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CROSS-ANALYSIS OF KNOWLEDGE AND SKILLS IN THE PERFORMANCE OF MOROCCAN PUPILS (15-16 YEARS) IN SOLVING ELECTRICITY PROPBLEMS

Ali OUASRI, Ph. D.

Centre Régional des Métiers de l'Education et de la Formation, Madinat Al Irfane, Souissi, BP 6210, Rabat, Maroc.

aouasri@yahoo.fr

Abstract: *This paper aims to cross knowledge and skills in analyzing the performance of Moroccan pupils (15-16 years) of third year classes of college in solving problems of electricity (Ohm's low, electrical power and electrical energy). The analysis of succeeded, failed and untreated tasks by pupils was carried out in terms of declarative, conceptual and procedural knowledge involved in (appropriate, analyze, achieve) skills relating to (1^{st}, 2^{nd}, 3^{rd} degree) skills. For problems built with explicit questions, the pupils showed medium performance in mastering and mobilizing the different skills involving declarative, conceptual and procedural knowledge, whereas pupils find it difficult to mobilize these skills to perform the complex implicit tasks, inherent to an open problem.*

Keywords: *problems solving; skills; appropriate; analyse; achieve; performance; procedure; complex; task; capacity;*

1. Introduction

The training of pupils in college is not limited to the transmission of scientific knowledge; it also aims to develop capacities and skills, which may be transferable from one situation to another, from one disciplinary field to another. Hence, problem solving implies the connection between learners' acquired skills and their ability to mobilize basic skills, thought strategies, and meta-cognitive skills in order to achieve what is asked of them in various situations (Proulx, 1999).

Considered as a cognitive activity serving the completion of a task in a given situation (Richard, 1990; M. Goffard, S. Goffard, 2003), the problem solving marks the transition from elementary activities to higher mental activities and intellectuals processes involving knowledge, which was acquired previously.

Several researches have focused on building of capacity and on improving pupils' performance in problem solving activities (Dumas-Carré et Goffard, 1997; Meltzer, 2005; Orange, 2005; Larkin et Rief, 2007; Ravanis, 2010; Mazouze, 2016; Ouasri, 2017a). These researchs have placed pupils at the center of their preoccupation, in a cognitivist approach of learning, which was used in understanding problem solving acquisition mechanisms (Proulx, 1999).

The analysis of the pupils' difficulties (15-16 years) of third year of Moroccan college in problem solving is carried out in terms of declarative and procedural knowledge, which were mobilized by pupils to perform tasks related to electricity problems (Ouasri, 2017b). The competency approach aims to enable pupils to use their knowledge and skills to solve problem situations (Perrenoud, 1997; Jonnaret 2002; De Ketele and Gerard 2005; Tardif 2006). It is from this perspective that we try to interpret the results obtained in this article containing six parts:

- The problem solving in the Moroccan school context;
- The conceptual framework describing declarative and procedural knowledge involved in solving problems, as well as skills, abilities and tasks.
- The work methodology and the problems submitted to the pupils.
- The two latest parts concern the obtained results, and the analysis and discussion before drawing some conclusions concerning the pupils' performance in solving electricity problems.

2. Context and Problem

Several researches have been carried out on the difficulties of pupils' appropriation of scientific concepts when solving problems in classes (Crahay et Lafontaine, 1986; Goffard, 1994; Rozencwajg, 1997; Giordan, 1998; Malafouse et al, 2001; Orange, 2005; Streveler, 2008; Mazouze, 2011; Ntalakoura et Ravanis, 2014; Mazouze et Lounis, 2015; Ouasri, 2017a, 2017b, 2017c, 2017d, 2017e). These difficulties are usually due to:

- A defective understanding of certain words by pupils the problems' statements;
- A lack of attention, rigor and investment at pupils;
- A lack of prerequisites at many pupils;
- A lack of strategies and logical reflexes among pupils (novices).
- A lack of mental representations of statements at pupils who, afterwards, cannot develop schemes to analyze, and interpret new information (Sweller, 2003).

It is concluded that, in electricity, pupils report particular representations of the electric current as a fluid whose intensity decreases throughout the circuit (Rozencwajg, 1997). In their school itinerary, the pupils who find one of the first functional physical laws, Ohm's law formulated mathematically, have to make an analogy between the proportionality in mathematics and this law in physics. Indeed, Malafouse et al. (2001) have interpreted the pupils' difficulties in terms of the breaking of rationality between mathematics and physics at the level of numbers dimensionality, the concept of proportionality, and the difference in the nature of validation rules.

Researchs have shown that many learners fail to build basic electrical concepts in a coherent framework, which prevents them to acquire a deep conceptual understanding of electricity, and of electrical circuit behavior (Başer et Durmuş, 2010; Başer and Geban, 2007; Glauert, 2009; Gunstone et al., 2009; Hart, 2008; Jaakkola et al., 2011; Streveler et al, 2008). Streveler et al. (2008) argue that conceptual understanding includes both knowledge on quantity (such as current intensity and potential difference) and knowledge of the relationships between these quantities (Ohm's law, for example).

The Ohm's law introduced in Moroccan school education in the third year of college (14-16 years) gives rise not only to experimental activities aiming the construction of electrical circuits, and the measurement of physical quantities (intensity, voltage, power and electrical energy) by pupils, but also to inductive modeling in order to achieve a functional relationship between physical seize, based on experimental results.

