Esta sección recoge estudios originales y rigurosos de interés general que involucren análisis, organización sistemática y reflexionada, explicación teórica y predicciones viables. En esta ocasión con un trabajo de interés escrito por nuestro amigo George Bodner, con su ex-alumna, la puertoriqueña Provi Mayo.

The bilingual learner: what happens when the language of instruction is not the language of discourse

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Abstract

Those of us who teach chemistry at the college or university level in the United States are faced with the problem of conveying our course content to an increasingly number of students for whom English is a second language; a problem that has been faced by our colleagues in Latin America for generations. We therefore conducted a study designed to probe the conceptual knowledge of bilingual students who studied chemistry from English language textbooks in a classroom environment in which the language of discourse was Spanish. Interviews were done with undergraduate science majors enrolled in general chemistry at the University of Puerto Rico and with graduate students in the Department of Chemistry at Purdue University. Analysis of the interview data led to the creation of five categories: (1) use of Spanish, (2) avoidance of communication, (3) confusion of terms; (4) use of examples and new words, and (5) use of terms without mastery.

Introduction

Language plays a crucial role in the learning of science by shaping the way students think and learn (Lemke, 1990). It may even determine the way the world is seen, as well as how it can be seen by a student (Hodson, 1998). Language can therefore serve as a barrier that must be overcome in the learning process. Thus, it isn't surprising that learning science can be a challenge for bilingual students when it is taught in their non-native language.

It has been several decades since Cummins (1978) noted that second-language learners suffer from low levels of achievement in both their first and second language, as well as academic failure when instruction occurs in their second language. More recent work has shown that bilingual children demonstrate a very low ability to solve problems that are given in their weaker language, even when these students have demonstrated competence in the concepts needed to solve the problems (Macnamara, 1995). Tobin and McRobbie (1996) noted, however, that the learning of chemistry was facilitated when students with limited English proficiency were given the opportunity to employ their native language as a tool to understand the material, and when teachers used the students' native language to facilitate the communication of scientific concepts.

Lemke (1990) argued that the learning of scientific vocabulary involves more than memorizing a list of terms; it is a process that entails the development of an understanding of the relationships between terms and their meanings. This process is more complex for students with diverse language backgrounds because comparable terms might not exist in both their language and in English or, even if they exist, they might not be used with the same frequency (Lee, Fradd & Sutman, 1995). According to Michaelis and O'Connor (1990), when students lack the vocabulary to express their science knowledge it does not necessarily mean that they do not know the concepts. It may mean that they lack the vocabulary to convey their understanding; that their discourse patterns are incompatible with the ways in which science concepts are discussed in English; or that they lack the social fundamental knowledge on how to participate in class activities with other students.

Our work was influenced by the distinction Vygotsky (1986) made between "scientific concepts" and "spontaneous concepts."

Scientific concepts originate in the highly structured and specialized activity of classroom instruction and impose on a child logically defined concepts; spontaneous concepts emerge from the child's own reflections on everyday experience.

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It can be argued that students have fully acquired a scientific concept when a relationship exists between what they have learned in school and real-world or normal-life examples. Building this relationship can be particularly difficult for the bilingual student, for whom scientific concepts learned in the classroom and spontaneous concepts that emerge from their everyday experiences occur in different languages.

When students fail to make a connection between scientific and spontaneous concepts, the scientific concept becomes nothing more than a phrase or definition the student holds in memory, without full understanding. Vygotsky (1986) argued that: "The difficulty with scientific concepts lies in their verbalism, i.e., in their excessive abstractness and detachment from reality." A verbalism can be defined as: "…a parrot-like repetition of words by the child, simulating a knowledge of the corresponding concepts but actually covering up a vacuum" (Vygotsky, 1986).

Setting and Sampling

Data were collected with two populations. The first sample consisted of a group of 11 freshmen science majors enrolled in a general chemistry course at the University of Puerto Rico – Río Piedras, one of the largest producers of Hispanic bachelor's chemistry graduates (Heylin, 2003). Most courses at the University of Puerto Rico are taught in Spanish, although some professors teach in English. It is assumed that students who attend the UPR know English, but this is not always the case.

