



# Relations of Cognitive and Motivational Variables with Students' Human Circulatory System Achievement in Traditional and Learning Cycle Classrooms\*

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## Abstract

This study is aimed at investigating the relationships among students' relevant prior knowledge, meaningful learning orientation, reasoning ability, self-efficacy, locus of control, attitudes toward biology and achievement with the human circulatory system (HCS) using the learning cycle (LC) and the traditional classroom setting. The study was conducted with two teachers and four classes for a total of 60 11th grade students from high school. One class for each teacher was assigned as an experimental group and treated with 5E LC instruction and the other class was assigned as a control group and treated with traditional instruction (TI). The Human Circulatory System Achievement Test (HCSACT) was administered twice as a pre-test and after the treatment period, as a post-test to both the experimental and control groups. The Learning Approach Questionnaire, Test of Logical Thinking, Self-Efficacy Scale, Locus of Control Scale and Attitude toward Biology Scale were also administered to all students. The results indicated that the LC improved students' achievement in the HCSACT compared to TI. Stepwise multiple regression analysis revealed that in the learning cycle classrooms, the main predictors of achievement on the HCSACT were students' reasoning ability (45.8%) and their prior knowledge (15.9%). In traditional classrooms, students' meaningful learning orientation (40%) and locus of control (9.8%) were the main predictors of achievement.

## Keywords

Cognitive Variables, Human Circulatory System, Motivation, Learning Cycle.

Research offers alternative strategies to improve meaningful learning in science. To promote meaningful learning, students can be encouraged to transfer theoretical knowledge into practical applications and to make connections between their pre-knowledge and new knowledge (Ausubel, 1963; Novak, 2002). The inquiry-based learning model has had a great influence on students'

meaningful learning, and the model is one of the active learning models which includes not only asking question but also investigating, analyzing, and discussing subjects.

The inquiry process encourages students to be active learners. Otherwise, rote learning occurs and several units and concepts can become unfamiliar and difficult to remember for students. Researchers

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state that rote learning leads to less understanding of scientific concepts and also generates misconceptions concerning those concepts (Williams & Cavallo, 1995). Especially in biology, the topics or concepts in each unit are closely related with each other, the human circulatory system being among such topics. According to the research, major concepts of the circulatory system which students do not fully understand are the structure and function of the human cardiovascular system, pumping mechanism of the heart, circulatory/respiratory relationships, systemic/pulmonary circulation, closed circulation, type of blood vessels, homeostasis, and the blood flow rate (Alkhalwaldeh, 2007; Arnaudin & Mintzes, 1985; Kwen, 2005; Sungur, Tekkaya & Geban, 2001; Windschitl, 2001; Yip, 1998). Students should connect each circulatory system concept with each other in a meaningful way in order to recognize better other biological concepts such as the digestive system, immune system and respiratory system (Alkhalwaldeh, 2007).

### Research on the Learning Cycle

Over the years, most of the educational research studies have presented different learning approaches to support meaningful learning in science. One of them is the learning cycle, an inquiry-based teaching strategy derived from Piaget's model of mental functioning. The learning cycle can be defined as an instructional model based on constructivist epistemology that promotes conceptual change.

There have been many studies carried out to assess the effectiveness of the learning cycle (Atay & Tekkaya, 2008; Balci, Cakiroglu & Tekkaya, 2006; Lee, 2003; Ates, 2005; Temel, Yilmaz, & Özgür, 2013; Yadav & Mishra, 2013). The results of these studies revealed that the learning cycle addresses students' developmental progress by using suitable investigations that students have employed in the science learning process. For example, Marek, Cowan, and Cavallo (1994) reported that the learning cycle instruction was more effective than expository instruction in promoting high school students' understanding of diffusion. Likewise, Balci et al. (2006) investigated the effects of the 5E learning cycle, conceptual change text, and traditional instructions on 8<sup>th</sup> grade students' understanding of photosynthesis and respiration. They reported that students who were instructed with the 5E learning cycle and conceptual change text instruction had better scores on the post-test than the students who

were instructed using traditional instruction. In addition to the research studies which are related to the effectiveness of the learning cycle in students' understanding of scientific concepts, science education researchers have attempted to investigate certain variables which may contribute to students' science achievement. Cognitive and motivational variables have been found to be related to students' understanding of scientific concepts, and it is shown that those factors have an effect on students' scientific achievement (Araz & Sungur, 2007). Therefore, cognitive and motivational variables should be taken into consideration while planning, developing and applying instructional strategies.

### Research on Cognitive Variables

Science education researchers stress the importance of cognitive variables influencing student achievement in science. Looking at the research evidence cited in the literature, it is understood that reasoning ability and learning approach are two important cognitive variables (BouJaoude, 1992; Cavallo, 1996). Reasoning is a process in which a conclusion is reached by taking all related factors into account. Individuals with the ability to use reason on a subject are well-informed about the related discipline, and when faced with a new situation they can analyze it in all aspects, explore it, make logical assumptions, explain their thoughts, reach conclusions and defend their conclusions (Umay, 2003). For this reason, students' reasoning abilities have been established as an important factor in science and achievement (Cavallo 1996; Enveart, Baker, & Vanharlingen, 1980; Lawson, Banks, & Logvin, 2007). In the literature, there are many studies related with students' reasoning ability and its relationship with students' understanding (Johnson & Lawson, 1998; Oliva, 2003; Sungur & Tekkaya, 2003; Yenilmez, Sungur, & Tekkaya, 2005). For example, Sungur and Tekkaya (2003) conducted a study to investigate the effect of reasoning on students' achievement in regard to the concepts of the human circulatory system as well as their attitude towards biology. They reported that there was a statistically significant mean difference between students at concrete and forma levels with respect to their achievement and attitude toward biology. Similarly, Johnson and Lawson (1998) investigated the effects of reasoning ability and prior knowledge on biology achievement in two different teaching classes as expository and inquiry. They indicated that reasoning ability determined achievement more than prior knowledge among

biology students, whether they enrolled in inquiry or expository classes. In inquiry classes, significant improvements in reasoning abilities of students were also detected.