The failure of Moroccan pupils in solving electricity problems is obvious, and their performance is therefore not satisfactory. Hence, some questions may be asked on the pupils' difficulties when solving electricity problems. Is the failure in mastering certaines skills due to the non understanding of electrical concepts (conceptual knowledge) by pupils, to the fact that pupils are unable to solve algorithmic problems, and to absence of mental reflections and strategies? Are pupils “novice problem solvers” who have lack of strategies in electric problem-solving?

An empirical research was conducted on Moroccan collegial pupils during problem solving situations in order to study such difficulties that expect pupils to master certain macro-skills (appropriate, analyze and realize) in relation with other skills (1^{st}, 2^{nd}, 3^{rd} degree) involving declarative and procedural knowledge. In this study, the simple and the complex nature of the tasks submitted to pupils will be established.

3. Conceptual framework

During last decades, the teaching-learning has undergone a transformation from a system centred on the transmission of knowledge to "passive" pupils towards a system that favours learning where pupils become actors in the construction of their knowledge; this transformation does not imply a simple opposition between transmission and learning, and thus between knowledge and skills. Hence, a competent pupil is able to think, to mobilize knowledge, to implement appropriate steps to solve a problem or perform a task. Knowledge and skills are therefore inextricably linked to any learning process.

In our previous work (Ouasri, 2016, 2017a, 2017b, 2017c, 2017d, 2018), we are interested in pupils' knowledge in solving problems of physics and chemistry; while the study of skills in problem solving is recently completed (Ouasri, 2017e). In the present study, knowledge and skills will be combined in the analysis of pupils' difficulties in solving electricity problems. The conceptual framework deals with certain skills that could be used by pupils to perform simple or complex tasks inherent to the given problems; but before, it is useful to briefly recall knowledge, especially from the point of view of cognitive psychology.

3.1. Knowledge

The cognitive psychology has been instrumental in understanding the processes involved in the teaching / learning of knowledge in problem solving (Newell and Simon 1972, Gagné 1985, Glover et al 1990). Knowledge is acquired through a process of three distinct stages: the encoding of declarative knowledge, the proceduralisation of procedural knowledge and the composition or organization (Neves and Anderson, 1981). The procedural knowledge is built over three non-discrete steps, which characterize different moments in evolution of qualitative skills (Anderson, 1983, 1995):

- The cognitive step: the learner identify the needed information to solve problems by following instructions, applying problem-solving operators, and using analogies between declarative knowledge and anterior behaviours.
- The associative step: the declarative representation is transformed into a procedural one, and errors characterizing the cognitive steps are detected and eliminated. The transformation ability, made with little errors, becomes better coordinated and faster.
- The autonomous step: is a step where adjustment and refinement of productions occur.

The ability becomes more automated, faster, and involves little cognitive intervention.

According to Anderson, a skill building is a cumulative process in which pupils should acquire knowledge and be able to apply the right skills according to the situation they would have to deal with. The selection of the right knowledge depends on an activation process that reflects the frequency of success of a skill in a particular context. Frederiksen and White (1989) proposed a mode of instruction based on decomposition of a task into sub-goals, and on the setting up of situations that allows acquiring progressively the skills related to these sub-goals. These authors showed that learners undergoing this training were more successful in completing tasks than others who completed tasks directly.

3.2. Capacities and skills

The notion of capacity is inherent to the skill one, which is considered as the ability to use know-how in such situation. The definition of capacity is not dependent of the skill definition, and this implies such difficulties to distinguish the two concepts. Educational institutions use frequently the skill word linked with ability. Meirieu (1988) has defined the capacity as a stabilized and reproducible intellectual activity in various knowledge fields, and the skill as an identified knowledge involving one or more abilities in a notional or a disciplinary field. This suggests that skill is an appropriate combination of different abilities in such situation. Gillet (1991) means by capacity the hypotheses that he forms on what students must develop through learning, and that they will be able to express in situations others than those involving skills.

Hence, a skill is considered as a set of potential behaviours (cognitive, affective and psychomotor), which allows a person to perform a “complex” activity. Linked to a professional or a social situation of reference, a skill includes knowledge, expertise, and know-how. In cognitive terminology, a skill involves simultaneously declarative, conceptual and procedural knowledge, and attitudes, which constitute together a powerful combination at “the expert” level. The terms of skill and capacity are therefore not synonymous. In problem-solving, a skill refers to an individual ability, which would be engaged in cognitive processing to understand, and solve problems without an obvious solution method; the ability includes individual willingness that could be engaged in a situation to exploit his potential as a constructive and thoughtful citizen.

In pedagogy, the problem-solving is similar to a complex task whose solving leads learners to use internal resources (knowledge, skills...) and external resources (documents, help methodologies, protocols, research...). The completion of a task requires learners to master various skills and capacities; the table 1 illustrates some macro-skills and associated capacities (Noirfalise and Porte, 1990).

Table 1: Some (appropriate, analyze and achieve) skills, and associated capacities

Skill	Examples of associated capacities
Appropriate the problem (Extract and use wise information)	- Make a model sheme. - Identify the relevant physical quantities, assign them a symbol. - Evaluate quantitatively unknown and unspecified physical quantities. - Relate the problem to a known model situation.
Analyze (Establish a solving strategy)	- Break down the problem into simpler tasks. - Start with a simplified version. - Explicit the chosen modeling (system definition, etc ...). - Identify and enunciate the physical laws that will be used.
Achieve (Implement the strategy)	- Lead the process to the end to explicitly answer the question. - To be able to efficiently carry out analytical calculations and numerical translation. - Use dimensionnel analysis.

