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Prospective Science Teachers' Declarative Knowledge about Newton's Laws of Motion

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ABSTRACT *This study identified prospective science teachers' declarative knowledge about Newton's laws of motion through quantitative and qualitative assessments. Their declarative knowledge was regarded as a contributor that might have an effect on their knowledge levels, achievement levels, and achievement scores. The contributors that might have an effect on their achievement scores were divided into two categories, namely, variables and factors. Their achievement level measured by their responses to the questions about their declarative knowledge varied between 43% and 45%, whereas their knowledge level varied from 12% and 34%. Thus, their achievement level did not represent their knowledge level. It can be argued that foresight is more influential than variables in answering questions about one's declarative knowledge.*

KEYWORDS : Declarative knowledge, students' knowledge and achievement levels, variables in achievement, factors in achievement

INTRODUCTION

There are three main reasons the present study analyzes students' declarative knowledge about Newton's laws of motion. First, declarative knowledge is an aspect of scientific knowledge. It especially comes into prominence in science classes, since they include scientific subjects such as physics, chemistry, and biology. Next, some of our knowledge is in fact declarative (Dacin & Mitchell, 1986; Runco & Chand, 1995). Third, comprehension is closely intertwined with declarative knowledge. In short, comprehension means turning our procedural knowledge into declarative knowledge (Ozenli, 1994, 1999).

Knowledge is divided broadly into two types, namely, procedural knowledge and declarative knowledge. Most of our knowledge is procedural or declarative (Dacin & Mitchell, 1986), and the collective use of procedural and declarative knowledge improves education (Willingham, Nissen & Bullemer, 1989). Furthermore, certain types of procedural and declarative knowledge may have an influence on creative thinking (Runco & Chand, 1995). Teaching science is a scientific discipline that includes fundamental definitions of science, and declarative knowledge can be produced through scientific methods (Good, Herron, Lawson & Renner, 1985).

Declarative knowledge is suggestive of actual knowledge (Sahdra & Thagard, 2003; Phillips & Carr, 1987). It is what we recognize and explain. It is also called explicit knowledge (Anderson, 1995, p. 234). Moreover, declarative knowledge is a type of knowledge that we are aware of and explain in a clear way (Baumard, 1999, p. 62). Unlike procedural knowledge, declarative knowledge is actual knowledge (cited in Sahdra & Thagard, 2003). It is divided into three sub-categories: common, technologic, and field of interest (Garzas & Piattini, 2007). Declarative knowledge is constructed by a partition of the data into its sub-units, a semantic coordination between such sub-units, and an analysis of the data code within the framework of possibilities through inductive and deductive processes at a certain epistemological level within the semantic web of scientific disciplines (Ozenli, 1999, A11). The logic of declarative knowledge is based on that of mathematics (McCarthy, 1988; Nilsson & Fikes, 1970; Bonner & Kifer, 1993).

Previous studies have reported that procedural and declarative knowledge are closely intertwined and one can be derived from the other (Li, Ang, Tong & Tueni, 1994; Berge & Hezewijk, 1999; Dacin & Mitchell, 1986; Sahdra & Thagard, 2003; Willingham, Nissen & Bullemer, 1989; Thagard, 2005; Hao, Li & Wenyin, 2007; Lawson, McElrath, Burton & James, 1991; Hanisch, Kramer & Hulin, 1991). According to Anderson (1983, 1993), declarative knowledge is the basis of data transfer. Declarative knowledge is used at various educational stages. It can be enhanced through various methods and techniques and can also contribute to their development (Drummond, Hernandez, Velez & Villagran, 1998; Howe, Tolmie, Tanner & Rattray, 2000; Kamouri, Kamouri & Smith, 1986; Johnson & Star, 2007; Kırkhart, 2001; Andre & Ding, 1991).

