Development of learning strategies with the support of instructional instruments

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Abstract

This work concern a project for developing effective learning strategies for Physics students in their first year of senior high school, in agreement with the general objectives of the Instituto de Educación Media Superior. Our project has an explicit and intentional purpose of designing, monitoring and analyzing diagnostic self-evaluation rubrics in connection with learning strategies. The diagnostics describe the initial conditions and the evolutions of the gradual applications of student learning strategies serving to generate significant learning skills as well as effective problem solving capacities. The strategies here considered were developed in four phases with specific purposes indicated in parentheses: initiation (acquisition and interpretation), processing (analysis and thinking), structuring (comprehension and organization), and closure (communication and evaluation). We have translated and adapted part of the DIAGNOSER instrument. That instrument served to follow up the products generated by the students according to the learning strategy that was under development. Every week the students worked on a learning product related to aspects such as these: skills and procedures required in scientific work, basic elements of the history and epistemology of the scientific topics under study, competences for making synthesis, and experimental cooperative projects. Present results show improvements that are significant although modest, despite the fact that serious learning and socioeconomic problems characterize the student population. Students improved in their capacity to remember and employ scientific knowledge; they also were capable of using different kinds of representations of data to deal with everyday situations and of proposing short justifications of their own decisions based on the scientific understanding of the physical phenomena.

Keywords: Learning strategies, Self-evaluation diagnostics, Instructional instruments.

Resumen

Este trabajo tiene que ver con un proyecto de desarrollo de estrategias efectivas de aprendizaje en estudiantes de Física del primer año del bachillerato, de acuerdo con los objetivos generales del Instituto de Educación Media Superior. Nuestro proyecto tiene el propósito explícito e intencional de diseñar, monitorear y analizar diagnósticos basados en rúbricas de autoevaluación en relación con estrategias de aprendizaje. Los diagnósticos describen las condiciones iniciales y la evolución de las aplicaciones graduales de estrategias de aprendizaje que sirven a los alumnos para generar habilidades significativas de aprendizaje y capacidades efectivas para resolver problemas. Las estrategias consideradas se desarrollaron en cuatro fases cuyos propósitos específicos se indican entre paréntesis: iniciación (adquisición e interpretación), procesamiento (análisis y razonamiento), estructuración (comprensión y organización) y cierre (comunicación y evaluación). Hemos traducido y adaptado parte del instrumento denominado DIAGNOSER, el cual sirve para dar seguimiento a los productos generados por los estudiantes según sea la estrategia de aprendizaje en consideración. Cada semana los estudiantes trabajaron en un producto de aprendizaje relacionado con aspectos tales como los siguientes: habilidades y procedimientos requeridos en el trabajo científico, elementos básicos de historia y epistemología relacionados con los temas en estudio, competencias para hacer síntesis y proyectos cooperativos relacionados con experimentos. Los resultados obtenidos a la fecha son significativos aunque modestos, a pesar de que la población de estudiantes se caracteriza por serios problemas de aprendizaje y de tipo socioeconómico. Los estudiantes mejoraron en su capacidad para recordar y utilizar el conocimiento científico; también fueron capaces de usar diferentes tipos de representaciones de datos para tratar situaciones de la vida cotidiana y proponer breves justificaciones de sus propias decisiones, con base en la comprensión científica de los fenómenos físicos.

Palabras clave: Estrategias de aprendizaje, Diagnósticos de auto-evaluación, Instrumentos instruccionales.

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I. INTRODUCTION

In terms of international standards, science education in Mexico at the junior high school level is very bad.

For instance, in 2006 our students occupied the penultimate place in Program for International Student Assessment (PISA) evaluations in science and 51% of the students were on level one or lower [1, 2]; three years later, this percentage improved a little going up to 47% [3, 4]. The implication of these figures is that those students are unable to remember simple scientific concepts and cannot make personal decisions based on the use of experimental data presented in a table. The situation is quite similar concerning reading comprehension and mathematics.

Many of our students at the senior high school level have the characteristics previously described. The entrance examination tests show that our students (ages 16 to 19) have troubles concerning effective ways to analyze, think and communicate ideas as well as to apply direct reasoning to concrete situations. Socioeconomic problems as well as high dropout percentages and severe academic backwardness also characterize our student population [5, 6].

