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Article Title: **Conceptual Models Of Human Respiration And Alternative Conceptions [That Present Possible Impediments To Students' Understanding]**

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Abstract: An understanding of human respiration is necessary for children to relate issues in the world around them to their own health, i.e. the hazards of smoking, pollution, and diseases of other body systems such as heart disease and cancer. While preliminary results of this study indicate that children have a vague notion of the danger and destructive nature of smoking, there appears to be an even wider gap in children's understanding of the structure and function of the respiratory system and its connection with smoking and pollution. If little or no connection is made between the essential functions of the respiratory system and the effect of smoking, pollution, and other health issues, can we expect children to take the warnings and lessons about health issues seriously?

For this reason, we have investigated the preconceptions held by students from nine to sixteen years old concerning the structure and function of the respiratory system and effects of smoking on this system. Many preconceptions held by students at a young age appear to be persistent in older children. In instances where more detailed answers were expressed by older students, they appeared to be comprised primarily of naive structural understanding and a belief that the lungs in some way affect oxygen transfer. However, little in-depth understanding was apparent. Initial analysis indicates that when students were asked what function the respiratory system played in the human body, their answers fell into three categories, they 1) described a behavior as a function, 2) described a naive function of the system, or they 3) gave no answer or a vague response unrelated to the question. It is important to note, however, that a few students from each group were able to discuss structures and functions of the respiratory system with accuracy and depth. This may indicate that the alternative conceptions surrounding human respiration are not due to the developmental age of the child, or to formal schooling, but rather to a lack of exposure to the material. This lack could lead the child to develop alternative explanations based on their own limited information. There also appears to be some evidence that some alternative conceptions do not constitute a major interference to subsequent learning. However, other Alternative conceptions do exist which provide major blocks to conceptual understanding.

This study provides a conceptual framework for understanding human respiration. It includes both naive conceptions and alternative conceptions in relation to target conceptions. This allows the analysis of students' conceptual maps and should help in the design of instruction.

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Conceptual Models Of Human Respiration And Alternative Conceptions [That Present Possible Impediments To Students' Understanding]

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Completion date: 8-21-97

ABSTRACT

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INTRODUCTION

The area of human biology is rapidly changing as new discoveries are made from the cloning of animals to treatment of disease. Unfortunately, this is an area which is often relinquished to health class, skimmed over quickly in most elementary and secondary schools outside of the biology classroom, or omitted entirely. In the area of educational research human biology often takes a back seat to physics. However, since the early 1990's there has been a persistent, if quiet, search to understand what students know about human biology and how this knowledge developed. While students' data base of facts concerning the internal structures of the body has increased, their conceptualization of the function of systems appears to have shown little or no development. What understanding is evident in the research of 1935 is also evident in the research of 1994 (Schilder & Wechsler, 1935; Nagy, 1953; Tait & Ascher, 1955; Gellert, 1962; Porter, 1974; Blum, 1977; Quiggin, 1977; Mintzes, 1984; Arnaudin & Mintzes, 1985; Bishop, Roth, & Anderson, 1986; Seymour & Longden, 1991; Chi, Chiu, & deLeeuw, 1991; Buckley, 1992; Sanders, 1993; Songer & Mintzes, 1994). This presents cause for concern as the conceptual understanding of students does not parallel the understanding necessary to make informed decisions in a fast paced world.

While function is considered a major prerequisite for assigning importance to a structure, little is still known about students' conceptions in this area. Students have been asked to name organs and assign behavior without delving into the reason behind this behavior. Songer and Mintzes (1994) stated that a conceptual understanding of respiration at a cellular level is "critical to an understanding of several of the organizing conceptual schemes of the discipline (*biology*), including energy flow in natural ecosystems and metabolic activities of multicellular organisms such as digestion, respiration, circulation, and excretion." However, teachers often find the topic difficult and discover that students have a poor understanding even after instruction (Igelsrud, 1989). This may account for the lack of time spent on function as compared to learning to name structures, especially in the younger grades.

WHAT DO STUDENTS KNOW NOW?

The ability to name internal body structures by students may have undergone an evolution since 1935, possibly paralleling science and technology's own development. This does not, however, appear to carry over into an understanding of how these structures work. At the same time, an understanding of human respiration, both pulmonary and cellular, has taken on added importance not only because it is crucial in understanding other critical areas of biology, but also because of the important connection to major issues in the world around us. With new advances in technology and media resources almost a routine part of everyday life, abstract biological concepts once unavailable to students may now be appreciated. Unfortunately, whether students have any new understanding of how their body works needs further investigation. In addition, even if students have been exposed, how have they assimilated or accommodated this new information, reconciling it to prior alternative conceptions or naive conceptions?

While past research gives us glimpses into students' conceptions, it has dealt primarily with structure and secondarily with function. Respiration was not the main focus of most of these studies but provided some small pieces of information gained as students either drew or discussed another system. The few studies that were devoted strictly to respiration were conducted at the high school and college levels or level (Bishop et al, 1986; Songer & Mintzes, 1994). However, it is evident that students bring with them many alternative conceptions developed throughout their elementary school years. The purpose of this study was to determine what preconceptions students in grades four through ten had about human respiration. Also, what preconceptions, particularly about function and mechanism, exist in young children that persist into the higher grades?

METHODOLOGY

The data collection consists testing of the instrument, and the collection of data through survey and interview. The data was then analyzed to develop an understanding of the preconceptions and also to develop a framework within which to view the preconceptions and understanding of respiration.

Development of Survey Instrument

A survey was developed to determine what preconceptions students had about human respiration. This consisted of five open-ended, free response questions and a drawing (see appendix A). A pilot of the survey conducted with twenty-five sixth graders, and videotaped interviews with eight students age 7 to 16, provided a test of the instrument. These led to minor modifications and ultimately acceptance of the tool. An explanation of a target model of respiration was subsequently developed in collaboration with experts in the field of biology. This later provided a framework for identifying and interpreting student's conceptual models of respiration (Figure 1).

