Development of a strategy accompanying the unit "Interaction, force and movement" to construct the concepts "Interaction", "Force" and "system" in junior-high schools: A research on processes and products

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Abstract

Students and science teachers at the junior high school (JHS) level often cannot use their knowledge of physics for explaining and predicting phenomena because they lack qualitative understanding of the domain. Furthermore, JHS science teachers avoid teaching physics because of deficiencies in their content knowledge and low confidence in their ability to teach this domain.

The main goal of this thesis has been to start a process of change that might alter this situation. We suggest that this can be attained by focusing on the development of qualitative understanding as a central goal of JHS physics.

In a preliminary study we found that even a sound understanding of physics concepts is not sufficient for enabling students to carry out the task of explaining qualitatively complex everyday phenomena. We hypothesized that this finding results from the fact that this task requires a multi-step procedure that students do not acquire by themselves. Hence we decided to develop a qualitative problem-solving strategy that would guide students in this problem solving task. This strategy would be taught in an integrated manner with the conceptual basis.

The thesis describes the development of this new instructional approach for teaching mechanics at the JHS level and the research that was conducted during its implementation. The approach integrates a conceptual framework

that emphasizes the concepts and principles of "system" and "interaction" and Newton’s third law, and a qualitative problem-solving strategy that uses visual representations extensively.

For enhancing the implementation of the approach, we designed workshops for JHS science teachers in which they experienced the new approach as learners, and we supported them while implementing the approach in their classes.

The research included (1) a diagnosis of reasoning and qualitative problem solving skills of students (n=480) and JHS science teachers (n=32) who were taught according to traditional instruction in the domain (2) an assessment of the new approach and its influence on students in achieving qualitative understanding in the domain (n=310), (3) an assessment of students' views and attitudes toward the new approach (n=180), and (4) an assessment of the changes in teachers’ views and confidence to teach physics following a workshop that is based on the new approach (n=92).

The research instruments included content and attitude questionnaires administered to the students and to the teachers in the workshops. Interviews were conducted to the teachers in the workshops and to the students at different stages of the studying the topic and six months after completing its study. Classroom observations were held during the design of the approach. The content questionnaires included standard tasks adapted from different international questionnaires such as the Force Concept Inventory (FCI) and tasks that were designed to assess specific understanding performances.

Results show that Israeli students, after traditional instruction, had difficulties in solving qualitative problem and demonstrated similar misconceptions as their fellow students worldwide. However, JHS students who studied according to the approach, advanced significantly from pretests to posttests both on the FCI (<g>*= 0.64), and on understanding performances that were defined according to our learning goals and the relevant facets defined in the literature. These students performed better than advanced high-school and college students on relevant FCI items and Israeli matriculation items. Furthermore, these students demonstrated in interviews an improved ability to explain and predict phenomena using physics ideas. The students liked the new approach and appreciated its contribution to their ability to better understand phenomena in their environment.

Other results show that introducing the approach to JHS science teachers developed their qualitative understanding and that their confidence to teach physics increased.

There was a strong correlation between teachers' views of their mastery of content and their view of their ability to instruct students (r Spearman =0.96, p<0.0001) or other teachers (r Spearman =0.62, p<0.006). We suggest that acquiring the ability to use physics ideas for explaining a large range of everyday phenomena empowers teachers and allows them to consolidate their knowledge.

The results illustrate the promise of the approach that we have taken to deal with the difficulties that students encounter in JHS physics. Presently, intensive work is being carried out in developing similar approaches integrating a problem solving strategy and a conceptual framework for instructing the topics of electricity and energy in JHS.

Presently, there is a nationwide implementation of the instructional approach developed in this study and there are on-going professional development programs for teachers throughout Israel that train them in using this approach.

* <g>= (posttest score-pretest score)/(100-pretest score),   after Hake (1998).