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Studying the Effect of the Teaching Language of Science on Students' Conceptual Understanding of Scientific Concepts and Facts

[1] Gaby Khoury, [2] Rawan Daher

[1] Lebanese International University, [2] Lebanese International University
[1]gaby.khoury@liu.edu.lb,[2] 60920001@students.liu.edu.lb

ABSTRACT —

This research seeks to study whether teaching science in a language different than the main spoken language has an effect on the students' conceptual understanding of scientific concepts and facts. The purpose of the study, in terms of both nature and emphasis, is to look into the effects of the teaching language mandated by the school on the students' conceptual understanding of science. Also, to investigate the challenges students face in Lebanese schools related to understanding science subjects when taught in a foreign language. This aims to better understand the effect of the teaching language on learning scientific concepts and facts in schools, and to provide educators with the necessary information to develop effective teaching strategies, and therefore, help their students better achieve in science.

A quantitative analysis has been conducted and information were retrieved from questionnaires given to instructors and students in both public and private Lebanese schools, including those in elementary and secondary levels, in order to advance our inquiry. Along with a deductive methodology and a survey research technique tailored to gathering and analyzing quantitative survey data, the research methodology chosen appeals to pragmatic viewpoints. Convenient cross-sectional time frames and non-random sample techniques were adopted in the meanwhile. Results showed that there is a direct relationship between the teaching language of science and the students' conceptual understanding of science. This proved that teaching science in a language different than the main spoken language of students affects their level conceptual understanding of scientific concepts and facts.

Index Terms—*Conceptual understanding, Teaching language, Foreign language, Lebanon.*

I. I. INTRODUCTION

From the significant differences between spoken and written Arabic to the widespread usage of non-native English and/or French that are officially utilized in the teaching and learning of science, mathematics, humanities, and social sciences, multilingualism plays an important role in the educational sector in Lebanon [5]. The new National Language Curriculum mandated all Lebanese schools to teach a second language in addition to Arabic what led to a very complex curriculum [5].

However, El Takach and Sinno (2020) contend that learning a foreign language may have an impact on students' academic success in their field of study [17]. For this reason, it is interesting to study the effect of the teaching language of science when taught in a language different than the main spoken language of the students on their conceptual understanding of scientific concepts and facts.

Many factors led to the adoption of French or English as the mandated teaching language of scientific subjects in Lebanese schools such as the French colonization and the adoption of English as an international language [16]. Thus, mastering the teaching language might affect the academic achievement of the students in the subject of study [17].

A study by Johnstone and Sleepeng (2001) stated that students who have difficulty learning science in a foreign language lost almost 20% of their capacity for scientific reasoning and analysis [22].

Another research done in Turkey showed that students who learn science in their native language (Turkish) have a better conceptual understanding of science than those who were taught science in a second language (English) [22].

However, it is very important to note the presence of two varieties of Arabic language in Lebanon [3]. The official language is the written Arabic used in governmental and official documents, news broadcasts, and for teaching humanities and literature subjects at school [9]. However, spoken Arabic includes expressions from both French and English. Thus, in this study, we don't aim at using the official written Arabic as a teaching language for science subjects since it differs from the main spoken language among Lebanese people.

A. Aims and objectives

This article aimed to establish how teaching science using the main spoken language of the students could enhance their conceptual understanding of scientific concepts and facts. It intended to do so through the use of a mono-quantitative research method. The study used surveys conducted with students and teachers at both elementary and secondary levels to find out if there is a significant difference between the students who learn science in a second language and those who are learning science in their main spoken language, in terms of conceptual understanding of scientific concepts and facts.

Numerous recommendations in the literature outline ways to enhance students' capacity to comprehend and use scientific ideas in daily life. However, this study aims to generate recommendations on how to build effective teaching methods and techniques based on the personal experiences of students and teachers. In particular, the study could pinpoint the strengths and weaknesses of the current curriculum (both science and second language curricula) and how they can be improved. Meanwhile, in terms of scope, the paper sets out to assess the current situation in valorizing Lebanon's multilingualism and to see to what extent the Lebanese teachers are willing to support their students by explaining in different languages or using non-traditional tools.