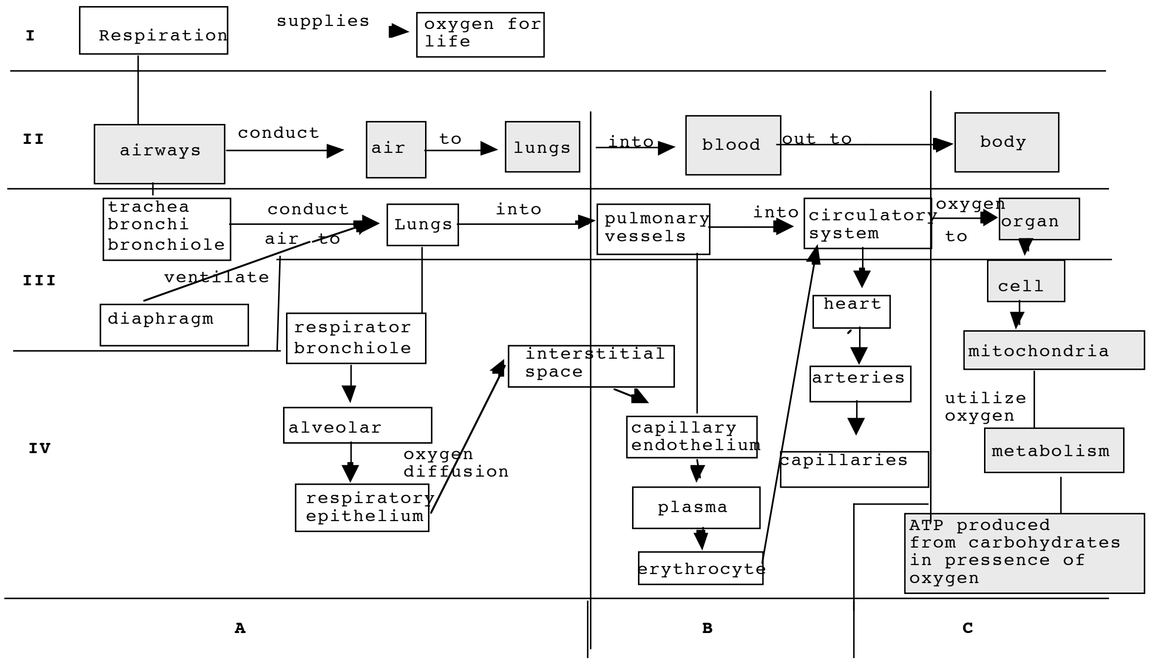

Figure 1

Framework representing levels of understanding of respiration

Participants and Data Collection

The survey was sent to 8 teachers at seven schools who had expressed an interest in participating in the study. None had taught the subject of respiration during the current school year. Survey participants consisted of 128 fourth, fifth, and sixth graders, 142 seventh and eighth graders, and 88 tenth and eleventh graders. There was an approximately even distribution of males and females. Students were from rural and small town elementary, middle and high schools in Massachusetts and Florida. While the number included some students from a variety of ethnic backgrounds, the majority were Caucasian. In addition, two students, M.C., a sixth grader (12 years old), and J.R., a tenth grader (16 years old), were interviewed in depth, each on two separate occasions.

ANALYSIS AND DEVELOPMENT OF FRAMEWORK

Written responses were sorted into grade level groups for analysis. Attempts to understand the naive conception and alternative conceptions found on analysis of the surveys led to the development of a graphic framework of respiration. While many naive conceptions and alternative conceptions were present at all grade levels, simply lists or percentages of these conceptions did not adequately explain the mental models students had formed. It appeared that students' models were not simply expert models with holes but complete models that varied in development and complexity.

After attempting many variations on a graphic framework that would both encompass the information from the surveys and provide a representation of developmental stages of learning we finally agreed on the framework represented in Figure 1. While this graphic framework appears complex, it is the result of much work in a field that is itself complex. It has evolved out of the initial analysis and coding of surveys, discussion with experts concerning their understanding of respiration, and collaborative discussions with experts in the field of alternative conceptions.

To aid in understanding the framework, I have broken it down into levels. These levels appear to represent a progression in complexity of mental models from Novice to Beginning Expert. They do not represent right or wrong answers just developmental levels. This is similar to Smith, et al (1993) who describe complex systems of understanding rather than isolated alternative conceptions or pieces of knowledge. Alternative conceptions that arise within a level will be discussed later in this paper when we compare the interviewed students' models to this framework.

Level I is the most Novice in which students recognized only that respiration was necessary for life. It appears to be primarily based on an external sensation of breathing that students connected to survival. The largest percent of students in grades 4-6 fell into this level.

In Level II one might think of this knowledge arrangement as a series of three black boxes (Figure 2). In this level students recognize that oxygen enters the lungs and moves in some way into the blood and then into the body. However, what occurs within the box and what structures are involved, does not seem apparent to the student.

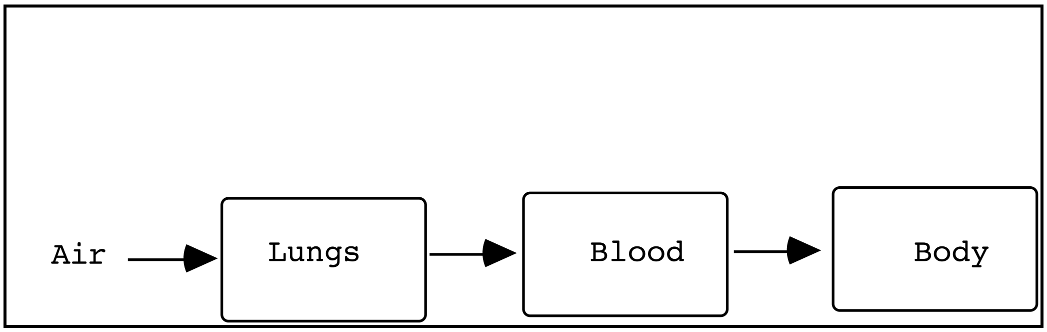

Figure 2: Black box representation of respiration

In Level III the student begins to have more depth of knowledge about both structure and mechanism, realizing oxygen is necessary to specific parts of the body. Level III shows a basic understanding of two systems of circulation involved in respiration, pulmonary and systemic. It also includes organs and tissues of the body as the target of oxygen transport.