The second sample was a group of five Hispanic graduate students enrolled in the Department of Chemistry at Purdue University. Four of these students came from Hispanic backgrounds, had grown up in an environment in which Spanish was the language of discourse, and had completed their bachelors degree in chemistry at either the Mayaguez or Río Piedras campuses of the University of Puerto Rico. A fifth graduate student was interviewed who had been raised in Puerto Rico, but who differed from the other graduate students because English had been the language of discourse at home and this student had obtained his undergraduate degree in the U.S. before entering the Ph.D. program at Purdue. This student provided a rare opportunity because, although he was bilingual, he was more comfortable with English than Spanish. We therefore asked him to answer the interview questions in Spanish.

Research Design

Data were collected in the form of interviews in which the bilingual undergraduate and graduate students were asked to answer questions or explain phenomena based on such basic chemistry concepts as density and the difference phases of water. In all but one case, the students were asked to answer the questions in English. As noted above, one of the graduate students was asked to answer the questions in Spanish. The interviews were audio-taped and then transcribed.

The undergraduates were asked:

- To explain why the particles in a Orbitz[1] soft-drink bottle were suspended in the solution;
- To predict what would happen to the volume of the system when a pair of ice cubes floating in water melted;
- To explain what the bubbles in a beaker of boiling water were made of; and
- To explain what happens when water evaporates.

Interviews with graduate students included both warm-up questions and interview questions taken from previous work with graduate students (Bodner, 1991). One of the warm-up questions noted that ice is less dense than water but steel is almost eight times as dense as water, and asked them to explain why the iceberg and the Titanic were both able to float on water before they collided. Another asked them to explain where the liquid that condenses on a cold soft-drink can comes from when the can is removed from a refrigerator on a hot, humid day. The graduate students were then asked:

- To explain what the bubbles in a beaker of boiling water were made of.
- To predict what happens to the weight of an iron bar when it rusts.
- To predict whether the meniscus in a mercury barometer curves in the same direction as the meniscus in a burette filled with water and to explain why or why not.
- To explain how putting salt on the surface of ice can melt the ice.

The interviewer in this study was a graduate student in the Department of Chemistry at Purdue who had

"Orbitz" is a soft drink marketed by the Clearly Canadian Beverage Company in which small droplets of solid xanthan gum are dispersed throughout the solution.

obtained her bachelor's degree from the University of Puerto Rico. As a participant observer, she was perceived by the students as a language-facilitating tool inasmuch as she could communicate with the students in both English and Spanish.

The theoretical framework for this study was symbolic interactionism (Blumer, 1969; Schwandt, 1997), which looks for a common set of symbols and understandings that give meaning to people's interactions (Patton, 1990). The methodological framework was phenomenography (Marton, 1981), which focuses on understanding a phenomenon from the participant's point of view. A detailed perspective on both the theoretical and methodological framework can been found elsewhere (Bodner, 2004).

The data collected from the undergraduates and graduate students were analyzed separately. The analysis began with a transcription of the interviews. Repeated reading of the interview transcripts suggested that the data from both sample populations could be classified into five categories: use of Spanish; avoidance of communication, confusion of terms; use of examples and new words; and use of terms without mastery. Once this stage of the analysis had been completed it became apparent that none of these categories dealt with the students' conceptual knowledge of science, they are all based on communication strategies.

Results

Use of Spanish

As might be expected, most of the undergraduates used individual words (or short phrases) in Spanish when they did not know how to use a term in English. Examples of this phenomenon include: "… That water comes from condendat … *condensación*. The water *vapor*, vapor *ambiente* (of the environment)." And, "… and when you boil the ice will *se derretirá* (will melt) and then the volume of the solution will be higher."

Some of the sentence structure in the students' answers suggests that they were thinking in Spanish and then translating into English while answering the question, which is consistent with the notion that spontaneous concepts based on experiences are stored in the minds of bilingual students in their native language. This is a potential source of difficulty when these students try to explain their scientific concepts in terms of everyday events because they have to translate to the second language to give an answer in English.

Students also used Spanish to clarify an idea they had expressed in English. In the following example, the student used an elaborate description in Spanish to explain that she meant repulsion, even though the word *empujándolo* (pushing it) was used.

