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SECONDARY AND UNIVERSITY STUDENTS' REPRESENTATIONS OF THE HUMAN CIRCULATORY SYSTEM

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ABSTRACT

This paper analyzes the effect of the compulsory and specific instruction on the human circulatory system representations in secondary and university students. We found differences according to the specific biological instruction.

SECONDARY AND UNIVERSITY STUDENTS' REPRESENTATIONS OF THE HUMAN CIRCULATORY SYSTEM

ABSTRACT

There is no agreement about the robustness of intuitive representations of the circulatory system and their susceptibility to change by instruction. In this paper, we analyze to what extent students with different kinds of biology instruction and age have been able to change their intuitive into scientific representation of the human circulatory system. We analyzed two aspects of the circulatory system representation: the models of the circulatory system (the relationship between heart-lung in the blood pathway) and the circulatory system pattern (the blood pathway between organs). Regarding the models of circulatory system, we found differences in the distribution of the groups according to the specific biological instruction. The majority of participants had an incomplete model, which did not include the lungs while the Health Science adolescents group had a scientific representation. As for the circulatory system pattern, we did not find differences between groups. However, we cannot conclude that the two aspect of the circulatory system representation (model and pattern) are independent. The data in this study show that compulsory Human Physiology instruction did not enhance the acquisition of a scientific representation of the human circulatory system.

INTRODUCTION

The few studies that have been carried out on intuitive representations of the human circulatory system in the adolescent and adult population (Catherall, 1981; Chi, de Leeuw, Chiu, and La Vancher, 1994; Chi, Siler, Jeong, Yamauchi, and Hausman, 2001; Chi, 2005; Gellert, 1962; Arnaudin and Mintzes, 1985, 1986; Sungur, Tekkaya and Geban, 2001; White, Albanese, Anderson and Caplan, 1977) have not all reached the same conclusions about the robustness of such representations and their susceptibility to change by instruction.

On one hand, Arnaudin and Mintzes (1985, 1986) analyzed alternative conceptions of the circulatory system in primary, secondary school and college students. They studied different concepts of the circulatory system, such as the structure and function of the blood and the heart, the circulatory pattern, the relationships between the circulatory and respiratory systems, and the nature of the closed circulatory system. To identify the type of circulatory pattern, students were asked to choose among several drawings showing alternative paths of a drop of blood on its journey from the heart to the toe. The results obtained revealed difficulties in their understanding, particularly of the blood's circulatory pattern. The question was "What path does blood take when it leaves the heart?" Only 7-15% at college freshman level in biology chose the scientific model: heart-toe-heart-lungs-heart. These students included the lungs in the path largely as their age and instructional level increased, but did so incorrectly. Arnaudin and Mintzes (1985, 1986) concluded that of all the different concepts analyzed regarding the circulatory system, the circulatory pattern is one of the most difficult to change.

Sungur et al. (2001) developed an instructional strategy to promote conceptual change concerning the human circulatory system. This instructional

strategy took into account the misconceptions that 10th grade students had about the circulatory system. Although the students exposed to conceptual change instruction, performed statistically better than those exposed to traditional instruction, students in both groups held some conceptions different from the scientifically acceptable ones, even after formal instruction.

On the other hand, Chi et al. (1994, 2000, 2001 and 2005) stated the idea that the intuitive representations of the circulatory system can be easily removed by instruction since, according to her model of conceptual change (Chi, 1992), there is no necessity to promote a radical conceptual change. The data to support her thesis came from studies whose main goal was to test the efficacy of several instructional strategies, such as self-explanation (Chi et al., 1994) and tutoring (Chi et al., 2001; Chi et al., 2004), while reading a text, but whose content-learning involved the domain of the circulatory system. A similar procedure was employed in these studies: pre-test - instructional phase – post-test. Several tasks were used to assess the 8th grade students' knowledge. The students had to draw and explain the blood path on an outline of the human body. The results showed that, in general terms, 71% of students had a scientific model of the circulatory system following instruction. However, as the post-test was made a week after the instructional phase, which posed an obvious problem, we cannot be sure on the long-term effect of that instruction.