Level IV is the beginning of an understanding of respiration at a cellular level. It is generally much more complex. The student displays an understanding of the basic structures of respiration down to the cellular level, understands the pulmonary/circulatory connection, and can explain at least at a beginning level energy production within all body cells.

While the Levels indicate a move from Naive (I) to Target (IV), the A, B, and C sections represent understanding about a system, a relationship between systems, and the connection between respiration at an organismic and cellular level. Section A is the pulmonary section, Section B the circulatory section, and Section C the organs and more specifically, the cells of the body where cellular respiration occurs. (see Appendix B for details of Levels).

We were then able to place students generally within Figure 1. However, when we began to look more closely at the patterns that emerged from this placement we saw a possible learning pathway that had developed. Learning pathways represent routes that students move through as they develop understanding in a particular area or domain (Scott, 1991). While it is felt that learning pathways are peculiar to each individual learner, similarities may also be found among students just as naive conceptions and alternative conceptions are prevalent in groups of students. This appears to be the finding in the current study. The shaded area across IIA, IIB, and IVC represents one such learning pathway (Figure 1). This is supported by evidence that a significant number of students (more at the 10-11 gr.) described conceptual models that represented naive or novice understanding at Level II A and B but were able to develop more depth of understanding at Level IV C. As this pattern evolved, it suggested to us that minimal understanding may progress along the shaded pathway and that this may in turn suggest possibilities for teaching strategies.

A related point that we discovered using the graphic in Figure 1 was that the majority of students fell within the first two levels, both indicating Naive conceptions. However, some students indicated more developed understanding particularly within Section C. This led to the speculation that possibly alternative conceptions and naive conceptions do not always block students progress. In other words, only knowing that oxygen entered through the lungs and then passed into the blood stream and was then carried to the cells of the body is a naive notion. However, when this notion existed together with typical alternative conceptions such as hollow, balloon shaped lungs, small lungs, and a dual role for the esophagus (food and oxygen transport), it did not appear to prevent students from also developing a beginning understanding of cellular respiration. This suggests that students were able to move beyond these alternative conceptions connecting pulmonary action with supplying oxygen to the cells of the body for ATP production. Therefore, is it possible that a conceptual model that resembles the learning pathway shown in Figure 1 may be achieved even without extensive knowledge of structures. Additionally, it may suggest that strategies for teaching about respiration might begin at the cellular level through introduction of a problem such as leg cramps resulting from running hard. This would allow students to work backwards to construct an understanding of what systems and interactions would be necessary to solve the problem.

RESULTS AND DISCUSSION

Analysis of the survey suggests three categories of conceptual understanding: Naive conceptions, Alternative conceptions, and Impeding Alternative conceptions. For the purpose of this study we have used the following definitions:

Preconceptions - include all conceptions or ideas the students bring with them to the survey situation.
Naive conceptions - include those conceptions students hold that, while not scientifically complete from an expert's view, are simplistic conceptions which may be due to lack of information.
Alternative conceptions - include conceptions that are different from the currently accepted scientific model.
Potentially Impeding Alternative conceptions - a set of coherent, alternative relations held by the student that may potentially impede instruction.

In this study there exists within preconceptions both naive conceptions and alternative conceptions. Possibly impeding alternative conceptions are a subset of alternative conceptions. It is felt that these possibly impeding alternative conceptions may necessitate the greatest cause for concern in conceptual understanding of human respiration as it is these alternative conceptions that prevent progress of learning along the shaded path in Figure 1.

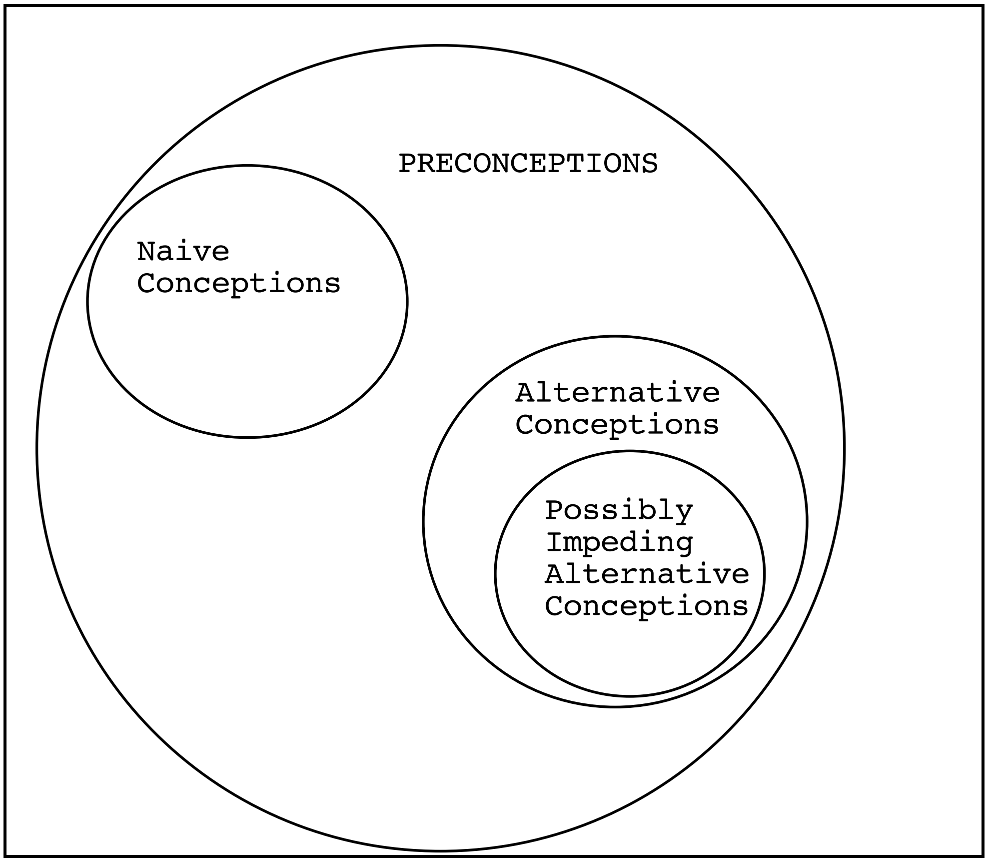

Figure 3: Types of preconceptions (Venn diagram of terminology)

Figure 3: Venn diagram of terminology

Naive Conceptions and Alternative Conceptions

Students at all grade levels held many naive conceptions about human respiration (Figure 4). These most often involved identification of 'breathing to live' with the function of respiration and confined the mechanism of respiration to simply breathing in and out. As students increased in age they also increased slightly in the sophistication of their beliefs. Beliefs for the majority of students at all ages still remained within the Naive range (I and II).