B. Research problem

Although research shows that increasing students' level of proficiency in the language used to teach science improves their conceptual comprehension of scientific terms, facts, and concepts. It is unclear how this issue can be resolved in Lebanese schools given the multilingualism and the diverse variety of curricula. On the other hand, some research indicates that improving students' conceptual comprehension of scientific terms, facts, and concepts increases their level of proficiency in the language used to teach science. Also, Studies have indicated that a student's competency in the target language has an impact on their academic progress. Their degree of language competence is proportional to how well they do in the topic areas [17]. The issue is more so because Lebanese students who study science in their mother tongue have less misinformation than those who study it in a second language. As a result, learning science in a foreign language has a significant impact on students' conceptual comprehension [9]. According to Short and Spanos (1989), students that have language difficulties won't be able to comprehend science topics [9]. Additionally, Martinez (2011) backs up his assertion by noting that 72% of grade 4 pupils scored below the necessary level in science and that 46% of them performed below average on the National Assessment Educational Progress in Arithmetic in 2005 [17]. However, Beal (2010) found that students' English proficiency may be used to predict their degree of math proficiency [10].

While the research problem covered issues about the students' conceptual understanding and the teaching language of science, the rationale of the study or reasons to carry it out was to propose a solution to a pressing issue. While this might be part of the rationale, it is preferable to identify the issue that the study actually seeks to solve before going on to explain why. Consequently, by going over the problem statement (*as educators and as curriculum developers, instructors in schools should help students learn scientific concepts and facts in the language they understand*), the authors seek to identify the best ways in doing so.

In attempting to investigate the above problem statement, and reach our objective, a mono-quantitative study was conducted by the researchers to determine if there is a significant relationship between students' understanding of science concepts and the language used to teach them. *Research questions*

Being revolved around non-experimental research, the current paper relies on a deductive approach based on a survey strategy. The quantitative technique, as opposed to the qualitative one will be adopted, as it is more likely to be accurate, where the research questions might be descriptive comparative or demonstrate a link between two variables. Additionally, in quantitative research, figures and statistics are employed to present information about the subject [27].

The research problem behind this study is *"Teaching science to students in a language that is different from their spoken language is affecting their conceptual understanding of science concepts and facts.* And the research question to be answered is "W*hat is the relationship between the teaching language of science and the students' conceptual understanding of science*?"

The corresponding hypotheses that are to be rejected or accepted, are stated as follows:

H0: There is no relationship between the teaching language of science and the students' conceptual understanding of science.

Ha: There is a relationship between the teaching language of science and the students' conceptual understanding of science.

By addressing students' conceptual knowledge and imparting autonomous science language instruction to them, this segment gives the theoretical framework of the study and develops the subject. In order to fully tackle some of the previously mentioned gaps (described in the research problem section), it is necessary to examine the effect of the teaching language of science on the students' conceptual understanding of science. The students' conceptual understanding of science is therefore our dependent variable (DV), and the teaching language of science is our independent variable (IV).

C. Study Context

The Mount Lebanon and Beirut Districts, namely, were the locations of the current investigation. The study mainly focused on both private and public schools, and on what is being done to address language proficiency concerns, and whether or not the curricula address the topic of multilingualism. Even though there haven't been many studies done in Lebanon to better understand how teaching in a second language affects students' ability to master a particular subject, like science, it's still important to recognize the difficulties that students encounter when learning scientific concepts in a language other than their main spoken one.

As literature found out, and while it is common that "*students might have gaps in the language skills (listening, speaking, reading and writing) what might have effects on acquiring and understanding scientific terms and processes*" [9], educators must be aware of these gaps and assist their students in

the learning process. Some suggestions might include *teaching science in the students' main spoken language* or *mastering the skills of the teaching language first*. Taking into consideration this point will assist us in studying *the relationship between the conceptual understanding of science and the teaching language of science*.

II. II. Literature review

The review begins by examining how Piaget's theory of cognitive development connects to the purpose of early childhood cognitive development. This will provide a theoretical framework for understanding the relationship between language acquisition and cognitive growth and how it could influence students' scientific learning outcomes.

The benefits of trilingual education, learning a foreign language, and alternative approaches to teaching science in a second language will also be covered also. The various factors that may influence students' linguistic abilities and their ability to understand scientific concepts when taught in a language other than their mother tongue will be clarified.

