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Possibilities and Challenges in Early Science Education: Exploring Heat and Sound

Extended summary

Selected physics contents (heat and sound) were taught through two pilot projects employing Inquiry-Based Science Education (IBSE) within a STEAM+X educational framework. This research investigated whether, and to what extent, primary school students can effectively interpret natural phenomena through the particulate nature of matter using Inquiry-Based Teaching Models (IBTMs). These innovative teaching models guide students through research activities, dialogue, critical thinking, and experiential learning, thereby contributing to the development of their persistence in problem solving, collaborative skills and unique creative abilities. The quasi-experimental study with parallel groups (experimental - IBTM and control – TTM (traditional teaching model)) involved 62 3rd and 4th grade students from two primary schools in Sombor, Serbia. To examine the students' prior knowledge about heat and sound, a pre-test was created, while the impact of IBTM and TTM on the quality of knowledge and the conceptual understanding was examined using the post-test. The tests contained 12 questions with 6 levels of achievement in accordance with the revised Bloom's taxonomy.

The IBTM on thermal phenomena consisted of four sequences: States of matter, Particulate nature of matter, Temperature, Heat, and Conduction of heat. The IBTM on sound and the properties of sound was applied through the following four sequences: Basic principles of inquiry learning, Sources and properties of sound, Sound propagation and echo, and Making posters - sound concept maps. Within all IBTM sequences of both models, the students, apply-

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ing the scientific method, defined their research questions, posed hypotheses, performed experiments, and wrote down observations and conclusions. During the implementation of the IBTM group work was applied, whereby teachers, through all stages, strengthened the development and improvement of the students' language competencies, such as understanding of a text that was read, group reporting on the research results, as well as discussions at the class level. The students of the control groups adopted the same teaching contents through the TTM, which is still the most represented approach in our teaching practice.

Even after the application of IBTM on thermal phenomena, there is still a misidentification of the concepts of heat and temperature, indicating the deep rootedness of the observed misconception. Moreover, the understanding of phase transitions is satisfactory only when it comes to water. Nevertheless, the applied model improved the phenomenological understanding of thermal conductivity and the process of mixing the substances at different temperatures, but not from the aspect of their particulate structure or through the interpretation of numerical data. The innovative teaching model improved students' understanding of the thermal insulation properties of materials and improved the ability to creatively solve problems (making a thermo-cup and proposing measures to save heat energy in the household).

The application of IBTM confirmed previous knowledge about some concepts (sound source, loud/quiet, decrease of intensity with distance from the source) and, at the same time, contributed to a better understanding of others, such as the reduction of sound intensity when passing through obstacles and the absence of sound in a vacuum. Moreover, IBTM enabled a deeper understanding of the stages of sound propagation from the source to the receiver, the connection between the height of the air or water column and the pitch generated in them, and contributed to the development of creativity in proposing activities that reduce the harmful impact of noise on people.

In the conducted pedagogical experiment, the students of both groups (E and C) showed better results on the posttest than on the pre-test, with the difference in achievement among the students of the E group being more pronounced. By testing the differences in achievement of the students of both groups on the posttest on heat and sound phenomena, the existence of a statistically significant difference in favour of the E group was determined. The magnitude of influence of the experimental factor is large in both cases, which confirms the effectiveness of the applied innovative teaching models on thermal and sound phenomena content. Consequently, this research provides guidelines for future application of the same or similar models, and on a larger scale, in terms of sample size and project duration, given that the obtained results are promising.

Keywords: initial science education, inquiry, STEAM+X approach, heat, sound

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