Students' beliefs about the circulatory system:

Are misconceptions universal?

Nicholas de Leeuw
University of Pittsburgh
820 Learning Research and Development Center
3939 O'Hara Street
Pittsburgh, PA 15260
EMAIL: NADST3@vms.cis.pitt.edu

Abstract

Misconceptions are a special case of false beliefs. They should be both robust and important to a person's belief system. Chi (1992) has asserted that in some domains, such as the circulatory system, students initial conceptions are of the same general ontological class as the textbook conceptions. They should therefore not be as robust as the initial conceptions in domains such as physics, in which the initial conception may be of the wrong class. The initial beliefs of 12 eighth grade students about the circulatory system included a variety of false beliefs. Statements of both correct and incorrect beliefs were used to generate maps of students' initial mental models. This allowed an assessment of the importance of the false beliefs. Even deeply embedded beliefs were removed by instruction. Importance was also measured by the impact of false beliefs on a pre-test, which was not significant. Resistance to instruction was tested by having students read a text. One analysis checked individual false beliefs, to see if contradiction by the text resulted in false belief removal. Beliefs which were contradicted were generally removed. These results are not consistent with the notion that students bring with them to instruction important and robust misconceptions about the circulatory system.

Introduction

Students in science bring with them to the classroom a host of incorrect knowledge. In some domains, notably physics, these beliefs have proven to be important barriers to the acquisition of the textbook, or veridical, knowledge (McCloskey, Caramazza, & Green, 1980, Clement, 1982, Reiner, Chi, & Resnick, 1988). It is not clear, however, if such barriers present themselves in all science domains, or if in some domains the misconceptions or false beliefs that are harbored in naive students will prove to be relatively unimportant.

In order to retain the meaning of "misconception", this paper will reserve that term for beliefs which are robust and consequential. Misconceptions are thus a subclass of false beliefs. There are two very general features which this study uses to distinguish misconceptions from other false beliefs, within a given student's understanding. First, misconceptions should be stable. That is, they should be used consistently, and they should resist removal. Second, misconceptions should be important to a subjects overall conception of the system. Isolated beliefs which do not impact the rest of a student's model are not misconceptions. Stable false beliefs which are deeply embedded in a student's understanding are.

This study examines the false beliefs of eighth-graders learning about the human circulatory system to see if these beliefs qualify as misconceptions, and also if they pose a significant impediment to learning.

Chi (1992) has asserted that in domains such as the circulatory system, students initial conceptions are of the same general ontological class as the textbook conceptions. For example, even an incorrect notion of blood is still in the category of matter. This is in contrast to domains such as physics, in which the initial conception may be of the wrong class, for example viewing light as a form of matter (Reiner, Chi, and Resnick, 1988). In Chi's view, this ontological compatibility should preclude the sort of robust misconceptions found in physics.

Previous research (Arnaudin and Mintzes, 1985, Catherall, 1981) has suggested that there are misconceptions about the human circulatory system. However, these authors looked at cross-sectional data, collapsed across belief categories. Although this approach is very useful in getting a general sense of what prior beliefs students hold, it cannot answer questions about how important specific beliefs are to a student's overall conception, because the component beliefs of a student's conception are never viewed as a whole. Nor can this approach address whether these beliefs can be removed, if they are challenged. A finding of no improvement with age may only suggest no instruction with age.

Table 1. Pre-test Terms

Questions

1) What is it? What kind of thing is it ? What does it refer to?
2) Where is it found in the body?
3) What is its structure, texture, or composition?
4) What does it do?
5) What is its purpose?

Terms

Aorta	Plasma
Artery	Platelet
Arteriole	Pulmonary Circulation
Atrium	Red Blood Cell (Erythrocytes)
Blood	Septum
Blood vessel	Systemic Circulation
Capillary	Valve
Circulatory System	Vein
Diffusion	Ventricle
Heart	Venule
Hemoglobin	White Blood Cell (Leukocytes)
Lungs	

In order to look at the importance of prior beliefs it is necessary to look at individual conceptions of the domain. To this aim, this study was designed to provide a detailed "map" of students' initial mental models, based on verbal transcripts. Using this tool, false beliefs could be evaluated in the context of an overall model. One measure of the importance of a belief will be how many other beliefs follow from it in the model.

To see how resistant a belief is to instruction, the study looks at students' beliefs before and after instruction. It also looks at the relationship of the instruction to the false beliefs. This can give a specific idea of how well a false belief survives direct or indirect contradiction. Overall, the aim is to discover whether the initial false beliefs of students are misconceptions which present a barrier to learning.

Method

Subjects were 8th grade students from a single local public school. Fourteen subjects were run in the talk out loud condition analyzed for this study, but only the first twelve subjects data were available in time for these analyses.

