II REVIEW OF LITERATURE

In this chapter, I discuss the main aspects of literature related to the study and I have divided them into eight subsections. I begin explaning the value of bilingualism in the sixties when linguists started to be interested in bilingual speakers and the impact that bilingualism had on them. Later, I discuss various definitions of bilingualism and I also propose my own definition. In a further section, I explain two important distinctions: additive and subtractive bilingualism, which need to be understood in order to distinguish the advantages and disadvantages of bilingualism.

In the next section, an important discussion on bilingualism and the brain is made to establish important bases for my study. I also explain how bilingualism is processed in the brain by mentioning different theories about it. Then, I relate bilingualism and education by providing linguists' opinions about learning in two languages. This section explains the difference between learning *a language* and learning *in a language*.

The next section has the focus on language and cognitive skills, which is also an important point for my study. I list, according to literature, diverse cognitive skills that bilingual learners have because of their bilingualism. I then relate bilingualism to mathematics, which is the subject I chose for the tests of my study. I discuss what has been said in literature about language competence and mathematics.

The last section is dedicated to gender[1] and language learning. In my study, I have separated the participants by gender to analyze their differences in learning. Also this section explains how boys and girls learn a language differently and its impact on learning content in a language.

2.1 View of bilingualism in the sixties

Lust and Yang (2004) describe the view of bilingualism that people had some decades ago. Bilingualism was often regarded as atypical and even abnormal when compared to monolingualism, according to Lust & Yang. Bilingualism was not only the source of cognitive retardation but also the cause of detrimental effects on intelligence and language development. According to Baker (2006), bilingualism in the past was accused of being the cause of split personality, causing cerebral confusion, and spiritual deprivation. This is why, to this day, there exist all these negative preconceptions about bilingualism. One of the main goals of my thesis is to change the beliefs that people have had regarding bilingualism. I would like to not only show that bilingualism does not cause cerebral or spiritual damage, but to demonstrate that it is actually good for cerebral development. It is now time to change what people have believed about bilingualism. This thesis will help to modify their view of bilingualism if they still have not and let apart these incorrect preconceptions.

[1] In the study, the term *gender* refers to biological sex.

In 1962, Lambert and Peal (cited in Lust & Yang, 2004) found out that bilingualism did not provoke any cerebral damage nor was it negative for the individual. They stated that bilingualism had been studied before but that the researchers had commited errors in interpreting the results by not taking into account many variables. The first time that researchers actually stated positive aspects of bilingualism was in 1962. Lambert and Peal found that bilingual speakers had many different positive aptitudes in cognitive skills, such as intelligence, creativity, concept formation, classification, analogical reasoning, and visual-spatial skill. After 1962, bilingualism started to have a positive connotation but the process was slow. The view that people had regarding bilingual speakers would not change from one day to the other. Today, bilingualism has gained acceptance although it was not a shared opinion some decades ago.

The fact that researchers (Lambert & Peal, 1962, cited in Lust & Yang, 2004) found that bilingualism had no negative effects on the brain does not mean that the opinion people had about it changed right after the study was done. It takes a long time for people to change their minds.

2.2 Bilingualism: Definition

One single definition of what exactly is understood by being bilingual does not exist. For some people being bilingual automatically means speaking the two languages perfectly, but can a language be spoken perfectly, even by native speakers? The term “perfectly” is inappropriate and this belief of speaking two languages perfectly when one is called bilingual should be avoided. It is

inappropriate because a speaker who is able to communicate orally, read, and write on a very high level of a second language still might make some mistakes or have some features of his native language. Even though this speaker might not achieve 100% competence in his second language, he is still considered a bilingual, according to my definition of bilingualism mentioned at the end of this subsection (see last paragraph of 2.2). It is better, at this point, to forget the idea that bilingual speakers always speak two languages “perfectly” since this is an illusion and does not occur very often. It would be wrong to expect a bilingual to speak his two languages without any features of a foreign accent, or without any grammatical, syntactic, morphologic or semantic mistakes. It also occurs to a native speaker who sometimes hesitate about a linguistic aspect of his own language.

Being bilingual does not especially mean that the person speaks two languages at the very same level. In order to be classified a bilingual, the speaker needs to have acquired knowledge in two languages and needs to be fluent in both languages as well. According to Hamers & Blanc (1993), bilingualism is a state of a linguistic community in which two languages are in contact with the result that two codes can be used in the same interaction and that a number of individuals are bilingual. And by being bilingual, Hamers & Blanc mention the state of an individual or a community characterized by the simultaneous presence of two languages.