NAIVE CONCEPTIONS				
	Conception	**Percent Responding**		
	Grade=	**10-11**	**7-8**	**4-6**
	N =	**88**	**142**	**128**
Function	to breathe	52%	73%	64%
	to live	23	57	39
	to provide oxygen to control body keep body working	30	13	7
	to provide oxygen to cells of body to function	9	5	0
Structure	no lungs	3	9	10
	no 'windpipe'	23	18	27
	no diaphragm	86	92	98
	no heart	41	56	55
	no connection between pulmonary and circulatory systems	66	61	87
Mechanism	no answer (associated with breathing to live)	13	32	47
	air moves in and out of lungs only	38	40	14
	air moves into lungs then to heart and back	38	37	20
	oxygen moves into lungs, to blood, to body	13	11	3

Figure 4: Naive conceptions of human respiration by FSM

However, some students appeared to have naive conceptions which may provide a bridge upon which future learning could be built. J.R. presents one such conception in his discussion of air movement into the lungs (Figure 5). His model suggests a beginning understanding of the pressure difference created by movement of the diaphragm, while not directly including the diaphragm either in his drawing or in the interview. J.R. states that air is pushed into the lungs and then let out into the blood. This pushing in of air may indicate a notion of the change in pressure within the chest as compared with the air pressure outside the chest. Since air is 'pushed' into the lungs by higher atmospheric pressure when the diaphragm moves downward, this may be a naive conception which can be built upon. However, without further investigation, it is difficult to rule out an underlying alternative conception.

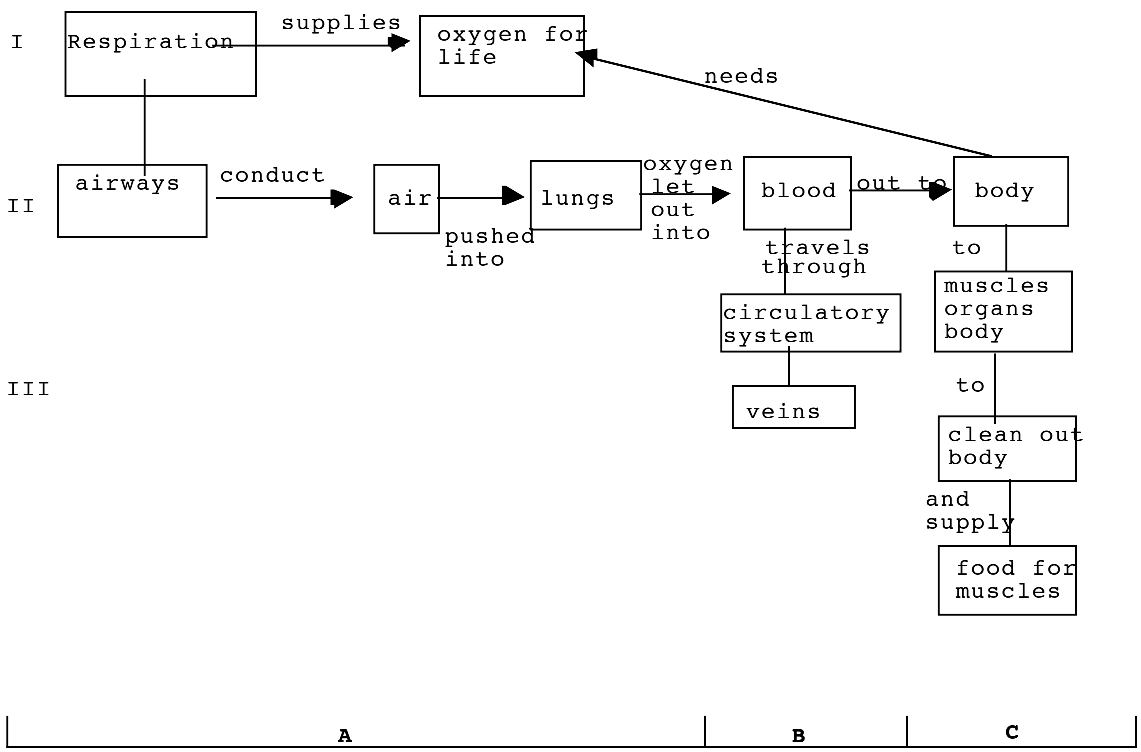

Figure 5: J.R’s model of respiration

Alternative conceptions were often noted in students' descriptions and drawings of structures (Figure 6). These involve small, hollow, balloon shaped lungs, non-connecting windpipes, and tubes carrying air directly to the heart. Omission of organs such as the heart and diaphragm, as well as pulmonary and systemic vessels is also apparent. A few students were able to develop a deeper conceptual understanding of respiration at a cellular level while still holding naive conceptions or alternative conceptions about the lungs. However, such depth of understanding did not appear to exist for many students. If many alternative conceptions do not greatly interfere with learning of higher level conceptions, then, are there some that could provide major hurdles for further understanding?

