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Influence of Motivational, Attitudinal and Metacognitive Skills in the Academic Achievement of Freshman Science and Engineering Students

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Abstract

Research in science education has addressed as one of its main lines the proposal of several comprehensive models of the components of problem solving. These models coincide in distinguishing between the variables that relate to the structure of knowledge in memory and those that relate to the cognitive functions that operate on that knowledge, to prepare, control and monitor the execution of a solution in a new task. It also recognizes a third component related to the motivation, attitudes and beliefs of the subject that solves problems. The ability to solve problems in a particular domain results from the complex interaction of the knowledge structure, cognitive functions and beliefs about oneself and about the task. The differences observed during the process, from the interpretation of the problem to the persistence in trying to solve it, can be attributed to variations in aspects of these three cognitive constructs. The purpose of this research was to evaluate two affective variables, the achievement motivation, associated with the interest for academic success; and the attitude towards chemistry learning, associated with the conceptions about it; as well as a cognitive variable such as metacognition, necessary for the development of several of the scientist's own abilities, in freshman science and engineering students of a Peruvian university. The level of correlation between these variables and their influence on the academic achievement of the students was determined. The results obtained show the high degree of correlation between the selected variables, although only achievement motivation turned out to be a variable predictor of academic achievement.

Keywords: *Achievement motivation, learning attitudes, metacognition, problem solving;*

1. Introduction

Undoubtedly, the development and strengthening of problem solving skills are the main objectives of Problem Based Learning (PBL). Therefore, it is necessary to review the dimensions that directly influence these skills. Several comprehensive models recognize as main dimensions the domain knowledge, the general strategies and the self-regulation and control skills. In addition, some models also recognize beliefs and affective variables as important dimension in the problem solver [1, 2].

Jonassen identifies external and internal factors that affect the problem solving process, the former are related to the nature of the problem (structuredness, complexity and abstractness) and the way in which it is represented to the learner. The representation of the problem and the way it is perceived by the student depend on the context and the modality used in its design. The internal factors are related to the characteristics of the learner and imply, on the one hand, the previous knowledge, in particular the structural knowledge; the experience; reasoning skills and, the cognitive functions deployed for the planning and monitoring of problem solving process. The latter are strongly related to the development of metacognitive skills. Another component of internal factors is related to affective elements, such as attitudes and beliefs about problems, problem mastery and the learner's perception of his own problem solving skills. In this way, the motivational components, such as the engagement, both at the beginning and during the process; effort; persistence in the task and decision making will have a strong effect on problem solving achievements [3,4].

The purpose of this research was to evaluate two affective variables, achievement motivation, associated with the interest for academic success; and the attitude towards the learning of chemistry, associated with the conceptions about it; as well as a cognitive variable such as metacognition, necessary for the development of several of the scientist's abilities, in freshman science and engineering students of a Peruvian university. The correlation level between these variables and their influence on the students' academic achievement were determined.

2. Methodology

2.1 Participants

The participants in this study were freshman science and engineering students from a Peruvian university, who were enrolled in a General Chemistry course. The study included only the students who answered the three instruments applied, therefore the number of participants was 38, the average age was 18 years and the range was between 16 and 20 years. 63.2% was male and 36.8% female.

2.2 Context of the study

The hybrid PBL model implemented involved the presentation of a PBL scenario at the beginning of each thematic unit (5 in total). Students, organized in groups of 4 members, must present their solution proposal at the end of the unit. Throughout the unit the groups developed collaborative learning activities with the teacher's mediation.

The evaluation of each unit considered 40% of the group work (PBL problem and learning activities) and 60% of individual assessment (problem solving). The final course grade considered two individual exams (problem solving), each weighed with 30%, the average of the evaluations of the thematic units, weighed with 20%, and the laboratory activities assessment weighed with 20%.

2.3 Instruments

Attributional Achievement Motivation Modified Scale (EAML-M) [5]. 30 semantic differential items valued on a gradient of 1 to 6 points. Highest scores in each item correspond to the most favorable sense of motivation for academic success. Total scale score reflects the level of achievement motivation in the learning context. The scale consists of six dimensions: interest and effort; interaction with teacher; task / ability; exam; collaborative interaction with peers; peer influence on learning skills. The maximum score obtainable is 180 and the minimum is 30. Cronbach's alpha value is 0.9026.