In her article about using two languages in learning mathematics, Moschkovich (2007) confirms that bilingualism has more than one possible definition. She cites De Avila & Duncan (1981) and Valdés-Fallis (1978), linguists

who have defined bilingualism using different terms and explanations, sometimes with interesting and innovative ideas, such as in Valdés-Fallis, who in 1978 also considered being bilingual any individual belonging to a bilingual community.

> Definitions of bilingualism range from native-like fluency in two languages, to alternating use of two languages (De Avila & Duncan, 1981), to belonging to a bilingual community. (Valdés-Fallis, 1978, p. 124).

According to my opinion, belonging to a bilingual community is not sufficient to be called a bilingual speaker. On the other side, expecting from the bilingual to speak the two languages perfectly is also too exaggerated. Further on (p.18), I give my own definition of what is for this thesis considered a bilingual speaker.

Bialystok (2001) mentions two kinds of descriptions of bilingual speakers, the unrealistic and the realistic definition. Speakers who have full fluency in two languages is the unrealistic definition of being bilingual whereas a more realistic definition would define the bilingual speaker as someone who can function in each language according to given needs. She uses the term *unrealistic* because of the fact that bilingual speakers most of the time do not speak both language at a very same level. So it is unrealistic to think that they achieve full fluency in both languages. The term *unrealistic* used by Bialystok for the first definition is, according to my opinion, not totally appropriate because there are many speakers who are fully bilinguals and feel secure in both languages. These speakers are called balanced bilinguals because they have a high language competence in both

languages, most very close to native speakers (Hamers & Blanc, 1993). The other type of bilingualism is called the dominant speaker, which means that the individual has a higher competence in one of the two languages. According to Bialystok, most bilinguals are dominant in one language, a fact that leads to conclude that a balanced bilingualism is less probable, but which does not mean at all, according to me, *unrealistic*. This is why I do not appreciate her expression of *unrealistic*. I would rather say that bilinguals are more frequently dominant speakers and less frequently balanced speakers, but both do exist.

Valdés & Figueroa (1994) state that a bilingual person is an individual who achieves a high level of language proficiency in the two languages. The language proficiency they achieve is very close to the one of native speakers but they also mention that linguists do not always agree with this definition. Rickerson (2004) defines those persons as true bilinguals, people whose skills in both languages are very strong.

There is no perfect definition of bilingualism. As mentioned, authors have tried to define this term but the definitions given have an aspect that other authors disagree with and this is why new definitions have been proposed, adapted, changed etc. I would like to define *bilingualism* the way I perceive it and the way I think is the most appropriate.

Bilingualism is, according to me for this study, the fact that a person is able to speak fluently, understand and be understood in two languages or variants of languages. I do not agree with Rickerson (2004) saying that it is necessary to be a

true bilingual to be called a bilingual person. Someone who is able to communicate in two languages, even though not perfectly, is bilingual. By mentioning *not perfectly* I mean that the bilingual is allowed to make a mistake, have features of the native language in the pronunciation of the L2, or hesitate about the use of a word. If that occurs, the bilingual is still a bilingual speaker, as long as this person is able to speak fluently and being understood. Even if the performance is not always 100% native-like, the bilingual speaker has the language competence and is able to find another way of explaining if his statement has not been well understood. Also, the bilingual speaker does not need to be automatically bicultural (see figure 1). Most of them are although a bilingual speaker is still bilingual if he is not bicultural. This means that the amount of cultural aspects acquired by the speaker is not a requirement to become bilingual.