Each student came into the lab individually for 3 sessions of about two hours. Each session was tape recorded and later transcribed. The first session consisted of a three part pre-test to evaluate their prior knowledge of the circulatory system. In the first part, students were given five questions to answer about 23 terms. The questions and terms are shown in Table 1. In the second part, students diagrammed the circulatory system. In the final part of the first session, students answered 42 questions about the system, in six categories. The categories specifically reported here were modelled after the kind of questions one finds in a textbook, in varying degrees of difficulty.

In the second session students read a text about the circulatory system, drawn from a standard biology textbook (Towle, 1989). After reading each sentence, students were asked to explain what it meant. The final session was a repeat of the pre-test, with some additional questions added.

Results

Students revealed a variety of false beliefs. Each false statement in the pretest was noted, and a list was compiled for each student. Restatements of the same belief were counted only once. The mean number of false beliefs per student, for the entire pretest, was 15.8. However, most of the students beliefs were never repeated. Because the main interest of the study was to identify initial false beliefs which were potentially stable and important, two filters were applied to the original set. The first filter was that the belief had to be mentioned in the first part of the pretest, the terms. It was clear from reading protocols that students revised their conceptions based on information inferred from the questions in the third part, so false statements made during the questions may have reflected a "contaminated" model. The second filter was that the student had to mention the belief more than once overall. This left only 2.8 false beliefs per subject, a total of 31 across 12 subjects. This set of relatively stable beliefs could be considered candidate misconceptions.

As a set, however, these beliefs did not seem to have been important to student's understanding. The number of false beliefs a student demonstrated did not predict their scores on the questions in the pretest, using either the full or filtered sets of false beliefs ($r^2 < .1$). This result averages across students and beliefs. It therefore leaves open the possibility that some of the stable beliefs did impact test scores, but that their influence was masked by less important beliefs.

A more extensive analysis was undertaken to asses the potential importance of individual false beliefs. This required mapping each student's mental model of the circulatory system, in order to look at how their false beliefs fit into that model.

The mapping looked at both correct and incorrect beliefs, and focused on functional connections within a student's model. The transcripts of each student's terms section of the pre-test was scoured for statements linking a structure (such as the heart), to a function (such as pumping blood). Templates of both correct and incorrect combinations were employed to aid in identification. These pairings of structure and function were mapped as nodes in the map of the student's model. Further examination of the transcript, again using templates, looked for causal or enabling links between these nodes. For example, if the student stated that the heart pumping blood allowed the arteries to carry blood, that was represented as an enabling link between two nodes. Figure 1 shows a map fragment generated from the following description of the artery:

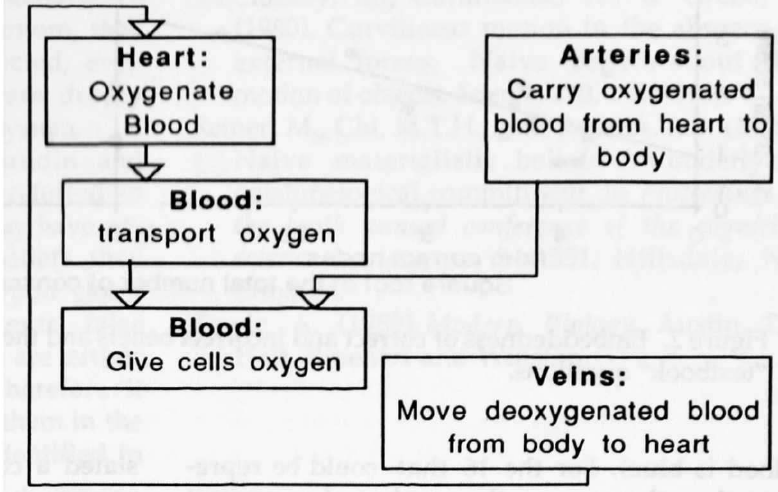

Figure 1. Map fragment.

> *"Umm.. well, the body keeps on... it always needs clean blood and the blood travels once through the arteries and when it's used it travels back up in the veins to go back to the heart, the heart cleans it again, umm... replenishes it with oxygen, umm... and then it goes again to all the parts of the body. Basically, clean blood is blood that has any supply of oxygen in it."*

In this little snippet of protocol several functions are pretty well articulated. The arteries job is to carry clean blood to all the parts of the body. The veins bring the used blood back to the heart. The heart cleans, or replenishes the blood with oxygen. And there is a strong hint that the body uses up that oxygen and deoxygenates the blood, though not enough to say for sure that the subject understands that.