In addition, the learning approach which measures students' learning orientation is another cognitive variable that affects students' understanding. Williams and Cavallo (1995) described the learning orientation as "the formation of viable relationships among ideas, concepts and information" (p. 313). Moreover, learning orientation can be defined as a student's approach to learning being consistent with their understanding (Akyürek & Afacan, 2013; Cavallo, 1996; Hasnor, Ahmad, & Nordin, 2103; Safdar, 2013). Unlike meaningful learning, rote learning can be explained as a way that new knowledge may be attained by verbatim memorization and incorporation into a person's knowledge without connecting it to previously acquired information or frameworks (Ausubel, 1963; Baird, 1986). In the literature, there have been many studies about the relationships between learning orientation, reasoning ability and students' meaningful understanding. For example, Cavallo and Schafer (1994) focused on the relationship between students' meaningful learning orientation, relevant prior knowledge, instructional treatment and the effects of the interactions of all these variables on students' meaningful understanding of meiosis and genetics, and the relationship between these topics. They found that meaningful learning orientation and prior knowledge of meiosis were significant predictors of students' meaningful understanding of meiosis.

### Research on Motivational Variables

Motivational variables are viewed as a significant predictor of students' classroom learning and scientific achievement since students who are more highly motivated are likely to give greater effort and persist longer at academic tasks than students who are less motivated (Pintrich & de Groot, 1990). Motivational variables are potential mediators of students' science achievement (Pintrich & Schunk, 1996). The concept of self-efficacy, which is mostly related with the motivational variable, lies in the center of Albert Bandura's social cognitive theory, which emphasizes the role of observational learning and social experience in the development of personality. According to Bandura (1995) self-efficacy is "the belief in one's capabilities to organize and execute the courses of action required managing prospective situations" (p. 2). Bandura's

theory explains that people with high self-efficacy believe that they can perform well and they are more likely to view difficult tasks as something to be mastered rather than something to be avoided. Most researchers found that an individual's self-efficacy plays a major role in how goals, tasks, and challenges are approached (Bandura, 1997; Schunk, 1995). Schunk (1991, 2003) stresses that when students work on tasks and become more skillful, they develop a sense of self-efficacy for performing well. Also, if students are aware of their objectives with the study of a subject, they think that they can improve their self-efficacy for learning. Linnenbrink and Pintrich (2003) stated "...besides the quantity of effort, the quality of effort in terms of deeper processing strategies and a general cognitive engagement of learning has been strongly linked to self-efficacy perceptions." (p. 129). Students who have a high self-efficacy are more likely to carry on a subject and to use more complicated learning processes and strategies when compared to students with lower self-efficacy (Linnenbrink & Pintrich, 2003).

Another motivational variable is locus of control, a term in psychology which refers to a person's beliefs about their failure and success in their life, either in general or in a specific area. Locus of control tries to link the gap between operant and cognitive psychology. It is generally stated that an individual's perceived control of the environment is measured by psychologists through personality traits and this was named as the locus of control (Martinez, 2003; Praag, Sluis, & Witteloostuijn, 2004). Locus of control can be considered as both internal and external. Firstly, Rotter (1975) defined internal locus of control as the belief that events or outcomes are dependent upon one's own behavior or on relatively permanent personal characteristics, such as ability. Students who take an internal responsibility for their academic performance have higher levels of overall achievement. However, external locus of control was defined as the idea that students do not have any control of what happens to them. That means students take an external responsibility for their academic performance. Previous studies consistently indicated that locus of control is the predictor of academic achievement and related behaviors (Kalechstein & Nowicki, 1997). The studies of Duke and Nowicki (1974) and Finn and Rock (1997) state that there is a relationship between an internal locus of control and academic success and an external locus of control and academic failure.

Finally, another important variable effecting students' achievement is the attitude toward biology. Relationships among students' attitudes toward science and achievement have been extensively examined in various studies (Dhindsa & Chung, 2003; Osborne, Simon, & Collins, 2003), and the main purpose of most of these studies was to explore the effect of attitudes on scientific achievement in general (Dawson, 2000). Also, researchers examined the effect of activity-based science programs on students' attitudes toward science (Balci et al., 2006; Freedman, 1997; Shymansky, Hedges, & Woodworth, 1990). For example, Freedman (1997) reported that laboratory instruction positively influenced students' attitude toward science, and influenced their achievement in scientific knowledge. Similarly, Shymansky et al. (1990) carried out a meta-analysis of earlier studies and found that children in hands-on programs demonstrated higher achievement, improved skills and developed a more positive attitude towards science. It is also known that there are some relationships between attitudes and a variety of variables such as grade levels, socioeconomic status, and gender (Freedman, 1997; Germann, 1988; Koballa, 1988; Parker, 2000; Shemesh, 1990; Talton & Simpson, 1986)