When a learner is confronted to a specific question in problem solving, he is led to:

- Articulate the data inherent to the personal experience, to knowledge and to documents. Useful data are not provided by a statement, but can be grouped together at the beginning or the end of the problem-solving activity; there may be missing data that learners would identify, and estimate their value (appropriate and analyze skills).
- Schematize, identify and name quantities, mobilize relevant physical models, to do previsions and/or provide arguments (appropriate and analyze skills).
- Build and implement a strategy that can use experience (analyze and achieve skills).

3.3. Tasks and skills

A simple task mobilizes only one capacity, and leads to verify the acquisition of procedures or "know-how". Hence, the question implies explicitly the domain in which the task would be realized. The restitution of knowledge is a part of a simple task. Solving complex task did not correspond to application of an automated procedure by pupils, but requires pupils to develop a strategy, and to implement combination of simple, automated, and known procedures, in the way that each pupil can adopt an individual approach to solve the complex task. The task's complexity is liked to others characteristic elements of a task. The transfer of register (moving from a curve to a numerical value, and to a qualitative interpretation, etc.) can be assigned to a question of complex character.

In addition, the task level difficulty has four sub-levels, and depends on the of the pupils' familiarization level with the reasoning. These levels may be described as:

- Level 1: almost non-existent reasoning (simple extraction of information);
- Level 2: reasoning poorly elaborated (direct application of a law, etc.);
- Level 3: reasoning moderately elaborated, in stages with moderate place of formalism;
- Level 4: reasoning elaborated with several parameters, possibly dedicated formalism.

On the other hand, the process on which pupils relies to answer the question can be described in different types of registers:

- Register 1: qualitative reasoning;
- Register 2: literal computation including manipulation of literal expression, dimensional analysis, etc ...;
- Register 3: quantitative reasoning including numerical application, evaluation of a seize order, drawing of a graph or a trajectory, extraction of slope coordinates, etc ...;
- Register 4: symbolic schematization referring for example to the scheme, experimental device, electrical circuit, etc...

Pupils encounter generally difficulties in solving complex tasks. Rey et al. (2003) defined explicitly the task as a human action with purpose and utility. Accordingly, the task can be reduced to an action or extended to a combination of actions, but it differs from the behaviour by its purpose perceived by the subject, which constitutes its unity. Rey et al. (2003) highlight three situations corresponding to three levels of a skill:

- Procedures: Procedural issues involving knowledge and automated rules.

-Elementary skill with framing is used when, faced to novel tasks, necessarily contextualized, a pupil must choose an appropriate procedure; such situation requires interpretation by the pupil.

- Complex skill is necessary to accomplish complex tasks as new situations requiring choice and combination of several procedures. The pupil must invent the solving process that is not given in instructions; the pupil has to perform an interpretation of the situation that determines his solving approach.

According to Rey et al (2003), a skill is considered as know-how to effectively perform a task, i.e. an action having a purpose; so a skill has three degrees:

- 1st degree skill: Know-how to perform an action in response to a preset signal, after training. This is the elementary skill or procedure;

-2nd degree skill: Know-how to choose from known procedures the appropriate one to a situation or to an unknown task. This is a basic skill with interpretation of the situation (elementary skill with framing).

- 3rd degree skill: Know, among the known procedures, to choose and combine those suitable for an unknown or complex situation or task. This is the complex skill.

Two conditions are necessary to solve complex problems (Rey et al. 2003): the mastery of required procedures to solve tasks, and the ability to determine the relevant traits, needed to solve the purposed task; this last condition refers to the framing.

4. Methodology

This study aims to analyze knowledge and skills of Moroccan pupils of third year classes of college in electricity problem solving. To do this, the pupils' productions are analyzed by dividing each question of the problems into tasks that would be carried out by these pupils; and then counting responses obtained in terms of successful, failed and untreated tasks (Tables 2-4). The tasks are identified and constructed by breaking down the questions of the problems 1 and 2, 3 submitted to pupils (Appendix); this makes it possible to analyze blockages and errors encountered by pupils during problem solving activities. It is to note that the breaking tasks were not submitted to pupils; they used only in developing analysis. The tasks' analysis is carried out in terms of knowledge (declarative, conceptual and procedural) in relation to the skills (appropriate, analyze, realize) skills, illustrated in Table 1 (Noirfalise & Porte, 1990) and (1st, 2nd and 3rd degree) skills that could be mobilized by pupils to complete these tasks. The methodology adopted here consists in defining the target population, the methods of investigation and the instruments of data collection.

4.1. Target population

The present study is realized on target population containing 166 pupils (15-16 years) of six classes of third year of college, in two colleges of

Temara city (Al Khawarizmi and Ibn Batouta colleges). The classes' pupils take advantage of 4 hours of physical sciences courses per week (two sessions of two hours). As in all Moroccan colleges, a weekly program of continuous teaching, from 8 h at 6 h, with a pause of two hours from 12:00 to 14:00 h, is adopted within these colleges. This population (common curriculum year) is chosen based on the fact that problem-solving activities are important for pupils at this grade in both continuous assessments and the year-end examination that allow these pupils to proceed to the first year of high schools. The acquisition of certain skills by pupils of this age in solving physical problems is another motivation for the choice of this population.

4.2. Investigation method and instruments

The analysis of pupils' written productions when solving electricity problems is made in terms of successful, failed and untreated tasks, accordingly to knowledge and skills that enable pupils to perform these tasks. To do this, we constructed analysis grids (tables 2-4) according to a constructivist approach that consider the questions of problems 1, 2, 3 (Appendix), which reflect the integral part of the third year program of the Moroccan college, concerning Ohm's law, electrical power and electrical energy, respectively.