In this study, knowledge and achievements levels of science teacher candidates about declarative knowledge issues in relation to Newton's laws of motion were determined with problem solving technic. Five independent variables were identified within problem solving technic. Knowledge levels of science teacher candidates were determined in three of five variables. Participants' knowledge on physic formula and basic mathematics were assigned as additional independent variables. Achievement level was assigned as dependent variable. Data were analyzed with VDOIHI. Possible effects of independent variables on dependent variable were discussed in science teacher candidates' levels including knowledge and achievements about declarative knowledge issues in relation to Newton's laws of motion. Problem solving technics were suggested in order to increase the achievements level regarding topic.

METHODOLOGY

The data for the study were collected from first-year prospective science teachers taking Physics 1, a course that covers Newton's laws of motion, through quantitative and qualitative case studies. A "holistic multi-state design" and "holistic single-state design" were used for the quantitative and qualitative parts of the study, respectively. The quantitative data were collected through a 7-item questionnaire designed with to collect personal information about students and a test that consisted of 12 multiple-choice questions on declarative knowledge, whose reliability and validity had been established beforehand. The questionnaire on personal information included questions about the participants' a) gender, b) university, c) type of high school, d) time spent studying Newton's laws of motion, e) methods of studying Newton's laws of motion, f) achievement score in General Physics 1, and g) achievement score in General Math 1. Questions as to declarative knowledge require the partition of the problem into sub-units and a semantic coordination (correlation) between these sub-units through inductive and deductive processes at a certain epistemological level (Ozenli, 1999). The test of the participants' knowledge level consisted of 12 questions, four borrowed from the literature (Halloun, Hake, Mosca & Hestenes, 1995; Wilson, 2000; Atasoy, 2008; Keleş, 2007) and eight developed by the researcher. The questions on declarative knowledge were based on comparisons of accelerated motion, spring force, Newton's laws, center of mass, centripetal force, gravitational force, potential energy, and Kepler's laws. They did not ask for any statistical values.

The qualitative data were collected through three measurement tools. The first was the Qualitative Measurement Tool 1 (QMT 1), which comprises four semi-structured questions. These questions were chosen for use on the test of declarative knowledge. The second, the Qualitative Measurement Tool 2 (QMT 2), includes physics formulas that are required for solving the problems on the QMT 1. In other words, the QMT 2 includes the procedures for the QMT 1. The QMT 2 has 27 semi-structured questions that measure whether students have a clear idea about the procedures for the QMT 1. The third measurement tool, the Qualitative Measurement Tool 3 (QMT 3), contains 50 semi-structured questions to measure their basic knowledge about math that is required for the questions in QMT 1. Forty-one of these questions were borrowed from the literature (Haeussler & Paul, 1993; Karakaş, 2001). The remaining nine questions were composed by the researcher.

The study participants were first-year prospective science students from faculties of education located in Turkey. The sample from which the quantitative data were collected comprised 599 first-year students studying at the Department of Science Teaching, Faculty of Education, at seven universities in Turkey, during the second term of the academic year 2009-2010. These students had already taken General Physics 1 and General Math 1. The universities were selected on the basis of their provincial achievement and the achievement of the universities themselves. The sample from whom the qualitative data were collected comprised seven students who participated voluntarily, had answered the questions included within the quantitative data collection tools, and whose achievement scores different in General Physics 1, General Math 1, and the questionnaire items.

The present study was implemented in two stages: a quantitative and a qualitative stage. At first, the data were collected through a questionnaire on personal information and test of declarative knowledge (quantitative stage). Afterwards, the QMT 1, QMT 2, and QMT 3 were administered (qualitative stage). Through these measurement tools, the data were collected in one session with two parts, namely, a written part and interview-based part. During the former, the students were informed about the measurement tools. Next, they were asked to solve the problems on the QMT 2, QMT 3, and QMT 1, in that order. During the second part, the data were collected through interviews in which the students were asked to explain how they had solved the problems on the QMT 1. When appropriate, their answers were compared with the data from the QMT 2 and QMT 3, and they were asked related questions. Furthermore, when the need arose, the students were asked to explain some of the data obtained from the QMT 1. For example, one problem on the QMT 1 could have been solved by drawing a free-body diagram. The students who did not do this were asked to draw the free-body diagram in the interview. The other six students took the written part and the interview-based part in the same order.