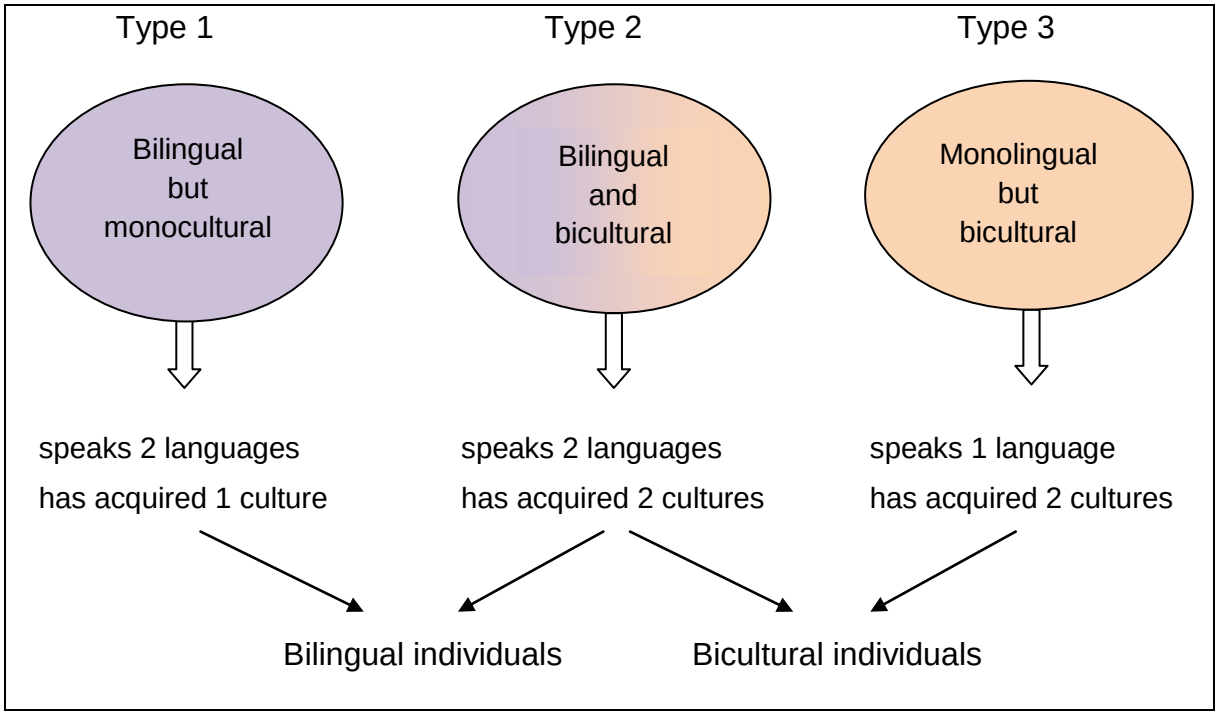

Figure 1: Types of situations in bilingualism and biculturalism

Figure 1, designed by myself, shows three different types of bilingualism and biculturalism. Type 1 indicates that the individual is bilingual but he has not acquired two cultures. This occurs when the bilingual has left his native country in an early age, has started to live in another country, speaks its language and has learned the culture of this new country without having forgotten his first language. This individual has two languages but one culture only. Type 2 shows an individual who is bilingual and bicultural. The speaker identifies himself with the two cultures of the two languages he speaks. This is the most common type. This would be for example a Spanish native speaker living in Mexico (language + culture) and speaking German and learning the German culture at the school environment (language 2 + culture 2). The last type would be an individual who has acquired two cultures but only speaks one language. This could occur when someone has emigrated to a new country, has acquired the culture of this country by living there but has not learned the language. For example, an Arab speaking woman lives in the United States, has acquired the culture of this country, and is part of an Arab speaking community in which all individuals share the Arab culture. If this woman has not learned English yet, she would be bicultural but not bilingual and would belong to type 3. To be called bicultural, the speaker needs to have acquired two cultures, most of the time this is only possible if the learner lives in a country where the culture of the language is transmitted directly. But in some cases, such as the one of the bilingual participants of the study, they have acquired their second culture at school. This is the environment where the German culture is shared. Monocultural, on the other hand, is an adjective that qualifies a person having acquired only one culture, such as the example for type 1 mentioned above.

For this study, the bilingual speakers are dominant and bicultural. They all belong to type 2. They all speak Spanish and German, are able to communicate orally and to write and read in both languages. They also are bicultural because they are in contact with both cultures in two different social environments, one at home and one at school. I am aware that the amount of cultural aspects of German is very limited, since the speakers do not live in a German speaking country. Culture is transmitted at school, being the only environment where the students are in contact with the German culture. Another possible term that can be used to describe the bilingual participants' setting would be *immersion*. This means that they are immerged in the second language during a part of the day.

2.3 Additive and subtractive bilingualism

The advantages that a bilingual speaker has are very different according to whether the child is an additive or subtractive bilingual. According to Lambert (1974, 1977, cited in Hamers & Blanc, 1993), the additive type has a positive connotation whereas the subtractive approach has a negative one. The additive bilingualism and culture result in positive effects to the learner whereas a subtractive bilingualism develops when the two languages are competing rather than complementary. If children have a subtractive bilingualism, they probably will have more disadvantages than advantages, such as forgetting their native language and not acquiring a high proficiency in the L2.

