The Relationship of Procedural and Declarative Knowledge of Science Teacher Candidates in Newton's Laws of Motion to Understanding*

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Abstract

In this research, it was found that the levels of procedural and declarative knowledge of science teacher candidates in Newton's laws of motion are 10%, 41% and 30%; whereas their success level was found to be 55%. These findings show that students' success levels do not reflect their knowledge levels. A decline by 31% (66%-45%) was observed in students' level of declarative knowledge; which suggests that students experienced some problems while converting procedural knowledge into declarative knowledge, and due to these problems, they failed to "understand" Newton's laws of motion adequately.

Key Words: Procedural knowledge, declarative knowledge, students' knowledge and achievement levels, understand

Introduction

The majority of what we know about the real world is composed of formal knowledge, which is about how to do something. This knowledge is mostly in the procedural form or in the form of sequence of steps in order to accomplish certain objectives (Georgeff, at all, 1985, Georgeff & Lansky, 1986; Baumard, 1999). Procedural knowledge is the one that shows how to accomplish a task, and is obtained through rules in which instructions are performed step-by-step (Hiebert & Lefevre, 1986; Star, 2002). Most of our knowledge is in procedural or declarative forms (Dacin & Mitchell, 1986; Runco & Chand, 1995; Baumard, 1999).

In the literature, it has been demonstrated that procedural and declarative forms of knowledge are interrelated and one can be derived from the other (Li, at all, 1994; Berge & Hezewijk, 1999; Dacin & Mitchell, 1986; Sahdra & Thagard, 2003; Willingham, Nissen & Bullemer, 1989; Thagard, 2005; Hao, Li & Wenyin, 2007; Lawson, at all, 1991; Hanisch, Kramer & Hulin, 1991). Some researchers suggest that accomplishment of a task transfer prompts formal and descriptive knowledge (Bovair & Kieras, 1991; Brooks & Dansereau, 1987; Dixon & Gabrys, 1991; Royer, 1986; Singley & Anderson, 1989; Harvey & Anderson, 1996).

Anderson (1976, 1983, 1993) underlines that knowledge starts with declarative actions, the conscious and control; and this control paves the way for procedural processes. Moreover, he argues that declarative knowledge forms the basis of knowledge transfers. Procedural knowledge, on the other hand, has significant roles in structuring concepts and obtaining declarative knowledge (Lawson, at all, 2000; Lawson, 1991). Procedural knowledge is about how to think (Sahdra & Thagard, 2003; Heyworth, 1999). It is linked with the performance change in knowledge, skills and tasks (Willingham, Nissen & Bullemer, 1989; Berge & Hezewijk, 1999; LeFevre, at all, 2006; Phillips & Carr, 1987). It is the knowledge that explains how to perform an action within the framework of clear procedures (Özenli, 1999).

Declarative knowledge is suggestive or real knowledge (Sahdra & Thagard, 2003; Phillips & Carr, 1987). It is the knowledge that we are aware of and we tell about. This is called open knowledge (Anderson, 1995, p: 234). Declarative knowledge is the knowledge that we are aware of and we can express clearly (Baumard, 1999, p: 62). It is, contrary to procedural knowledge, real knowledge (Sahdra & Thagard, 2003). Its logic is based on mathematical logic (McCarthy, 1988; Nilsson & Fikes, 1970; Bonner & Kifer, 1993). Declarative knowledge is "understood" in maximum amplitude on the basis of the code's "possibility"; by partitioning expression into its constituents, through inductive-deductive cognitive processes, within the semantic web of implicitly-internalized scientific disciplines and at the selected epistemological level (Özenli, 1999, A11).

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The use of procedural and declarative knowledge forms together improves education (Willingham, Nissen & Bullemer, 1989). Besides, procedural and declarative knowledge types can influence creative thinking (Runco & Chand, 1995). These knowledge forms can be developed through different methods and techniques; or they contribute to the development of different methods and techniques (Drummond at all, 1998; Howe at all, 2000; Kamouri at all, 1986; Johnson & Star, 2007; Kırkhart, 2001; Andre & Ding, 1991).