> S: "I am not sure what xanthan gum is made out of and what is keeping it suspended … I can't explain what it is like *como empujándolo para que no se vaya para arriba o no se vaya para abajo*"[2]

It was interesting to note that students sometimes explained a phenomenon incorrectly in English only to explain it correctly when they switched into Spanish. Consider the following answer to the question that deals with the level of water in a container after a pair of ice cubes melt. The student started with a conceptually incorrect answer based on the assumption that water molecules expand.

> S: Because when … (long pause) … No it (the level) is lower because the ice melts, the (water) molecules expand.

But, when he elaborated on this in Spanish, his explanation was more conceptually correct because it explained in simple words the change in the organization of water molecules when the ice cubes melt.

> S: … como en el estado líquido están unidas sin estar en el mismo orden y en el sólido están unidas en el mismo orden o secuencia.[3]

One of the students asked for permission to write out the answers to the questions and then read them aloud. We noted that the answers were all written in Spanish. The student then translated the answers in his mind before uttering them in English. The text written by the student during the interview is transcribed below.

> Yo entiendo que las bolitas se mantienen suspendidas en la solución quizás por su densidad, el contenido de moléculas de O_2 las cuales permiten que estas bolitas se mantengan a flote. También el nivel donde se encuentran las bolitas en la solución puede variar de acuerdo a la masa de éstas. Yo pienso que mientras más O_2 tenga la

[2] Translation: Like pushing it so it does not go up or go down.
[3] Translation: (Talking about water) … in the liquid phase they are united in different order and in solid they are in the same order or sequence.

bolita, ésta se ubicará más arriba. También con la masa podemos decir que si ésta es menor ésta también estará suspendida más arriba en la solución."[4]

The Spanish text is consistent with the suggestion that inner speech (or speech-for-one-self) is a necessary element for concept development, and that inner speech for bilingual students occurs in their native language (Howe, 1996).

It is worth noting that the undergraduates asked to have one of the questions translated into Spanish on several occasions. When this was done, their answer was more complete than for other questions that were only asked in English.

The graduate students used Spanish less often; only one graduate student used Spanish more than once during the interview. This student took more time to answer the questions and gave answers whose sentence structure suggested that he was translating his answers into English as he was giving them. Consider the following excerpt from his interview:

S: Because sea water has lots of salt and everything and makes it more dense and because of "fuerza boyante," I do not know how to translate that. That is to … "contrarrestar la fuerza de gravedad."[5] Gravity goes down and "fuerza boyante" goes up. That makes you float and makes things float on water.

Avoid Communication

A second category that arose during analysis of the data contained instances when students chose to avoid communication by refusing to answer the question; by stating that they did not want to continue with the interview; or by saying: "I don't know," even though they were able to respond to the questions when allowed to explain their ideas in Spanish. This occurred more often among the undergraduates, perhaps because the graduate students had more experience talking about science in their second language.

The tendency to say "I don't know" or to refuse to respond further, once explanations were begun, happened repeatedly. Consider the following excerpt, for example.

S: I think that the little balls are suspended in the solution because the density of them is less than the solution. And I do not know … *está muy difícil, no sé.* [Translation: It is too hard, I do not know]

This phenomenon occurred, as might be expected, when the students had no idea what to answer, as judged by their inability to answer in either English or Spanish. But it also occurred when they did not know how to communicate their thoughts in English.

Consider the following excerpt describing condensation, for example, in which the student starts to explain his answer but gets frustrated because he can't convey his thoughts without using Spanish and eventually gives up on his attempt to answer the question.

S: *Agua de vapor se vería* [Translation: The water vapor will look] … I think it will be B (pointing to a picture) because when the water evaporates you got in the *cilindro envase aquí* (container here) you have some molecules of water in gas and also oxygen and *hidrógeno* (hydrogen) in the *gas* phase. I do not want to say anything else.

Although he expressed frustration with the requirement that he answer in English, this student started the interview in that language. His answers, however, were short and uncommunicative. He then started to switch between Spanish and English while answering the questions, using certain Spanish words that are scientific and others that are part of everyday vocabulary. As the interview continued, he started to use Spanish to answer the questions, providing answers in his native language that were both more eloquent and more accurate than those given in English. At the end of the interview, this student commented on his prior experiences at an institution where the textbooks and class materials were in English while the discourse and exams were in Spanish.