Our review of the related literature proposed that cognitive and motivational constructs of students and methods of instruction have important impacts on student achievement. However, there were limited studies about the relationships between motivational and cognitive variables and high school students' biology achievement through different instructional methods. For the present study, we chose the human circulatory system because it is one of the most important and difficult topics of the biology curriculum. Student understanding of the concepts of the human circulatory system are related to their understanding of the main concepts of homeostasis, as blood circulation is fundamental for the maintenance of a stable internal environment in the body. Thus, students can understand the relation of body systems with each other when they understand how the blood circulation mechanism works in human body and realize the central role of the circulatory system in homeostasis (Alkhalwaldeh, 2007). Students who understand the mechanism of the circulatory system from a scientific viewpoint can also understand the main role of it and how the system is related with other important bodily systems. Students can have some misconceptions about biological concepts because of personal experience, a lack of understanding

during instruction, or because of teachers who are less competent in subject-matter knowledge (Sungur et al., 2001; Yip, 1998).

In light of the findings in literature, this study aimed to discover answers to the following questions:

- a) What is the relationship among 11<sup>th</sup> grade students' prior knowledge, meaningful learning approach, reasoning ability, self-efficacy, locus of control, attitudes toward biology and achievement in the human circulatory system in learning cycle and expository classrooms?
- b) What are the contributions of 11<sup>th</sup> grade students' relevant prior knowledge, learning approach, reasoning ability, self-efficacy, locus of control and attitudes toward biology on their achievement in the human circulatory system in learning cycle and expository classrooms?
- c) Which variable best predicts student achievement in expository and learning cycle classrooms?
- d) What is the effect of learning cycle instruction on 11<sup>th</sup> grade student achievement in the human circulatory system?

## Method

### Participants

The target population of this study consisted of all the 11th grade high schools students in Yenimahalle, Ankara. Frequently it was extremely difficult to select a random sample. Therefore, convenience sampling was used to choose a study sample from the target population. After selecting from one of the high schools in the Yenimahalle area, four classes were enrolled in the study. Therefore, 60 11th grade students from four classes of two teachers were involved in this experimental study. Experimental and control groups were assigned randomly. Each teacher had one experimental and one control group. 31 students were instructed using the 5E learning cycle instruction in the experimental group and 29 students were instructed using expository instruction in the control group. Students in both groups had similar characteristics with respect to socio-economic status as obtained by school documents regarding gender and the educational levels of their mother and father.

### Instruments

The seven measuring tools used for this study were the Human Circulatory System Achievement

test, Learning Approach Questionnaire, Test of Logical Thinking, Locus of Control Scale, Self-Efficacy Scale, Attitude towards Biology Scale and observation checklist.

**Human Circulatory System Achievement Test (HCSACT):** The Human Circulatory System Achievement test (HCSACT) was used in this study in order to examine the students' understanding about the human circulatory system. It was developed by the researchers based on the related literature and some biology textbooks. The HCSACT covers the biological content presented in the 11<sup>th</sup> grade national biology curriculum in Turkey. It consists of 25 multiple choice questions related to all concepts of the human circulatory system such as blood, blood vessels, pumping mechanisms and structure of the heart, systemic circulation and pulmonary circulation, identification of sinoatrial node and atrioventricular node, identifications of blood pressure, hypotension and hypertension. Two science educators and one biology teacher examined the content validity, format, and clarity of each item on the test. The reliability coefficient computed by Cronbach alpha estimates of internal consistency of this scale was found to be .68. According to George and Mallery (2003), the internal consistency coefficient gives the lowest value that reliability is allowed to have, and in social sciences a general reliability value over .60 is considered to be acceptable makes the test points reliable. The HCSACT was administered as a pre-test and post-test to both control and experimental groups to assess student achievement in biology on the human circulatory system.

**Learning Approach Questionnaire (LAQ):** The Learning Approach Questionnaire is a 22 item, four-point Likert-type instrument which is scaled by absolutely disagree, disagree, agree, and absolutely agree. It is used to measure a student's approach to learning, ranging from meaningful to rote (Cavallo, 1996). Students responded to each statement by indicating their agreement, ranging from "Absolutely agree" (4 point) to "Absolutely disagree" (1 point) to overcome the inclination of respondents to choose the neutral option. The scores obtained, therefore, range from 88 to 22. Rote scores from the LAQ were reverse scored so that a high score would show a more meaningful learning orientation and low scores would show a more rote learning orientation. Yenilmez (2006) translated and adapted this questionnaire into Turkish. The Cronbach alpha coefficient for the whole scale was found to be .60.

**Test of Logical Thinking (TOLT):** The Test of Logical Thinking (TOLT) developed by Tobin and Capie (1981) is used to measure five modes of formal reasoning: proportional variables, controlled reasoning, probabilistic reasoning, co-relational reasoning, and the combinational reasoning of the students. The test is composed of 10 items: items 1 and 2 measure proportional variables, items 3 and 4 measure controlled, items 5 and 6 measure probabilistic, items 7 and 8 measure co-relational, and items 9 and 10 measure combinational reasoning. Students respond to each item by selecting a response from five possibilities, and then are asked to choose from one of five provided justifications. The correct answer is calculated by adding the correct choice to the correct justification. The TOLT scores range from 0 to 10. Test scores from 0-3, 4-7, and 8-10 are used as a basis for categorization of the subjects as low level, medium level and high level of formal thought (Oliva, 2003). Geban, Askar, and Ozkan (1992) translated and adapted the TOLT into Turkish. The Cronbach alpha coefficient for the whole scale was found to be .65.