This representation allows the chain of consequents from a given belief to be counted. For example, in the fragment shown in Figure 1, the node *Heart oxygenates blood* has two consequents, while the node *Blood gives cells oxygen* has none. Not all of the false beliefs that passed through the filters described above could be coded into this representation, because they did not involve any function (for example, the belief that some

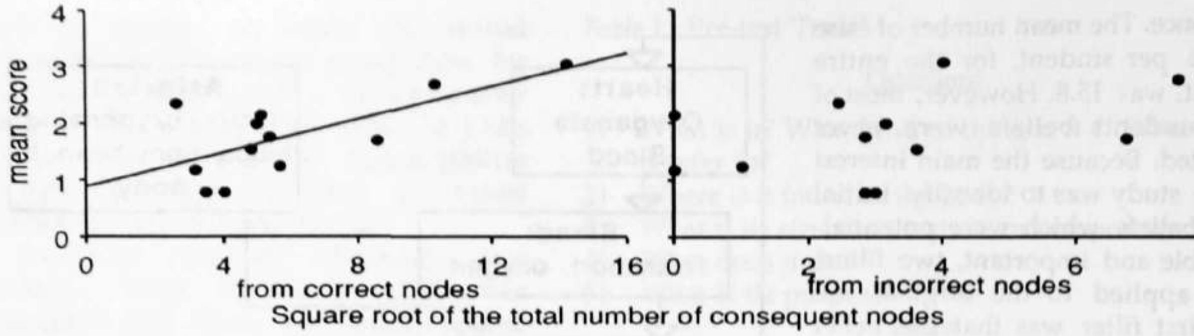

Figure 2. Embeddedness of correct and incorrect beliefs and their relations to pretest scores for "textbook" questions.

blood is blue). For the 16 that could be represented on these maps, the number of consequent nodes that followed them was taken as a measure of their embeddedness.

In order to see if more embedded beliefs were more important to students overall understanding of the circulatory system, a measure was devised of the total embeddedness of all the false beliefs in a students model. This measure totalled all the chains following false beliefs in the map of the student's model, and took the square root of this total. A contrastive measure took the square root of all the chains following correct nodes in the model. Figure 2 shows these measures against students performance on the "textbook" portion of the pretest. The embeddedness of correct nodes was predictive of the test score (r^2=.47, p<.025) but the embeddedness of incorrect nodes was not (r^2=.13, p>.25).

The embeddedness of particular false beliefs was also not a predictor of their removal. This analysis looked at the set of 16 false beliefs which could be "mapped." They were rated as removed if the subject both refuted the belief and stated a correct conception of the same phenomena during the course of the three sessions. For example if the false belief was, "the heart oxygenates blood," the subject had to say that "the heart does not oxygenate blood", and that "the lungs do oxygenate blood", for the belief to be counted as removed. Only one of the 16 beliefs was not removed, and it had a depth of only one node. For the 13 that were removed, the average depth was 6.8 nodes. Two beliefs met one, but not both, of the criteria for removal. Each of these had no consequent nodes (a depth of zero).

For the 31 false beliefs that passed through the two stability filters, there was an additional analysis to look at their resistance to removal. An important aspect of this analysis was looking at whether and how the text contradicted these beliefs. If the text explicitly refuted a belief (e.g. "the heart does not oxygenate blood" or "blood does not change in any way as it passes through the heart") that was counted as a direct contradiction. Contradictions which required further inference (e.g. "the lungs oxygenate blood" and/or "the heart pumps blood") were counted as indirect. Removal was rated in the same way as for the previous analysis. Table 2 shows that most false beliefs were removed, unless the text did not contradict them.

Table 2. False belief removal and text contradiction.

Contra-diction In Text	Total	Removal Yes	Maybe	No
Direct	9	6	2	1
Indirect	17	13	3	1
None	5	0	0	5
Total	31	19	5	7

Discussion

The pattern of results in this study is not consistent with the notion that students bring with them to instruction stable and important misconceptions about the circulatory system. Although some relatively stable beliefs were identified, these turned out to have no influence even on pre-test performance. Furthermore, they were generally removed if contradicted, even (and perhaps especially) if they were deeply embedded in a student's model of the system.

Although earlier studies (Arnaudin and Mintzes, 1985 Catherall, 1981) have referred to misconceptions in this domain, they may have attributed greater importance to the beliefs they identified than they warranted. Upon closer examination, it appears that students' false beliefs about the circulatory system are either unstable or unimportant, or both. Therefore it does not seem worthwhile to consider them in the same class of misconception as those identified in physics.

Chi (1992) offers one explanation for this lack of persistent misconceptions. It may be that the false beliefs about the circulatory system do not present an important barrier to learning because students can change their conceptions without reassigning them to a new ontological class. Of course, there are alternative explanations. It may be that the knowledge students need to learn about the circulatory system is less principle based than, for example, Newton's laws. It may be that there is less math involved. It may well be that all of these elements play a role. Comparing these possibilities awaits further research.

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