S: … yo estudié medicina en Tampico y vine aquí a coger una clase para el "transcript" … y allá los textos son en Inglés y los exámenes son en español. Cuando veo el examen nos ponen texto en español y yo no sé ni que son y es por

[4] Translation: I understand that the balls remain suspended in solution may be because of their density, the amount of O2 molecules which help them float. The level where the balls are in the solution can vary depending on their mass. I think that the more O2 the ball has, the higher it will be. We can also say that if the mass is smaller then it will be suspended higher in the solution.

[5] Translation: To counter the force of gravity.

> eso que están poniendo entre comillas las palabras en inglés.[6]

The undergraduates were particularly likely to become frustrated when they could not communicate their ideas in English. When this happened the students simply stopped talking and asked to end the interview.

Confusion of terms

The participants in this study often confused terms or used terms in an inappropriate way when they were communicating scientific ideas in their non-native language. In the Orbitz task, for example, some students had difficulty describing the behavior of the particles suspended in the solution. One student, for example, referred to these particles as "ions."

> S: I think that these ions (are) really hard to distinguish, the little balls are less dense than the liquid and that is why they are floating around.

Later he refers to them more accurately as little balls, but uses an inappropriate term to describe their weight: "… maybe the little balls, the weight is very short." Careful analysis of the transcript suggests that this student, like so many others, simply confused terms while searching for the correct words to express in English what he was thinking in Spanish.

Terms that have no relationship to each other were often confused by participants in this study. While trying to explain where the water on the outside of a cold soft-drink can comes from, for example, one student used the term "osmosis" where "condensation" would be appropriate.

> S: The thing is that we always see osmosis keeping some particles of water outside the bowl as we see them we think that it is water falling out of the glass but it isn't.

Use of examples and new words

A fourth category was created that include excerpts from the interviews in which the students used examples and new words to communicate their thoughts. About half of the undergraduates used this strategy. One of the students tried to use the example of someone drowning when he explained what he meant by the term "suspension".

> S: I think they are suspended (talking about Orbitz drink) because … most things are suspended because they have air, right? For example when somebody drowns if they have water in their lungs they sink, that would explain but … if they have air in their lungs they automatically floats that would explain (pointing to particles in top and middle of the bottle) …

At times, students either created new words or used words in the incorrect context when trying to transmit their ideas. Consider the example shown below, in which a student tried to explain what happens when there is a change in phase from a liquid to a gas. The student uses the term "joint" to explain the breaking of intermolecular bonds that occurs during this phase transition, perhaps because this word is very similar to the Spanish "junto" which means "together, or united."

> S: I think you are going to have some of them (molecules) going apart and some of them collapsing into each other and is like breaking the *joints*.

As might be expected, the meaning of what is being said is often lost when students make up new words or use examples. This is a source of frustration for both the student and the instructor because the student finds that he or she cannot accurately convey material they know or understand when asked to express their knowledge in a foreign language.

The tendency to coin new words was also observed with the graduate student raised in an English-speaking environment who was asked to answer the interview questions in Spanish. This student used the word "desolvatación" when discussing the effect of solvents on solutes. In Spanish, the process by which a solute is dissolved is called "solubilizar" or "disolver" (Kaplan, 1998). Even though it was obvious what this student was trying to convey, the word "desolvatación" does not exist in Spanish.

Usage of terms without mastery

This category was used to classify excerpts from the interviews in which the students were using scientific terms either incorrectly or without the ability to explain their meaning while answering the interview questions. Most of the interviews with the under-

[6] Translation: ... I studied medicine in Tampico and came here to take a class I needed for the transcript ... there the textbooks are in English and the exams in Spanish. In the exam they put the text in Spanish and sometimes I do not know what it is until they put the key words in English in quotation marks by the Spanish term.

graduates contained one or more examples of this phenomenon. In the following excerpt, for example, the student incorrectly speculates on the possibility that the liquid in the Orbitz drink impedes the effect of gravity on the particles in the solution.

> S: Maybe the liquid holds (it) because there is something in the liquid that the weight of things is not the same as when you put something on the earth or something like that and I think that's why this can float or swim in here. And, that is it.