Precisely, one of the aims in our previous research (López-Manjón and Postigo, 2005; López-Manjón, Postigo and León, in press) was to analyze to what extent the scientific representation of the circulatory system, as a result of the compulsory instruction, has a long-term effect. Thus, we chose adolescent and adult participants with different levels of biology instruction and for whom the

instruction also took place at different times (high school students before and after specific biological instruction and their Social Science teachers and Biology teachers). We assessed such knowledge using several tasks, one of them was the same task that Chi et al. used (1994), that is, the drawing of the path of a drop of blood in an outline of the human body (generation task). The other was a modification of the one of Arnaudin and Mintzes (1986), a recognition task in which participants must choose the blood path in an outline among several ones. The results showed that there were no statistical differences in the distribution of circulatory representations among groups. The total mean percentage that showed a scientific representation was of 15% in the generation task meanwhile in the recognition task the mean percentage was of 14.2%. However we could point out that the task format influence the intuitive representations. In the generation task we found more frequently representations that did not take into account the lungs, meanwhile in the recognition task there were more representations with lungs although in an incorrect way (López-Manjón, Postigo and León, in press). The Biology teachers group generated the higher proportion of the scientific representation than the other three groups, although the actual percentage was quite low (33.3%) even in their case. In fact, Biology teachers obtained lower percentage of scientific model than expected by their background education. However, it should be pointed out that Biology teachers in the Mexican curricula had not received specific instruction in Human Physiology and they had focused more on animal and plant physiology. From our point of view, the above data show that after years of compulsory instruction (high school adolescents and Social Science teachers) about the circulatory system and even after two weeks of specific

instruction (high school students' post instruction), it is difficult to acquire a scientific representation about the blood path.

All the studies cited in this paper refer to one aspect of the circulatory system representation, that is, the way blood takes in the relationship between the heart and the lungs as in the Chi and Arnaudin studies. However, the analysis of the drawings and description in our previous studies mentioned (López-Manjón and Postigo, 2005; López-Manjón, Postigo and León, in press) allowed us to detect one aspect of the representations that was not taken into account in the sparse previous studies (Arnaudin and Mintzes, 1985, 1986; de Leeuw, 1993; Chi, 2005). That aspect refers to the way blood goes from heart to a target organ, that can either go directly or pass through other organs. We identified two different patterns in the representation of the blood path: centralized pattern and circular pattern. The scientific representation of the blood path could be named as **centralized pattern** in which the artery goes out of the heart and bifurcates in secondary routes, gets to the capillaries, and comes back, through veins, to the heart again. However, some participants drew a path, which we have called **circular pattern** or a **beltway pattern**. The blood not following a direct path from the heart to the target organ and return characterizes this pattern. On the contrary, in its way to or from the heart it takes a circular route to other body parts. We can find this pattern in a whole version (as in Figure 1) or passing only through the brain before going to the target organ. In Figure 1, we can observe a prototypical example of each pattern.

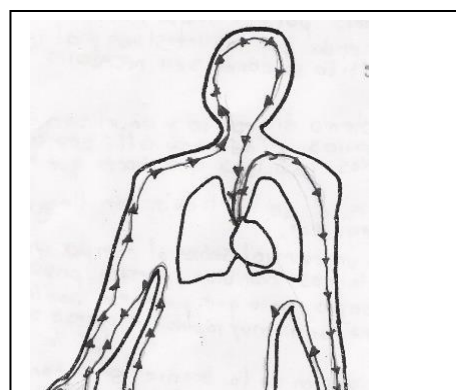
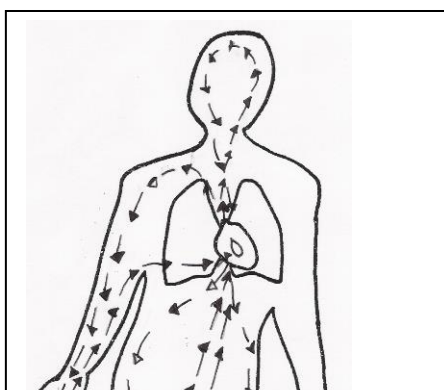


Figure 1. - Examples of participant's drawings of the different patterns of the blood.

