Proactive and Retroactive Effects of Courses in Sequential Physical Science Learning: A longitudinal Evaluation

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Abstract

This longitudinal study of learning in sequential physical science courses in grades 8 to 10, ages 13 to 16, provides evidence for proactive and retroactive facilitation of long-term retention by curriculum continuity, and for retained knowledge that cannot be readily retrieved yet is functionally available for further learning.

Education is a gradual process, the ultimate outcomes of which are produced by cumulative effects of educational experiences. Hence, investigations of long-term outcomes of introductory courses are crucial for careful development of advanced courses. In spite of the fact that the desirability of longitudinal studies is an undisputed issue, such studies are scarce. This is disturbing, in view of conclusions of short-term studies that were found to have only limited validity in terms of long-term implications. Furthermore, retention of learning is often investigated through psychological experiments on immediate memory of fragmentary information that has questionable relevance for school learning.

The present longitudinal study was designed to investigate effects of interrelations between courses in sequential school science learning upon long-term retention. It focused on the learning of chemistry-related physical-science topics in junior high school and its implications for further studies in senior high school.

The study was carried out with a nation-wide sample of Israeli students. It was replicated with two cohorts, one year apart, which were followed up from the beginning of grade 8 in junior high school until the end of grade 10 in senior high school, ages 13 to 16. The total entry sample consisted of 3167 grade 8 students, one third of whom were located in grade 10. The attrition of the sample was involved with selection, hence all long-term conclusions were based on analysis of longitudinally-matched data.

Two groups of students were investigated. Both studied in grade 7 the same introductory physical science course on the particulate structure of matter, but only one group continued to study related topics in grade 8 through a chemistry-oriented course. None of the groups studied a chemistry-oriented course in grade 9 and both encountered chemistry only in grade 10. The assessment applied a multiple-instrument strategy. Thus, to assess acquisition of knowledge and learning difficulties in junior high school physical science, multiple-choice tests were used in conjunction

with both students’ and teachers’ evaluation scales. Likewise, several instruments were employed for providing measures of long-term retention: recall, recognition and feeling of familiarity, relearning and transfer retention. The data processing used a battery of uni- and multivariate statistical analyses.

While the study was primarily concerned with long-term outcomes, it started by addressing the teaching and immediate learning outcomes of the grade 8 chemistry-oriented course (entitled “From Elements to Compounds”). The data provided evidence that chemistry can be learned meaningfully in junior high school. The contents chosen and the strategy adopted in the grade 8 course were found to be suitable for a target population of average and above average ability students, provided that their teachers (most of whom initially trained as biology teachers) receive appropriate training and year-round guidance with emphasis on subject matter.

The major findings and conclusions on long-term cognitive outcomes are the following:

1. Both proactive and retroactive facilitation effects exist between consecutive courses in sequential learning: (a) prior knowledge acquired in grade 7 facilitated further learning in grade 8; (b) retention of the grade 7 subject matter over a two-year interval was higher in the group which had studied physical science continuously during both grades 7 and 8. These long-lasting effects are not due to mere rehearsal, since the concepts of the grade 7 course were used but not re-taught in grade 8.
2. Long-term retention of grade 8 chemistry learning exists, despite the fact that chemistry is taught again only in grade 10: (a) at the beginning of grade 10, students who had previously studied chemistry in grade 8 had higher recall and recognition scores; (b) their feeling of familiarity, exhibited by a self-report on retention, was higher; (c) relearning and transfer retention tasks showed significant “savings.” Students’ feelings of familiarity with previously studied topics were found to be higher than their recall and recognition test scores. The results of the relearning and transfer retention suggest that the higher familiarity is, at least partly, a reflection of retained knowledge that cannot be readily retrieved yet is functionally available for further learning.

The longitudinal findings suggest that science learning is cumulative in a more complex way than often supposed. Curriculum continuity facilitates learning and retention, both proactively and retroactively, and long-term retention has many facets, with gaps between immediately retrieved and functionally available knowledge. Ausubel’s learning theory provides explanations.

The findings and conclusions are, apparently, ecologically valid and educationally significant, since learning outcomes of an actual sequence of school courses were assessed longitudinally. The main educational implication is that investments in introductory science courses have more and better long-term payoffs if their contents are adjusted with those of subsequent courses, with attention to students’ functionally available prior knowledge at each grade level. The general message of this study is that a program composed of a hierarchical sequence of learning units is superior to a discontinuous array of discrete courses. Curriculum developers should strive for carefully related sequences of courses, teachers should help their students grasp continuity between courses, and researchers should initiate more longitudinal studies aimed at gaining better insights into proactive and retroactive effects of curriculum and instruction on learning and long-term retention.