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The rubric as an assessment tool for solving problem situations in the physics and mathematics teaching context

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Abstract. Polya propose the didactic problem-solving strategy to strengthen the teaching and learning processes in the mathematic field. Thus, this strategy can be applied in other fields such as physics teaching the article proposes an evaluation strategy based on the design of a rubric to assess the processes associated with solving mathematical problems, as a classroom research work based on Research, Pedagogical Action. As one of the results, an analytical rubric composed of criteria and indicators associated with the steps of Polya problem solving is proposed, as well as a reflection associated with the teaching of problem solving in the engineering area.

1. Introduction

When approaching the evaluative process in the field of educational sciences, it directly implies recognizing the relationship that this dimension has with other categories of the formative process [1]. Precisely, reference is made to the critical construction of the curriculum [2], specifically the physics curriculum [3].

The above, leads teachers, in this case, in the field of mathematics, to think from this transversal perspective, the teaching and learning processes of mathematics [4], where pedagogical and didactic reflection [5], reveals that curricular framework between what the management of evaluation implies from the recognition of that relationship that the formation and application of mathematics has in sciences such as physics and engineering [6].

Now, within the elements that should be formed in the teaching of mathematics, physics, and others natural sciences it is indeed the ability of students to pose and solve problems [7], which could be presented in various contexts, for example, in contexts of other sciences or in contexts of real-world problem situations related to physics. In this sense, problem situations are seen as an opportunity to develop not only mathematical thinking skills in students, but it is a strategy that allows them to develop critical and autonomous thinking and motivate them, based on their own self-regulation of learning, they can advance in the development of thinking and learning specially in the physics teaching field [3].

From this logic, one of the didactic methods most used nowadays for the formation and teaching of problem solving in physics and mathematics is precisely the one proposed by [3,8,9], which, for our case, has been used in the physics and mathematics courses aimed at students of our engineering faculty. It is necessary to highlight the incorporation of the Polya methodology in the physics didactic for solving physics problems seeking the consolidation of critical and scientific thinking in students of both physics and mathematics courses at our engineering faculty [3,9].

Obviously, in the field of teaching, regardless of the didactic strategy applied to mediate learning, one must always think from classroom management, assessment. Thus, these strategies or tools for the evaluation used in the teaching process of mathematics, should be a point of concretion from the work of physics and mathematics didactics developed by teachers, which will depend, on the one hand, on knowledge wise or disciplinary and, on the other hand, pedagogical knowledge, the latter, will depend mainly on the conceptions that teachers have [10] about the curriculum, pedagogy, didactics and naturally, the applied evaluation.

From this context, it is important to recognize, not only the theories or approaches that educational evaluation has, but it is also important to recognize the dimensions, typologies, strategies, and tools that enable the management of evaluation in the classroom [11]. In this way, the article proposes an evaluation strategy based on the design of the rubric for the assessment of the processes of solving physics problems constructed by university students.

Independently of the application context, the rubric as an evaluative strategy is an evaluation matrix that allows addressing and strengthening formative evaluation in students [12], in which some of its purposes are to carry out transparent evaluations, increase the degree of objective of the evaluation and significantly decrease the subjective degree of the evaluative process. The rubrics can be holistic or analytical [13], the first does not define criteria but rather make a general assessment of the competence or learning result to be evaluated, while the second allows to detail elements such as: the criteria , the indicators and the level of assessment or scale applied [14], establishing a detailed monitoring of the evidenced learning of the students [15], as well as, they are a fundamental tool to develop feedback processes to the students regarding the results obtained, in this case, in problem solving in mathematical wave contexts. It is necessary to point out that in the already published article [16] an analytical rubric was presented to evaluate the processes of mathematical argumentation in the classroom, while this article shows a proposed rubric for the evaluation of problem solving both in teaching of physics as of mathematics.

2. Methodology

The study was based on the critical paradigm of education, specifically in the qualitative approach, with a pedagogical action research design [17], assumed as a variant of educational action research justified in [3,9] and [18].