The circular pattern was more often found in the non-expert groups: 75% of the Social Science high school teachers and 42.5% high school students without specific instruction. Nevertheless, it is necessary to emphasize that in this task, it was asked to draw the route of a drop of blood through a hand, that is, just one place to go. In this sense, it was only considered the route towards an organ and not towards other organs in the body.

Consequently, we wanted to analyze this aspect of the circulatory system representations modifying the instructions of the task used in previous studies, (López-Manjón and Postigo, 2005; López-Manjón, Postigo and León, in press) so, two target organs (hand and foot) were included in the drawing instructions. Thus, we could see whether this modification can influence the frequency of the pattern of the blood path (centralized pattern vs. circular pattern) and also the relationship between this aspect of the representation (pattern) with the model itself

(relationship between heart-lungs) in groups with different levels of instruction about the circulatory system.

Therefore, the objectives of this study were to analyze the circulatory system representations taking into account:

- a) a modification of the task (including in the drawing instructions two target organs).
- b) the analysis of the characteristics of the circulatory system pattern (centralized pattern vs. circular pattern).
- c) and the influence of the biological instruction level (compulsory and specific instruction).

METHOD

Participants

The participants of this study were 153 divided into four groups of subjects with different levels of instruction and age (high school and university). The two high school groups comprised, on one hand, of 37 high school students who had a specific curriculum for students that wanted to enroll at the Health Science university studies (Health Science adolescents with an average age of 17.65). On the other hand, 37 high school students, with only compulsory instruction on the human circulatory system received in secondary studies and with specific curricula devoted to Social Science studies (Social Science adolescents with an average age of 17,32). One of the university groups was composed of 32 first year Psychology university students, with only compulsory instruction about human circulatory system received in secondary studies (average age of 20.39). The other university group was composed of 47 last year Psychology university students who had

received a specific cardiovascular instruction in the Physiology practical subject in the previous course (average age of 22,23). The high school students were recruited from a state-run high school and the psychology students from a state-run university in Madrid (Spain).

Materials and procedure

The task consisted of drawing the blood-path on an outline of the human body containing only the heart and lungs. In this task, participants were asked to draw the path of a drop of blood on its journey through the circulatory system from the heart via a hand and a foot and describe the path in writing. The task was given collectively in the participants' usual classrooms, with the session lasting about ten minutes.

Analyses criteria

As it was mentioned in the introduction, we analyzed two aspects of the circulatory system representation. On one hand, what we called models of the circulatory system, that means the relationship between heart-lung in the blood pathway and on the other hand, what we called the circulatory system pattern that means the blood pathway between organs.

The drawings were classified in the same way according to Arnaudin and Mintzes' (1985) criteria, although we added one more model, F, found in our previous pilot research. Therefore, we identified six circulatory system models, which describe the path that a blood drop would follow in its way through a hand and a foot and specifically the relationship between the heart and lungs:

- Model A: heart-foot (or hand)-heart
- Model B: heart-foot (or hand)-lungs-heart

- Model C: heart-foot (or hand)
- Model D: heart-lungs-foot (or hand)-heart
- Model E: heart-lungs-heart-foot (or hand)-heart (the scientific one)
- Model F: heart-lungs-foot (or hand)-lungs-heart

Later, taking into account that some of the above models share some features, the drawings were classified into four further categories from the least correct to the most correct model from a scientific standpoint. The four categories used were:

- 1) **Model 1 (C)**: a non-closed system. The blood goes to the hand and does not return (Incorrect Model).
- 2) **Model 2 (A)**: a closed system without lungs. Single loop model or systemic circulation model (Incomplete Model).
- 3) **Model 3 (B, D and F)**: a closed system with incorrect path to the lungs (Incorrect Model).
- 4) **Model 4 (E)**: a closed system with correct path to the lungs. Double loop model or systemic and pulmonary circulation model (Scientific Model).

In addition, the drawings were classified again, taking into account the pattern of the path of the blood between the two target organs. Thus, we found two categories:

- 1) **Centralized pattern** in which the artery goes out of the heart and bifurcates in secondary routes to arrive to the capillaries coming back, through veins to the heart again.
- 2) **Circular pattern** in which the blood does not follow a direct path from the heart to the target organ. On the contrary, in its way to or from, it takes a circular route to other body parts.