In tasks' analysis, we identify the competency (s) mobilized (appropriate, analyze, realize) displayed in Table 1. In addition to this, the identification of declarative and procedural knowledge those are necessary to carry out these tasks is carried out. This makes it possible to study the mastery of the skills by the pupils who are confronted with the different difficulties during the resolution of problems.

5. Results

We have decomposed the pupils' productions into simple units, i.e. into tasks (T1, T2,...) to be performed in solving electric problems. Next, we assigned to each task knowledge and skill (s) that pupils should master and mobilize to complete this task. Hence, the tasks' analysis results are given in Table 2 for problem 1, Table 3 for problem 2, and Table 4 for problem 3.

Table 2: Results of problem 1: Ohm's Low study (DK: declarative knowledge, PK: procedural knowledge, Ap: appropriate, An: Analyze, Ac: achieve, Suc: successeded, Fai: failed, Unt: untreated.

Q	Tasks to be realized	Knowledge		Skills			Suc	Fai	Unt
		DK	PK	Ap	An	Ac			
1	**T1:** Rewrite clearly the problem's goal	*	*	+	+		20	22	118
	T2: Give the relationship between the generator voltage and the diode voltage	*		+			20	22	118
	T3: Calculate the voltage		*		+		20	22	118
	T4: Give the Ohm's low	*		+			150	6	4
	T5: Deduce the relationship of the resistor R		*		+		140	16	4
	T6: Choose the good value of the voltage	*	*	+	+		16	26	118
	T7: Calculate the resistor value		*		+	+	16	26	118
	T8: Choose among the purposed resistors one to be sued.	*	*	+	+	+	8	34	118

Table 3: Results of problem 2: Electric power study

Q	Tasks to be realized	Knowledge		Skills			Suc	Fai	Unt
		DK	PK	Ap	An	Ac			
1	**T1:** Give the relationship between P, I, U	*		+			150	8	2
	T2: Deduce I as function of P et U		*		+		140	18	2
	T3: Convert units accordingly to the international system	*	*	+	+		120	36	4
	T4: Calculate the current intensity that crosses the installation.		*		+	+	118	38	4
2	**T5:** Give the relationship between U, I, P	*		+			150	8	2
	T6: Calculate the maximal power of the installation		*		+	+	138	12	10
	T7: Give the relationship between the power and the total power	*	*	+	+		142	8	10

3.1	**T8:** Convert units accordingly to the international system	*	*	+	+		136	14	10
	T9: Calculate the total power		*		+	+	130	20	10
3.2	**T10:** Give the power of the Iron	*		+			146	4	10
	T11: Add the power of the iron to the relationship between the total power and the power of each device		*		+		142	8	10
	T12: Calculate the total electric power of the installation		*			+	138	12	10
	T13: Give the relationship between the maximal and the total powers	*	*	+	+		122	28	10
	T14: Deduce if you can also use an iron		*		+	+	122	28	10

Table 4: Results of problem 3: Electric energy study

Q	Tasks to be realized	Knowledge		Skills			Suc	Fai	Unt
		DK	PK	Ap	An	Ac			
1	**T1:** Establish the relationship between energy E, the cost of the kilowatt hour Cw and the total cost C	*	*	+	+		130	24	6
	T2: Deduce the expression of energy E		*		+		126	28	6
	T3: Calculate the energy E		*			+	120	34	6
2	**T4:** Give the relationship between energy E, total power P_t and times t	*		+			128	24	8
	T5: Deduce the expression of the total power		*		+		122	30	8
	T6: Calculate the total power		*			+	120	32	8
3	**T7:** Write the number of garlands		*		+		90	42	28
	T8: Write the number of bulbs in each garland		*		+		90	42	28
	T9: Deduce the total number of bulbs		*		+		90	42	28
	T10: Give the relationship between the number of bulbs, the total power P_t and power of each bulb P		*		+		74	52	34
	T11: Calculate the power of each bulb		*			+	74	52	34
4	**T12:** Explain as a sentence the procedure to follow	*	*	+	+		96	24	40
	T13: Convert weeks to days	*	*	+	+		90	30	40
	T14: Establish the relationship between cost and duration of a single day with cost and duration of three weeks	*	*	+	+		82	38	40
	T15: Deduct the amount paid by the family		*		+	+	78	42	40

6. Analysis and discussion

The analysis of the results consists of counting the successful, failed and untreated tasks from the pupils' written problem-solving work, then identifying these tasks according to whether their answer requires declarative, procedural knowledge in relation to the skills (appropriate, analyze, achieve) and those named (1^{st}, 2^{nd} and 3^{rd} degree) skills. It is important to correlate the macro-skills as identified by Noirfalise and Porte (1990) with those determined by Rey et al. (2003) as skills of three degree. In this analysis, we admit the following correlation: (appropriate $\rightarrow$ 1^{st} degree skill, analyze $\rightarrow$ 2^{nd} degree skill, and achieve $\rightarrow$ 3^{rd} degree skill). To better analyze the tasks, we transformed the data in Tables (2-4) into graphs (Figures 1-3) using the Excel software.

6.1. Analysis in terms of tasks

We admit on the one hand the correlations between declarative knowledge and (appropriate) skill, and on the other hand between procedural knowledge and (analyze and achieve) skills. Then, we identify the skills in relation with the simplicity or the complexity of the tasks to be carried out, i.e. we carry out an analysis in terms of skills of 1^{st}, 2^{nd} and 3^{rd} degrees, based on what is described in the conceptual framework.

6.1.1. ***Problem 1: Skills related to the*** *Ohm's Low*

The percentage representation (%) of pupils that succeeded, failed and did not treat the tasks of the problem 1 concerning the Ohm's Low is given in Figure 1. This problem contains only one open question whose resolution requires pupils to complete eight tasks that involve certain knowledge and skills.

