight curiosity, motivation, fascination, emotion and the desire to discover new answers as cornerstones of learning, and all those qualities seem to be inherent in bilingual teaching. Thus, we set out to analyze the influence of language-skill development programs on the emotions and academic performance of students in the learning context of natural sciences. Our aim was to analyze the influence of bilingual education programs (Spanish/English) on the emotions and academ-

ic performance of students during their studies of natural science in the monolingual community of Extremadura.

Objectives

In light of the above review of the literature, this study proposes the following two aims:

1. To determine whether the use of a second language (English) affects students' emotions while learning natural sciences in the 5th and 6th grades of elementary education.
2. To determine whether the use of a second language (English) affects the academic performance of students while learning natural sciences in the 5th and 6th grades of elementary education.

Method

The design of the study follows a descriptive, non-experimental and cross-sectional quantitative model. This methodology allows us to analyze the variables of the study through an analysis oriented to testing and contrasting hypotheses (Latorre, Rincón, & Arnal, 2003). We also recognize our study as non-experimental since the role of the researcher in this type of study is limited to observing already existing situations (Rodríguez & Valldeoriola, 2014). Finally, we identify our study as cross-sectional, since data collection is conducted at a specific point in time (Hernández-Sampieri, Fernández, & Baptista, 2006).

Sample

The sample was selected using convenience sampling. It comprised a total of 286 students of between 10 and 13 years of age ($M= 10.53$; $DT= .67$), from the 5th and 6th grades of elementary schools in Badajoz (Spain). One of these schools is signed up under the Spanish Ministry of Education-British Council scheme, while the other school applies a traditional teaching model. The students belonging to the bilingual school represent 43% of the sample ($n= 123$ subjects), while those enrolled in the monolingual school represent the remaining 57% ($n= 163$ subjects). Both schools are located in the same neighborhood and all the students have a very similar cultural and socioeconomic background. According to the teachers, the level of linguistic competence is quite homogeneous, being generally less than a B1.

Instrument

The design of the study follows a descriptive and cross-sectional observational model. To obtain the data, a questionnaire based on the Inventory of Attitudes towards Mathematics (Sánchez, 2014) was used as a measuring instrument. This questionnaire is an adaptation and extension of the Fennema-Sherman Scale (FSS) (1976), a tool used for evaluating attitudes and emotions involved in learning mathematics.

The initial questionnaire had to be modified to adapt it to the selected sample and was subsequently subjected to inter-rater reliability tests by a panel of experts from the University of Extremadura (Spain). Consequently, the number of questions was reduced for this study (from 43 to 28) and the assessment scale was also adapted (from 5 to 3 possibilities: 1. Never, 2. Sometimes, and 3. Always). As for the ranking scale, the following qualitative categories were used: 1. Fail 2. Sufficient, 3. Good 4. Very Good, and 5. Excellent.

After the above changes, the final result was a questionnaire with 28 questions grouped and classified into three sections, each centered on an area of study. The third section focused on emotions and was composed of six questions (see Table 1).

Table 1

Items designed to capture the positive and negative emotions experienced by students in CCNN and Science classes

Positive emotions
CCNN/Science is my favorite subject
I have fun in CCNN/Science classes
I feel very proud when I pass a CCNN/Science exam
Negative emotions
I find CCNN/Science boring
I feel nervous during CCNN/Science classes
I get angry when I don't understand something about CCNN/Science

Procedure and statistical analysis

The process of filling out the questionnaires began by obtaining the consent of the schools and establishing a schedule for the activity. The supervising teachers of each class were in charge of distributing the questionnaire to their students, who answered all the questions anonymously. Previously, a pilot study was carried out to check the duration of the activity and also to verify that each question was clearly formulated, ensuring that no complications arose while filling them out. The students spent approximately 20 minutes on this task.

Once all the questionnaires were collected, some had to be discarded due to errors in their execution, so the final number we worked with was 286. Next, a descriptive statistical analysis was carried out using mean, frequency, percentage and standard deviation. With the aim of assessing the normality of the data, the Kolmogorov-Smirnov normality test was applied. Randomness was also determined using the run test of randomness, and finally the homogeneity of variance was tested by carrying out Levene's test. The sample did not follow a normal distribution and therefore it did not meet the necessary conditions for the application of parametric tests.

An inferential analysis was then performed using the Mann-Whitney U Test for independent samples, given that the sample distribution did not conform to normality

(K-S Test). The data were processed using the SPSS (Statistical Package for the Social Sciences) software version 21®, with a 95% confidence level.

Results

Emotions in the study of CCNN and Science

For the study of *emotions*, a descriptive analysis was performed of the positive emotions (*enjoyment, fun and pride*) that students felt when studying the subjects of CCNN and Science. The same procedure was used for the negative emotions (*boredom, nervousness and anger*). The results are shown in Tables 2 and 3.