The study designed by Clarkson (1992) can show that the additive type is related to positive effects whereas the subtractive approach to negative effects on the learners. Additive bilingualism occurs usually when the two languages

complement one another (or the speaker is a balanced/competent user of both). Subtractive bilingualism occurs when the two languages compete with each other. But there is another factor that has an effect on the type of bilingualism. For the additive type, Baker (2006) refers to languages that are prestigious and powerful. On the other hand, the subtractive type can come from two languages which are not highly valued by the dominate society (at least one of the two languages). This may lead to negative effects caused by a lack of motivation, a lack of possibilities to apply the language, a lack of knowledge of the language, the self-esteem of the speaker, the non-acceptance of the language by the society, the loss of the minority language and many other factors that devalue this language. Baker defines subtractive bilingualism saying that both languages are underdeveloped, maybe because of lacking prestige. It refers to the negative affective and cognitive effects of bilingualism. Additive and subtractive bilingualism are influenced by attitudes and the attitudes that people create about a language play a crucial role for the communities speaking this language. Having positive attitudes towards the language can lead to additive bilingualism, whereas having negative attitudes can lead to subtractive bilingualism. Attitudes do not cause one or the other type of bilingualism but they affect or influence it. What causes additive or subtractive bilingualism has to do with how speakers use the language and that use might be affected by their attitudes. In his study, Clarkson explains the results saying that the language proficiency level of the bilingual students who did poorly on the tests was very low in their L1 as well as in their L2. The language proficiency level of the students who perform better, on the other hand, was high in both languages. These results conclude that a high language competence is needed in both

languages in order to gain positive aspects of bilingualism. If one of the two languages is not valued and a high competence is not achieved, the speaker will definitely have negative effects. An example of a subtractive bilingualism that leads the individual to negative cognitive and affective effects could be a speaker of a minority language, not well accepted by the majority language, who does not achieve a high competence in the L1 and needs to learn an L2 without having the appropriate basis of the native language. In subtractive bilingualism, the native language is less robust; society assumes that it will be used only temporarily until replaced by the dominant language as the group assimilates. Most immigrants to the United States, Canada, and Australia experience subtractive bilingualism; their skills in their native languages erode over time, and English becomes their dominant language, according to August & Hakuta (1998). Ríordáin & O' Donoghue (2008) mention that competence in the language of communication/interaction is a prerequisite for engagement in the learning process when content in taught is another language than the first language.

In the present study, the bilingualism approach taken by the students is additive, and because of the requirements needed to enter the bilingual group, the participants have a high competency level in German. Cummins (1976, cited in Ríordáin & O' Donoghue, 2008) insists that the student needs to achieve a certain language level in L2 to be competent in the content class. The participants of the present study have a sufficient level of German in order to avoid disadvantages caused by the lack of language competence. The fact that they were accepted into the bilingual group already means that they achieved a high level of language

proficiency in German because they passed the language test that the school provides for children who have the desire to enter the bilingual group. The test has been designed by language teachers and revised by the coordinators of German teaching. If the children pass the test, they are accepted to the bilingual group under certain conditions. They have to fulfill the expectations (language level, attitude towards learning, motivation, progress within the group, etc.) in order to be able to stay in the group. If they do not achieve the language level expected or any of the conditions required, they can no longer stay in the bilingual group. The pupils of the bilingual groups for my study do not have to perform a language test again because the test they took has the level equivalent to a C1 language level[2] (on the Common European Framework), which means close to native-like competence. So they have an additive approach of bilingualism, which, according to the authors mentioned above, leads to positive cognitive and affective effects.

2.4 Bilingualism and brain functions

Bialystok and Hakuta (1994) state that knowing two languages is much more than simply knowing two ways of speaking. They mention that the mind of a speaker who has learned two sets of linguistic aspects for a single conceptual representation has entertained possibilities that the monolingual speaker has not. Paradis (2000) states the following concerning the topic:

[2] A C1 speaker can understand a wide range of demanding, longer texts, and recognize implicit meaning. The speaker can express him/herself fluently and spontaneously without much obvious searching for expressions and can use language flexibly and effectively for social, academic and professional purposes. He/she can produce clear, well-structured, detailed text on complex subjects, showing controlled use of organizational patterns, connectors and cohesive devices.

> No function is available to the bilingual speaker that is not already available to the unilingual, unidialectal speaker. The only difference seems to be the degree of use the speaker makes of each of the relevant cerebral systems. (p. 54)

According to this statement, can we believe that if bilingual learners have two lexical memory stores, do they simply grow a new one when they start to learn a new language? Is it a previously un-tapped part of the brain?

In literature, four controversial hypotheses can be found about how languages are processed in the brain. The following subsections will critically discuss these hypotheses.

2.4.1 The classical language area hypothesis

This hypothesis used to be well accepted, explains Mundhra (2005), before other studies about brain areas or brain damages demonstrated why this hypothesis could not be true. It was first believed that all languages are localized in the same cerebral areas and that language processing in the human brain was completely done by the two classical language areas (Broca's area and Wernicke's area). The syntactic processing is supported by Broca's area while the semantic processing is supported by Wernicke's area. However, Mundhra mentions a study (Damasio, Tranel, Grabowski, Adolphs & Damasio, 2002) that has shown that languages are not only processed by these two areas, but other parts of the brain are also involved in the process. Linguists (Crystal, 1987, cited in Nagai, 1997; Paradis, 1995, cited in Bialystok, 2001) and neurolinguists (Fabbro, 1999, cited in Bialystok,

2001; Fabbro, 2001; Marrero, Golden & Espe-Pfeifer, 2002) have studied aphasia in bilinguals and have observed that bilingual speakers who had suffered from brain damage were able in some cases to recover one of the two languages they used to speak (it is not always the native language, in some cases, the second language was the one that has been recovered). This would imply that the languages are not stored in only one area of the brain and explains why the classical language area hypothesis was no longer accepted.