ALTERNATIVE CONCEPTIONS ABOUT RESPIRATION				
		Percent Responding		
	Conceptions : **Grade =**	**10-11**	**7-8**	**4-6**
	N =	**88**	**142**	**128**
Function	to pump heart and/or circulate blood	24%	14%	9%
	to provide oxygen to the brain only	9%	5%	0%
	to provide oxygen as food or fuel	6%	4%	>1%
	other (clean blood, feed blood cells, warm body)	1%	7%	10%
Structure	small lungs	90%	93%	68%
	shape: tubes	4%	2%	9%
	balloon	60%	63%	42%
	other	36%	22%	40%
	hollow	70%	53%	60%
	one lung only	16%	13%	23%
	'windpipe' with no connection	20%	14%	38%
	'windpipe' labeled esophagus	20%	23%	>1%
	'windpipe' connected to other organs	14%	14%	2%
	diaphragm incorrect size, shape, location	12%	7%	0%
	tube from heart to lungs	5%	9%	9%
	tube directly from nose/mouth to heart	9%	8%	4%
	heart imbedded in lung	26%	15%	16%
	organs directly connected to lung	14%	5%	3%

Mechanism	air moves into empty cavity or directly into body	0%	3%	4%
	air goes directly to heart and no further	1%	3%	2%
	air goes directly to heart then to body	2%	2%	0%
	air goes to lungs and directly to body	3%	3%	>1%
	air goes to lungs and directly to other connecting organ	0%	1%	0%
	cellular respiration and/or production of energy occurs in lungs only and sends energy to body	3%	2%	>1%

Figure 6: Misconceptions about human respiration by FSM

Impeding Alternative Conceptions

It appears that within alternative conceptions there exists a subgroup of conceptions which act as major stumbling blocks for conceptual understanding in many students. In this study impeding alternative conceptions about function and mechanism in human respiration seemed to be related. When students believed that the function of respiration was to pump the heart and/or cause the blood to circulate, they usually described the mechanism of respiration as air flowing from the mouth/nose directly to the heart or just moving between the lungs and heart. This idea may be related to Schilder and Wechsler's (1935) finding that children relied on external sensations to describe unseen processes. Breathing in and out is a rhythmic sensation which may be connected to the rhythmic beating of the heart and pulsating of the blood through vessels and experienced as a sensation unrelated to it's true function. M.C. did describe oxygen moving into the lungs. This may be related to his experienced sensation of breathing. He also had the sensation of his heart beating. However, it was the interpretation of these sensations and his attempt to rely on other existing schemata to explain the sensations that led to his model of the lungs as a piston, moving in and out (Figure 7).

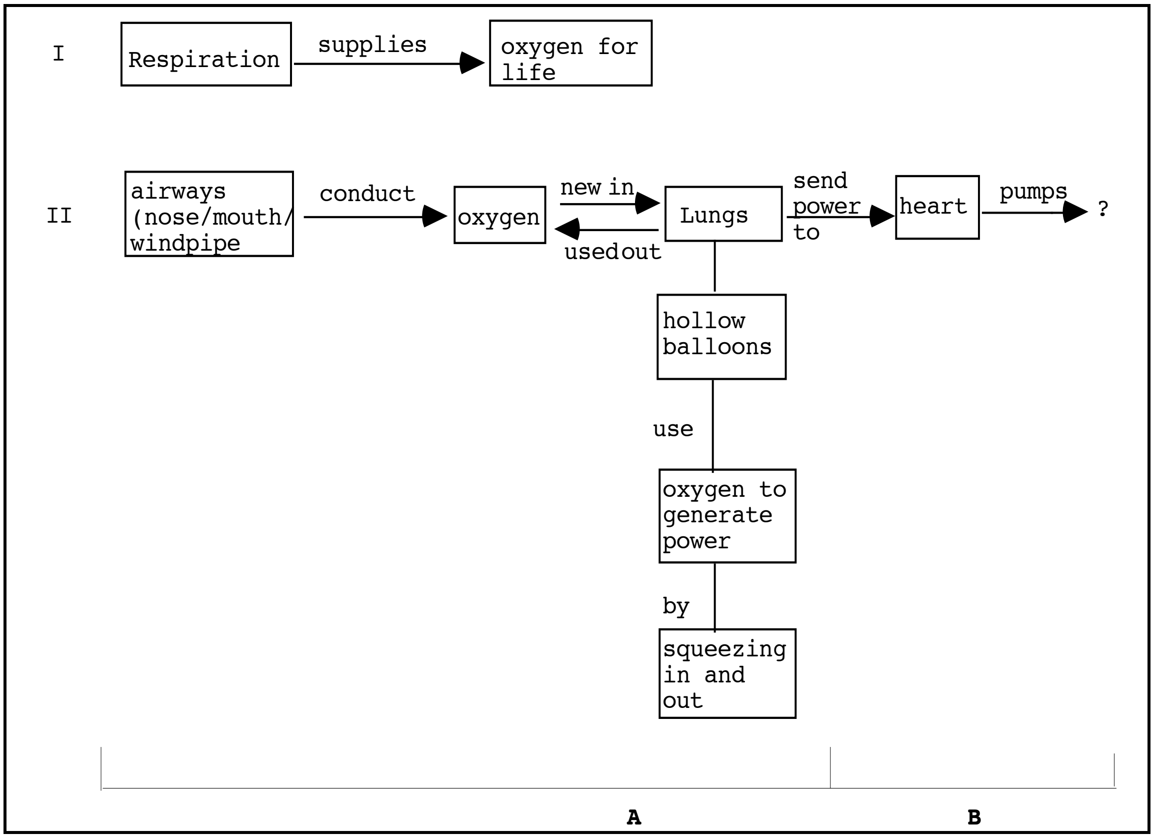

Figure 7: Interpretation of M.C.'s model of respiration

Figure 7: M.C.'s model of respiratio

A related impeding alternative conception is the idea that energy is generated in some manner in the lungs and then sent out either to the heart causing it to pump and blood to circulate, or directly out to the whole body to give it energy. Often combined with the hollow, balloon shaped lung alternative conception, oxygen was seen as a kind of fuel which was burned in a combustion-like event. These students appeared to have some beginning understanding that there was a connection between respiration, oxygen, and energy production. Because they saw this occurring only in hollow lungs, however, there may be no reason to speculate on cellular respiration occurring in all cells of the body.

A rich example of this impeding alternative conception was given in the interview with M.C. He described the lungs as "just like a balloon with air in it." This balloon analogy was further confirmed by M.C.'s explanation of the affect of smoking on the lungs. M.C. describes the smoke going into the lungs and moving to the "outside and sticks to you lungs. It like stays in the middle, and then after a while will settle, and fall down to the bottom and it will just like, go around your lungs." He goes on to say that the space will eventually fill up with the smoke and shut off the lungs. This was accompanied by a sketch showing the smoke sticking to the inside of a balloon shaped lung and then gradually filling up all the inner space.