A. Cognitive Development in Early Childhood

Early childhood cognitive development describes the constant and slow changes that occur in a child's brain processes and capacity for comprehending, learning, remembering, reasoning, and logical thought throughout the course of the first few years of life [30]. This development, which includes the growth and enhancement of a number of cognitive capacities, including attention, perception, memory, language, problem-solving, and critical thinking, lays the foundation for future academic performance and success in life [30]. In addition to genetic and environmental factors, social interactions, play, and exposure to a variety of stimuli and experiences are just a few examples of the experiential variables that shape it [21].

According to the Swiss scientist Jean Piaget's who is well-known for his cognitive development theory, kids actively shape their knowledge of the world through their experiences, and their cognitive development happens over the course of numerous stages [30]. All children go through four phases of mental development, according to Piaget's theory: the sensorimotor stage, the preoperational stage, the concrete operational stage, and the formal operational stage. In accordance with each stage of cognitive development, children exhibit new intellectual capacities and an escalating level of complexity in their comprehension of the world [10]. In light of the current study and Piaget's theory, it is crucial for kids to acquire and master a second language in their early years so they may apply it to other disciplines [10].

Regarding the connection between learning a language and understanding academic subjects like science, Piaget believed that language and the mind are intimately intertwined. To understand complex concepts, like those in science, children must be able to explain and transmit their ideas through language. As their linguistic abilities develop, children are able to think more sophisticatedly about scientific subjects and can also express such notions to others. The language of education has a big influence on how well students do academically in science because it offers students the means to engage with and grasp difficult scientific topics [21].

Another philosopher who has written about language learning is the renowned linguist Noam Chomsky. According to Chomsky's theory of Universal Grammar, humans are born with the ability to acquire languages [8]. In Particular, children are born with a language acquisition device (LAD), which enables them to learn the grammar of any language they are exposed to [8].

Chomsky's theory holds that there are universal principles underlying all languages and that the LAD enables children to spontaneously and subconsciously catch up on these principles. In other words, children don't necessarily need to have language explicitly taught to them; rather, they might learn it organically via exposure to their environment [8].

On the other side, research discovered that young children's cognitive development can be aided by early exposure to scientific ideas [34], [35]. The study showed that young infants who were exposed to scientific language and concepts had higher cognitive development than their non-exposed counterparts.

Lev Vygotsky's theory of language development is another theory that addressed cognitive growth and language learning. This theory is predicated on the notion that social interactions and cultural environment are vital to language learning and development. Vygotsky felt that language is not just a tool for communication but also for thinking and problem-solving [24]. Language acquisition, in accordance with his sociocultural theory of development, is a process that is directly related to how children engage with their social and cultural surroundings, including how they interact with adults and more literate peers [24].

The relevance of social and cultural elements on a child's cognitive development and success in language learning is emphasized by Vygotsky's theory. Vygotsky recognized the value of social, cultural, and historical artifacts in children's cognitive development as well as the part played by the dynamic social environment in the relationship between teacher and student [33]. On second language learning (SLL) and second language acquisition (SLA), the key ideas of Vygotsky's theory, such as language usage, the zone of proximal development (ZPD), peer interaction, and learning as a mediated process, have a considerable influence [33]. Overall, developmental, educational, and art psychology have all been inspired by Vygotsky's unique and novel concepts. The use of Vygotsky's sociocultural theory can shed light on SLL and SLA practices [33].

B. Foreign Language and Trilingual Education

One definition of a foreign language from the Oxford English Dictionary is "a language not spoken by the people of a certain place, country, or region, or not used as the medium of instruction in schools in that place, country, or region" [29]. According to the Cambridge Dictionary, a foreign language is "a language that is not your own" [12].

However, a lot of philosophers and theorists have investigated how to learn other languages. One such theory is Noam Chomsky, who created the concept of universal grammar, which contends that people possess a natural aptitude for language acquisition [15]. According to Chomsky's theories, all people have the capacity to learn language from birth and language learning is caused by a certain brain structure [15].

According to Papaja and Staszkiewicz (2018), a foreign language is a language that is not the native tongue of a person or a group. It is a language that is acquired via formal education or contact with individuals from many cultures. When two persons do not speak the same language, they communicate using a foreign language [31].