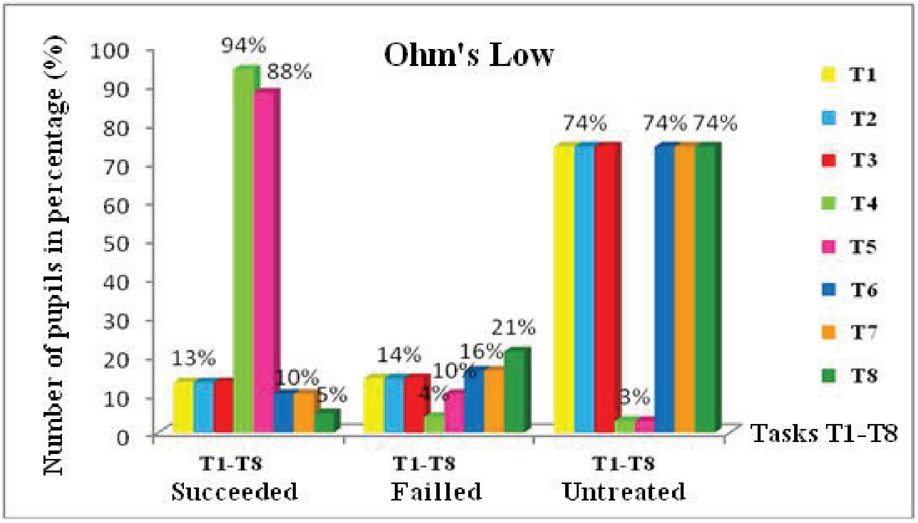

Figure 1. Performance of pupils in realizing tasks related to apprehension and application of Ohm's Low (problem 1).

The first three T1-T3 tasks were succeeded with a low score, 12.5% (20 pupils from 160); this shows that the majority of pupils could not apprehend and calculate the difference between the generator voltage and that of the diode. Failure in these relatively complex tasks implies that pupils, at this grade level, have difficulties either to mobilize knowledge and procedures (1st degree skill), but also elementary skills "procedures with framing" (2nd degree skill), which could be mobilized when, faced with an unprecedented task, necessarily contextualized, the pupils must choose the appropriate procedure.

The Task T4 succeeded at 94% (pupils) mobilizes only (appropriate) pupils' skill, i.e. declarative knowledge of Ohm's law; this skill refers to procedures (1st degree skill). The T5 task completed at 89% (140 pupils) requires pupils to mobilizes their (analyze) skill; this elementary skill considered as of 2nd degree refers to elementary skill named "procedures with framing", i.e. a procedural knowledge that allows deducing the resistor from the application of Ohm's law.

The T6-T8 tasks completed at 10% (16 pupils), 10% and 5% (8 pupils), respectively, aim to calculate and choose among the purposed resistors the one to be used, based on a clear choice of the good value of the voltage. Task T6 requires pupils to mobilize (appropriate and analyze) skills involving declarative and procedural knowledge about the choice of a voltage; these skills refer to procedures (1st degree skill) and procedures with framing (elementary skill of the 2nd degree). The task T7 requires the mobilization of procedural knowledge, i.e. the mastery of the (analyze and achieve) skills that refer to the skills of the 2nd skills (procedures with framing) and 3rd degree skills (complex skills). The success of the task T8, assumed to be complex, requires pupils to master elementary and complex skills. To accomplish the complex tasks, pupils should make a choice and a combination of several procedures. The failure in these three complex tasks, in particular T8 task, shows that pupils at this level of education find it difficult to mobilize not only knowledge, but also the complex skills which (of 3rd degree), which consists in knowing how to choose and to combine, among known procedures, those suitable for an unknown and complex task.

6.1.2. Problem 2: Skills related to electric power

The percentage representation (%) of pupils that succeeded, failed and did not treat the tasks of the problem 2 concerning the electrical power is given in Figure 2. This problem contains four questions whose resolution requires pupils to realize 14 tasks that involve certain knowledge and skills on electric power.

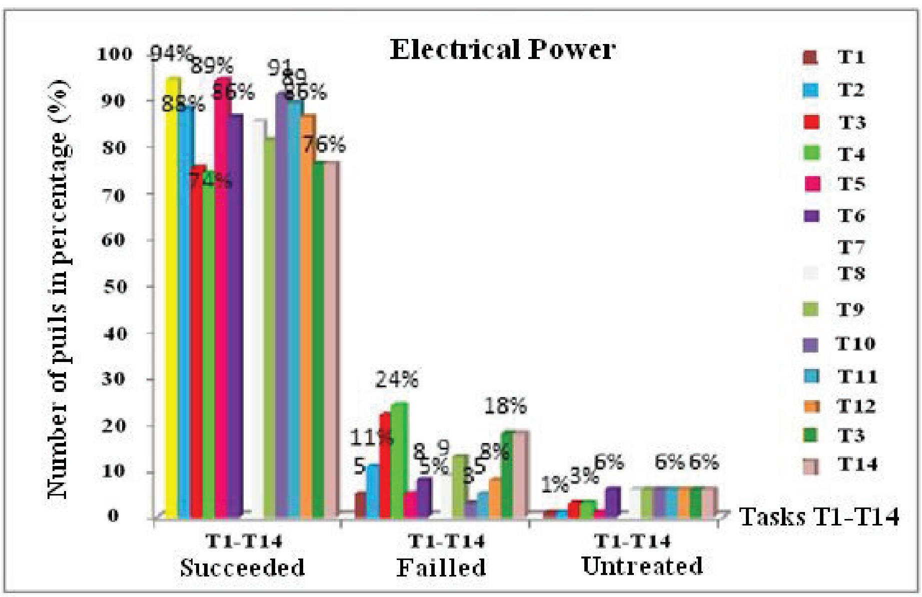

Figure 2: Performance of pupils in realizing tasks related to apprehension and application of electric power (problem 2).