**The Self-Efficacy Scale (SES):** The Self-Efficacy Scale is a self-report questionnaire, which was taken from the Motivational Strategies for Learning Questionnaire (MSLQ). Only items belonging to self-efficacy were used to measure students' self-efficacy. Nine items regarding perceived competence and confidence in performance of class work are the sub-scale of self-efficacy. The responses were scored on a 5-point Likert scale, where 1 point was given to "Strongly Disagree" and 5 points were given to "Strongly Agree". The SES scores range from 9 to 45. Students scoring high on this sub-scale were sure that they could learn and understand the material being taught in the class and they could carry it out well in the class. Ozkan (2003) translated and adapted these items into Turkish. The Cronbach alpha coefficient for the whole scale was found to be .84.

**The Locus of Control Scale (LOC):** This instrument, developed by Rotter (1966), aspires to offer an idea about the students' level of internal control. There are 9 pairs of statements in the LOC scale in the study. Student selected one statement from each pair which best reflected their belief. The LOC scores range from 0 to 1. Kagitcibasi (1972) adapted and translated this instrument into Turkish. The Cronbach alpha coefficient for the whole scale was found to be .83.

**The Attitude towards Biology Scale (ATB):**

The instrument ATB scale, developed by Geban, Ertepinar, Yilmaz, Altin, and Sahbaz (1994) is used in this study. This scale consists of 15 items and it is designed to be rated on a 5-point Likert type response format (strongly disagree, disagree, neutral, agree, and strongly agree). The ATB was administered as a pre-test to both control and experimental groups to assess students' attitudes towards biology. Possible ATB scores range from 15 to 75, with higher scores demonstrating positive attitudes towards biology and lower scores demonstrating negative attitudes towards biology. The Cronbach alpha coefficient for the whole scale was found to be .82.

**Observation Checklist:** In the study, the researchers prepared a handout explaining learning cycle applications and a guide to proceed in the instruction to increase treatment fidelity. During the treatment, both the control and the experimental groups were observed to identify whether the teachers followed the treatment rules. This checklist consists of 12 items, two of which (item 5 and item 10) are negative form for the learning cycle activity criteria. The first author and another observer observed both experimental and control group classes during the study and filled out the observation checklist for both groups. A total of 12 classroom observations have been done for the purpose of treatment verification. Eight observations were conducted by the researcher and four observations were conducted by the researcher and another observer together.

**Teaching and Learning Materials**

A total of 11 learning cycle activities were prepared to involve students actively in the human circulatory system by making use of a wide range of sources (Bosak, 1991; Gungor, Köksal Akyol, Subaşı, Ünver, & Koç, 2002; Tolman, 1996). All the activities were designed with simple materials such as plastic water bottle, balloon, different colored pencils, papers, scissors, clocks, mammalian heart, gloves, pinafore, study paper, jar, reed, toothpick, ruler, city map, tin box etc.

Finally, a handout was prepared for both students and teachers. Some information about the human circulatory system, pictures and explanations about the subject, were given in this handout. This handout was also delivered to the control group students.

**Treatment**

The students in the experimental groups and the control groups were treated with different methods of teaching. The instruction for each group spanned four weeks and addressed a unit on the human circulatory system. In the experimental group, 5E learning cycle instruction was used. For each phase of the 5E learning cycle, different activities were prepared (Table 1). The 5E learning cycle plan was prepared for the topics of heart, blood vessel, blood circulation, and blood pressure by taking the national 11<sup>th</sup> grade biology curriculum into consideration.

Table 1  
*Learning Cycle Activities about Human Circulatory System*

Content	Name of activities
Heart	1. Exploration of the heart
	2. Exploration of the human heart
	3. Structure of the heart
	4. The mechanisms of heart function
Blood Vessels	1. Exploration of blood vessels
	2. Structure of blood vessels
Blood Circulation	1. Understanding of blood circulation
	2. Large and small blood circulation
Blood Pressure	1. Blood Pressure
	2. Pulse rate
	3. Measuring tension

In the engagement phase, the teacher tried to capture the students' attention and access prior knowledge about the structure and function of the heart and blood vessels, the mechanisms of blood circulation and the importance and meaning of blood pressure and tension in the subject of the human circulatory system. The activity in this phase built a connection between past and present learning experiences, representation of prior conceptions, and organized students' thinking toward the learning outcomes of current activities. For example, for the topic of the heart, in the engagement phase of the learning cycle, a case and small activity were used to engage students. However, at the beginning of activities, students filled up the first part of the KWL chart by answering two questions: What do I know and what do I want to know about the heart. The KWL chart tracks what a student knows (K), wants to know (W), and has learned (L) about a topic can be used before, during, and after research projects. Then, students read a case about a man who had a health problem in the past and answered the questions related with this story, briefly. Also, they performed an activity to focus on the subject of the



Figure 1: Example of Roundhouse Diagram on Systemic Circulation.