The school where this project is under development belongs to the public senior high school system under the direction of the Instituto de Educación Media Superior (Institute of Senior High School Education). It is important to note that the plans of study designed and implemented by this Institute must be based on the following general objectives to be accomplished by the students: 1-to understand that science is a form of interpreting the world and it is a result of historical, social and cultural processes; 2- to recognize fundamental principles and laws in order to relate them to the environment of the students; 3- to apply basic analytical and experimental methods to explore fundamental principles and laws corresponding to the themes of the course; 4 - to elaborate strategies to solve qualitative and quantitative problematics in the context of the themes of the course, and 5-to value the importance of his(her) commitment with the community [7].

Nevertheless, it is under such conditions that teaching Physics must be organized by facing the following problem: How can we help our students to participate actively in their own learning and to support them to attain relevant and successful results.

As a first step in this direction, in what follows we describe a project aiming to develop appropriate learning strategies with the support of a diagnostic instrument serving to detect the most serious learning deficiencies concerning Physics. Section II presents the main characteristics of the project and section III comments on main results and future actions.

II. DESCRIPTION OF THE PROJECT

By following the theory of strategic learning [8, 9], the main purpose of learning strategies is to allow the students to become self-sufficient learners capable to acquire significant knowledge and to solve problems. According to Pozo and Postigo [10], learning strategies can be classified in classes serving for purposes such as: Acquisition, interpretation, analysis and thinking, comprehension and organization, and communication. We have reorganized these strategies into the four phases and included one more purpose (evaluation). The corresponding purposes for each phase are described in parentheses: initiation (acquisition and interpretation), processing (analysis and thinking), structuring (comprehension and organization), and closure (communication and evaluation).

Essentially, the project here considered consists in designing a set of learning activities in order to support the students to work through the successive four phases previously described. In view of that, a diagnosing instrument has been prepared with a twofold purpose: (1) to follow up the level of mastery in the application of each learning strategy and (2) to analyze its effect on the degree of knowledge of Physics shown by the students before and after the instruction sessions where the strategies were explained and applied. It must be stressed that the four phases correspond to a continuing process, not necessarily linear, in which one phase could coexist in its developments with others. Up to now, we mainly have focused on the first strategy for acquisition and interpretation with gradual and slow interconnections with the other three strategies.

In order to study the development of the students in connection with the required competences for understanding and using the proposed learning strategies, we have followed a procedure that includes four steps (S):

S_1: *Follow up and self-evaluation of the degree of mastery of the strategy*. This step is initiated by doing a motivating experiment and guiding a discussion with the students to show to them how to interpret the experiment according to the learning strategy. Individual written opinions are asked and then commented in the classroom. Afterwards, a different experiment is presented without any intervention from the teacher. A checklist is provided in both cases serving as a guide to the students as well as a record of their own responses. At the end of each one of these activities, a self-evaluation instrument is applied with a double purpose: that each one of the students could think about and comment on his (her) own performance and degree of understanding of the learning strategy, as well as to have a record of the difficulties presented during the applications of the strategy. These diagnostic self-evaluation instruments consist in rubrics related to the details of the application of the strategy in connection with two issues: to be conscious of their own achievements and to understand what the student needs to work more. A follow up instrument is also applied and analyzed at different moments of the course.

S_2: *Observation and analysis of the degree of learning attained by the students concerning Physics knowledge*. For this purpose, we have translated and adapted part of the DIAGNOSER instrument that is available in Internet [11]. This instrument refers to Physics High school conceptual aspects and contains generators of questions and thematic questionnaires as well as the possibility of preparing reports of the performances either of individuals or of the entire classroom. Furthermore, some other items coming from PISA tests in science [12] and the IB Questionbank-Physics [13] have been translated and used with the aim of evaluating the quality of student learning according to international standards [14, 15]. In this project we deal with two kinds of Physics courses that follow the general objectives of the school system previously described in section I: Física I in the first semester includes matter and heat, and Física II in the second semester includes mechanics and electromagnetism.