There are several advantages to learning other languages, including cognitive, scholastic, and social advantages. One benefit is that it helps foster better interactions and communication with people from diverse cultures [31]. Additionally, it can improve cognitive skills like creativity, problem-solving, and remembering. Additionally, improving academic performance might be a result of studying a second language [31]. According to several studies, studying a foreign language might help pupils do better in subjects like arithmetic, science, and reading. For instance, the study conducted by Papaja and Staszkiewicz discovered that studying a foreign language might enhance students' conceptual knowledge of science [31].

Learning a foreign language can enhance academic achievement in other courses, such as science. According to research, bilingual kids do better academically overall and are more likely to seek further education [20]. According to research done in the United States, high school students who studied foreign languages performed better on standardized math and science examinations than their classmates who did not [36]. Additionally, the ability to communicate and build relationships with people from diverse backgrounds can be improved socially by studying a foreign language [23].

However, learning a foreign language may be tough, and students may run into a number of problems as they go along. The most typical difficulty is learning new words. It can be challenging to learn new vocabulary when learning a foreign language, especially if the grammar is complicated and there are numerous anomalies. According to research, students who have trouble learning vocabulary in their second language may have trouble comprehending lectures and texts [1].

Grammar is another difficulty in learning a foreign language. It can be challenging to learn the grammatical rules of a foreign language, and it might take a long time to become proficient. Many languages have complex grammatical structures that are very different from the learner's native language's grammar. For instance, because Arabic and English have distinct sentence structures and word order, Arabic speakers may find it difficult to understand English grammar. According to studies, learners who have trouble understanding grammatical norms may find it challenging to express themselves clearly in a foreign language [2].

As a result, learning a foreign language can be tough, and students may run into issues with vocabulary, grammar, and cultural differences. Learning about these difficulties can aid instructors and students in creating solutions. For instance, according to a study by Aslan and Ciftci (2019), students may overcome language obstacles and advance their comprehension of science by utilizing visual aids, hands-on activities, and peer assistance [4].

On the other side, a system of education in which students are trained in three distinct languages is referred to as "trilingual education". Trilingual education, as defined by Baker and Jones (2018), entails the use of three languages, two of which are those that are commonly spoken in the region and one of which acts as the teaching language. The goal of trilingual education is to encourage students to become multilingual and linguistically competent, which is important in today's globalized society [7].

Learning three languages has several benefits, including cognitive, linguistic, and societal benefits. For instance, trilingual education can enhance one's capacity for problem-solving, creativity, and cognitive flexibility [6]. Trilingual education can promote language fluency, reading skills, and multilingualism [7]. Communication skills, intercultural competence, and cultural awareness are all enhanced by sociocultural, trilingual education [19].

Despite the benefits of trilingual education, there are challenges in implementing it. A few of these challenges include the scarcity of qualified teachers who are proficient in all three languages, the challenge of finding relevant teaching resources in all three languages, and the potential for language mixing or language loss [7]. These challenges are particularly relevant to the topic, which focuses on the effects of teaching science in a language different than the local dialect. This topic raises awareness of the potential difficulties that students can have while picking up scientific terminology in a third language, which may have an effect on their academic achievement.

C. Teaching Science in a Foreign Language

In order to guarantee that students comprehend scientific concepts clearly, teaching science in a foreign language is a difficult endeavor that requires careful planning and implementation. *Immersion, bilingual education, content and language-integrated learning (CLIL), and "Language Support Programs"* are some of the methods that have been suggested to help with scientific teaching in a foreign language [25].

However, a number of studies have discovered that teaching science in a foreign language presents certain difficulties [26], [17]. Both authors' research indicates that instructors have significant challenges and a dearth of terminology relevant to the subject matter taught (science) in the second language (English). More specialized study on the impact of teaching in English or French on students' academic progress was prompted by these findings and consensus on the difficulties of doing so.

But as several studies have found, teaching science in a foreign language has its challenges [26], [17]. Teachers have major difficulties and a lack of vocabulary that is pertinent to the subject matter being taught (science) in the second language (English) [26]. [17]. These results and agreement on the challenges of doing so encouraged more in-depth research on the effects of teaching in English or French on students' academic advancement.