heart and the teacher showed some interesting/surprising pictures about the heart to attract student's attention. In the exploration phase, students completed various activities that helped them use their prior knowledge to generate new ideas, explored the four chambers of the heart, the role of arteries, veins and capillaries and also, the structural differences between blood vessels, the pathways of blood flow, and finally, the meanings of hypertension and hypotension. For instance, in the exploration phase for the topic of heart, students performed two activities to explore the subject. In the first activity, students worked in groups and each group investigated a real mammalian heart by dissecting it and naming each part of the mammalian heart in the diagram. With this activity, students explored the right and left atria, right and left ventricles and muscles of the heart. The second activity in the exploration phase of the learning cycle was done to explore the functions of the heart. Students worked in groups and they used simple materials such as plastic water bottles, balloons, jars, and reeds to investigate the contraction and blood pumping mechanisms of the heart in this phase. In the explanation phase, students were provided with some opportunities to demonstrate their conceptual understanding. In this phase students explained their understanding of the concepts of

the human circulatory system. Students answered the questions on the worksheet given by the teacher to explain their understanding of the concepts and processes. Also, they discussed the answers in class. Then each student watched an animation about the structure and mechanisms of the human heart, blood vessels and blood circulation from their computer. In the elaboration phase, students developed a deeper and broader understanding and they applied their understanding of the concepts of the human circulatory system by giving some examples from their life. For example, each student was expected to write a paper to describe his/her meals and exercise during one week. With this activity, students used their learning of how to protect their heart health and applied it to their daily life. Finally, the evaluation phase encouraged students to assess their understanding about the main idea of the human circulatory system. Each student formed a "Roundhouse Diagram" and completed a "KWL chart" about the heart, blood vessels, blood circulation and blood pressure to assess their knowledge. For example, in the Roundhouse Diagram, students wrote the basic important concepts about the heart on the diagram like sinoatrial node and atrioventricular node, contraction-dilation mechanisms, heart muscle, right and left atrium, right and left ventricle,

Kalp		
(Ne Biliriyorum)	(Ne öğrenmek istiyorum)	(Ne öğrendim)
K What I Know	W What I Want to Know	L What I Learned
<ul style="list-style-type: none"> <li>* Kalp soldadır.</li> <li>* Kan pompaları.</li> <li>* Kırmızıdır.</li> <li>* 4 bölmelidir.</li> </ul>	<ul style="list-style-type: none"> <li>* Kalbin yapısı nasıldır?</li> <li>* Kalp kasi nasıldır?</li> <li>* Kalp damarları nasıl tıkanır?</li> <li>* Kalbimiz nasıl çalışır?</li> </ul>	<ul style="list-style-type: none"> <li>* Kalp 4 odacıklı,                             <ul style="list-style-type: none"> <li>↳ Sağ Kulakçık</li> <li>↳ Sağ Kornek</li> <li>↳ Sol Kulakçık</li> <li>↳ Sol Kornek.</li> </ul> </li> <li>* Kanın akış yönü tek taraflı</li> <li>* Temiz ve kirli kan karışmaz.</li> <li>* Sinoatrial düğüm (SA), Atriavent. düğüm (AV)</li> <li>* Koroner damarlar kalbi besler.</li> </ul>

Figure 2: Example of K-W-L Chart in Heart.

places of the heart, blood pumping mechanisms etc. (Figure 1). In the KWL chart, students had answered the questions “What do I Know?” and “What do I Want to Know?” at the engagement phase, and “What did I Learn?” at the evaluation phase (Figure 2).

In the control group, expository instruction was given. Teacher-centered instruction was applied and students were generally taught with a note taking strategy. Teachers gave important concepts in an organized structure and wrote notes on the chalkboard about the definition of major circulatory system concepts as stated in the biology textbook. Students mainly listened to their teacher and took notes from the chalkboard throughout the lesson. The teacher generally focused only on the human circulatory system and did not make any associations with other related issues such as the respiratory, digestive, excretory etc. systems. The teacher used some pictures, diagrams and maps about the structure of the heart, blood vessels and pulmonary and systematic circulation. Students followed those visual aids. After completing the topic, the teacher gave students adequate time to ask questions about the subject. Students discussed the concepts under the teacher’s guidance and

the teacher re-explained any subject which wasn’t understood. The teacher handed out worksheets for the rest of the lesson. Students completed the worksheets and the teacher checked their answers in the classroom. Actually, in expository instruction, the important point was that the teacher set up and directed the lesson and they did not plan the lesson for allowing students to work within a small group of peers. Moreover, students did not perform activities which foster a deeper and more active learning process. Students learned from the authority of the textbook and the teacher rather than from experiences, observations or hands-on activities.

### Procedure

The experimental research method was used in this study because it is the best way to establish cause and effect relationships between variables. The effect of learning cycle instruction on student achievement in biology was examined in this study. A quasi-experimental study design was preferred for use as an experimental model since it did not include random assignment. At the beginning of the study, the teachers were trained by the researchers. Each

Table 2  
Descriptive Statistics for the Variables of the Study

Instruments	Possible Range	Actual Range	Mean	SD
HCSACT (PRE-ACH)	0-25	2-13	6.77	2.28
HCSACT (POST-ACH)	0-25	5-20	12.60	4.07
LAQ	22-88	29-76	58.83	7.8
TOLT	0-10	2-9	5.67	1.23
SES	9-45	19-44	35.65	6.87
LOC	0-1	.11-.88	.52	.19
ATB	15-75	39-59	49.33	5.16

teacher was conscious about how to teach a subject in both experimental and control groups. A teacher handout which explains learning cycle activities step by step for experimental groups was prepared, and a handout which explains the human circulatory system concepts for both experimental and control groups was given to the teachers. In this way, teachers could know how to teach the human circulatory system in both an experimental group and control group setting. Moreover, the teachers allowed the primary researcher of this study to observe their classes.

HCSACT, LAQ, TOLT, SES, LOC and ATB instruments were administered to both groups. Teachers allocated one class hour for students to complete the TOLT and appropriate time was also given to complete the LAQ, SES, LOC and ATB scales. Teachers explained the meaning of the tests and the scales given to each class at the same time. The students were also informed that the results of the test would not affect their grades.