These tables indicate the frequency of the emotions the students experienced measured in percentages, taking into account whether they studied Science or CCNN.

Table 2

Percentage of bilingual students and the frequency with which they experience each emotion while studying Science.

BILINGUAL (Science)						
	POSITIVE EMOTIONS			NEGATIVE EMOTIONS		
	Enjoyment	Fun	Pride	Boredom	Nervousness	Anger
1. Never	56.6	27.0	22.1	29.5	18.0	55.7
2. Sometimes	34.4	57.4	50.0	58.2	41.0	33.6
3. Always	9.0	14.8	27.9	12.3	41.0	10.7
Total	100.0	99.2	100.0	100.0	100.0	100.0

The above table (see Table 2) shows the emotions of bilingual pupils classified by type of emotion and frequency. The subjects were asked to rate from 1 to 3 (1. Never, 2. Sometimes and 3. Always) the frequency with which they experienced a series of both positive and negative emotions during their Science class.

In the set of positive emotions (*enjoyment, fun and pride*), the highest percentage (57.4%) corresponded to the emotion of *fun*, with a frequency of “sometimes”. This means that the positive emotion of *fun* was the one most frequently experienced by bilingual subjects. However, this emotion was not the most frequent since it did not “always” occur, but bilingual students recognized that they felt it “sometimes”. Following the same type of analysis for the set of negative emotions (*boredom, nervousness and anger*), the highest percentage (58.2%) corresponded to the emotion of *boredom*, with a frequency of “sometimes”. As in the previous set, this means that the negative emotion of *boredom* was the one that most bilingual subjects identified.

Subsequently, it can be seen that the most frequently experienced positive and negative emotions were *pride* and *nervousness* respectively. That is, only 27.9% of students

reported “always” feeling *proud* during Science classes while 41.0% of subjects “always” felt *nervous* during the process of learning Science.

In Table 3, which corresponds to the non-bilingual students who study CCNN in Spanish, the results for the set of positive emotions coincide with those obtained by the previous group in terms of both the frequency and the type of emotion experienced, since 50.3% of the sample of non-bilingual students said they “sometimes” felt *fun* in their CCNN classes.

Table 3

Percentage of non-bilingual students and the frequency with which they experience each emotion while studying CCNN

NON-BILINGUAL (CCNN)						
	POSITIVE EMOTIONS			NEGATIVE EMOTIONS		
	Enjoyment	Fun	Pride	Boredom	Nervousness	Anger
1. Never	33.7	12.9	16.0	51.5	25.2	54.0
2. Sometimes	36.8	50.3	35.6	37.4	41.7	36.2
3. Always	29.4	36.8	48.5	10.4	33.1	9.8
Total	100.0	100.0	100.0	99.4	100.0	100.0

As regards negative emotions, the highest percentage (54.0%) corresponds to *anger*; this time however, the students experienced this emotion with a frequency described as “never”, which can be considered as a positive result since it means that slightly more than half the sample coincided in stating that they “never” felt *bored* during CCNN classes.

As for the emotions most often repeated, the results observed in row “3. Always” coincided with those of bilingual students, with the most repeated positive and negative emotions being *pride* and *nervousness*, respectively. The difference with the previous group lies in the percentage of students who experienced each emotion. 48.5% of non-bilingual students said they “always” felt *proud* in the CCNN subject, compared to 27.9% of bilingual students in Science. As for the emotion of *nervousness*, 33.1% of non-bilingual students admitted that they “always” felt *nervous* in the same subject, while in the sample of bilingual students the percentage rose to 41.0%.

Finally, in order to understand which group of students (bilingual or non-bilingual) “always” experienced certain emotions, these were grouped in Tables 2 and 3 and synthesized into positive and negative; then the percentage of the sample for each emotion was calculated. Figure 1 shows the percentage of students who recognized that they “always” (frequency 3. Always) felt positive or negative emotions during their Science/CCNN classes.

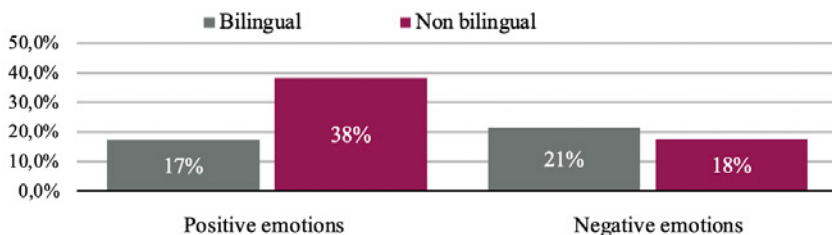


Figure 1. Percentage of bilingual/non-bilingual students who always feel positive or negative emotions

Figure 1 shows that in the set of positive emotions, the highest percentage corresponds to the group of non-bilingual students (38.2%), while in the group of negative emotions the highest percentage is among bilingual students (21.3%). These data indicate that subjects who take CCNN in Spanish reported feeling positive emotions more frequently during CCNN classes, while bilingual students reported feeling more negative emotions during Science classes.