The construction of the analytical rubric for the assessment of the problem-solving process in physics and mathematics was led by three professors of the area of exact sciences of the Universidad Simón Bolívar, San José de Cúcuta, Colombia, and two professors from the department of mathematics and statistics of the Universidad Francisco de Paula Santander, San José de Cúcuta, Colombia, as an exercise of pedagogical deconstruction in the field of evaluation in the teaching of physics and mathematics with students of the engineering faculty.

The analytical rubric was designed in an excel matrix based on the theoretical discussions of [8] and [9] and on the methodological discussions for the design of analytical rubrics presented in [12], [13-16], in which, based on the focus group, the criteria to be evaluated, the indicators associated with each criterion and the assessment scale were defined, as well as the qualitative description of each of the scales provided in this evaluation instrument.

3. Results

Down below, is presented the analytical rubric instrument built for the assessment of the processes of solving physics and mathematical problems in students of the engineering faculty. A total of 4 criteria were defined for the rubric [16], in which each of them represents the steps involved in solving Polya problems [9], step 1 “interpreting the problem”, step 2 “configure a plan”, step 3 “execute the plan” and step 4 “look back”.

The Table 1, Table 2 Table 3, and Table 4, it can be seen the general structure of the analytical rubric, which define the indicators associated with each criterion, the rubric's assessment scale and, of course, the qualitative description of the rubric scale [14].

Table 1. Analytical rubric for the assessment of step 1 of the Polya problem solving.

Criterion 1. Understand the problem					
Indicators	Excellent (4.6 - 5.0)	Outstanding (4.0 – 4.5)	Good (3.5 – 3.9)	Acceptable (3.0 – 3.4)	Poor < 3.0
Restatement of the problem in written or oral form in their own words	The restated problem situation is relevant and consistent with the initial problem situation	The problem situation restated is relevant and / or coherent with the initial problem situation	The restated problem situation is related to the reality of the initial problem situation	The problem situation restated is not relevant or coherent with the initial problem situation	Does not rethink the initial problem situation
Data extraction from the problem situation presented	Extracts all the data given in the problem situation.	Extracts at least 80% of the data given in the problem situation	Extracts at least 70% of the data given in the problem situation	Extracts at least 60% of the data given in the problem situation	Extract less than 50% of the data given in the problem situation
Identification of unknown situations in the problem (do you know where you want to go?	Identifies all the unknown situations and data in the problem	Identifies relevant situations or unknown data in the problem	Identifies any of the unknown situations in the problem	Identifies situations or data not relevant to the problem	Does not identify unknown situations or data in the problem

Table 2. Analytical rubric for the assessment of step 2 of the Polya problem solving.

Criterion 2. Configure a plan.					
Indicators	Excellent (4.6 - 5.0)	Outstanding (4.0 – 4.5)	Good (3.5 – 3.9)	Acceptable (3.0 – 3.4)	Poor < 3.0
Use of mathematical language to represent information (variables, physical and mathematical expressions and so on.)	Represents in a relevant way all the information given in physical and mathematical language	Represents all the information given in physical and mathematical language, but, with certain language errors	Represents some information given in physical and mathematical language	Represents some information given in physical and mathematical language, but, with errors in the use of language	Does not represent in physical and mathematical language the information given in the problem
Construction of mathematical premises	Constructed premises are relevant and complete	Constructed premises are relevant and necessary	Constructed premises are relevant but not sufficient	Constructed premises are not relevant	Does not build premises
Approach of strategies and/or physical and mathematical procedures for solving the problem (diagrams, equations, formulas, figures and so on)	The strategies and/or physical and mathematical procedures proposed are pertinent and sufficient	The strategies proposed and/or physical and mathematical procedures are pertinent and /or sufficient	The proposed strategies and/or physical and mathematical procedures are relevant but not sufficient	The strategies proposed and/or physical and mathematical procedures are not pertinent or sufficient	Does not propose strategies or physical and mathematical procedures to solve the problem

Table 3. Analytical rubric for the assessment of step 3 of the Polya problem solving.