M.C. has also developed an elaborate analogy of a car engine to explain respiration which further builds on the combustion of oxygen idea. He says,

> its like a generator. Fuel goes in to the piston, and it moves up and down, and the spark plug gives a shock to like spark up, and then it, all the energy goes into wherever you need it to... if you don't let the person have any air it doesn't go into the lungs. Well, if there's no gas going into a motor, it doesn't run. It's sort of like with the human body, if no air goes to the lungs, you aren't running.

He likens the oxygen to the fuel, the lungs to a cylinder, and the motion of "squeezing in and out, just like a piston." When questioned further on the idea of a spark initiating this combustion inside the lungs, M.C. stated that the spark initially came from the heart and also stated that the heart was the spark plug. However, there appears to be some kind of feedback mechanism between the lungs and heart in which M.C. stated, "lungs, they, when the oxygen goes in, I guess, the lungs will get the power to send energy to the heart to start pumping" but at the same time he said that the lungs must be sparked by the "spark plug heart" to begin the process of energy production.

The impeding factor in this alternative conception appears to be the centering of energy production within these hollow, balloon like lungs. All energy production is seen as occurring here and then being sent out to the heart and in some instances to the whole body. When further questioned about oxygen in the blood, M.C. believed there might be a little but saw no function for it. For this student all energy production relied solely on oxygen as a kind of fuel burned in the lungs.

When M.C.'s conceptual model (Figure 7) is compared to the framework depicted in Figure 1, it suggests that M.C.'s understanding of what occurs within the lungs will be a significant barrier to further development of accepted models. M.C. has no oxygen flow beyond the lungs but only energy being sent out to the heart to cause it to pump. Therefore, a true circulatory connection is lacking as is oxygen transport to the rest of the body. It suggests that while this notion of energy production within the lungs persists, conceptual change about cellular respiration would be difficult.

By comparison, in J.R.'s graphic representation (Figure 5), we see that, while he retained a naive conception of the lungs and blood (Level II), he was able to reach a higher level of understanding within the body (Level IV C) because there appears to be no Impeding Alternative Conceptions blocking his way. J.R. did not hold beliefs about energy production in the lungs and while not sure about how and where this might occur, had some notion that it was associated with oxygen transport from the lungs through the blood to the organs and tissue of the body.

In summary, Possibly Impeding Alternative Conceptions occurred across grade levels and may provide major barriers to subsequent learning. The primary impeding alternative conceptions identified in this study include: 1) stating the function of respiration as simply breathing, 2) believing that the lungs act as a combustion chamber for energy production which uses oxygen as the fuel, and 3) viewing the lungs as hollow, balloon shaped structures. In addition, the alternative conception that 4) the heart is powered either by oxygen channeled directly to it from the outside or from the lungs, similar to an engine being powered by fuel, appears to preclude a need for cellular respiration and thus present an impeding alternative conception. While alternative conceptions were noted in the interview with J.R., they did not appear to be impeding as in M.C. and as such would probably not be major blocks to further understanding.

Conceptions of the Effects of Smoking

Results of the effect of smoking suggest that the students' beliefs about smoking may also fall into the category of Impeding Alternative Conceptions. The majority of students at all grade levels stated that smoking "makes the lungs black" or "makes it hard to breath and clogs the lungs" (Figure 8). This view is not totally unscientific and may be built on naive conceptions or alternative conceptions about the structure and function of the lungs. Another explanation may be mass media and educational attempts to inform students about smoking that use graphic depiction of black lungs, coughing, and difficulty breathing. However, while students may have repeated the words, they showed little understanding of how lungs became black or what effects this had on the rest of the body. Interestingly, the idea that smoking could lead to death was only mentioned by 7% of 4-6 and 7-8 graders, and 0% of 10 graders. This difference may suggest that there is growing skepticism about the effects of smoking as students get older. Therefore, the alternative conception could lead to indifference toward the effects of smoking and therefore a critical block to both learning and selection of healthy habits.

Alternative conceptions about smoking included making the lungs black, making it difficult to breathe, and making the inhaled oxygen dirty.