The students' declarative knowledge about Newton's laws of motion was determined depending on the contributors that might have an effect on their knowledge levels, achievement levels, and achievement scores. Their knowledge levels were determined by the APS values of the three variables "definition," "formula," and "operation," which were measured in the qualitative stage. Since the variable "given-asked" constituted the data for the study and the variable "free-body diagram" was merely a method to make it easier for the students to solve the problems, the APS values of these variables were not considered indicators of the participants' knowledge levels. Their achievement levels, on the other hand, were measured by the test of declarative knowledge and the QMT 1 in the quantitative stage and qualitative stage, respectively. Their achievement in the qualitative stage was assessed through the written part. The students' correct answers on the test of declarative knowledge were regarded as "The percentage of correct answers on the test in Table 1," whereas the correct answers they provided on the QMT 1 were accepted as "The ASS Value by Percentage." Their achievement levels in the QMT 2 and the QMT 3 were determined as well.

The contributors that might have affected their achievement scores were divided into two groups, namely, variables and factors in achievement. The factors in achievement were determined through the quantitative and qualitative stages. Some of the factors measured through the quantitative stage cannot be changed. Even so, they can be improved, which is actually one of the objectives of education. On the other hand, the factors measured through the qualitative stage[1] can be changed.

Some of these factors were measured by the questionnaire items on personal information. The other factors in achievement were measured by the QMT 2 and QMT 3 during the written part of the qualitative stage. An attempt was made to determine whether there was a significant correlation between the items included in the questionnaire on personal information and the test of declarative knowledge. The factors between which there was a significant correlation are those that had an influence on achievement. On the other hand, the factors between which there was no significant correlation are those that did not have an influence. The effects of the factors "QMT 1" and "QMT 2," which were measured in the qualitative stage, were calculated for the results of student achievement by percentage, i.e., on achievement level.

In this study, the variables in achievement were measured through the written and interview-based parts in the qualitative stage. The variables in achievement are as follows: a) given-asked, b) free-body diagram, c) definition, d) formulas, and e) operations. The students' scores in these variables were calculated in order to determine the effect of the variables on their score in the QMT 1 (i.e., student achievement level). Their declarative knowledge about Newton's laws of motion was determined with a consideration given to the fact that their scores in the variables might have an effect on the results of student achievement.

An interval scale was used for their achievement scores in General Physics 1 and General Math 1. A nominal scale was used for their gender, university, type of high school, time spent studying Newton's laws of motion, methods of studying Newton's laws of motion, the test of declarative knowledge, QMT 1, QMT 2, and QMT 3.

SPSS was used for the analysis of the correlations between the answers to the questionnaire on personal information and the test of declarative knowledge. The data obtained through the QMT 1, QMT 2, and QMT 3 were analyzed through a software program developed for Probability and Possibility Calculation Statistics for Data Variables (VDOIHI), Statistical Methods for Combined Stage Percentage Calculation (Yılmaz, 2011; Yılmaz & Yalçın, 2011).

Statistical methods for a combined stage percentage calculation determine the values of variables and allow an analysis of the effect of these variables on the results. In this method, the variable to be measured is divided into stages, which, in turn, is divided into the smallest meaningful pieces. Afterwards, they are scored. The smallest meaningful pieces are scored as -1, 0, and 1. Furthermore, the stages of a variable are divided into three stages, namely positive, negative, and unconnected stages. Afterwards, an attempt is made to analyze the effects of these stages on the results by percentage. The smallest meaningful pieces of the same stages of a variable are combined and turned into a single stage (Yılmaz & Yalçın, 2011).