D. Students' Conceptual Understanding

Conceptual comprehension, according to Osborne and Gilbert (1980), comprises the development of a comprehensive and connected knowledge of fundamental concepts and principles in a certain subject area [28]. It involves making connections between various ideas and applying these notions to difficult problems. The ability to think critically, assess knowledge, and make connections between different pieces of information is known as "*conceptual understanding*". It involves more than just memorization. Since it enables people to apply their knowledge in real-world situations and to continue learning and growing throughout their lives, it is usually considered a key goal of education [28].

Additionally, conceptual knowledge may be characterized as the capacity to comprehend the fundamental ideas associated with a given subject or issue. Conceptual comprehension, according to Bransford, Brown, and Cocking (2000), entails the ability to apply knowledge to solve problems and anticipate the future by forming connections between new information and past knowledge [11].

Moreover, the conceptual understanding of science necessitates a thorough comprehension of the fundamental ideas and tenets of science. It entails grasping the connections between various scientific ideas and how they relate to actual circumstances, going beyond rote memorizing of scientific data [28].

In summary, according to previous research, students' conceptual knowledge of science may be significantly impacted by the language of education. Students may have significant difficulties when science is taught in a language other than their mother tongue, particularly in terms of language comprehension. According to Furnham and Bochner (1986), under some circumstances, this might result in poorer levels of conceptual comprehension and academic accomplishment in science [18].

III. III. Methodology

The chosen strategy necessitates the use of closed-ended questions and Likert scales in organized surveys to collect data. The researchers' capacity to identify the appropriate data was essential to the investigation. Utilizing a hypothetico-deductive approach, a descriptive result was produced. This research strategy entails developing hypotheses based on accepted theories, drawing logical conclusions from those theories, and then putting those conclusions to the test through data gathering and analysis. The findings of a study like this are then used to develop literature and support theories [32].

The participants were selected using a non-random sample technique, and a one-time study with a cross-sectional temporal horizon enables the researchers to determine whether *the use of bilingual and trilingual education affects the students' conceptual understanding of science*, and if so, *how*. For this purpose, the researchers consider collecting data from multiple sources and used triangulation for comparing and verifying results.

In order to better understand the phenomena of this study, the sample was selected by non-random sampling from 2 public schools and 2 private schools in the districts of Beirut and Mount Lebanon. The focus was on specific participant characteristics.

The elementary level (grades 1 through 6) was chosen since at this age, pupils are learning a second language and are just being exposed to basic vocabulary [13]. Students in the secondary level (grades 10 to 12) were chosen because, at this level, they demonstrate awareness of the second language taught and utilized in a scientific environment and have an understanding of both general and specific ideas in spoken discourse [14]. Science teachers were chosen in order to better understand the difficulties that both they and their students have with conceptualizing science. A very brief survey that helped to better understand the history of the school and of the pupils, was given to selected principals.

The total number of participants was 352 referred to 4 schools and including 328 students, 20 teachers and 4 principals.

IV. IV. Findings

This section pertains to the findings of the research. All results represented reality, as the sample population on which we based our research already reflected the views of the students and educators on the effect of the teaching language on the students' conceptual understanding of science.

A. Results from Primary Data

The first section displays the findings from surveys of elementary and secondary school students taken during the academic year 2022–2023. The goal of the survey was to learn more about the students' primary spoken language, their proficiency in several languages (including Arabic, French, English, and others), as well as how well they performed in science. The results of this survey aimed to show if *being weak in French will lead to being weak in science.*

The analysis shows a strong correlation between the two variables where a 10% increase in French level corresponds to a 4 % increase in science performance based on academic records. This result is true for both elementary and secondary students, however to a lesser degree for elementary students as discussed next.

The regression analysis done on secondary students' data in the first test, shows a strong and significant relationship between the two variables with a slope of 35% showing that science performance strongly correlates with French level as shown below.

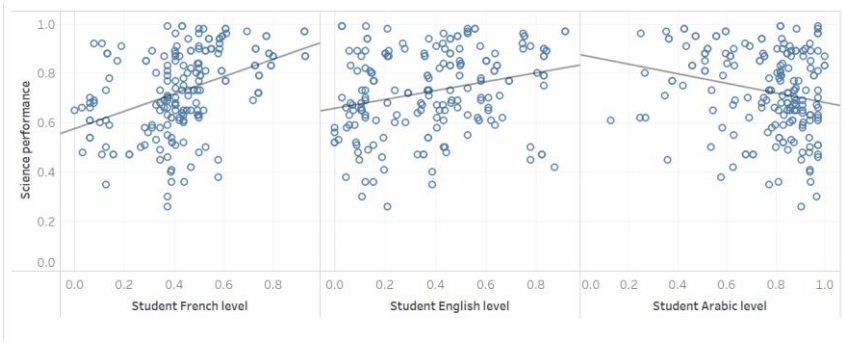

Figure 1 - Scatter chart representing the relation between science performance and languages proficiency.

