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אילו "מושגים בסיסיים ואפליקציות בננוטכנולוגיה" כדאי ללמד בבית ספר תיכון?
מחקר דלפי של קהילת מומחים

What "essential concepts and applications in Nanotechnology" should be taught in school science?
A Delphi study of the expert community

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Abstract

Nano scale science and technology (NST) is an important new field in modern science. It deals with the ability to create materials, devices, and systems having fundamentally new properties and functions by working at the atomic, molecular, and macromolecular levels. Since NST is a new field, the questions: What (NST) concepts and nanotechnology applications should be taught in high school science? How to teach these concepts for promoting students' deeper understanding of these concepts? And where should they be integrated in the Israeli middle and high school science curriculum? were still open questions when I started working on this thesis.

In the current PhD thesis, I sought to answer these leading questions in three sequential stages, using different methodologies and participants for each stage, when the main goal of the research is to methodologically examine how to take the NST field and integrate it into high school science teaching. The answer for the first stage leading question was based on a community of experts in nanoscience research and in science education. A three-round Delphi study of the expert community was applied to reach consensus. Eight NST essential concepts and five nanotechnology applications that should be taught in high school level were identified. Each concept was accompanied by its explanation, definition, why it is important to be taught, followed by connection between the NST concepts that are needed for teaching the selected applications. The eight NST essential concepts are: *(1) Size-dependent properties, (2) Innovations and applications of nanotechnology, (3) Size and scale, (4) Characterization methods, (5) Functionality, (6) Classification of nanomaterials, (7) Fabrication approaches of nanomaterials and (8) The making of nanotechnology*. The five NST suggested applications are: (1) *nanomedicine*, (2) *nanoelectronics*, (3) *photovoltaic cells*, (4) *nanobots*, and (5) *self-cleaning*.

For the second stage leading question: how to teach these concepts for promoting students' deeper understanding? Three essential concepts were selected. For the first two (size

and scale and size dependent properties) a nanotechnology module was developed for ninth grade students in the context of teaching chemistry. A wide spectrum of instructional methods was implemented to support students' understanding. Students' interviews and the content of students' final projects were used and analyzed to learn how using a variety of teaching methods influenced students' understanding of two essential concepts (size and scale and size dependent properties) in nanotechnology. The teaching methods that were effective in promoting students understanding are: (1) Game-based learning, (2) Learning with visualization, (3) Learning with movies and animations, (4) Learning with models, (5) Storytelling and narratives, (6) Everyday life example, (7) Project base learning.

For the third concept, the making of nanotechnology, the main goal was to learn how students' participation in a one-day nanotechnology conference *NanoIsrael 2014* influenced their perceptions regarding the concept. It was found that the students' participation in the conference influenced their emotional perspectives, their knowledge concerning nanotechnology, as well as their curiosity and interest in science and their motivation and future plans.

The third stage was conducted to find the essential NST concepts insertion points in the Israeli middle and high school science curriculum, as were suggested by chemistry teachers. The NST concepts were suggested to be integrated in most of the Israeli middle school science and high school chemistry curriculum. In this stage a group of teachers who learned nanotechnology course, suggested the insertion points in the curricula. And a second group of teachers who participated in an on-line nanotechnology course were responsible for the validation of these results.

The results of the three research stages provide three vital dimensions that are important for a research-based development of nanotechnology education. They formulate recommendations regarding what essential NST concepts to teach, how to teach them and where to teach them in the curriculum consequence. They can also constitute as guidance for constructing comprehensive nanotechnology program and can serve as a tool for analyzing and evaluating existing nanotechnology programs intended for middle and high-school levels.