FINDINGS AND CONCLUSION

The students' achievement levels regarding their declarative knowledge about Newton's laws of motion were determined by their answers to the questions included on the test of declarative knowledge. The study found that the students had an achievement level of 43% in the quantitative stage. They scored a combined 3,090 points on the 12 questions on declarative knowledge. The maximum number of points that can be obtained on the test is 7,188. Therefore, the students had an achievement level of 0.43 on the test of declarative knowledge. Table 1 presents the percentage of their correct answers out of the maximum score that can be obtained from the measurement tool implemented in the quantitative stage of the study, and the findings and results obtained from the measurement tools in the written and interview-based parts of the qualitative stage.

The achievement levels of the students who participated in the qualitative stage of the study were determined by their answers to the questions on the QMT 1, i.e., through the written part. It was found that the seven students who participated in the written part had an achievement level of 45% on the questions on declarative knowledge about Newton's laws of motion. They scored 12.60 points for the answers they provided to the four questions on declarative knowledge. The maximum score that can be obtained from the questions on declarative knowledge is 28. The students had an achievement level of 0.45 in the questions on declarative knowledge. Their achievement levels determined by the quantitative and qualitative assessments are close to each other; therefore, they can represent each other. Their achievement levels on the QMT 2 and QMT 3 were 59% and 82%, respectively.

The students' knowledge level in the variable "definition" was 21% (0.21) and 31% (0.31), whereas in the variable "formula," it was 27% (0.27) and 34% (0.34). On the other hand, their knowledge level in the variable "operation" was 12% (0.12) and 14% (0.14). The results show that the students had similar knowledge levels in the variables "definition" and "formula," which suggests that they are equally familiar with the memorized knowledge required for the questions. The IS, ANS, and NAPS values of these two variables were close to 0, which shows that their memorized knowledge was not based on misconceptions. Their knowledge level was lower in the variable "operation" when compared to "definition" and "formula," which may lead one to think that they had problems with the procedures for the questions and were unable to establish the semantic coordination between sub-units. They had a low knowledge level in this variable as a result of the fact that they had had low levels in the other variables. The IS value of the variable "operation" was 0.30 and 0.29. These values were higher than the students' knowledge level in this variable and also in the other two variables, which suggests that the students had a higher tendency to use misinformation when they attempted to come up with an answer to the questions. Their knowledge level was not close to their achievement level (measured by the knowledge test and the qualitative application), which suggests that the latter does not represent the former.

This paragraph describes the factors that might have had an effect on the students' achievement scores in their declarative knowledge about Newton's laws of motion. The t-test analysis showed that the male students had significantly[2] higher scores than the female students. The analysis of variance (ANOVA) yielded significant[3] differences in the students' declarative knowledge depending on the university where they studied. A Scheffe test was conducted in order to determine between which universities the difference existed. The test showed that the students from the 1st university had significantly[4] higher scores on the questions on declarative knowledge than those from the 2nd, 5th, and 6th universities; those from the 3rd university than those from the 5th and 6th ones; those from the 4th university than those from the 2nd, 5th, and 6th ones; and those from the 7th university than those from the 2nd, 5th, and 6th ones. The ANOVA reported no significant[5] difference in scores depending on the type of high school the students had graduated from, amount of time spent studying Newton's laws of motion, or methods of studying Newton's laws of motion. The correlation analysis of the scores in General Physics 1 yielded a slightly significant and positive correlation. (r = .189, p = .000). The same was found for the scores in General Math 1 (r = .144, p = .001). Therefore, it was concluded that gender, differences in university, and achievement scores in General Physics 1 and General Math 1 are factors that influenced the students' declarative knowledge. However, the type of high school they graduated from, time spent on studying, and methods of studying Newton's laws of motion were not factors in their declarative knowledge.

The factors in the QMT 2 and QMT 3 determined in the qualitative stage were interpreted on the basis of the findings obtained in the written part. The students' knowledge on the QMT 2 affected their scores on the QMT 1, i.e., their achievement level, by 59%. Their knowledge shown in the QMT 3 affected their scores on the QMT 1, i.e., their achievement level, by 82%.

