Designing a **S**ystems **T**hinking **H**ierarchical model for **B**iology **E**ducation (STH-BE) and implementing it in the teaching and learning of the human transport system in junior high school

-Abstract-

In accordance with the constructivist approach to learning and teaching, the meaning of knowledge development is the construction of knowledge while linking new information to the learner's prior knowledge. According to the constructivist-cognitive approach, learning is a gradual process of concept development, which requires reorganization of the information by the learner. When trying to create new cognitive structures one of the challenges is the construction of cohesive and coherent knowledge, by integrating and joining units of knowledge while identifying the connections between them. The systems approach to teaching and learning enables the analysis of taught occurrences from a meta-cognitive point of view while emphasizing the connections and interactions in the system, which encourages the formation of coherent knowledge. The immense complexity characterizing biological systems, which include numerous components at varying levels of organization, and the standard methods of teaching, which emphasize components and structures, but insufficiently address interactions within the systems and seldom connect between levels of organization, create great difficulties on the way to a deeper understanding of natural phenomena. Therefore, it became necessary to develop effective tools for characterizing and analyzing systems thinking in biology and for organizing the knowledge of teaching and learning biology with a systematic approach. For this reason I designed a **S**ystems **T**hinking **H**ierarchical model for **B**iology **E**ducation (STH-BE), which is based upon the integration of three existing theoretical frameworks of systems thinking. I have written a systems thinking teaching model based on the STH-BE model and combined it with the teaching-learning materials that I developed on the subject of the human circulatory system for the 7th grade. This subject is considered to be one of the main subjects taught in biology in junior-high in school. In addition, I examined the influence of the new teaching-learning materials that I developed on the teaching and learning processes in the classroom from a systematic standpoint. One hundred and sixty three 7th grade students and three teachers participated in the study. The research tools selected for characterizing systems thinking are: Concept maps, Repertory Grid questionnaires, interviews and observations in the classroom. The study findings indicated that the transition between the ability to connect components at one level of

organization (horizontal coherence) to the ability to connect between components at different levels of organization (vertical coherence) is more difficult for the students, than the transition between the ability to identify simple relationships to the ability to identify dynamic relationships in the biological system. This finding led to the change of the hierarchical order in the theoretical STH-BE model and to the proposal of an updated model.

Learning while using the teaching-learning materials for the development of systems thinking has advanced the junior-high school students' abilities in all systems thinking skills, in accordance with the hierarchy in the updated STH-BE model. The greatest improvement was observed in the students' ability to identify components in the system at one level of organization (macro level) and the least improvement was observed in the students' ability to organize the system components in a framework of interactions. Furthermore, it was observed that the improvement in the students' ability to identify dynamic relationships between components at different levels of organization was greater than the hierarchical improvement in other skills. Moreover, the findings showed that the use of teaching-learning materials for the development of systems thinking caused the development of systems thinking among the teachers using the teaching-learning materials in the following aspects: (1) differentiating between structures and processes, (2) connecting between components and processes and creating a system, and-(3) differentiating between organizational levels in the system.

An analysis of the classroom discourse indicated that questions, which generate a discussion in the level of systems thinking matching the level of the students' systems thinking, encourage a fruitful debate between the teacher and her students, while questions that generate a discussion in the levels of systems thinking higher than that of the students do not encourage a discussion and cause a response in a lower level of systems thinking. Questions from the textbook guided the discussion gradually and encouraged productive discourse in a consistent level of systems thinking. The comparison between the characteristics of the teachers' systems thinking and the change in their students' knowledge structures indicates a possible connection between the significance the teachers place on the connections between levels of organization and the representation of these connections in their students' concept maps.