An observation checklist was used for both groups during the study to confirm the proper treatment implementation. The checklist showed the degree to which the course was taught with the appropriate method.

#### Data Analysis

The data obtained via the achievement test and questionnaires were analyzed by means of SPSS 15.0 statistical software. Descriptive statistics were conducted to measure student achievement pre-test (PRE-ACH) and post-test (POST-ACH), LAQ, TOLT, SES, LOC and ATB scores for the human circulatory system. Pearson correlation analysis and Multiple Regression Analysis were also carried out for experimental and control groups to show the relationships among the variables of the study.

#### Results

In this section, the results of the analysis for each of the four research questions are described in separate subsections.

#### Descriptive Statistics

Descriptive statistics related to the scores for the students' human circulatory system achievement pre-test (PRE-ACH), post-tests (POST-ACH), LAQ, TOLT, SES, LOC and ATB scores for both experimental and control groups are presented in Table 2. As reported in Table 2, most of the students had a low level of relevant prior knowledge about the circulatory system. However, it was found that most of the students had higher scores on the POST-ACH and the mean increases from 6.77 to 12.60. Similarly, most of the students had higher scores on the LAQ and TOLT. Moreover, a reasonable number of the students had higher scores on the self-efficacy scale and half of the subjects had an internal locus of control. Finally, the students had both positive and negative attitudes towards biology. This means that students had a more moderate attitude towards biology.

In addition, the subjects were classified in relation to formal thought as low level (scores from 0-3), medium level (scores from 4-6), and high level (scores from 7-10) by using the TOLT (Soylu, 2006; Yenilmez, 2006). In this study, 5 (8.3%) of the students had a low level of formal thought, 44 (73.3%) of the students had a medium level of formal thought, and 11 (9.14%) of the students had a high level of formal thought (Table 3).

Table 3  
Distribution of Students with Respect to Level of Formal Thought

Formal Reasoning Level (N)				
	Low	Medium	High	Total
Girls	2	21	6	29
Boys	3	23	5	31
Total	5	44	11	60

**The Relationships among Variables of the Study**  
**The Relationship among Students' Cognitive and Motivational Variables and Achievement in the Human Circulatory System in Learning-Cycle and Expository Classrooms:** Pearson correlation analysis was carried out on the experimental and control groups to notice the relationships that might exist among students' prior knowledge, learning approach, formal reasoning ability, self-efficacy, locus of control, attitudes toward biology and the human circulatory system achievement using two different types of instruction, learning cycle instruction and expository instruction (Table 4).

According to the results of the Pearson correlation analysis, in learning cycle classrooms, student understanding of the human circulatory system was basically related to their relevant prior knowledge ( $r=.30, p=.001$ ) and formal reasoning ability ( $r = .231, p = .000$ ). It is concluded that students having higher prior knowledge scores and high formal reasoning abilities had a better understanding of the human circulatory system in learning cycle classrooms. In expository classrooms, students' achievement in the human circulatory system was basically related to their meaningful learning orientation ( $r = .319, p = .000$ ), self-efficacy ( $r = .262, p = .008$ ), locus of control ( $r = .235, p = .000$ )

and attitudes toward biology ( $r = .256, p = .000$ ). This means that students with a higher meaningful learning orientation, self-efficacy beliefs, locus of control orientations and more positive attitudes toward biology had a better understanding of the human circulatory system.

**Contributions of Students' Cognitive and Motivational Variables on Achievement:** Multiple Regression Analysis (MRA) was used to determine the contributions of cognitive and motivational variables on student achievement in the human circulatory system for the learning cycle and expository classrooms. In the study, the pre-test scores, meaningful learning orientation, formal reasoning ability, self-efficacy, locus of control, and attitude toward biology were the independent variables and post-test scores were the dependent variable (Table 5). Before the analysis, all MRA assumptions such as linearity, homoscedasticity, outlier, and normality were checked.

The multiple correlation (R) was .61 with  $R^2 = .37$  for the learning cycle classrooms. According to this result, the model significantly explained the 37% variation in student achievement over the experimental group. Students' prior knowledge ( $p = .000$ ) and reasoning abilities significantly ( $p = .000$ ) contributed to their achievement in the human circulatory system. On the other hand, a negative association was found between students' attitude towards biology and their achievement.

Table 4  
Correlation Coefficients among Variables of the Study for Each Group

Group		PRE-ACH	POSTACH	LAQ	TOLT	SES	LOC	ATB
Experimental group	PRE-ACH	-	.30**	.070	.390**	.087	.320**	.182*
	POSTACH	-	-	0.175	.231*	.010	.098	.077
	LAQ	-	-	-	.030	.231*	.152	.101
	TOLT	-	-	-	-	.378**	.318**	.181
	SES	-	-	-	-	-	.231*	.201*
Control group	LOC	-	-	-	-	-	-	.462**
	PRE-ACH	-	.128	.082	.290**	.261**	.161	.241
	POSTACH	-	-	.319**	.021	.262*	.235*	.256*
	LAQ	-	-	-	.201*	.216*	.218*	.062
	TOLT	-	-	-	-	.104	.237*	.089
Control group	SES	-	-	-	-	-	.230*	.040
	LOC	-	-	-	-	-	-	.201*

\*\* Correlation is significant at the .01 level \*Correlation is significant at the .05 level

Table 5  
Independent Contributions of Independent Variables to Achievement in Human Circulatory System