The effects of the variables measured through the written part on the results are as follows:

The students' knowledge in the positive stages of the variable "given-asked" had an effect of 7% on the ASS value. However, their unconnected knowledge, negative knowledge, and positive knowledge in the negative stages did not have an effect (0% for each). A score of zero had an effect of 93%.

Since the students had no positive knowledge about the variable "free-body diagram," the ASS score was not affected by this variable.

The students' knowledge in the positive stages of the variable "definition" had an effect of 20% on the ASS value. However, their unconnected knowledge, negative knowledge, and positive knowledge in the negative stages did not have an effect (0% for each). A score of zero had an effect of 80%.

The students' knowledge in the positive stages of the variable "formula" had an effect of 27% on the ASS value. Their unconnected knowledge affected the ASS value negatively by 1%. Meanwhile, their negative knowledge affected it negatively by 0.39%, and their positive knowledge in the negative stages had an influence of 0.79%. A score of zero had an effect of 70%.

The students' knowledge in the positive stages of the variable "operation" had an effect of 12% on the ASS value. Their unconnected knowledge and negative knowledge affected the ASS value negatively by 29% and 9%, respectively. Their positive knowledge in the negative stages might have had an influence of 1%. A score of zero had an effect of 76%.

The collective effects of the four variables of the questions on the QMT 1 on the results are as follows: Knowledge of these variables in the positive stages had an effect of 16% on the ASS value. Their unconnected knowledge and negative knowledge had negative effects of 8% and 2%, respectively. Their positive knowledge in the negative stages might have had an influence of 0.60%. A score of zero had an effect of 80%. Knowledge on the QMT 2 is thought to have had an effect of 58%, whereas knowledge on the QMT 3 is believed to have had an effect of 82%.

The effects of the variables measured through the interview-based part on the results of "ASS" are as follows:

The students' knowledge in the positive stages of the variable "given-asked" has an effect of 3% on the ASS value. Their unconnected knowledge, negative knowledge, and positive knowledge in the negative stages did not affect the ASS value (0% for each). A score of zero had an effect of 97%.

Since the students had no positive knowledge about the variable "free-body diagram," the ASS score was not affected by this variable.

The students' knowledge in the positive stages of the variable "definition" had an effect of 31% on the ASS value. Their unconnected knowledge and negative knowledge affected it negatively by 3% and 0.70%, respectively. Their positive knowledge in the negative stages might have had an influence of 0.70%. A score of zero score had an effect of 65%.

It is thought that the students' knowledge in the positive stages of the variable "formula" had an effect of 34% on the ASS value. Their unconnected knowledge and negative knowledge had negative effects of 1% and 0.30%, respectively. Their positive knowledge in the negative stages might have had an influence of 0.70%. A score of zero had an effect of 63%.

The students' knowledge in the positive stages of the variable "operation" had an effect of 14% on the ASS value. Their unconnected knowledge and negative knowledge had negative effects of 29% and 9%, respectively. Their positive knowledge in the negative stages had an influence of 1%. A score of zero had an effect of 74%.

The collective effects of the four variables of the questions on the QMT 1 on the results are as follows: The students' knowledge in the positive stages had an effect of 18% on the ASS value. Their unconnected knowledge affected the ASS value negatively by 9%. Meanwhile, their negative knowledge had a negative effect of 2%. Their positive knowledge in the negative stages had an influence of 0.70%. Finally, a score of zero had an effect of 78%. The students' knowledge on the QMT 2 and QMT 3 was found to have an effect of 58% and 82%, respectively.

DISCUSSION AND IMPLICATIONS

The APS values of the variable "given-asked" were close to 0 (0.07 and 0.04),[6] which shows that the students were not able to comprehend the data for the questions on declarative knowledge. Furthermore, the values indicate that they could not divide the data into its sub-units or establish the semantic correlations between sub-units. The variable "operation" had the highest IS, ANS, and NAPS scores of all the variables. The low APS value of the variable "given-asked" and the high scores of the variable "operation" suggest that the students attempted to answer the questions without comprehending the data.