Procedural understanding (comprehension) is defined as proposing questions about how science is understood through observations and what the observations are; as establishing connections between plans, hypotheses and estimations; and as searching for, collecting and interpreting data (Harlen, 1999, 2000; Harlen & Holroyd, 1995, 1996; Traianou, 2006). Understanding (comprehension) is defined within the framework of cybernetic and mathematical logic as follows: "*Understanding, within the incoming information or data flow, refers to the conceptualization of the integration of the regularities and the cognitive modules that seem relatively independent from each other within the semantic web; and thus being able to decode what is perceived in the semantic memory unit by converting the "procedural knowledge" form into "declarative knowledge" form* (Özenli, 1999, p: A7)".

In this research, students' levels of procedural and declarative knowledge and their success levels in Newton's laws of motion will be determined, and the relationships of these levels with understanding will be examined. The questions of the assessment instrument that will be used in the examination of the relationship between understanding and procedural and declarative knowledge will be divided into variables, and the variables will be divided into stages. Then, "Probability and Possibility Calculation Statistics for Data Variables (VDOIHI) and Statistical Methods for Combined Stage Percentage Calculation (Yılmaz, 2011; Yılmaz&Yalçın, 2011)", which are based on scoring the above-mentioned stages, will be employed. Thus, the data to be obtained from the research and the definition of "understanding" will be correlated.

Material and Method

Data of this research were collected through a qualitative case study from first-year Science Teaching students who were taking the General Physics I Course in the scope of which Newton's laws of motion were taught. In the research, the "integrated single case pattern" was employed. The data were collected using three assessment instruments. The first of them, "The Qualitative Measurement Tool 1 (QMT 1)", consists of eight semi-structured questions that are aimed at measuring students' procedural and declarative knowledge. Procedural knowledge questions cover the subjects of motion with friction force, free fall, angle fire, constant speed motion, centripetal acceleration, accelerated motion and spring force. Declarative knowledge questions, on the other hand, cover the subjects of accelerated motion, spring force, Newton's laws, mass center, centripetal acceleration, gravitational force, potential energy and Kepler's laws.

The questions of the assessment instrument are comparison-oriented rather than asking numerical values. Some of the questions were derived from the literature while some others were formulated by the researcher (Halloun, a all. 1995; Baharestani, 1999, p: 87; Wilson, 2000; Atasoy, 2008; Keleş, 2007). The second one, "The Qualitative Measurement Tool 2 (QMT 2)", consists of physics formulae to be used in the solution of the questions of QMT 1. In other words, QMT 2 is the procedures of QMT 1. It consists of 25 semi-structured questions aimed at assessing whether students know the procedures of QMT 1 or not. The third one, "The Qualitative Measurement Tool 3 (QMT 3)", is composed of 50 semi-structured questions aimed at assessing the basic mathematics knowledge that should be used while answering the questions of QMT 1. 41 of these questions were obtained from a resource in the literature (Haeussler & Paul, 1993; Karakaş, 2001), while the rest were formulated by the researcher.

Data of the research were collected from seven first-year Science Teaching students who took the courses of General Physics I and General Mathematics I in the second semester of the 2009-2010 Academic Year. After informing the first student about the assessment instruments, he was asked to answer QMT 2, QMT 3 and QMT 1, respectively. In the analysis of these data, the software developed for Probability and Possibility Calculation Statistics for Data Variables (VDOIHI) and Statistical Methods for Combined Stage Percentage Calculation (Yılmaz, 2011; Yılmaz&Yalçın, 2011) was employed. Students' procedural and declarative knowledge in Newton's laws of motion was determined with reasons that were likely to influence their knowledge levels, success levels and success scores. Students' knowledge levels were determined through the APS values of the variables of definition, formula and operation.

Since the given-asked variable, research data and free-body diagram variable are variables that would make the solution easier, APS values of these variables were not considered to be knowledge level. Students' success levels were determined through the ASS % value of QMT 1. In addition, students' success levels in QMT 2 and QMT 3 were also determined. Factors influencing success were measured through QMT 2 and QMT 3. The variables influencing success were defined as; a) Given-Asked, b) Free-body diagram, c) Definition, d) Formula and e) Operations. In order to determine the "ASS" influence of the variables on the result of QMT 1; the scores that students obtained from these variables were calculated. By also calculating the possibility of students' scores to influence "ASS" %; their procedural and declarative knowledge in Newton's laws of motion was found.