Criterion 3. Execute the plan					
Indicators	Excellent (4.6 - 5.0)	Outstanding (4.0 – 4.5)	Good (3.5 – 3.9)	Acceptable (3.0 – 3.4)	Poor < 3.0
Implementation of the strategies proposed to solve the problem	Implements all the relevant strategies proposed for solving the problem	Implements several of the relevant strategies posed for the solution of the problem	Implements some of the relevant strategies posed to the solution of the problem	Implements few of the relevant strategies posed in the solution of the problem	Does not implement the relevant strategies proposed for solving the problem
Use of the proposed physical and mathematical procedures to solve the problem	Uses all the relevant and proposed physical and mathematical procedures for the solution of the problem	Uses several of the relevant and proposed physical and mathematical procedures for the solution of the problem	Uses some of the relevant and proposed physical and mathematical procedures to solve the problem	Little use of the relevant and proposed physical and mathematical procedures for the solution of the problem	Does not use the relevant and proposed physical and mathematical procedures to solve the problem
Application of physical and mathematical concepts in solving the problem	The applied physical and mathematical concepts are coherent and relevant for the solution of the problem	The applied physical and mathematical concepts are coherent or relevant to the solution of the problem	The applied physical and mathematical concepts are coherent or pertinent but not sufficient for the solution of the problem	The applied physical and mathematical concepts present conceptual errors	Does not apply physical and mathematical concepts to solve the problem

Table 4. Analytical rubric for the assessment of step 4 of the Polya problem solving.

Criterion 4. Look back					
Indicators	Excellent (4.6 - 5.0)	Outstanding (4.0 – 4.5)	Good (3.5 – 3.9)	Acceptable (3.0 – 3.4)	Poor < 3.0
Conclusion to the problem situation	The conclusion presented is consistent, relevant and complete	The conclusion presented is consistent, relevant but not complete	The conclusion presented is consistent or relevant but incomplete	The conclusion presented is not related to the reality of the problem	Does not present the conclusion to the problem
Satisfaction of the answer and transfer to the "common" language	The answer satisfies the solution to the problem to a high degree and is presented in common language	The answer satisfies the solution to the problem and is presented in common language	The answer satisfies the solution to the problem but does not present it in a common language	The answer does not satisfy the solution to the problem	Does not present a clear answer to the problem situation posed

The indicators associated with criterion one "understand the problem" (see Table 1), were: the rethinking of the problem in writing or orally with their own words, Extraction of data from the problem situation presented Identification of unknown situations in the problem, that is, that the student has the possibility of asking himself, do you know where you want to go?; Regarding the indicators associated with criterion two "Set up a plan" (see Table 2), there were: Use of physical and mathematical language to represent the information (variables, mathematical expressions, etc.), construction of mathematical premises and the approach of strategies and/or physical and mathematical procedures to solve the problem, such as: use of diagrams, equations, formulas, figures and so on. On the other hand, the indicators associated with criterion three "Execute the plan" (see Table 3) were: Implementation of the strategies proposed for the solution of the problem, use of the physical and mathematical procedures proposed for the solution of the problem and the application of mathematical concepts In solving the problem, Finally, for the indicators associated with criterion 4 "Look back" (see Table 4), the conclusion to the problem situation and the satisfaction of the response and transfer to the "common" language were defined.

Each of the indicators related to the criteria was assigned a rating scale of Excellent (4.6-5.0), Outstanding (4.0-4.5), good (3.5-3.9), acceptable (3.0-3.4) and poor (<3.0). Likewise, for the qualitative drafting of the qualification levels, the “only” scale was considered, as established in [14], the hierarchy in the construction and development of human thought.

4. Conclusions

The construction of analytical rubrics as evaluation strategies in solving physical and mathematical problems, allow to assess complex aspects, not so precise and subjective, contributing to an easily understandable evaluation for the participants of the "teacher-student" process, while generating a fair and transparent evaluation.

The construction of analytical rubrics allows a detailed monitoring of student learning, generate elements of accurate and timely feedback, as well as the possibility of approaching formative assessment as a learning opportunity for students and teachers related to physics and mathematics teaching.

The application of rubrics as an evaluation strategy accounts for the entire process developed by students, that is, it allows the evaluation to be used as a learning opportunity for both students and teachers it reveals elements of the learning process, that is, the strengthening for a formative and true evaluation in the physics and mathematics teaching.

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