The relationship between secondary school students' science achievement and language competency is seen on the scatter chart of Figure 1. The first graph shows a correlation between student scientific achievement and their proficiency in French. Moving from left to right, the data exhibit an upward trend, and the data are less erratic, indicating a strong connection between the two variables. The second graph shows a correlation between student scientific achievement and English proficiency. Moving from left to right, the data exhibit an upward trend, although this pattern is less pronounced than the prior one.

The third graph, on the other hand, demonstrates a negative correlation between student Arabic proficiency and science achievement. Moving from left to right reveals a downward tendency in the data. Additionally, the data is more concentrated near the end of the axis and less dispersed, demonstrating a strong negative correlation between the two variables.

The ANOVA test done on secondary students' data also shows a strong and highly significant relationship between the two variables since the results show that strong French speakers perform more than 20% better in science than weak speakers do as shown below.

Groups	***Count***	***Sum***	***Average***	***Variance***
Strong French	75	59.94	0.79	0.02
Weak French	75	48.61	0.64	0.02

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.85	1	0.85	35.01	2.18	3.9
Within Groups	3.61	148	0.02			
Total	4.47	149				

Figure 2 - Summary results of One-way Anova for the Secondary level

At this point, the French level has proved to be the best predictor and has the best correlation with science scores because the schools that participated in the study are French–based schools. English level still has a somehow moderate positive correlation with a slope of 18% probably because of the "well–rounded student effect". Whereas the Arabic level has a negative correlation with a slope of -19% because it negatively correlates with the science performance and subsequently the French level. A binary view shows that strong French students are 14 points higher than weak French students which is equivalent to a 21% increase. This is confirmed by the ANOVA test analysis added above which rejects the hypothesis that these two groups (strong French speakers and weak French speakers) have the same performance in science.

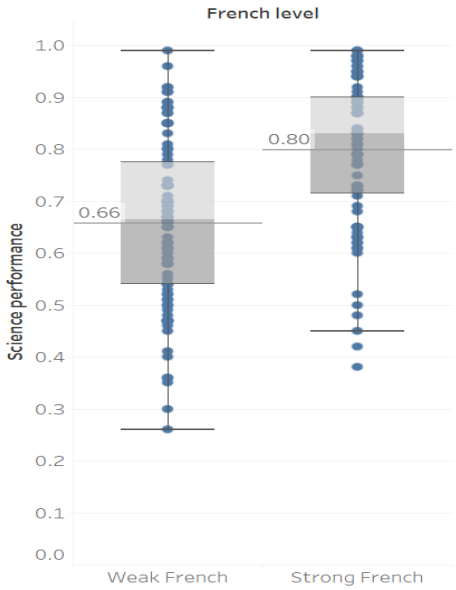

Figure 3 - Whisker chart representing the relationship between science performance and level of French of secondary students

The whisker chart above shows that for the Strong French students have better performance in science than the Weak French students. The first box (Weak French) shows a symmetrical distribution of the data where the median lies almost in the middle of the box, however, the second box (Strong French) shows a positively skewed distribution of the data where the median lies in the upper part of the box. Also, a binary view shows that Strong French students are 14 points higher than Weak French students which is equivalent to 21% increase.