RESULTS

Circulatory system models: relationship heart-lungs

The distribution of the different circulatory system models along the groups (see figure 2) was analyzed by a Chi-square test with adjusted standard residual. The results showed that there are significant differences among groups (χ^2 (9, N = 153) = 70,065, $p < 0.000$) in relation to the circulatory system models.

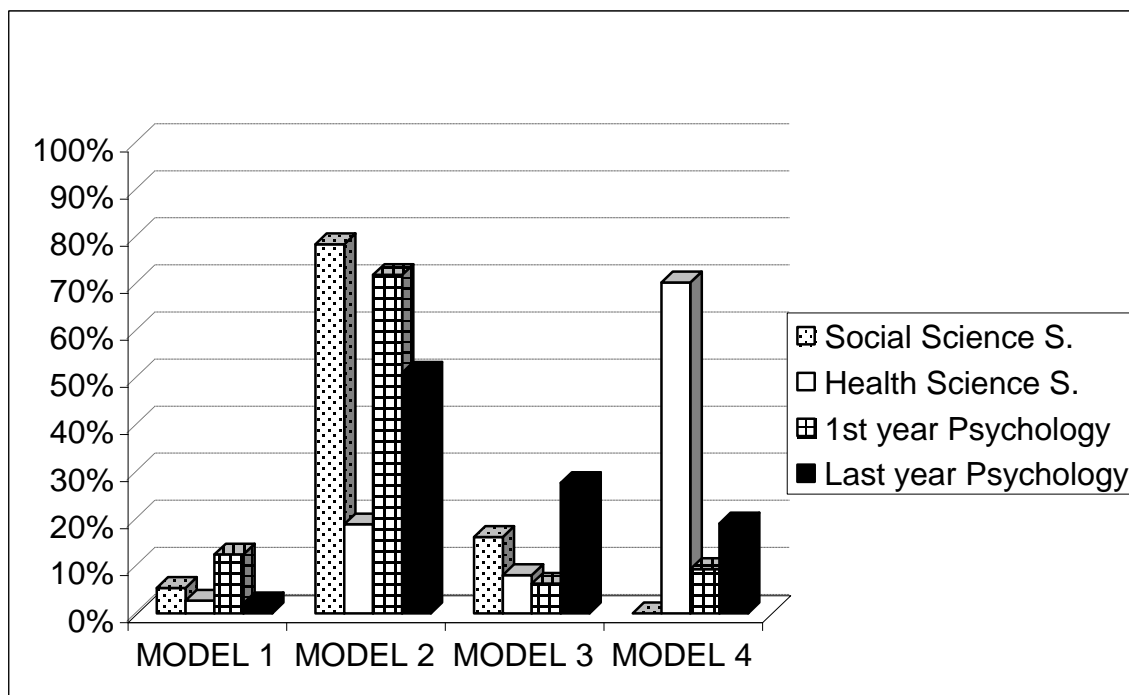


Figure 2. - Mean percentage of circulatory system models in each group.

On one hand, the first year Psychology group and the Social Science adolescents group had a representation according to the model 2 (78.4% and 71.9% observed respectively compared to 54.2% expected). That is, both groups drew a blood pathway taking into account only the role of the heart without including the lungs. However, it is interesting to notice that in the first year the Psychology group was the only group where we found representations related to the model 1, in which it

was not taken into account the return way to the heart, higher than expected (12,5% observed against the 5,2% expected). On the other hand, the Health Science adolescent group maintained mainly representations according to the model 4 (70.3% observed percentage against the 24.8% expected), that is, the scientific model. The last year Psychology was a group, which behaved in a different way related to the other ones. The 51.1% had a representation according to model 2 (with the same tendency than the first year Psychology group and the Social Science adolescent group), however there is a significant displacement of cases to the model 3 (27.7% observed against the 15.7% expected) which included the lungs in the blood pathway but in an incorrect way.

Therefore, regarding the distribution of participants along the four models of circulatory system, there are no differences between the Social Science students and the first year Psychology students, which maintained an incomplete model (model 2). It seems clear that the scientific model was found mainly in the Health Science adolescents following the last year Psychology group (19.1%).