The first question 1 corresponds to four tasks that aimed to calculate the intensity of the current flowing through the installation by applying the relationship between P, I and U; these tasks were succeeded at 94% (150 pupils), 88% (140 pupils), 75% (120 pupils) and 74% (118 pupils) respectively. The T1 task completed with a higher score require the pupils to mobilize (appropriate) skill corresponding to a declarative knowledge about the relationship between P, I and U. The T2 task realized also with a high score mobilizes at pupils (appropriate and analyze) skills in relation to declarative and procedural knowledge allowing to express the current I as a function of P and U. The T3 and T4 tasks completed with comparable and relatively high scores require pupils to master (appropriate, analyze, realize) skills, with declarative and procedural knowledge concerning as well as the conversion of units into accordingly to the international system and the numerical calculation of the intensity of the current flowing through the installation. For T1-T4 considered as simple tasks, it can be said that the majority of pupils (74-94%) were able to mobilize successfully procedures (1^{st} degree skills) and procedures with framing (elementary skills referring to 2^{nd} degree skills) to complete these simple tasks, which do not require enough thought and strategy to be successful.

The second question contains T5 and T6 tasks that were succeeded at 94% (150 pupils) and 86% (138 pupils), respectively. These scores are comparable to those achieved in similar T1 and T2 tasks that required pupils to master and mobilize the same knowledge and skills.

The T7-T9 tasks of question 3, were completed with high scores 89% (142 pupils), 85% (136 pupils) and 81% (130 pupils), respectively. These tasks aim to calculate the total power by applying the relationship between power and total power. The task T7 requires students to master declarative and procedural knowledge on the relationship between power and total power; the high success score of this simple task implies that the majority of pupils master the (appropriate, analyze) skills, i.e. the 1^{st} degree skills (procedures) involving declarative knowledge, and basic skills of 2^{nd} degree (procedures with framing) referring to procedural knowledge. The T8 and T9 tasks completed also with relatively high scores mobilize (appropriate, analyze, perform) pupils' skills that are based on declarative and procedural knowledge about the conversion of units accordingly with the international system, and about the numerical calculation of total power. Hence, we can said that the majority pupils have been able to mobilize successfully first-level and second-level skills in order to carry out these simple tasks, which do not require enough thought and strategy to be successful.

The question 3.2 corresponds to T10-T14 tasks that have been succeeded with high scores 91% (146 pupils), 89% (142 pupils), 86% (138 pupils), 76% (122 pupils) and 76% (122 pupils), respectively. These tasks are intended to determine whether the subscriber who operates an electric oven (230V-44kW), two radiators (230V-900W), and four incandescent lamps (230V-100W) may additionally use an iron (230V-1000W). The Task T10 evokes a declarative knowledge about the meaning of the iron indices

(V, W), which explains the important score of its realization. The successful completion of other tasks requires pupils to appropriate declarative and procedural knowledge on calculation of total power, and on its comparison with the maximal power in ordre to deduce whether the iron could be added. The high success scores of these tasks implies that the majority of the pupils master as well as (appropriate) skills considered as the 1st degree skills, and (analyze, realize) skills that refer to elementary skills of 2nd degree (procedures with framing) and to 3rd degree (complex skills), respectively. Achieving these tasks implies that pupils master analysis, comparison, deduction, and calculation the skills that allow them to develop strategies and logical thinking when solving problems on electrical power and its use in their daily life.

6.1.3. Problem 3: Skills related to electric energy

The percentage representation (%) of pupils that succeeded, failed and did not treat the tasks of the problem 3 concerning the electrical energy is given in Figure 3. This problem contains four questions whose resolution requires pupils to realize 15 tasks that involve certain knowledge and skills on electric energy

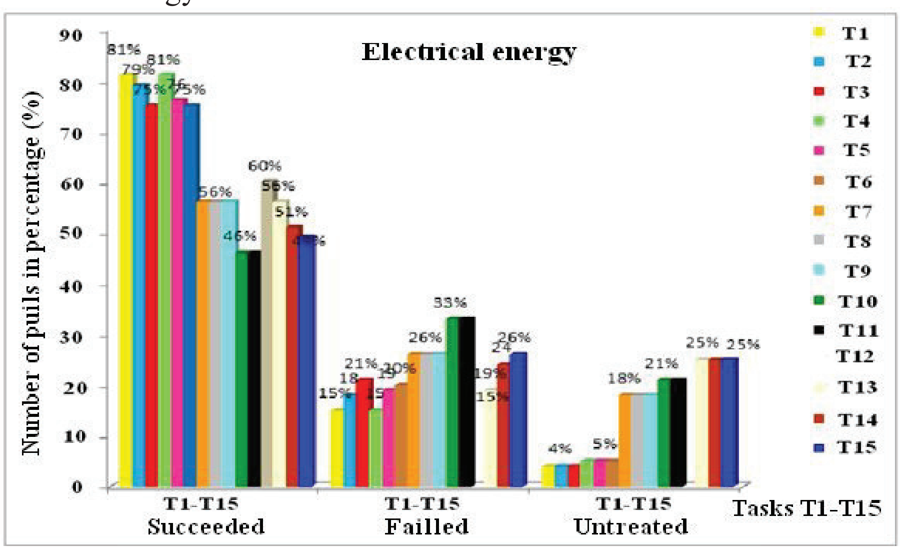

Figure 3: Performance of pupils in realizing tasks related to apprehension and application of electric energy (problem 3).