Once the descriptive analysis was completed, an inferential analysis was carried out using the Mann-Whitney U test to verify if there were significant differences in the above-mentioned emotions (see Table 4). The data shown in this table reveal the existence of significant differences ($p = 0.001$) between both sets. It can therefore be inferred that students from the non-bilingual school experienced more positive emotions than students from the bilingual school in the subject of natural sciences.

Table 4

Mann-Whitney U Test of independent samples in emotions

Null hypothesis	Test	Sig.	Decision
Distribution of Emotions is the same within the school categories	Mann-Whitney U Test of independent samples	.001	Reject the null hypothesis.

Academic performance in the study of CCNN and Science

For this section of the study, a series of questions relating to student grades was used. The results shown were obtained through analysis of parametric tests and independent samples, comparing the bilingual and non-bilingual groups.

The academic performance of the subjects was recorded in the first question of the questionnaire: "What was your score in Science/CCNN last year?"

Once all the questionnaires were collected, the average score obtained by each group (bilingual/non-bilingual) was calculated. Table 5 shows that although the academic results were quite good in both groups, the students in the non-bilingual sample obtained higher scores (average 8.63) than those in the bilingual sample (average 7.72).

Table 5

Average scores by school type

	School Type	S	Average	Standard Deviation	Standard Error of Mean
Score	Bilingual	116	7.7	1.3	.12
	Non-bilingual	141	8.6	1.1	.09

Table 6 shows a more detailed analysis of the percentage of students for each grade. It is important to highlight that the percentage of non-bilingual students who obtained "1. Fail" CCNN was 0.0%, compared to 1.7% of bilingual subjects. In addition, more than half of the non-bilingual sample (65.2%) obtained "5. Excellent" in CCNN, this percentage being almost double that of bilingual students learning Science. Finally, it should be noted that while 34.6% of bilingual students obtained the grade of "2. Good", only 8.6% of non-bilingual students obtained this same qualification.

Table 6
Percentage of students for each grade

Grades	Bilingual	Non-bilingual
Fail	1.7	0.0
Sufficient	6.1	2.8
Good	34.6	8.6
Very Good	24.0	23.4
Excellent	33.6	65.2
Total students	100.0	100.0

After this descriptive analysis, in order to check if there were significant differences between the scores an inferential analysis of both groups was carried out using the Mann-Whitney U test (see Table 7).

Table 7
Mann-Whitney U Test of independent samples in scores

Null hypothesis	Test	Sig.	Decision
Distribution of Scores is the same within the school categories	Mann-Whitney U Test of independent samples	.000	Reject the null hypothesis.

The data found in Table 7 show that there were statistically significant differences ($p = .000$) between the grades obtained by both groups in favor of non-bilingual students. This means that students who follow a traditional teaching model and take the subject

of natural sciences in Spanish obtained higher grades than students who belong to the bilingual school and take the same subject in English.

Discussion and conclusions

Taking into account the considerations outlined above and the aims of this research, it may be concluded that the language (in this case Spanish or English) used to teach a subject significantly affects both the grades and the emotions of the students.

Regarding the *emotions* experienced by the students during the learning process of the subject of natural sciences, certain differences may be observed in favor of non-bilingual students, since they experienced more positive emotions than those who studied Science in English. Despite the fact that a number of studies have already examined the emotions of students in relation to the subject of science (Borrachero, Costillo & Mellado, 2016; Dávila, del Rosal, & Bermejo, 2016), the research to date has not specifically linked the language of study with the emotions of elementary school students in science subjects, which would have been useful to compare our data. We therefore support the conclusions of Mellado et al. (2014), who emphasized the need to continue studying emotions from the perspective of the didactics of science on the basis that self-knowledge, self-control and their regulation by students and teachers is essential for effective development of the teaching-learning process. However, Durán-Martínez, and Beltrán-Llavador (2017) found in their study of elementary school teachers' perceptions of bilingual programs that the teachers showed a lack of enthusiasm for the textbooks, as well as pointing out deficiencies in language proficiency training and resources, organization and coordination.