2.4.2 The two-switch hypothesis

Bilinguals used to be described as having two independent systems and that they could use both, switching from one to the other, explains Neufeld (1976). Neufeld mentions that, earlier, authors were arguing that it was not possible to have one storage for two languages because of the interference of the two languages. If bilinguals had one storage only, they would constantly mix up their two languages and not be able to speak more than one language at the time. Others disagreed with this view of language processing. Neufeld (1976) mentions McNanama (1971) who pointed out that bilinguals can use one language without having any interference from the other language. They can keep their languages distinct from one another. Bialystok (2001) explains this fact by arguing that some bilingual speakers develop an “enhanced ability to selectively attend to information and inhibit misleading cues” (p. 245). The bilingual is able to focus on one important aspect only, blocking out the less important information. This ability is called *selective attention* by Bialystok. Because the bilingual has this ability to select and sort the information he needs, he is able not to pay attention to what he does not

need. This is what happens in the bilingual brain when he uses two languages and does not mix them up.

Hamers & Blanc (1993) explain that the existence of a switch mechanism for languages was a debate in the 1970s. McNamara (1967, cited in Hamers & Blanc, 1993) did not completely agree with the switch hypothesis and proposed a two-switch model, one for the verbal input controlled by the environment and one for the independent verbal output. This mechanism would allow the bilingual learner to encode in one language and to decode in another. The two languages would be simultaneously active but independent from each other.

The debate about how many storages there are in the bilingual brain continues to interest both linguists and neurologists. They do not all agree with one single hypothesis; the opinions about language processing are still controversial and the is why many theories have been proposed. The two-switch hypothesis was confirmed and adopted in the 70s, as Hamers & Blanc (1993) had mentioned, but was then contradicted by other hypotheses (discussed in the next subsections) only to reappear as a possible assumption as a result of new research. Hernandez & Bates (1999) believe that a bilingual speaker has two storage areas, one for each language. They explain it by looking at the effects of brain lesions on the processing of a bilingual's two languages. Brain lesions that affect one language and not the other would lead to the conclusion that languages are represented in different areas of the brain.

2.4.3 The tripartite system hypothesis

Many researchers have investigated bilingualism and the brain, especially because the hypotheses that have been proposed still do not satisfy all researchers. Ojemann & Whitaker (1978, cited in Javier, 2005) found that some speech areas in the brain were involved in the two languages whereas other areas were specific to each language. Another study realized by Rapport, Tan & Whitaker (1983, cited in Javier, 2005) analyzed speech production and brain areas and they reported as well that bilingual speakers have different areas for each language.

Tomioka (2002) describes the tripartite system hypothesis claiming that identical items of L1 and L2 are stored as one item, but different items are stored separately in each system. Items that are in the intersection of the L1 and L2 systems are stored only once. The tripartite hypothesis differs from the other hypotheses in which language items cannot be stored as part of L1 if they are already stored as part of L2.

The Laboratory for the Neural Bases of Bilingualism in Texas (n.d.) affirms that neuroimaging work done with bilinguals shows that the two languages have different patterns of neural activity. Languages are connected with neural channels which influence each other. For example by learning a third language, the bilingual speaker can associate the two languages he already knows to help develop the third language. He can use the knowledge of both languages (syntactic, morphological, phonetical, lexical etc.). The more languages a speaker knows, the more connections he has between the storages in the brain.

2.4.4 The revised hierarchical model

Foreman (2002) argues that when learning takes place early on, the brain treats multiple languages as one language but when one learns later in life, the sorting out seems to be done more spatially. Foreman also mentions a study conducted by a neuroscientist (Hirsch, 1997) that discovered that people who are fully bilingual in French and English use the same area of the brain as an internal dictionary, regardless of which language they are speaking. By contrast, people who are not truly bilingual need to recruit additional brain areas to find words in their non-native language. Kovelman, Baker & Petitto (2008) have the same opinion arguing that children who are bilingual from birth onwards will grow as if there were two monolinguals housed in one brain. Kovelman et al. looked at where reactions took place in the brain during language tasks for both monolingual and bilingual participants. Like Hernandez (2009), they found areas of the brain being used by bilinguals that were not found in the monolingual brain. Hernandez also says that many researchers speak about mixed models in which coexisting processors are linked together in a hierarchical structure system that gave the hypothesis its name. French & Jacquet (2004) describe the hypothesis as one of the newest theories that explains how languages are processed in the bilingual brain. The authors explain that there are two separate lexical stores (one for each language) and one common conceptual store which are all connected and influenced by the others. This model explains why some bilingual children have a higher proficiency level in one language when they talk about one particular topic (related to that language) and in the other language when they talk about another topic. For