The first question involves T1-T3 tasks that were succeeded with relatively high scores, 81% (130 pupils), 79% (126 pupils), and 75% (120 pupils) respectively. The success of these tasks requires pupils to master (appropriate, analyze and achieve) skills involving declarative and procedural knowledge, which allow them to calculate the energy E by establishing the relation between the energy E, the cost of the kilowatt hour Cw and the total cost C. The high success score observed for these tasks considered as relatively simples means that most pupils do not have difficulties in performing these tasks, and then mastering procedures skills of 1st degree, elementary skills (procedures with framing) of 2nd degree, and complex skills of 3rd degree.

Tasks T4-T6 (second question) were succeeded with relatively high scores: 77% (122 pupils), 75% (120 pupils), and 75% (120 pupils), respectively. Hence, the pupils do not have difficulties in mastering the different skills (appropriate, analyze and achieve) based on declarative and procedural knowledge allowing to deduce and calculate the total power by using the relation between the energy E, the total power Pt and the time t. It is to note that these pupils master skills of different degree.

Question 3, which aims to calculate the power of each bulb, refers to five procedural tasks among them T7-T9 are succeeded at 56% (90 pupils), and T10-T11 at 46% (74 pupils). Hence, about the half of pupils are found to have difficulty in mastering the (analyze) skills to use the problem data to deduce the relationship between the number of bulbs, the total power Pt and that of each bulb P, and also (achieve) skills to perform the numerical calculation of the power of each bulb. For these tasks, only half of pupils master elementary skills (of2nd degree) and complex skills of 3rd degree.

Question 4 corresponds to four tasks (T12-T15) succeeded at 60% (96 pupils), 56% (90 pupils), 51% (82 pupils), and 49% (78 pupils), respectively. These tasks aimed to determine the cost disbursed by the family to use all bulbs for three weeks; this may done by establishing a relationship between the cost and the duration of a single day with the cost and duration of three weeks. To complete these tasks, pupils are required to master (appropriate, analyze and achieve) skills, which involve declarative and procedural knowledge. The achievement scores of these tasks imply that about half of the pupils master skills of 1st degree (procedures), elementary skills of 2nd degree (procedures with framing), and complex skills of third degree.

6.2. Knowledge and skills analysis

In this part, we analyze the success of pupils in solving tasks, which depends on their ability to mobilize knowledge and (appropriate, analyze and achieve) skills that pupils have to master in solving electrical problems, with recourse to associated capacities (Noirfalise & Porte, 1990). Table 5 shows the total number of skills assigned to various tasks inherent to the three problems, the average number of pupils mastering each skill, and the average percentage of the skills' success. The analysis is developped based on the skills' categories as have been defined by Rey et al. (2003).

The three problems (Appendix) contain 37 tasks, identified in Tables 2-4. Among the total tasks, 17 are considered as tasks requiring pupils to master appropriate skills, 27 as tasks corresponding to analyze skills, and 11 as tasks that are related to achieve skills. It is to note that only succeeded tasks were considered in the presented results. The representation of the results is given in Figure 4.

Table 5: Average percentage of success of (appropriate, analyse and achieve) skills inherent to purposed electrical problems

Skills	Total number of skills	Average number of pupils mastering skills	Average percentage of mastering skills (%)
Appropriate	17	100.35	62.72
Analyse	27	96.22	60.14
Achieve	11	97.46	60.91

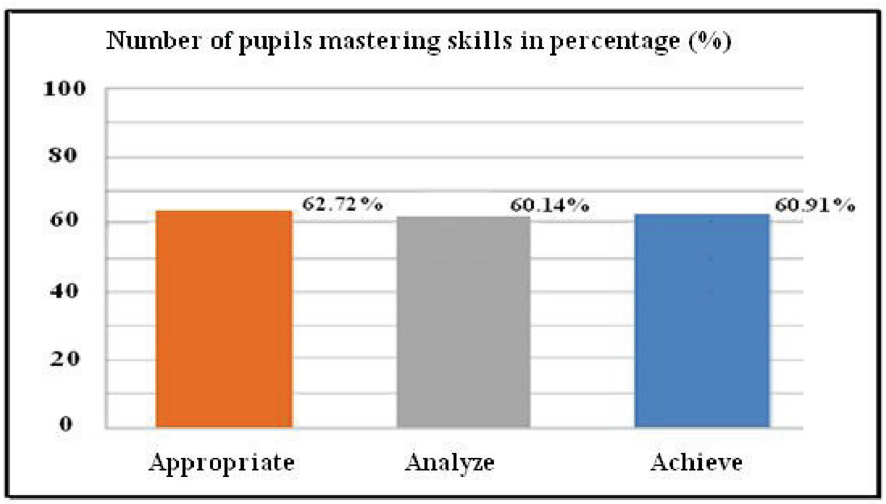

Figure 4: Representation of pupils mastering different skills in terms of percentage (%).

The results show that 17 (appropriate), 27 (analyze) and 11 (achieve) skills were successfully mobilized by pupils to success completely the various tasks related to the three purposed problems. Hence, the pupils have succeeded appropriate skills at an average score of 62.72% (100.35/160), analyze skills at 60.14% (96.22/160), and achieve skills at 60.91% (97.46/160).