Methods of Teaching						
Variables	Learning Cycle Instruction			Traditional Instruction		
	B	$\beta$	t	B	$\beta$	t
PRE-ACH	.104	.055	.241	-	-.189	-.907
				.147		
LAQ	-.108	-.211	-1.047	.455	.191	.950
TOLT	.030	.337	.383	-.149	-	.493
				.098		
SES	.78	.111	.529	.742	.278	.299
LOC	.176	.009	.035	2.537	.251	1.25
ATB	-2.11	-.025	.097	6.84	.055	.252

\*Significant at the .05 level

Moreover, the multiple correlation (R) was .55 with  $R^2 = .31$  for the expository classrooms. According to this result, the model significantly accounted for the 31% variation in students' achievement over the control group. Students' meaningful learning orientation ( $p = .001$ ) and locus of control ( $p = .000$ ) significantly contributed to their achievement in the human circulatory system. Conversely, the relationship between students' reasoning ability and their achievement was negative.

**Determination of Which Variable Best-predicted Students' Achievement:** Stepwise multiple regression analysis was used to answer the second research question as to determine which variable best predicted student understanding in the expository and learning cycle classrooms (Table 6).

The results of the study showed that for the learning cycle classrooms, students' reasoning ability was the main predictor of performance on post-test scores, explaining 45.8% of the variance, while students' prior knowledge explained the remaining 15.9% variance on the post-test scores and attitudes towards biology explained 5.7% of the variance on the post-test scores from the learning cycle classrooms. Nonetheless, with the expository classroom, a meaningful learning orientation was the main predictor of performance on the post-test scores, explaining 40% of the variance, and locus of control accounted for 9.8%. The remaining 5.7% of the variance was explained by pre-test scores and locus of control on the post-test scores in expository classrooms.

In short, students' reasoning ability was the main predictor of performance for the post-test in learning cycle classrooms, while students' meaningful learning orientation was the main predictor of performance in expository classrooms.

Table 6  
Stepwise Multiple Regression Results for the Traditional and Learning Cycle Classrooms

		$\beta$	Adjusted $R^2$	F
POST-ACH				
Traditional Classroom (Control Group)	LAQ	.319	.28	22.10
	TOLT	.191		
	PRE-ACH	.189		
	LOC	.216		
Learning Cycle Classroom (Experimental Group)	PRE-ACH	.210	.53	20.35
	TOLT	.340		
	ATB	.164		

Significant at the .05 level

### Effect of Learning Cycle Instruction on Students' Achievement in the Human Circulatory System:

One-way ANOVA was conducted to determine the effects of the teaching method on student achievement in the human circulatory system post-test. Significant differences were found between the experimental group (learning cycle instruction) and the control group (expository method) in favor of the experimental group ( $F(1, 28) = 2.136$ ,  $p = .000$ ). This means that students in the learning cycle classrooms significantly did better than the students in the expository classrooms on the post-test of the human circulatory system.

### Discussion

The purpose of this study was to investigate the relationship among high school students' prior knowledge, learning approach, reasoning ability, self-efficacy, locus of control and attitudes toward biology in relation to student achievement in the human circulatory system using the learning cycle and expository classrooms. When we looked at each variable, in the expository classrooms, the results of the present study revealed that students' meaningful learning orientations were the main predictor of performance for the post-test, explaining 40% of the variance. Participants of the study had relatively high meaningful learning orientations ( $\mu = 30.60$ ). The participants had a tendency to use a meaningful learning approach in their science lessons in which constructivist curriculum was integrated. This means that when students had high meaningful learning orientations, they also had higher achievement in the human circulatory system. This result was not surprising considering the fact that many studies indicated

that meaningful learning orientation is important for meaningful understanding of any science subject (Reap & Cavallo, 1992). Since meaningful learning is a productive process, the students are studying to construct an understanding of the information and observations. The result indicating the predictive influence of meaningful learning orientation is consistent with the study of Cavallo (1996), who revealed that meaningful learning orientation explained more of the variance (13%) in the biology concepts as opposed to reasoning ability (3%) in classrooms. Likewise, Atay and Tekkaya (2008) stated that meaningful learning approach is an important predictor for a significant portion of the eighth grade students' performance on genetics. Cavallo and Schafer (1994) investigated the connection between students' meaningful learning orientation, relevant prior knowledge, instructional treatment and the effects of interactions of all these variables on tenth grade students' meaningful understanding of meiosis. The authors found that meaningful learning orientation contributed to student understanding, independent of aptitude and achievement motivation. Another predictor of student achievement in the human circulatory system for expository classrooms was locus of control. According to the results of the present study (the mean LOC score is .52) students had internal control expectancies, and received a sense of personal responsibility for what happens in the human circulatory system. Previous studies indicated that they can control their understanding of the human circulatory system (Makri-Botsari, 1999; Pintrich & Schunk, 2002). The teacher's attitude, activity-based homework, and curriculum may promote a development of internal locus of control. The previous studies reported the relationship between achievement and locus of control and concluded that there is a positive relationship between an internal locus of control and academic achievement (Anderson, Hattie, & Hamilton, 2005; Bar-Tal & Bar-Zohar, 1977; Findley & Cooper, 1983; Rowland, 1990; Wishart, 1997). These research studies stated that more internal beliefs are associated with greater academic achievement. Another important variable for student achievement in the human circulatory system in expository classrooms was self-efficacy. A study by Schunk and Pajares (2001) stated that when compared with students who have indecision about their learning capabilities, those who feel efficacious for learning or performing a subject contribute more willingly, work harder, persevere longer when they encounter difficulties, and achieve at a higher

level. Another study was conducted by Lawson et al. (2007) and they compared the relationships of self-efficacy and reasoning ability to the achievement in introductory college biology. The authors reported that self-efficacy estimates and achievement were higher for the concrete tasks than they were for the formal tasks and higher for the formal tasks than for the post formal tasks. In the present study, student self-efficacy was found to be related to their locus of control ( $r = .230$ ). According to this result, students who have internal control expectancies also have high self-efficacy scores. However, this result was not unexpected because student self-efficacy beliefs influence their options of task, effort and achievement (Bandura, 1997; Schunk, 1995). Studies showed that when students have high self-efficacy beliefs, they demonstrate more engagement in the lessons and they learn more and perform better (Linnenbrink & Pintrich, 2003).