This indicates that they had a groundless self-confidence that led them to make mistakes. These mistakes were revealed by the IS value of the variable "operation" in Table 1, as it was the highest value obtained through the written application.

It can be argued that the students' answers to the questions on declarative knowledge were not significantly affected by the variables. In order for the variables to have an influence on the results, the first attempt should be to increase the APS values of the variable "given-asked." Next, a corresponding increase should be seen in the APS values of the variables "definition" and "formula." Thirdly, it might be a good idea to increase those of the variable "free-body diagram." Finally, an attempt should be made to increase those of the variable "operation." Since the variable "operation" was influenced by the others, it is likely that it will be easier to increase its APS values. Table 1 suggests that the students' achievement level (ASS value) is not correlated with their knowledge level. In other words, their achievement level does not represent their knowledge level. The APS values of the variables should be maximized, and the IS, ANS, and NAPS values should be minimized in order to enable their achievement level to represent their knowledge level.

The total APS values of the five variables were 0.16 and 0.18, whereas their total ASS value was 0.45 (Table 1), which suggests that the students were influenced more by foresight than by the variables when they answered the questions on declarative knowledge. This might have been caused by the fact that the questions were based on comparisons. Furthermore, the fact that their achievement level does not represent their knowledge level might have resulted from the questions based on comparisons. If the problem is a result of the questions based on comparisons, it might be prevented by the use of another measurement tool that requires students to come up with certain statistical values. In other words, the measurement tool should consist of questions that require certain statistical results in order to enable knowledge and achievement levels to represent each other.

This study found that gender, achievement score in General Physics 1, and achievement score in General Math 1 were factors in the students' achievement level. In addition, their achievement level was not affected by their university, type of high school, time spent studying Newton's laws of motion, or methods of studying Newton's laws of motion. The QMT 2 was a factor in their achievement level; even so, one cannot argue that it had a significant influence on it. The QMT 3 was another factor in their achievement level, yet the APS value of the variable "operation" was lower than that of the variable "formula," which suggests that the measurement tool did not have a profound influence on their achievement level.

*This article is derived from İsmail Yılmaz's doctoral thesis.

Table 1: The percentage of the students' correct answers out of the maximum score that can be obtained from the measurement tool used in the quantitative stage of the study, and the findings and results obtained from the measurement tools in the written and interview-based parts of the qualitative stage

Points/ Variable	Given-Asked			Free-Body Diagram			Definition			Formulas			Operations			Sum of Variables		
	Written	Interview	Difference %	Written	Interview	Difference %	Written	Interview	Difference %	Written	Interview	Difference %	Written	Interview	Difference %	Written	Interview	Difference %
P	2.00	1.00	-100.00	0.00	0.00	0.00	90.00	143.00	58.89	58.00	67.00	15.52	30.00	34.00	13.33	180.00	245.00	36.11
BGS	294.00			28.00			497.00			217.00			315.00			1351.00		
İS(S)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	300.00	0.02	0.02	0.00	0.30	0.29	-3.33	0.08	0.09	12.50
APS(S)	0.07	0.04	-42.86	0.00	0.00	0.00	0.21	0.31	47.62	0.27	0.34	25.93	0.12	0.14	16.67	0.16	0.18	12.50
ANS(S)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	100.00	0.00	0.00	0.00	-0.10	-0.10	0.00	0.02	0.02	0.00
NAPS(S)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	100.00	0.01	0.01	0.00	0.02	0.02	0.00	0.00	0.00	0.00
SS(S)	0.93	0.96	3.23	1.00	1.00	0.00	0.79	0.66	16.46	0.71	0.64	9.86	0.77	0.75	-2.60	0.80	0.78	-2.50
QMT 2 S	0.59																	
QMT 3 S	0.82																	
The Response Rate to the Test	0.43																	
ASS	0.45	0.48	6.67															

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