Findings, Conclusion and Interpretations

Students' success level from procedural and declarative knowledge questions related to Newton's laws of motion was found to be 55%. In this assessment instrument; students' success level from procedural knowledge questions is 66%, and from declarative knowledge questions is 45%. Students' success level in QMT 2 was found to be 57% and in QMT 3 82%. Although students' success level was higher in procedural knowledge questions than in declarative knowledge questions, they were found to be more successful in the procedures of declarative knowledge questions. In other words, students failed to reflect their higher procedural knowledge to their success levels in declarative knowledge. Their knowledge levels are 10%, 41% and 30%, respectively. Since students' success levels are higher than their knowledge levels, it can be stated that their success levels do not represent their knowledge levels. Students' procedural knowledge level is higher than their declarative knowledge level in Newton's laws of motion. It could be argued that there exists a direct proportion between QMT 1 and QMT 2 success levels as they got values close to each other.

The effects of the variables measured through on the result "ASS" are as follows (in Table 1):

It is thought that the students' knowledge in the positive stages of the variable "given-asked" has an effect of 10% on the ASS value. Their unconnected knowledge cannot affect the ASS value (0%). Similarly, their negative knowledge cannot have an influence on the ASS value (0%). Their positive knowledge in negative stages cannot have an influence on the ASS value (0%). It is thought that zero score has an effect of 90% on the ASS value.
It is thought that the students' knowledge in the positive stages of the variable "free-body diagram" has an effect of 6% on the ASS value. Their unconnected knowledge cannot affect the ASS value (0%). Their negative knowledge is thought to affect the ASS value negatively by 9%. Their positive knowledge in the negative stages might have an influence of 3% on the ASS value. It is thought that zero score has an effect of 91% on the ASS value.

It is thought that the students' knowledge in the positive stages of the variable "definition" has an effect of 10% on the ASS value. Their unconnected knowledge cannot affect the ASS value (0%). Similarly, their negative knowledge cannot have an influence on the ASS value (0%). Their positive knowledge in negative stages cannot have an influence on the ASS value (0%). It is thought that zero score has an effect of 40% on the ASS value.
It is thought that the students' knowledge in the positive stages of the variable "formula" has an effect of 41% on the ASS value. Their unconnected knowledge is thought to affect the ASS value negatively by 2%. Their negative knowledge is thought to affect the ASS value negatively by 1%. Their positive knowledge in the negative stages might have an influence of 2% on the ASS value. It is thought that zero score has an effect of 57% on the ASS value.

It is thought that the students' knowledge in the positive stages of the variable "operation" has an effect of 30% on the ASS value. Their unconnected knowledge is thought to affect the ASS value negatively by 23%. Their negative knowledge is thought to affect the ASS value negatively by 8%. Their positive knowledge in the negative stages might have an influence of 5% on the ASS value. It is thought that zero score has an effect of 57% on the ASS value.

The collective effects of the four variables of the questions in the QMT1 on the result are as follows: Their knowledge in the positive stages has an effect of 25% on the ASS value. Their unconnected knowledge is thought to affect the ASS value negatively by 8%. Their negative knowledge is thought to affect the ASS value negatively by 3%. Their positive knowledge in the negative stages might have an influence of 2% on the ASS value. It is thought that zero score has an effect of 70% on the ASS value. Their knowledge about the QMT2 is thought to have an effect of 57% on the ASS value whereas their knowledge about the QMT3 is believed to have an effect of 82% on the ASS value.

Discussion and Suggestions

The APS value of the variable of given-asked is higher in procedural knowledge questions than in declarative knowledge questions. This finding shows that the data was better perceived in procedural knowledge questions. However, this relative finding cannot rule out the fact that the perception has a value of around 10%. Students were unable to perceive the data of questions. Given the fact that they answered the questions with a data perception of 10%, it is impossible to argue that they used knowledge consciously. On the other hand, the reason students scored at the level of 55% (success level "ASS") might be that specific numeric values were not asked in questions. In other words, in questions who had a certain number of possible correct answers, selection of one of these possibilities might have contributed to this result.

These results may also be explained with the idea that students matched the perceived (inadequate) data with memorized data, solved the question to a certain extent and then decided on the answer. In this research, the point to which students were able to take their matches can be taken as the APS value of the operations variable. This value is .30. The overall APS value of five variables is .25. The ASS value of .55 indicates that the role of estimation in students' success levels is very significant.