In order to interpret the causal relation between the independent variable and the dependent variable, two main stages of causal interpretation were used. The first one is referred to as the "Direct Causation" or "a better comprehension hypothesis" showing that the teaching language of science affects the level of conceptual understanding of science. In other terms, being good at French helps students understand their science teacher better and therefore get higher scores. The second stage is referred to as the "confounding variable" or "well-rounded performer hypothesis". This hypothesis states that students who are "smart" or "good" tend to perform well in all disciplines. Hence, whenever a student has high scores, these scores will be high in French as well as in science, but if a student has low scores, these scores will be low in both French and science. In fact, these two hypotheses complement each other and the reality is probably a combination of both effects. The second hypothesis is well documented and relates to the students' overall capability and mental faculties of achieving well at school in all disciplines. The first hypothesis should be (at least partially) true because the causation mechanism can be traced with one of the questions where the students answered "Agree" on average with the statement "The teacher helps me understand better by explaining in another language". This suggests that bilingual teaching, mainly when it comes to the use of spoken Arabic (or "Lebanese Arabic") as highlighted later in the analysis of the interviews, helps improve the students' conceptual level of understanding science, which then leads to higher scores. It is very important to mention at this level that the "spoken Arabic" mentioned in different parts of this study differs from the "Formal Arabic" or the "Official Arabic" language. The "Official Arabic" language is used by the government for legal documents or by schools to teach certain subjects such as History and Geography, but the "spoken Arabic" or what is called "Lebanese Arabic" is the common language used on daily basis communication between the Lebanese.

B. Interpretations

Based on the results given above, the null hypothesis is to be rejected, while the alternative hypothesis is to be accepted. This means that there is a relationship between the level of the students' conceptual understanding and the teaching language of science.

The results of this study agree with a large body of the literature review. According to Ahmad et al. (2012), research has shown that students who have difficulties acquiring the vocabulary of a foreign language, struggle with understanding lectures and texts [1]. Wagaba (2010) studied the same topic and concluded that learning science in a foreign language is challenging for the students who don't master the teaching language. This aligns with the results of the quantitative analysis of this study where the results showed that there is a relationship between the level of the students' conceptual understanding of science concepts especially at the secondary level and the teaching language of science mandated by the school.

Although the results of this study align with other studies cited in the literature review, further research is suggested to be conducted. It is important to highlight the challenges students face in the Lebanese context and how to overcome them.

It is important to mention the weaknesses of the study and suggestions for further research. Starting first with the teacher sample bias where secondary students' analysis was done on 9 teachers only. In this case, there's a high chance that students' science scores are mainly impacted by the quality of the teacher regardless of the spoken language (experience, qualification, teaching methods, etc.). In other words, the sample is so small, that it can easily be

the case that the French-only teachers happen to be more experienced, while the bilingual ones happen to be less experienced. As a result, it would be falsely concluded that bilingual teaching leads to worse student performance.

In order to decrease the previously mentioned weakness and avoid such bias, the following solutions are suggested: (1) Increase the number of teachers in the analysis to more than 30 (while identifying them in the student survey in order to match the data), and/or (2) controlling for overall teacher performance/quality by adding extra variables such as the number of years of experience, qualifications, etc.

Another weakness is a "Causal inference" problem where it is hard to tell whether the students who are weak in French are underperforming, they are doing so (1) because their low level of French (which is the teaching language of science mandated by the school) is leading to a lower level of conceptual understanding of science concepts and facts, or (2) because their weakness in French is simply an indicator that they are already weak in all the school subjects including science, hence expecting low scores and academic achievement in science subjects.

Our analysis above already points in a direction that has a clear and significant effect. The below additional research can help better isolate and quantify this effect. It is suggested to improve the view of causality by expanding the set of variables that include both leading and lagging variables: questions on student comprehension and preferences, actual student science scores, overall student scores, mapping the dataset to specific teachers, including the overall teacher's performance/scores. This allows us to ask more nuanced and targeted questions such as "Are weak French speakers struggling equally in disciplines with high usage of French (science) versus those with lower usage (math)? Does language intensity matter?

Another solution suggests doing a time-based analysis where teaching language changes, for example by following the same students over two (or more) years to see how scores change based on changes in teacher's use of Arabic. This gives a better view of causality because students' overall intellectual capacity and language abilities will not have changed much, however, the teaching methods will change hence better isolating their effect. For example, a group of high achieving students that are weak in French can be followed up over 3 years, where year 1 is with a bilingual teacher, year 2 with a French-only teacher, and year 3 with a bilingual teacher. If there's a dip in science scores in year 2, then this would be strongly suggestive of a causal effect of French-only teaching on science scores for this type of student.

One more solution suggests establishing a comparison between two schools that have similar acceptance criteria or the same entry-level for students. The first school can be chosen as a monolingual school where only French is used as language of instruction of science. The second school can be chosen as a bilingual or trilingual school where two or more languages are used as teaching languages of science. The students' academic achievement in a particular grade and section will be recorded all around the year and compared at the end of the academic year. This would be strongly suggestive of a causal effect of French-only teaching on science scores based on the type of teaching model of the school.