Metacognitive Activities Inventory (MCAi) [6]. 27 items that use a five-level Likert scale with the purpose of exploring the use of the regulatory component of metacognition (planning, monitoring and evaluation) in the context of solving university chemistry problems. The MCAi score expresses the percentage of the maximum points that can be obtained in the inventory. Greater use of metacognitive strategies is associated with higher score values. Cronbach's alpha value is 0.85.

Colorado Learning Attitudes about Science Survey (CLASS) for use in Chemistry [7]. The original version consists of 50 items for which a Likert scale of five levels is available. A favorable score is considered as the percentage of responses that agree with the expert response, an unfavorable score is the percentage of responses that do not agree with the expert response. For the purposes of this study the instrument was adapted using only 36 items. In the pilot application four optimal dimensions were identified in terms of reliability and interpretability: personal interest (α: 0.633), conceptual learning and problem solving (α: 0.738), atomic molecular perspective of chemistry (α: 0,700), making sense and effort (α: 0,571) [8].

2.4 Procedure

The three instruments were administered during the last two weeks of class. The average time to answer each instrument is 30 minutes.

2.5 Analysis of data

The data were analyzed using Statistical Package for the Social Sciences (SPSS) 21 software ®. Level alpha was established a priori in 0,05. A descriptive analysis of the instruments scores was performed. Correlation between the three variables was determined. Linear regression analysis was made, stepwise method. The dependent variable was academic achievement expressed as the final course grade. The possible predictor variables considered were MCAi, EAML-M and CLASS scores expressed as percentage.

3. Results

Table 1 shows descriptive statistics for total scores obtained in the three instruments used and the final course grade.

	M	SD
EAML-M score	65,512	11,513
MCAi score	69,830	9,024
CLASS score	49,268	23,567
Final course grade	60,000	7,352

Table 1. Descriptive statistics for EAML-M, MCAi, CLASS scores and final course grade (N = 38).

Table 2 shows the Pearson correlation coefficients for the study variables total scores and the final course grade.

Variable	EAML-M	MCAi	CLASS	Final course grade
EAML-M	1			
MCAi	0,625**	1		
CLASS	0,414**	0,552**	1	
Final course grade	0,356*	0,039	0,058	1

* p < 0,05; ** p < 0,01

Table 2. Correlation matrix of study variables and final course grade (N = 38).

Significant positive correlation between the three study variables can be observed. In particular, the relationship between motivation and metacognition has been widely discussed, recognizing its ambivalent nature. Metacognitive analysis of the activity itself can significantly influence the apprentice's motivational schemes. At the same time, achievement-oriented motivation is based on knowledge of one's own capacity, interest and effort invested in achieving a goal. Therefore, it can be expected that subjects with a high achievement motivation present a greater degree of metacognitive knowledge.

On the other hand, it is known that feelings and emotions have a direct influence on learning and behaviors. However, the affective aspect is complex since it implies a diversity of variables such as norms, values, opinions, beliefs, attitudes, etc. Attitudes imply a favorable or unfavorable predisposition towards the object of learning and, in this way; they could influence the motivational and metacognitive aspects of the process.

The results of the linear regression analysis indicated that the total score of EAML-M was a predictive variable for the final course grade, $F(1, 36) = 5.211$, $p < 0.05$. The R^2 value was 0.126, which indicates that 12.6% of the variance is explained by the total score of EAML-M. Table 3 shows the summary of the regression model applied following the stepwise method.

Variable	B	SD	β	t	p
Constant	45,124	6,614		6,823	< 0,001
EAML-M score	0,227	0,099	0,356	2,283	0,028

Table 3. Stepwise linear regression analysis summary in predicting final course grade

Linear regression analysis considering EAML-M total score as dependent variable and MCAi and CLASS as possible predictors showed that only the regulatory aspects of metacognition, evaluated by MCAi, were predictors of EAML-M total score, $F(1, 36) = 23{,}127$, $p < 0.001$. R^2 value was 0.391.

4. Conclusions

As indicated above, problem solving involves a series of complex and interrelated processes whose diversity and variability have a decisive influence on the learner achievements. In this study, the purpose was to analyze some of the most important aspects related to the student, that is, the internal factors associated with the problem solver.

The results show that, indeed, the influence of the variables studied on academic achievement is important, highlighting in a relevant way the achievement motivation. It can be affirmed that motivation constitutes the triggering element of learning process, which allows the student to assume the challenge posed in the task and to be persistently engaged in the search for the solution. The influence of metacognitive activities on motivation has been proven with the results obtained. The aspect related to attitudes towards chemistry learning did not show a significant influence on academic achievement; however its relationship with motivational and metacognitive aspects was evident.

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