The students often used scientific terms without being able to explain what the term meant or how it was related to the question. The terms most often used without mastery in this study were *pressure*, *vaporization*, *molecules*, *mass*, *osmosis*, and *energy*. Most of the time, when asked to explain what they meant, the students did not respond. Consider the following answer to a question in which the student was asked to either show or explain what water molecules look like after water has evaporated.

> S: "Some of them keeping together (talking about water molecules in vaporization) in that shape because they are going outside of the liquid state to the gas. It won't be blank because the particles are always around, matter is neither created nor destroyed so …"

When asked to explain what he meant, the student stopped talking and refused to continue. The phrase "matter is neither created nor destroyed" seems to be an example of a scientific concept that has become a verbalism. There was no evidence that the student understood the concept. He only seemed to remember a definition or a phrase encountered in a textbook or a class.

Another example of this phenomenon can be found in the following attempt to explain what happens when ice cubes in a glass of water melt.

> S: I think that when the ice melts I think that the water level is going to be higher because when this melts there are more … no wait I changed my mind … I think it is going to be the same. … Because when the ice is in the water it is going to have some weight and there is something with weight and water … and when they melt the proportion is going to be the same if you put a liquid. That the ice cubes solid or liquid is same.
> The student knew the water level would stay the same after the ice cubes melted but could not explain his answer using science concepts appropriately.

In the following example, the student confuses the term "hypotonic" with "isotonic." The student states that the particles all have the same pressure and that it might have something to do with the term "osmosis" that he mentioned before. This student mentioned similar terms throughout the interview without any evidence that he understood their meaning.

> S: If the balls have … more density they are suppose to get at the bottom and when they stay. All the balls have the same density, hypotonic, maybe it has to something with osmosis … they all have the same pressure.
> It is interesting to note that more than half of the graduate students also seemed to use science terms without completely understanding their meaning. One graduate student, for example, used the term "temperature" incorrectly in explanations of the answers given to several questions. In the following excerpt, the student appears to be reciting a memorized phrase rather than explaining the answer to the question.
> I: if you have an iron bar and you leave it in the open, it rusts. What happens to the weight of that iron bar?
> S: It increases
> I: Why? (The student seems very defensive and annoyed that I asked why.)
> S: (Sighs) Well … (thinks for a while). Why it increases? … The weight? No the weight decreases because it is inversely proportional to temperature, whatever!!!!
> I: Why do you think it decreases?
> S: Because it is inversely proportional.

Conclusion

For each of the five categories into which student responses were classified, the undergraduates exhibited the indicated behavior significantly more often than the graduate students, perhaps because they have had less experience talking about science in their second language. Our results are consistent with Spurlin's (1995) argument that it takes five to seven years for students to develop the academic aspects of the second language, even though conversational skills in the second language are developed within two years of exposure.

The reality is that many second-language students are not fluent enough in academic English to succeed in science. Each of the five categories of behavior that arose in our study could have a potentially negative effect on the teacher's perception of the academic ability of the student if they occurred in a working classroom. The tendency to avoid communication, create new terms, exhibit confusions about terms, and use terms without mastery can easily be interpreted as signs of a lack of understanding, rather than the students' inability to express their understanding in a language in which they are not fluent. These students face the obstacle of mastering technical or scientific terms as well as the language of discourse in which these terms are taught.

A common theme arose in this study of bilingual students who all share a common first language. Both the undergraduate and graduate students suggested that it was easier for them to remember concepts they learned from an English textbook when the appropriate Spanish term was included in parentheses on exams or handouts next to key English terms. This is consistent with the work of Glanzer and Duarte (1971), who found that repetition of a concept in two languages led to higher levels of recall than repetition in a single language, and with the work of Tobin and McRobbie (1996) described in the introduction. Our work also suggested that bilingual students benefit from working in groups with students with the same pair of languages, regardless of which language is the primary language. As might be expected, participants in this study suggested that access to scientific dictionaries, such as Kaplan's (1998) *Chemistry Dictionary* would be helpful.

In a political environment in which monolingual versus bilingual education generates heated debate, we would like to suggest that bilingual education has distinct advantages. But only when it is truly bilingual, when discourse in the classroom occurs in both languages and when the connections between the native language and the language in which science is taught are emphasized.

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