After analyzing the *grades*, the results show statistically significant differences depending whether the students attend bilingual or non-bilingual schools. Once again, the non-bilingual school obtained the highest grades. These results coincide with those of Anghel, Cabrales, and Carro (2013, 2016), Fernández-Sanjurjo, Fernández-Costales, and Arias (2017), Hughes and Madrid (2019) and Sotoca (2013) regarding bilingual and non-bilingual schools in the Autonomous Community of Madrid. On the other hand, they differ from those of Aragón (2007), Archila (2013) and Bolarín, Porto, and García-Villalba (2012), who claim that bilingual teaching in science improves student performance and fosters meaningful learning. However, the lack of homogeneity in the level of bilingualism in our sample must be taken into consideration, since the students who participated in the present study were not *balanced bilinguals*. Certain aspects of bilingualism that may influence cognitive growth are unlikely to have a significant long-term effect unless the subject is a truly *balanced bilingual* (Cummins, 2001). A uniform level of knowledge of the classroom language is consequently a determining factor when balanced across the four language skills: writing, listening, reading and speaking.

In this context, it is also worth mentioning the studies carried out by Conchero (2016) and González, Fernández, and Arias (2017), who focused on comparing the content taught in the subject of natural sciences in bilingual contexts. Also, while Conchero (2016) carried out a comparison of the subject matter of a Science book (in English) with that of CCNN (in Spanish) from the same publisher, González et al. (2017) focused on comparing the content of the subject of natural sciences according to two different educational methods (the Spanish bilingual system in English versus the British system taught in English schools in Spain). The results obtained by Conchero (2016) show

that while the basic contents were similar in both books, the English book had less support content than the Spanish book, as well as less revision and complementary activities. On the other hand, González et al. (2017) observed that the content in the bilingual Spanish method is much more advanced than in the British system, leading them to raise the need to restructure bilingual education in Spain.

For all of the above reasons, after completing our analysis it may be concluded that learning science in a second language (L2) has a negative impact on students' emotions and grades. In spite of all this, it is important to point out that the results obtained are limited exclusively to the students who took part in this study and these results cannot in any way be extrapolated to any other type of sample or research situation.

Finally, it would be interesting in the future to expand this research using neuroimaging techniques such as those employed by Leivada, Westergaard, Duñabeitia, and Rothman (2020), or the technique of facial color analysis used by Benitez-Quiroz, Srinivasan, and Martínez (2018) and Jack, Garrod, and Schyns (2014) to obtain a more innovative and comprehensive analysis of students' emotions regarding the teaching of science. Furthermore, it would be enriching to investigate the emotions experienced by students when using Smart Notebooks or during Flipped Classroom methodology, as they have shown benefits for both learning of science subjects and development of foreign languages (Bravo-Torija, Martínez-Peña, Embid, Carcelén, & Gil-Quílez, 2016; Briová, 2019).

In addition, since the teachers' value judgments are transmitted directly to the students (Borg, 2015; Mellado et al., 2014), it would be interesting to expand this research by including the teaching staff in order to understand and analyze their perceptions and attitudes. Durán-Martínez and Beltrán-Llavador (2017) state that the teachers who took part in their study reported a series of positive consequences of bilingual education, such as an improvement in children's competence in English, a greater demand from parents for bilingual programs and the use of more dynamic methodologies by the teachers themselves.

Educational implications and research limitations

Although the lack of knowledge regarding the linguistic competence of teachers may be considered a limitation, it has been found that even if the teachers have an extensive knowledge of the language or are actually native speakers, it does not guarantee better teaching of Science: "A survey of more than one hundred teachers in bilingual schools throughout Spain by the researcher Inmaculada Senra [...] revealed that half of them were not trained in specific methodologies in order to teach a second language through other subjects" (Sánchez, 2019). It is therefore crucial to provide teachers with the necessary tools to enable them to develop didactic units and flexible curricula adapted to the needs of the learners (Bueno, 2012; Stratulat, 2013).

In addition, Archila (2013) found that when studying the influence of a foreign language on students, the analysis of verbal skills is one of the central problems that arise when trying to assess the learning of bilingual subjects. Should they be assessed independently from the perspective of each language? Or should it be assumed that the language organization of bilingual subjects is different and therefore cannot be assessed from the perspective of monolingual strategies? The bilingual population is very heterogeneous and balanced bilinguals are highly unusual, since they are almost

always characterized by dominance of the mother tongue (L1) in certain contexts or subjects and of the second language (L2) in others.

The first global policy in this field was implemented in 2010 (MEC, 2011). This study is based on the conviction that the lack of specialization in language skills of previous curricula makes it necessary to develop new lines of research in this direction. Several limitations can still be identified in this work and future research should address them. Nevertheless, this study may be considered an initial attempt to determine the relationship between Spanish-English bilingualism and students' emotions and academic performance.

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