example, a bilingual German-Spanish speaker who lives in Mexico starts a conversation about Mexican History with another German-Spanish speaker. He uses German because they both have the same native language and that should not cause any problems of understanding the conversation but suddenly changes the language into Spanish, and that gives him a larger vocabulary to express one's thoughts about Mexican History. If they had had the conversation about German literature, they probably would have switched the language into German again. This is explicitly explained with the model suggested by Levelt (1989) about language production. The author says that a bilingual speaker has three production components which are used to produce language: 1) the conceptualizer, responsible for generating the communicative intention; 2) the formulator, which converts the message into a phonetic plan, and 3) the articulator, the output or the motor execution of the message. Levelt mentions that bilingual speakers have strong connected channels between the three modules. It is possible that the speaker conceptualizes the intention in one language but that the formulator converts this intention into another language which is then produced by the articulator. The formulator is the module that turns the speech plan into words by activating the items in the lexicon that correspond to the different chunks of the message. The formulator stimulates the choice of the correct lexicon in the language needed.

The revised hierarchical model seems to me to be the more logical hypothesis about how bilinguals process their languages. I agree with the theory of having two separate storage areas, one for each language and one common

conceptual store (French & Jacquet, 2004). This would also explain why some bilinguals who have suffered from brain damage are able to recover one of the two languages only. I also find the language processing model proposed by Levelt (1989) very useful because it explains how the bilingual brain has developed strong connections between the cerebral areas. This supports the argument that bilinguals acquire stronger cognitive skills compared to monolinguals. They are able to use their cognitive skills for various tasks, including the encoding and decoding in two languages.

The constant use of the two languages not only results in stronger cerebral connections in general but also in highly developed relations between cognitive skills and the two languages. Müller (1998) mentions *cognitive transfer*, a process that occurs in bilinguals when they transfer their cognitive skills from one language to the other one, the same way they transfer linguistic information from L1 to L2. They are able to make those linguistic and cognitive transfers thanks to their strongly related channels.

2.5 Learning content in two languages

Although learning content in a second language is still not well accepted everywhere according to my own experiences as a teacher, research continues to show that learning in two languages is positive for the brain. According to Espinosa (2008), children are totally capable of learning content in two languages. Their benefits from learning more than one language are not only linguistic but also cognitive. This is supported by Hutson (2008) who argues that bilingual education

increases logical thinking; by Bialystok (2001) who mentions the better cognitive control of linguistic processes by bilinguals over monolinguals and by Hamers & Blanc (1993) who point out the positive cognitive aptitudes bilinguals have when compared to speakers of one language only.

Brisk (2006) also refers to learning content in two languages and calls it “partial immersion”. She describes partial immersion as the process of acquiring a language through content matter instruction. It is important to notice that some authors will use the term “immersion” when talking about learning content in a language other than the native language.

Speaking about learning content in a second or foreign language, Clarkson (1992) mentions that competence in two languages is an important factor because being bilingual with low competences in the two languages is not an advantage for mathematics learning. According to Clarkson, bilingual programs should encourage the use of the two spoken languages. So if pupils can achieve high competences in two languages, they will have advantages in learning and will be able to take content classes in the L2.

The language competence of the participants of the present study is not an issue because at the institution, both languages are taught, developed and valued. All the bilingual participants do have a high language competence in their native language and this variable is crucial, according to Clarkson (1992), for the bilingual pupils to acquire and apply the cognitive skills.

Finally, a last aspect to be aware of is that when pupils learn content through a second language, the learning is on the topic, as mentioned previously, and not on the language itself. This means that the students are able to learn and improve a language by using it and not talking about it. Learning content in a second language is not learning grammar or syntax rules, it goes beyond that since the students are able to use grammar without even knowing it. According to Thornbury (1999), grammar should not be taught as a separate discipline at all. The author believes that it is possible to acquire a second language without talking about grammar, but only by using it and this is exactly what learning content in a second language does. It is here important to mention that the second language students need to have achieved the threshold level of language (explained in details on p.36) in order to be using the grammar in a content class.