Except the problem 1 containing only one open question with implicit tasks, considered as complex as has been indicated from the success percentage of implicit tasks, the two other problems are considered as simple, since they are constructed of questions, which enable the pupils to realize tasks during problem solving. Considering the simplicity or complexity of tasks, we consider that pupils' performance in solving these problems is medium, and not enough satisfactory. Validation percentages show that pupils are more proficient in appropriate skills than in analyze and perform skills during solving electrical problems; this result seems to be provided and normal.

Taking into account the validation percentages, we find that more than half of the pupils were able to master:

- Appropriate skills and certains associated capacities, by making a model sheme of problem solving, identifying the physical quantities with their symbol, and thus connecting the problem to a known model situation.
- Analyze skills with associated capacities, by decomposing the problem into simple tasks, explaining the chosen modeling (system definition ...), and enunciating the physical laws that could be used. Hence, these pupils seem to have reasoning attitudes that allow them to build problem-solving strategies.
- Achieve skills and associated capacities, by developing an approach that leads to answer explicitly the asked questions, and by carrying out efficiently analytical and numerical calculations.

Considering the macro-skills as identified by Noirfalise and Porte (1990), and skills of three degree as determined by Rey et al. (2003), and based on the purposed correlation: (appropriate $\rightarrow$ 1st degree skill, analyze $\rightarrow$ 2nd degree skill, and achieve $\rightarrow$ 3rd degree skill), one can conclude that more than half of the pupils were able to master:

- 1st degree skills, as elementary skills involving knowledge (declarative and conceptual knowledge), and automated rules in electrical problem-solving.
- 2nd degree skills, as elementary skills with interpretation, which allow pupils to choose an appropriate procedure (procedural knowledge) to solve electrical problems.
- 3rd degree skills, i.e. complex skills needed to accomplish complex tasks, which enable pupils to do choice and combination of several procedures to solve complex tasks considered as new situations for pupils

In the end, we can say that several pupils have failed to master the studied skills. This implies these pupils encounter difficulties, errors and blockages in performing certain tasks related to the purposed problems, especially the complex tasks of problem 1 which involves skills considered of second and third degree. The results' analysis reveals a decreasing in percentage of pupils achieving relatively complex tasks, at the end of problems, which require combination between strong base of knowledge and strong base of skills

The validation of a skill cannot be done only by mastering declarative and procedural knowledge (procedural, framing procedures: 2^{nd} degree skills). This implies a mastering level of a capacity in a particular context of the class. Considering the relationship between knowledge, abilities and attitudes, a skill is conceived in the tasks' complexity, as in the case of the problem 1, where the majority of pupils cannot realize these tasks with success; this can be explained by different reasons such as:

- Understanding lack of physical language, and concepts (conceptual understanding), difficulties to exploit laws and physics principles, etc...
- Lack of mental representations or the inability to develop schemes, which enhance pupils to solve electrical problems (procedural knowledge). Several pupils did not categorize some implicit tasks to elaborate the appropriate scheme that would allow them to complete successfully the complex tasks.
- Lack of strategies and logical reflexes (algorithms) that enhance pupils to organize and arrange declarative, conceptual and procedural knowledge in logical way to answer asked questions.

7. Conclusions

This study aims to cross analysis in terms of the knowledge and skills mobilized by the Moroccan pupils (15-16 years) of the second year of the college during the activities of solving electricity problems. Methodologically, the written productions of novice problems solvers learners, which have been administered to problem solving activities, were analyzed and discussed. The analysis focuses on knowledge and skills that could master the pupils to perform various tasks in solving electricity problems involving Ohm's Law, electrical power, and electrical power.

The pupils' difficulties were discussed in terms of appropriate, analyze and achieve skills (First, second and third skills degree) that pupils could master to complete implicit tasks of the purposed electrical problems. Generally, pupils were found to be able to mobilize appropriate skills more than (analyze and achieve) ones, and to have difficulties to perform tasks considered as complex at the end of problems.

For the first open problem containing one question with implicit complex tasks, pupils encounter difficulties to complete these tasks, as has been shown by a clear decrease in the number of pupils validating the different skills. For the other two problems built with explicit questions, pupils have relatively succeeded to mobilize skills (appropriate, analyze and achieve) skills, i.e. (1^{st}, 2^{nd} and 3^{rd} degree) skills involving declarative, conceptual and procedural knowledge.

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Appendix

Problem 1

A woman has several electrical devices: an LED whose operating voltage is 2V, a DC generator of 6V, and three resistors of 330Ω, 220Ω, and 180Ω. Knowing that the intensity of the current passing through the diode is 20mA; can you help this woman so that she can choose from the three resistors, the one that can be used with the diode?

Problem 2

An electrical installation has a circuit breaker calibrated at 30A. It operates under 230V voltage.
1. The power fixed by a subscriber is 6kW. How much intensity can he have?
2. How much power does the subscriber really have in his installation with the circuit breaker calibration?
3. The subscriber operates at the same time an electric oven (230V- 44kW), two radiators (230V-900W), and four incandescent lamps (230V-100W).
3.1. What power does he use?
3.2. Can he also use an iron (230V-1000W)? Justify your answer.

Problem 3

A family wants to decorate the outside of their home with two garlands of 160 bulbs each; it costs him 35 DH (1USD = 10DH) per day for 4 hours of daily operation.
1) Calculate the energy transformed by the lamps each day. The price per kilowatt hour is 1.5 DH.
2) Deduce the power transformed by the all the lamps.
3) Calculate the power of a lamp assuming that all lamps are identical.
4) How much will this family have paid for this lighting if it decorates his house for 3 weeks?