In addition to prior knowledge, reasoning abilities was another variable which was a predictor for student achievement in the human circulatory system in learning cycle classrooms. Firstly, reasoning abilities explaining 45.8% of the variance was important for student achievement in the human circulatory system in the present study. As mentioned before, students' cognitive status changes over time and they do not learn if they do not have the required cognitive skill. In the literature, there are many studies connected with exploring students' reasoning abilities and its relationship to students' understanding (Huppert & Lazarowitz, 2002; Johnson & Lawson, 1998; Musheno & Lawson, 1998; Sungur & Tekkaya, 2003; Yenilmez, 2006; Yenilmez et al., 2005). Lawson and Thompson (1988) stated that the reasoning abilities of students are one of the factors that can contribute to a student's failure to understand scientific conceptions. Additionally, in the study of Cavallo (1996), it was reported that reasoning ability (9%) is the best predictor of student achievement in solving genetics problems in laboratory-based learning cycle in a biology course. Additionally, Sungur and Tekkaya (2003) explored the effect of reasoning ability and gender on achievement in human circulatory system concepts and attitudes toward biology. They found that there was a significant mean difference between concrete and formal students with respect to their achievement and attitude toward biology. Similarly, Huppert and Lazarowitz (2002) stated that concrete and transition operational students instructed with the computer simulation method achieved significantly higher achievement than

their counterparts instructed with the traditional method. In the present study, it was indicated that the majority of students are formal reasoners. The distribution of the students' scores on TOLT for both learning cycle and expository classrooms revealed that the majority of the students (73.3%) were at a medium formal level, while 8.3% of the students were at a low formal level. The reason for students' reasoning abilities to be the first predictor of achievement explaining 45.8% of the variance may be explained by the high number of students having formal reasoning abilities. Together with all explanations, please keep in mind that reasoning skills may not be the only factor that affects student achievement but also students' other attributes may be another reason for better achievement. However, in the current study, we dealt with reasoning ability as one of the cognitive variables and tried to explain the relations between reasoning skills and student achievement in the human circulatory system.

Another purpose of this study was to examine the effects of different teaching strategies (learning cycle versus expository instruction) on student achievement in the human circulatory system. According to the results, learning cycle instruction formed better attainment of human circulatory system concepts when compared to expository instruction. This result illustrated consistency with the role of the learning cycle which is a model of instruction based on scientific inquiry. This model encouraged students to develop their own understanding of a scientific concept, explore and deepen that understanding, and then apply the concept to new situations. Findings in the literature indicated that the learning cycle is a more effective teaching model that helps students to refine their ideas about science concepts when compared to expository instruction (Atay & Tekkaya, 2008; Balci et al., 2006; Barman, Barman, & Miller, 1996; Cavallo, 2003). The results of the study offered the use of learning cycle as an alternative teaching strategy to provide students with a better understanding of the concepts of the human circulatory system. Teachers should ensure that their students become active, so biology lessons are student-centered, not teacher-centered. In all phases of the learning cycle, students performed activities in groups which fostered a deeper and more active learning process. In addition to exposing students to different approaches and ways of thinking, working with other students in groups also gave students the opportunity to learn from and teach

each other. Therefore, group work provided an opportunity to obtain conceptual understanding. Additionally, biology teachers should develop new learning cycle lesson plans for the topic of both the human circulatory system and other subjects of biology to increase student achievement.

The present study suggested the possible predictors of achievement in biology. Thus, an increase in the level of these variables results in an increase in the level of student achievement. Curriculum developers, teachers and school psychologists should consider these variables to be able to increase student achievement. The present study has some limitations for researchers to consider in any attempt to generalize the results. First, the subjects of this study were limited to sixty eleventh grade students at one private school located in a large urban area. Data from other school districts and from different school types might provide different results. Therefore, our findings should be viewed with caution. Future studies could examine the effects of different teaching approaches on various biological topics. Moreover, based on the findings of the current study, researchers could use qualitative methods such as interviews to indicate the relationship between learning approaches and other motivational/cognitive variables. Additionally, future studies could examine the relationship among students' prior knowledge, learning approach, reasoning ability and self-efficacy, locus of control and attitudes toward biology in relation with student achievement in different biological topics, and at different grade levels. Moreover, the contribution of additional cognitive and motivational variables such as achievement motivation, goal orientation, beliefs or attitudes toward school to the understanding of the human circulatory system, or other topics can be investigated. Furthermore, the learning cycle instruction can be implemented during a whole semester so that other science/biology topics can be included.

In conclusion, the current study was designed to add to the growing body of literature regarding the relationship among cognitive and motivational variables in relation to student achievement in the learning cycle and expository classrooms. It is hoped that this investigation will serve as a motivating force for further research in the area of science and biology education.

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