2.6 Bilingualism and cognitive skills

Do bilingual speakers have the same cognitive aptitudes as monolinguals? Many studies have shown that bilinguals have positive effects in several areas. Galambos & Hakuta (1988, cited in Myers-Scotton, 2006) compared bilingual and monolingual learners in making grammatical judgments and they found out that bilingual speakers had a consistent advantage over monolingual speakers. According to Hamers & Blanc (1993) bilingual students show in general more positive cognitive aptitudes than monolingual students such as mental flexibility, verbal and non-verbal intelligence, dealing with abstraction, forming concepts, sensitivity to semantic relations between words and many others. In their study, Bialystok, Craik, Klein & Viswanathan (2004) found that those who had been

bilingual most of their lives were better able to focus their attention on the demands of a complex set of rapidly changing tasks than those who had only been monolingual. Bialystok et al. also mention that bilingualism increases the attention ability.

Souviney (1983, cited in Clarkson, 1992) states that language ability also increases memory. This opinion is shared by Ransdell & Arecco (2001) who stated that bilingualism has positive aspects on long-term working memory.

Clarkson (1992) studied the competence of mathematical problem solving in monolingual and bilingual learners. His study demonstrated that bilingual students did not have any disadvantages in mathematics and in fact bilinguals perform overall better on mathematic tasks than monolinguals.

Bilingual students might have less vocabulary in their spoken languages, says Bialystok (2001) than monolingual students have, but they have more cognitive aptitudes which are not confined to the linguistic domain but extend as well to non-verbal cognitive abilities. She also mentions that bilingual children in general outperform monolingual learners in tasks involving the cognitive control of linguistic processes. These results were also found in Clarkson's study (1992). They build the bases for my own study; I expect to have similar results.

2.7 Mathematics and language competence

Mathematics education research in bilingual settings has identified language as a social tool in the classroom and as a vehicle for mathematics learning as important

areas of investigation (Gorgorio & Planas, 2001, Secada, 1992, cited in Barton, Chan, King, & Neville-Barton, 2004). Clarkson (1992; 2006) wanted to show that bilingualism is not necessarily a disadvantage for learning. Each of his studies based on mathematics learning showed that bilingual students have more advantages than monolingual students. The fact that the content is taught in a language other than the native language has not shown any inconveniences in mathematical competences.

Ríordáin & O' Donoghue (2008) investigated the relationship between language and mathematics. They tested bilingual students of Gaelic and English in Ireland who are native Gaelic speakers having mathematic content classes in English, their second language. Ríordáin & O' Donoghue (2008) mention that competence in the language of communication/interaction is a prerequisite for engagement in the learning process. Mathematics learners are required to have competence in the language of instruction (Gaelic) and in the language of mathematics (English) and they state that mathematics understanding is influenced by language, personal conceptions and culture.

Cited in Ríordáin & O' Donoghue (2008) Cummins (1976) assumed that there may be a threshold level of language competence that bilingual learners must achieve in order to avoid cognitive deficits and to allow the potential benefits of being bilingual. He called this hypothesis the *Threshold Hypothesis*. Ríordáin & O' Donoghue had questioned this hypothesis in their study but discovered evidence to support it. For my study, I take into account Cummins' hypothesis. I agree with the threshold level a bilingual speaker needs to have in order to benefit

from the spoken languages. This is why the proficiency level of the participants in my study is a controlled variable. I go into details at the end of this subsection.

The following figure (Takakuwa, 2005) shows explicitly the *Threshold Hypothesis* proposed by Cummins (1976).