The fact that QMT 2 values calculated for procedural knowledge questions is close to the APS values of the formula variable shows that students matched data with their memorized knowledge. They failed to do this matching for declarative knowledge questions. It could be argued that the role of the APS value (7%) of the given-asked variable is very high in this finding. Although QMT 3 value was .82; students' lower APS scores in the operations variable than in the formula variable show that they failed to follow procedures different than previous problems. Besides, the higher decrease in the APS value of the declarative knowledge than of the procedural knowledge in these variables might point to the presence of semantic level problems.

Since converting procedural form of knowledge into declarative form can be called understanding based on its definition; it is seen in Table 1 that students' declarative knowledge success level declines by 31% (%66-%45) compared to procedural knowledge success level. This suggests that students experience some problems while converting procedural knowledge into declarative knowledge and they are unable to adequately "understand" Newton's laws of motion due to these problems. Some of these problems are related to the knowledge level. On top of them is the inability to perceive data. In addition, the lower APS value of the variable of operation compared to those of the variables of definition and formula indicates that students experience semantic problems. Another indicator of this problem is the lower knowledge level of declarative knowledge variable of formula when compared to QMT 2 success level. Using the free-body diagram in the restructuration of data by partitioning it into its constituents can positively contribute to restructuration. However, students' procedural knowledge level in this variable is 12% and declarative knowledge level is 0%.

This explains why the sub-units that constitute the data could not be structured. In order to alleviate these problems, firstly, data should be perceived, that is, what is given and what is asked in a question should be taught. This variable does not only constitute data, it also involves the roadmap of the question. The variable of given-asked is a variable where data is perceived and it is partitioned into its constituents. Increasing the knowledge level in this variable will not only improve students' success levels but also enable knowledge and success levels to represent each other. Free-body diagram, formula and operation are the variables where the semantic coordination is established between the constituents of data. In addition, the variable of given-asked plays an important role for the knowledge levels in the variables of free-body diagram, formula and operation to represent one another. By integrating the units who are semantically coordinated at the variable of operation, understanding can be achieved through the conversion of procedural form of knowledge into semantic form of knowledge. Findings of this research indicate that knowledge levels in these variables are low and, thus, Newton's laws of motion could not be understood. To ensure understanding, knowledge levels in these variables should be maximized and IS values need to be minimized. In addition, increasing the success levels of QMT 2 and QMT 3 factors might contribute to the realization of understanding.

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Table 1: Students, scores of variables of QMT1 and achievement levels

Points/ Variable	Given-Asked			Free-Body Diagram			Definition			Formulas			Operations			Sum of Variables		
	Procedural	Declarative	Procedural and Declarative	Procedural	Declarative	Procedural and Declarative	Procedural	Declarative	Procedural and Declarative	Procedural	Declarative	Procedural and Declarative	Procedural	Declarative	Procedural and Declarative	Procedural	Declarative	Procedural and Declarative
P	33,00	2,00	35,00	13,00	0,00	13,00	0,00	90,00	90,00	63,00	58,00	121,00	100,00	30,00	130,00	209,00	180,00	389,00
BGS	350,00	294,00	644,00	147,00	28,00	175,00	0,00	497,00	497,00	147,00	217,00	364,00	273,00	315,00	588,00	917,00	1351,00	2268,00
İS(S)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02	0,02	0,02	0,15	0,30	0,23	0,06	0,08	0,08
APS(S)	0,12	0,07	0,10	0,12	0,00	0,06	0,00	0,21	0,10	0,55	0,27	0,41	0,48	0,12	0,30	0,34	0,16	0,25
ANS(S)	0,00	0,00	0,00	-0,18	0,00	-0,09	0,00	0,00	0,00	-0,01	0,00	-0,01	-0,05	-0,10	-0,08	-0,03	-0,02	-0,03
NAPS(S)	0,00	0,00	0,00	0,05	0,00	0,03	0,00	0,00	0,00	0,02	0,01	0,02	0,07	0,02	0,05	0,03	0,00	0,02
SS(S)	0,88	0,93	0,90	0,81	1,00	0,91	0,00	0,79	0,40	0,43	0,71	0,57	0,40	0,77	0,59	0,58	0,80	0,70
QMT2 S	0,54	0,59	0,57															
QMT3 S	0,82	0,82	0,82															
ASS	0,66	0,45	0,55															