The impact of metacognitive instruction and explicit teaching system thinking on the biological core concept Homeostasis understanding

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Abstract

Homeostasis is a fundamental principle in biology and in the biology curriculum, in Israel and throughout the world. Biological systems, like living organisms, are complex systems. Understanding this fundamental principle, homeostasis, requires systems thinking, which is considered a high order skill, and makes integrative understanding of life systems and processes possible. Previous research on understanding homeostasis has exposed difficulties in students' systems thinking. Recent studies have shown that there is a need for explicit teaching of this fundamental principle, homeostasis, based on systems thinking.

Developing metacognition awareness has been shown effective in cultivating high-level cognitive skills among students. It is also likely to help in learning and understanding the systemic character of homeostasis. Metacognition awareness is a long term acquisition, as compared to content dependent cognitive skills, and can be activated for use in a variety of contexts and subject matters. Teaching to use metacognitive processes is critical and even likely to help with studying complex systems.

This study examines the contribution of both instructional methods, systems thinking instruction and metacognition instruction, to perceiving this fundamental principle, homeostasis.

The research questions:

1. How does the combination of the metacognition instruction with the systems thinking method of instruction affect student perception of this fundamental principle, homeostasis?
2. How does the combination of the instructional methods affect students' systems thinking with respect to the fundamental principle of homeostasis?
3. How does the combination of the methods of instruction affect students' metacognition awareness?
4. What characterized the perception of homeostasis by students who participated in the study after they studied this fundamental principle?
5. What characterized systems thinking by students who participated in the study after they studied this fundamental principle?
6. What characterizes attitudes of students who have been through the combined instruction method with respect to the metacognition instruction method?

Both methods of instruction were embedded into computerized-learning tasks, the subject of which was homeostasis in the human body, and were conducted by all of the students who participated in the study. The study is a quasi-experimental field study, using a 2x2-research design, and included 153 students who were divided into four groups:

1. MEST (Metacognition & Systems thinking) – received a combination of both methods of instruction.
2. ST (Systems thinking) – received instruction for systemic thinking.
3. ME (Metacognition) – received instruction for metacognition.
4. CG (Control Group) – studied without any instruction.

The research tools included *pre* and *post* questionnaires regarding perception of homeostasis, as well as systems thinking, and metacognition questionnaires. In addition, the second learning task also served as a research tool regarding the perception of homeostasis, systems thinking and metacognition awareness, as well as interviews upon completion of learning.

- In response to the first research question: The perception of homeostasis rose significantly in all treatment groups, and no advantage was found for combining the two methods of instruction.
- In response to the second research question: Some systems thinking skills were advanced by MEST instruction, in a concrete study task.
- In response to the third research question: no significant progress was found for metacognition awareness, and no differences were found between the different research groups.
- In response to the fourth research question: The characteristics of homeostasis – effectiveness, dynamism and environment are familiar and relatively understood, primarily for ST and MEST students. Understanding of the characteristics, feedback mechanisms, and energy is low since it involves broad biological knowledge and abstraction abilities that tenth grade students are lacking. Erroneous perceptions were identified in relation to the characteristics of homeostasis.

  In response to the fifth research question: An improvement was found in systems thinking skills on the structure level of the STH (Systems thinking Hierarchy) model. Difficulties were found in systems thinking skills on the synthesis level of the STH model.

- Understanding the dynamics of the p[illegible]anced under the influence of ST instruction and primarily under MEST instruction. ME instruction was found to have compensation capability for

understanding dynamism, which allows for completing the missing information, and its processing by means of self learning when necessary. The single implementation skill we addressed, according to the STH model was advanced among a few students, primarily MEST students.

- In response to the sixth research question: The students reported their doubts with respect to the MAI (Metacognitive Awareness Inventory) questionnaire, which checked metacognitive awareness, their hesitation with respect to metacognition instruction, which requires thinking, and with respect to its new questions. Students preferred cooperative learning supported by the teacher, over individual, self-learning. It was found that the students who received instruction, and particularly MEST, developed metacognitive-awareness, despite not yet having developed a metacognitive discourse.

When students completed their studying, a positive correlation was found between systems thinking and the perception of homeostasis for MEST and ME students, and also between the perception of homeostasis and systems thinking. Likewise, a correlation was found while studying between metacognitive awareness and system thinking and promoting the perception of homeostasis. The opposite held true for students in the three instructed groups, a correlation was found between the perception of homeostasis and systems thinking, and between both of them and metacognitive awareness, in contrast to the control group.

We recommend using systems thinking instruction and metacognitive instruction for teaching various subjects in biology, as well as for other subjects, based on the instruction conducted in our study. It is recommended that this instruction be embedded in study tasks and conducted alternately, gradually, and with extensive exercises, as is specified in this study. When saying "conducted alternately" we refer to embedding systems thinking instruction in some lessons and metacognitive instruction in other lessons, into teaching sequence lessons of certain subject. These instructional methods should produce metacognitive discourse in the classroom, as well as a systems thinking discourse, which are particularly vital, and likely to cultivate high cognitive skills.

Contribution of the research:

In the theoretical field, this study examined the contribution of metacognitive instruction in combination with systems thinking instruction. Both are content contingent, for the improvement of homeostasis, and understandi III cs of the fundamental principle – homeostasis. Likewise, they serve to improve metacognitive awareness and systems thinking among students, as well as to improve attitudes of the participants in the study towards instruction.

In the practical field, the study proposes a learning tool that combines metacognitive instruction with system thinking instruction as a model that is likely to help in the future, in teaching other fundamental principles in biology, as well as in other subjects. The learning tool is likely to help in developing high cognitive skills and cultivating independent study.

Presently, in the twenty-first century, students need to be prepared to be perpetual students, scientifically literate, with high cognitive skills. Researchers recommended promoting self-learning based on metacognition supervised by science teachers. Application of these instruction strategies will result in promote self-learning and achievements. Likewise, it is evident from this study that it is vital to include the development of self-learning with respect to the goals of the biology curriculum, and all other subjects. In order to implement this goal, and with the understanding that leading changes in approaches to teaching is done by teachers in the classrooms, it is important to cultivate their teachers' knowledge about metacognitive instruction in pre-service and in-service training sessions.

It is vital that teachers have metacognitive awareness, and be convinced of the necessity of this method of instruction as a tool for cultivating supervised and self-learning. Subsequently, they will be able to instruct their students using this approach.

Cultivation of the citizen of the future with healthy literacy, to understand the human body in a holistic manner has become an educational challenge in recent years. Understanding the human body as a complex system, as a whole, and not as a collection of organs and components, is to understand the concept of homeostasis, and this is critical to the health and quality of the life of the individual and the human race. Therefore, it is even vital to include the development of system thinking skills with respect to the teaching goals for biology and teaching in general. For the purpose of applying this important goal, it is important to develop teacher’s knowledge about system thinking and to train them in developing system thinking instruction, so that they will be able to apply it with their students.