S_3: *Design of a program of learning activities.* These activities consider the following: efficiency in the uses of language, codes and representations in science, problem.

Solving including experimental work, understanding about the scientific process, discussion of some illustrative and relevant historical episodes and their cultural contexts, and an integrated organization of physic concepts, models, laws and theories. Such activities are organized at the individual and even at the cooperative level. The students worked on four types of learning products on a weekly base. Each set of four products constitutes a learning cycle of gradual applications of the strategy. Next Table I shows in the first column the type of expected product and in second to fifth columns, the gradual increase in the complexity or degree of difficulty of each learning cycles (C_1 to C_4).

TABLE I. Type of products presented during each learning cycle.

Type of product	*Learning cycle C_1* Skills and procedures required in science	*Learning cycle C_2* Competences for making synthesis	*Learning cycle C_3* Interpretations of representations	*Learning cycle C_4* Experimental cooperative projects
P_1 Problem solving	Descriptions of what is known and what is unknown.	Critical comparisons of models and theories of interest.	Key questions and presuppositions that might contribute to the solution.	Ask a question leading to a relevant project of interest for the students.
P_2 Elements of history and epistemology	Story line of the main contributions to the solution and description of its cultural contexts.	Analysis of concepts and conceptual relationships that have been used in the solution.	Beliefs, knowledges, misconceptions, and innovations.	Identify past attempts to find answers to the question and describe methods of solutions.
P_3 Organization of the information	Short explanations of key topics.	Diagrams and synoptic charts for relevant facts, questions and answers.	Mental maps representing concepts, models and theories.	Plan for an experimental test in order to answer the question.
P_4 Relationships among concepts and their representations	Relate concepts with symbols in the equations solving the problem.	Relate questions with answers and compare among them.	Relate characteristics of equations with the graphics representing experimental data.	Analysis of data and discussions of different answers.

S_4: *Analysis of results and comparison with a control group*. The semester was divided in four monthly periods and the students were asked to work on a weekly product and to prepare a portfolio for the discussion, reflection and planning of each period. Furthermore, every month the students had a test related to Physics content. In the control group no specific activities were developed according to any learning strategy what so ever but the same content of the discipline has been thought.

This project was initiated in August 2009 and has been developed in two steps, one for exploration and another for experimentation. Later on there will be a third step for evaluation of project. The exploratory step consisted in the identification of the most critical problems related to learning skills when the students arrive at the school and of the possible learning strategies most appropriate for overcoming to those problems; it included the preparation of instructional instruments for diagnosis, some of them adapted from DIAGNOSER and PISA.

The experimental step focused on the first learning strategy called initiation and including the applications of the instruments for diagnosis and follow up. Just for illustration, the detailed structure of this strategy for acquisition and interpretation had six elements [16, 17]: (E_1) to plan what is required for knowing or understanding, (E_2) to observe and find relevant information, (E_3) to distinguish what is known or ignored, (E_4) to find and understand the information about what is ignored, (E_5) to think about the validity of what is understood, and (E_6) to remember the acquired relevant information to relate to what is known. In the first applications of this strategy, we observed more difficulties with elements E_2, E_4 and E_5, related to three characteristics of the usual learning context in which the students have been living: the superficiality of their search procedures, the abstractness of some contents, and the rarity of the metacognitive thinking.

Compared with the equivalent results of the control group, the results of the group where the learning strategies were applied have shown general improvement concerning skills for thinking, analyzing, and communicating ideas. For instance, these improvement were evident in the following aspects: assistance to classroom sessions (80%

compared to 50%), solution of reactives with higher cognitive degree of difficulty (75% compared to 45%), number of questions asked by students during the test in order to understand the questions and to ask for some guidance (50% less than in the control group), and risk for drop out (7% compared to 18% in similar populations of 28 students).

After working with the learning strategies, the students were much less impulsive and superficial in problem solving tasks. For instance: they spend time understanding the question to be solved and observed more carefully what they need to do; they could identify, look for and interpret the required information and relate new acquired knowledge with what they already knew, and they considered in a metacognitive way the validity of their results. Furthermore, three quarters of the students could solve PISA type of reactives at level 3, instead of being at level 1 or even lower than that, as they were at the beginning of the course.

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