Circulatory system pattern: the relationship between organs

The distribution of the different groups along the two circulatory system patterns (centralized and circular) was analyzed by a Chi-square test. The results showed that there are not significant differences between groups (χ^2 (3, N = 153) = 0,717, $p < .05$). That is, all groups show a similar distribution in the variable circulatory system pattern. In addition, we analyzed the distribution of the two circulatory system pattern along the four models of circulatory system by a Chi-square test (with adjusted standard residual). Although the results showed that there were not significant differences (χ^2 (3, N = 153) = 5,946, $p < .05$), the

adjusted residuals were close to it and showed an interesting tendency. Specifically in the centralized pattern was observed a displacement of cases to the scientific model (model 4) while in the circular pattern is observed a displacement of cases to the model 3 (see figure 3).

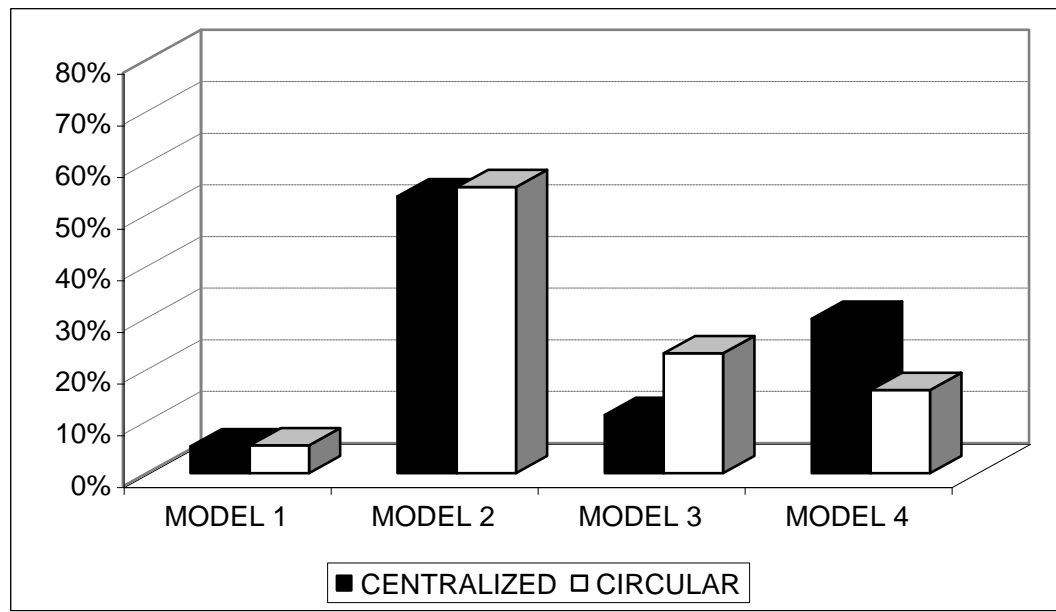


Figure 3. – Percentage of the participants using the distribution of the centralized or circular pattern along the circulatory system models.

There are similar distributions of centralized or circular pattern in the answers corresponding to model 2 (incomplete model) and model 1 (incorrect model without lungs).

CONCLUSIONS AND IMPLICATIONS

What kinds of representations about the human circulatory system do high school and university students with different level of instruction hold? Is the compulsory instruction enough to change from an intuitive representation to a scientific one?

The data in this study show that compulsory Human Physiology instruction did not enhance the acquisition of a scientific representation of the human circulatory

system. We found statistical differences in the distribution of the groups. Firstly, we can say that the majority of participants had a representation according to the model 2 in which the lungs were not included. The Health Science adolescent group was the only one who had a majority scientific representation (model 4). This result is consistent with our previous data (López-Manjón and Postigo, 2005) in the generation task.

Specifically, if we analyze the distribution of the different circulatory system models along with the four groups of participants the results show a sequence, from less elaborated representations, to the scientific model of the circulatory system. Therefore, the two groups with only the compulsory instruction (Social Science students and the first year Psychology students) maintained an incomplete model (model 2). The other two groups (Health Science students and the last year Psychology students) maintained respectively a scientific model (model 4) or near to the scientific model (model 3, insofar as they included in the blood pathway the lungs but in an incorrect way).