V. V. Conclusion

The results shows that the teaching language of science does affect the students' conceptual understanding of science when the language of instruction mandated by the school is different than the main spoken language of the students. Students who are weak in French perform better in science when the teacher explains in both French and Arabic. However, many students explained that the Arabic language they are mentioning is not the formal Arabic used to teach Geography or History, but their main spoken Arabic is the "Lebanese Arabic" language. At this level comes the case of the Arabic diglossia which should be taken into consideration when including bilingual or trilingual education. Moreover, the results highlighted the importance of including visual aids and technological tools that can assist and support students who struggle with teaching language.

A. Responses to Research Questions

The authors respond to the research questions and present a summary of the findings. It was found that *there is a relationship between the conceptual understanding of science and the teaching language of science*. As such, *enhancing the language skills of the teaching language will improve the academic achievement of students in science.*

The findings of this study have significant implications for educators and curriculum designers in multilingual education contexts. The study's results suggest that teaching science in multiple languages, or with the use of non-traditional tools such as audiovisuals or translational software, might have positive impact on the students' conceptual understanding of science when this latter is taught in a language different than the student's main spoken language.

However, educators should be mindful of the potential challenges that arise from language switching and consider the language proficiency levels of students. Additionally, the study highlights the need for innovative teaching approaches and materials that can effectively facilitate conceptual understanding of science.

Furthermore, the ministry of education should recognize the importance of supporting language development in multilingual education and consider strategies to address language barriers and promote equitable learning opportunities.

By taking these implications into account, the ministry of education along with principals and educators can work together to enhance science education and improve students' conceptual understanding of science in multilingual education contexts lacking non-traditional tools.

B. Recommendations

Several recommendations are suggested to improve science education and promote better conceptual understanding among students.

First, providing adequate teacher training. Teachers should be trained to teach science in a language that is appropriate for their students. This training should include strategies for making science concepts accessible to students who are learning science in a second language.

Second, creating appropriate instructional resources. The development of instructional resources that are suitable for students learning science in a second language should be a priority for educational institutions. These resources ought to be created to support students in understanding scientific ideas regardless of their level of language skills.

Third, creating a supportive learning environment. Teachers should create a supportive learning environment where students feel safe to ask questions, express their ideas, and make mistakes in any language they choose. This can help students develop their language skills and improve their conceptual understanding of science.

Fourth, use visual aids and practical exercises. To assist pupils in grasping science subjects, teachers should use visual aids and practical experiences. These techniques can aid students learning science in a second language in visualizing abstract ideas and gaining a deeper comprehension of the subject.

Fifth, encouraging parental involvement. Parents should be encouraged to participate in their children's science education. This can help parents understand the language and concepts that their children are learning in science and support their children's learning at home.

By implementing these recommendations, educational institutions can promote a better conceptual understanding of science among students who are learning science in a second language. These recommendations can also help teachers create a more inclusive and supportive learning environment for all students.

In summary, these recommendations for further research aimed to address the gaps and limitations identified in the study regarding the effect of the teaching language of science on the students' conceptual understanding of science within a multilingual education context. By exploring these areas, researchers can enhance our understanding of the complex relationship between language, education context, and science learning outcomes.

C. Future studies

Several areas for future research are recommended in light of the constraints of this study regarding the impact of the scientific teaching language on students' conceptual understanding of science in a trilingual educational system and with the absence of cutting-edge instruments and teaching strategies.

Incorporating an experimental study methodology, on the other hand, may offer a thorough knowledge of the impacts of language instruction on students' conceptual comprehension of science. In order to gain insight into students' experiences, perceptions, and challenges related to learning science in a multilingual educational context, researchers will combine qualitative approaches like interviews and classroom observations with quantitative measures of conceptual understanding (represented by the academic achievement of the students).

Last but not least, comparison studies among various educational contexts and nations, especially those with access to non-traditional resources, might help to understand the particular difficulties and advantages of multilingual education on students' conceptual comprehension of science. By comparing outcomes between monolingual education settings and those with different language instruction approaches, researchers can identify the specific impacts of the multilingual context on students' science comprehension.

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