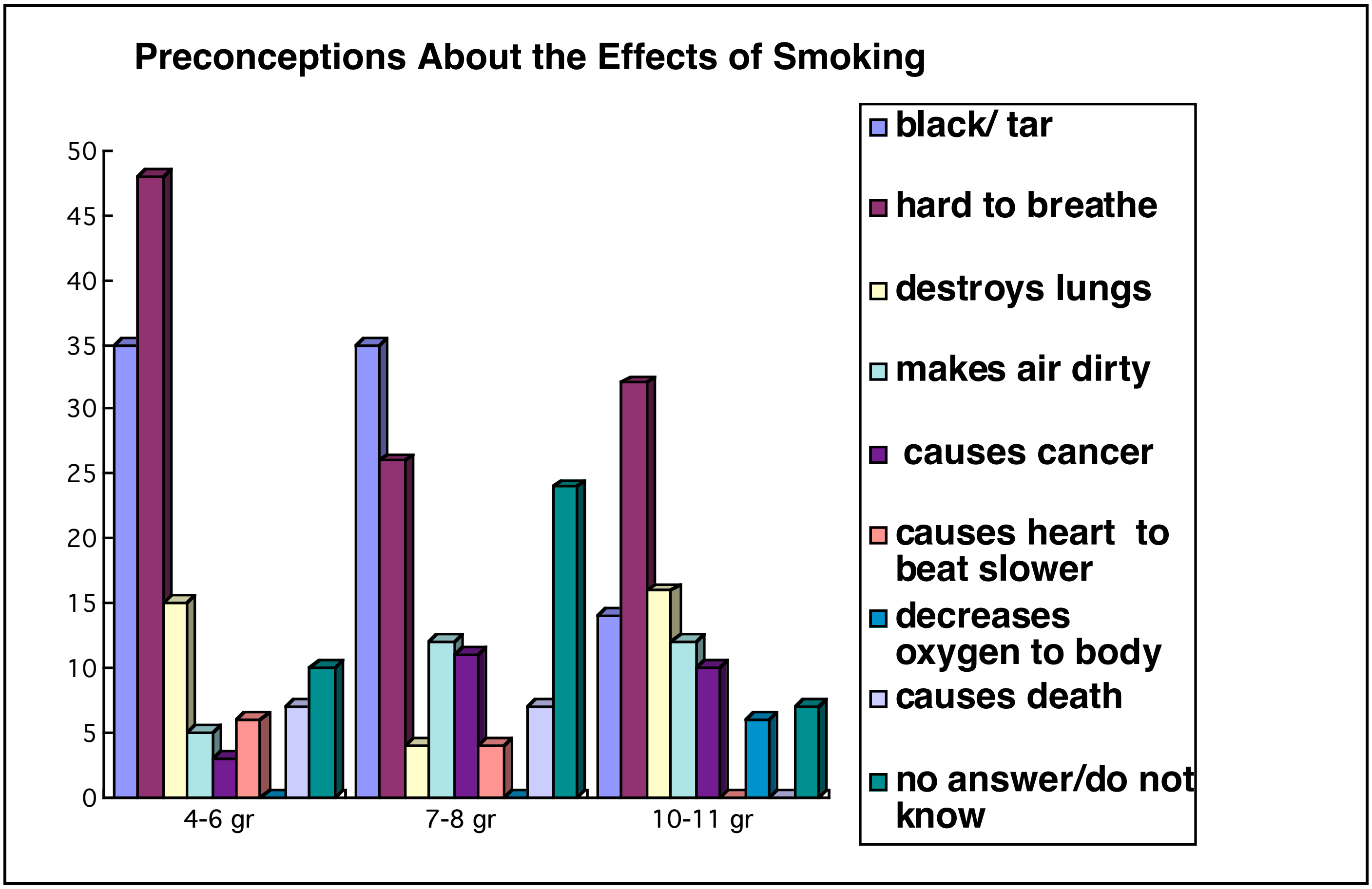

Figure 8: Students' conceptions of the effects of smoking (See end for black and white version of this figure)

In summary, alternative conceptions about smoking included making the lungs black, making it difficult to breathe, and making the inhaled oxygen dirty. Students in the younger grades expressed a concern that permanent damage and even death may be the result of smoking. However, older students expressed fewer beliefs that smoking was the cause of death. The possibility that this could interfere with students' selection of healthy habits may be cause for concern. This also raises the question of whether there is a connection between the alternative conceptions and naive conceptions about human respiration and alternative conception and skepticism about smoking. Further research in this area could provide some clues.

CONCLUSION

Students in this study presented a variety of conceptions about human respiration. These ranged from naive conceptions, possibly due to lack of exposure to information, to more complex alternative conceptions. Many of these alternative conceptions involved ideas about the structure of organs and tissue involved in respiration both at the organismic and cellular level. Alternative conceptions included 1) hollow, balloon shaped lungs, 2) energy production within the lungs through the combustion of oxygen, 3) power generated in the lungs which is sent to the heart to make it pump, 4) lack of pulmonary circulation, and 5) superficial effects of smoking. These particular alternative conceptions, in addition, appear to impede the student's learning along the shaded path to cellular respiration as indicated in Figure 1.

The current research builds on previous understanding about alternative conceptions and naive conceptions about human respiration. We have listed both naive conceptions and alternative conceptions according to their frequency in the study population. However, while lists of alternative conceptions are useful, we believe that it is our construction of the relationships between these naive conceptions and target conceptions that provides a map of important new information. This map, in turn, provides a framework within which to both place and analyze students' conceptions. It has also suggested a possible learning pathway that may help in developing teaching strategies.

Findings suggest that some alternative conceptions may not affect further conceptual understanding at a higher level. Students may be able to hold very naive conceptions or alternative conceptions about structure and mechanism of respiration without interfering with development of understanding about cellular respiration. On the other hand, some alternative conceptions may impede this understanding. When further cognitive development is impeded, alternative conceptions are of a more critical nature. This suggests that ascertaining students' preconceptions prior to teaching is imperative. Further organization of students' conceptual models relative to target conceptions will then help in the design of instruction.

IMPLICATIONS AND LIMITATIONS

Understanding the naive conceptions and alternative conceptions students hold and which of the alternative conceptions may impede further conceptual understanding is essential in developing effective teaching situations. While research provides examples of common alternative conceptions, it has not attempted to distinguish Impeding Alternative conceptions or to provide a map of conceptual understanding in respiration. Since conceptual change is difficult at best, this study suggests that an understanding of alternative conceptions that impede students' progress be addressed. It is hoped that information gained from this study will be useful in developing teaching strategies for this purpose. Future research should investigate methods of conceptual change teaching using analogies, discrepant events, student experimentation, observation, and technology, as well as Socratic interaction.

Since this study involved students with limited ethnic diversity from a rural setting only, it is suggested that more extensive surveying be conducted in urban schools and with a diverse population. Further follow-up on the interviewed students could also provide more depth of understanding about what factors affected the development of certain models and use of analogies. This may provide more insight into methods for using analogies in helping students construct new knowledge.

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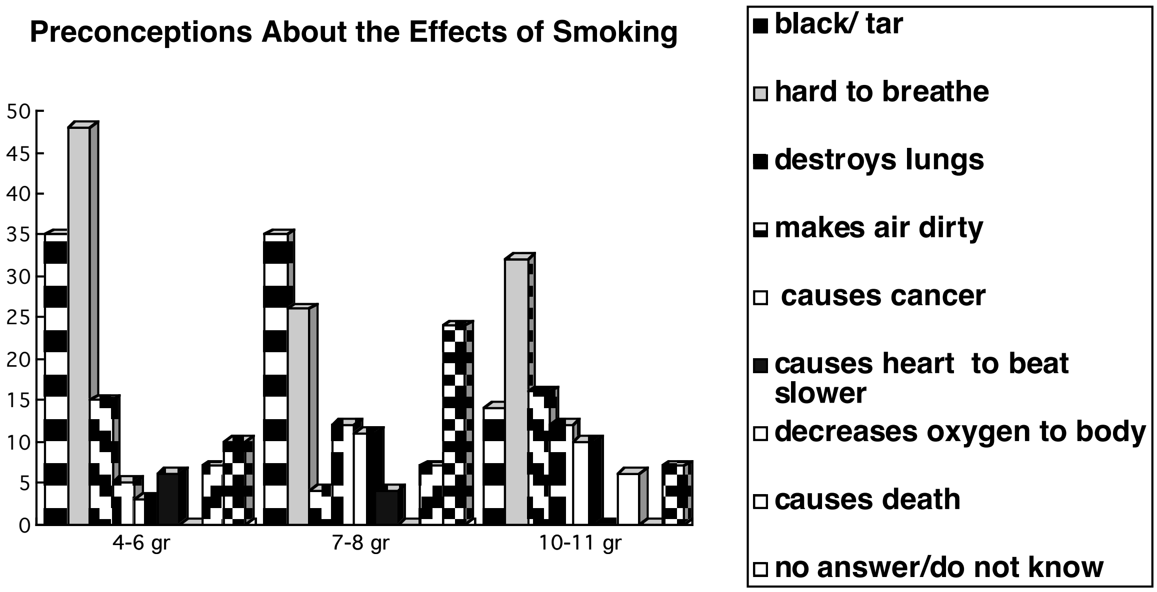