In conclusion, the compulsory instruction about the Human Circulatory System was not able to change this aspect of the representation, that is, the pathway between the heart and the lungs. However, we found an effect of specific instruction in the Health Science group that showed a scientific representation (70.3%). The understanding of the circulatory system seems to pose a major conceptual difficulty and our data confirm the findings of other researchers (Arnaudín y Mintzes, 85, 86; Sungur et al., 2001) in demonstrating the robustness of such intuitive representations.

With respect to the circulatory system pattern, we had not found significant differences among groups, that is, all groups showed a similar distribution in the

two patterns. However, we cannot conclude that the two aspects of the circulatory system representation (model and pattern) are independent. We can observe a tendency to associate the centralized pattern with the scientific model (model 4) while in the circular pattern a displacement of cases to the model 3 is observed (see figure 3). There are similar distributions of centralized and circular patterns in the results corresponding to model 2 (incomplete model) and model 1 (incorrect model without lungs).

According to previous research (Pozo, Gómez Crespo and Sanz, 1999; Pozo and Gómez Crespo, 2005) in the chemistry domain, instead of using the microscopic (or scientific) level of representation to better understand the nature of the matter, students use the macroscopic (or intuitive) level to explain the microscopic level of representation provided by their instruction. The data we have obtained in relation to the circulatory system show a similar pattern. With the exception of the Health Science students, the participants did not use the scientific representation to understand the path of the circulatory system, even though they had been exposed to it during their period of compulsory education. They try to make sense of certain scientific ideas such as the blood flows throughout the whole body by including it in their representations and constructing a specific path for them (circular pattern).

Human circulatory system understanding is more complex than teachers and cognitive researchers think. Almost all people may mention that the function of the heart is to pump blood; however, we think they did not conceive it as a double pump. The understanding of the heart as a double pump implies taking into account concepts belonging to the physics domain; such as pressure and force, (other authors also add the necessity of chemical concepts, e.g., Sungur et al.). In the recognition task about the human circulatory system (López-Manjón and

Postigo, 2005) we found that most of the people have a representation that include a wrong relationship between the heart and the lungs (model 3). This representation is incompatible with a real comprehension of the role of the heart as a pump. Blood cannot go from lungs to the toe because lungs are not a muscle and cannot pump blood; only the heart has this capacity. However, participants in that study were not aware of that inconsistency.

It was even hard to conceive the heart as a simple pump. The analysis of this idea was one of our objectives in this study. Thus, we can infer that the participants who showed a centralized circulatory system pattern have a real comprehension of the heart as a pump in opposition to those participants who hold the idea of a circular circulatory system pattern. Although we had not found difference between both circulatory system pattern along groups and circulatory system models, we would hypothesize that there are two related aspects of the same representation included the heart as a pump. The results showed, on one hand, an association between the centralized circulatory system pattern and scientific model (implying a correct conception of the heart as a pump). On the other hand, there was an association between circular circulatory system pattern and a model that included a wrong relationship between the heart and the lungs. That means an incorrect conception of the heart as a pump. According to Arnaudin & Mintzes (1985) to learn that, the function of the heart is to pump blood is one of the easiest ideas to acquire. We think that this idea would be acquired easily as rote learning, which does not mean to understand it as we can see in these data.

We are not sure of the Chi (2005) idea that intuitive representations about the circulatory system do not imply a radical conceptual change. We think that in order to understand the circulatory system it has to be conceived as a new

ontological category of “emergent processes” (Chi, 2005) in the extent that it involves a system of interacting components tending to equilibrium under certain conditions by the mechanism called homeostasis. Thus, we can explain the difficulty of changing their intuitive representations instead of scientific ones.

Nevertheless, there are still insufficient data to say whether learning about the circulatory system involves a conceptual change. However, what this research suggests is that there are intuitive representations of the circulatory system that persist despite the compulsory education. Analyzing the nature of intuitive representation can offer clues to understand and design not only compulsory education but also health programs directed to the adult population to promote conceptual change.

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