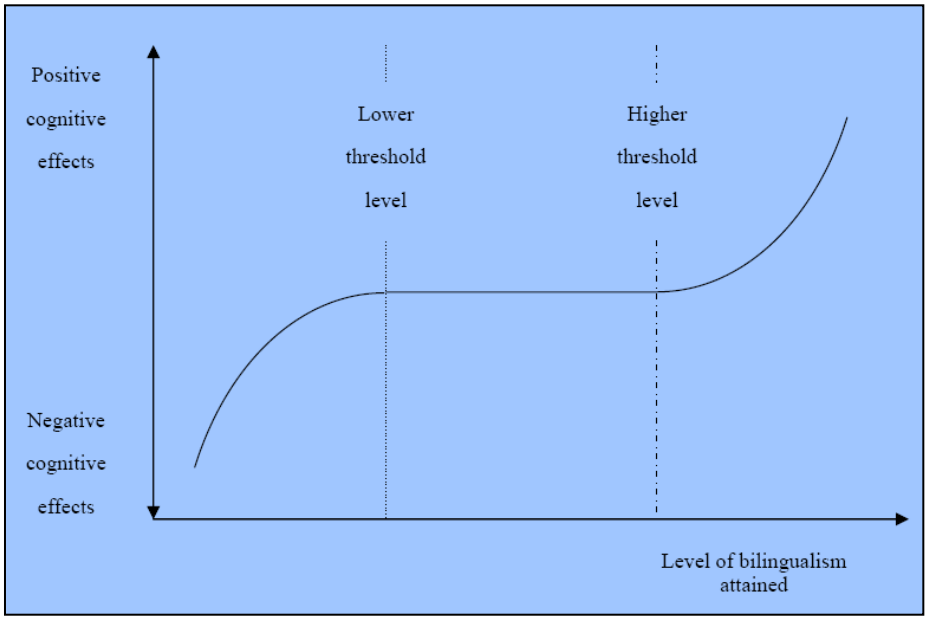

Figure 2: Threshold Hypothesis proposed by Cummins (1976)

Bilingual children must attain at least the lower threshold level in either language to avoid negative effects on their cognitive development, explains Takakuwa (2005). However, the fact that the bilingual child attains the lower threshold level does not automatically guarantee cognitive advantages. The child needs to attain the higher threshold level in both languages to obtain positive effects on his cognitive development. To summarize it can be stated that the higher the level of bilingualism and the higher the threshold level the child achieves, the more positive cognitive effects he will have. The *Threshold Hypothesis* explains why some children benefit from bilingualism whereas others do not. What

Cummins (1976, cited in Ríordáin & O' Donoghue, 2008) here means is the differences between subtractive and additive approach of bilingualism, described in section 2.3.

Cummins (1976, cited in Ríordáin & O' Donoghue, 2008) is not the single author who mentions that language proficiency is a crucial factor when learning content in a second or foreign language. Barton, Chan, King, & Neville-Barton, (2004) explains the importance of the level of language competence in the L2 for the success in learning content. They also mention researchers, such as Halliday (1978), MacGregor & Moore (1991) and Gorgorio & Planas (2001) who have investigated bilingualism, mathematics and cognitive skills and they all reveal several reasons why language is important for the education of mathematics. Most of the time, the reasons given explain that a lack of language competence in the L1 as well as in the L2 tends to lead to a subtractive approach of bilingualism, as Cummins had already discovered in his own study. This kind of approach might make the acquisition of the cognitive skills more difficult than it is for additive bilinguals.

In 1983, Dawe conducted a study in order to discover if additive bilinguals outperformed monolingual English speakers in mathematic problem solving and logical thinking. His findings correlate with Cummins Threshold Hypothesis (1976, cited in Ríordáin & O' Donoghue, 2008) indicating that language is clearly connected to mathematics learning.

According to the findings of the studies mentioned, language is an important variable that affect the results. For these reasons, in my study, the language variable is controlled; also the bilingual participants' education takes place in an additive setting. If the children participating in the study did not have a high level of German, they would not be in the bilingual group of the institution. As previously mentioned, in order to enter the bilingual group, they had to pass a language test. So if their proficiency level in L2 is sufficient, they can take content classes in the L2. The language test is written by language teachers, native speakers of German, and revised by language coordinators. The test is designed according the language goals of the Baden-Württemberg syllabus for German. The test changes depending on the age and there are six tests, one for each primary level. The children are tested on listening comprehension, writing, reading and grammar competence.

2.8 Language and gender

Boys and girls process language differently. First language acquisition has been studied by many researchers and findings have shown that gender plays a role in how a child acquires a language. Melville (2006) states that girls prefer to use a system that is based on memorizing words and associations between them, whereas boys rely primarily on a system that governs the rules of language that is why girls and boys use different approaches in order to acquire their native language.

According to Melville (2006), neuroscientists from Georgetown University Medical Center have investigated differences between gender in learning the first language and they found out that boys and girls use different parts of their brains to process some basic aspects of grammar. Burman (2007) who investigated first language acquisition and sexes discovered that girls used both the left and right sides of their brains for language-related activities, whereas boys primarily used the left side. Thus, boys acquire their first language differently than girls do. So the differences between gender in first language acquisition led me to the decision to separate boys and girls for my study. I want to analyze their results separately in order to find out if the fact that they process language differently affects their results on cognitive tests.

Various authors (Cook & Cook, 2009; Lipsett, 2008; Huang, 1993) have already studied gender in mathematics competence. Interesting findings show that differences between girls and boys usually start with puberty but the participants in the present study do not have reached puberty yet. Does this mean that their results still should be similar? Lipsett mentions that if differences in mathematics appear, they generally come from the inequality of how boys and girls are treated in that society. She basically says that if both gender is considered equally, they should not show relevant differences in their mathematics results.

The next chapter explains and shows the methodology of the study considering the literature background found about the topic. The methods and procedure were designed in order to find out answers to the research questions, as well as to support or reject the hypotheses.