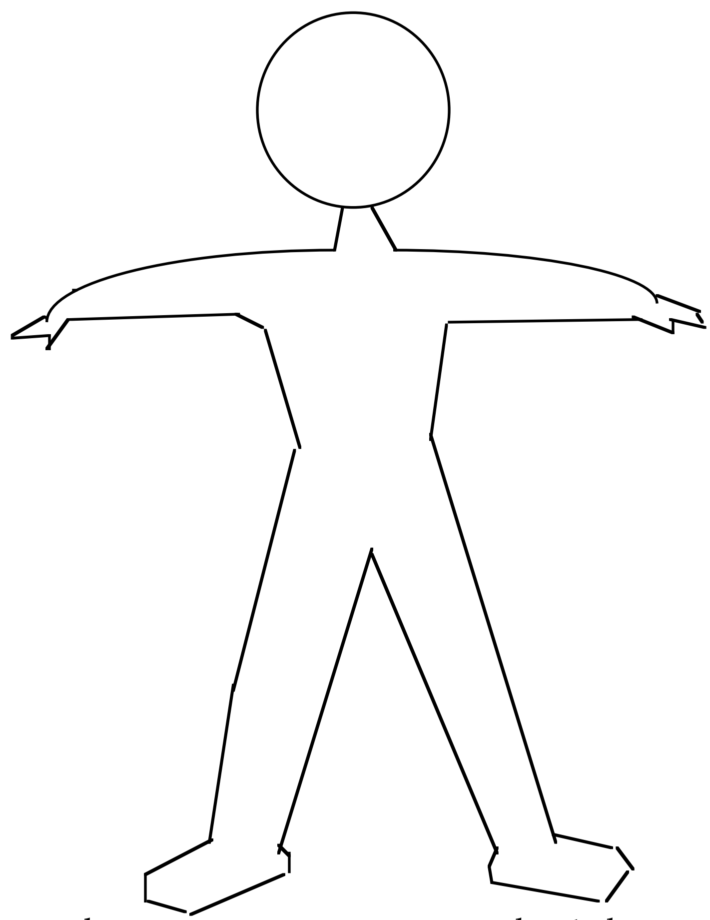
Figure 8: Students' conceptions of the effects of smoking (B&W version)

APPENDIX A

RESPIRATION SURVEY

Directions: This survey contains open-ended questions. Please answer each question with either a drawing or a few sentences. In referring to the respiratory system we are including both the structures involved in breathing and in cellular respiration.

1. In the outline below, <u>draw</u> and <u>label</u> the organs of the respiratory system as you would find them in the human body.



2. Why do humans have a respiratory system? Why do humans need to breathe?

3. <u>Describe</u> the path air take after it enters the body through the mouth and nose, is utilized by the body,

and then exhaled. Identify the contents of this air as it moves through the body.

4. What would happen to a human if he/she were deprived of all oxygen? Explain why this would happen.

5. Select two of the animals below and describe how the respiratory systems are alike and different from that of humans:

   earthworm fish grasshopper

6. How does smoking and air pollution affect the respiratory system? Other systems in the body?

APPENDIX B

ORGANISMIC LEVEL RESPIRATION:

Level I

F = to provide oxygen for life
S = nose, mouth, windpipe
M = air enters nose/mouth and travels into body

Level II

Diaphragm:
F = ventilation of lungs
S = smooth muscle fibers
M = movement down increases thoracic cavity to allow decrease in pressure in the lungs compared to atmospheric pressure causing air to rush into lungs

Airways: (conductive zone)
F = air conduction
S = nose, mouth, 'windpipe',
M = air move into and out of lungs by way of airways

Lungs: (respiratory zone)
F = provide surface for air to move into blood
S = solid, spongy structure that fills chest cavity
M = conducts air

Level III

muscle fibers:
F = contraction and relaxation of diaphragm
S = elongated muscle cells
M = contraction and relaxation of cells working together cause whole diaphragm to move

trachea, bronchi, bronchioles:
F = air conduction
S = trachea, bronchi, bronchioles
patency maintained by cartilage rings in trachea and bronchi;
bronchioles depend on lung structure for patency
M = movement of air into and out of lungs

Alveoli:
F = diffusion of gas into blood
S = cells formed into a sac with thin walls made of squamous cells (type I) and surfactant secreting rounded cells (type II)

M = diffusion of oxygen through respiratory epithelium in alveoli, into interstitial space; surfactant secreted by type II cells prevent cohesive collapse lungs

Pulmonary Vessels:

F = transport oxygen in blood
S = capillaries that form network around alveoli
M = diffusion of oxygen through capillary endothelium, into plasma, into erythrocytes where attaches to hemoglobin

CELLULAR LEVEL RESPIRATION

Level IV

Capillaries

F = transport of oxygen to cells
S = smallest of blood vessels, thin walls, closed system
M = diffusion of oxygen through capillary wall into cell

Cells:

F = provide environment where metabolism can occur
S = individual cells which may differ in size and shape according to type
M = oxygen diffusion across cell membrane and transport to mitochondria

Mitochondria

F = carry out metabolism for energy
S = inner and outer membrane; intermembrane sacs; 1000-1200 mitochondria per cell
M = ATP produced from 2 carbon sugars in the presence of oxygen. Oxygen is necessary to dispose of the steady stream of spent hydrogens, combining to make water. The oxygen utilized by this process is supplied by the lungs through pulmonary respiration.