Styles of reasoning according to the taxonomy structure of observed learning outcome of John Biggs in the students of geometry of the specialty of mathematics

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Abstract. The objective of this investigation was to determine the styles of reasoning according to the taxonomy structured of observed learning objectives of John Biggs in the students of geometry of the specialty of mathematics of the “Universidad Pedagógica Experimental Libertador”, Venezuela. The stated problem is that teachers of mathematics must know the problems of teaching mathematics; besides, they should know how their students learn, since according to the reasoning styles of John Biggs, one can determine how and with what depth a person learns. The methodology is quantitative, not experimental, and descriptive at the field level, where specialized literature was reviewed, and the results obtained from the application of the test with the super-item, as a data collection instrument, were analyzed by objectives based on the construction of the database in statistical package for the social sciences, the statistical analysis and the detailed interpretation of the procedure performed for each item, which allowed the analysis and interpretation of the results. These results reach the uni-structural level catalogued by Biggs as inferior or superficial. Therefore, recommendations are offered to improve the learning level of the students in question.

1. Introduction

Even though colleges and universities do not educate all kinds of young people, they certainly have a responsibility to help their own students develop civic behaviors and values, including habits of participation, tolerance, and collaboration, since, as stated by [1], higher education, through its teaching, research and extension functions, is a complex organization designed essentially to manage knowledge in order to train competent professionals; [2] shows that, during the last 25 years, both psychological and psych pedagogical research no longer focuses on teaching in such a way that the student takes an interest in the contexts learned, a situation that occurs at all levels of education, including universities. This challenge has generated much research at all levels on what and how students develop their learning processes. In this sense, [3] affirms that two lines of thinking are becoming increasingly important in higher educational practice. The first derives from constructivist learning theory, and the second from the instructional design literature. Constructivism comprises a family of theories but all have in common the centrality of the learner's activities in creating meaning. These and related ideas have important implications for teaching and assessment. Instructional designers for their part have emphasized alignment between the objectives of a course or unit and the targets for assessing student performance.
On the other hand, [4] expresses that since education began to focus on the student as the subject who learns, the authors began to analyze not only the tactics used by the teacher to develop their classes, but also the learning strategies used by students. In this way, the main reasons considered to give form to this work arise, first of all, from the existence of studies that demonstrate how the system of didactic strategies used by teachers to facilitate knowledge in students affects the quality of learning. Accordingly, [5] maintains that when we speak of significant learning or deep focus, it refers to learning with a meaning, and two fundamental variables are related, learning and classroom climate.

The second reason is based on the fact that generally, in all phases of learning, data knowledge is measured primarily by understanding concepts and principles. The knowledge of the phases of significant learning allows this type of learning to be applied correctly, since there is an initial phase, an intermediate phase, and a final phase. These phases, according to [6] "follow one another in order, so that learning finally has a valid meaning and takes place in a context known to the learner".

The quality of education is defined by [7] as "the higher academic formation imparted in its theoretical-practical set, which allows graduates to respond to the demands of their profession and, at the same time, enter the labor market". When the university adheres to its mission of training a professional with competencies that accredit him or her in the domain of knowledge indispensable to carry out competitively in the performance of his or her profession, it fulfills one of the academic challenges that demands immediate attention. However, the lack of motivation, resources and access to databases in Venezuela prevents the development of an education that favors reflection, understanding, interpretation and the application of knowledge. Some of the predominant models in university education have a technical character, since they emphasize the development of competencies oriented towards the instrumental resolution of professional practical problems, according to [8].

However, the authors of this work have observed that mathematics is shown at the university object of this study as an indispensable knowledge and its mandatory application is demanded in diverse daily and professional activities, but the reality shows that this is one of the most inaccessible knowledge for many students, especially the university ones, since it represents a large number of academic difficulties and failures, including inadequate performance since it has been observed daily apathy and lack of interest in learning traditional teaching methodologies. This is due to lack of resources the obsolescence of curricula and obviously, exogenous factors impossible to hide in Venezuela, such as the current economic situation.

Considering the premises presented above, the essence of this research is to determine the style of reasoning of students of the specialty of mathematics. Among the instruments created for this purpose, the taxonomy structure of observed learning outcome (SOLO) proposed by [9] has been selected. The decision is based on the existence of research where this taxonomy has been used at university level, in which it has been possible to verify its congruence in order to determine different levels in the structure of the students' responses to diverse themes, subjects or isolated learning, as well as the styles of reasoning classified according to the taxonomy SOLO of Biggs.

2. Theoretical underpinning of research

2.1. John Biggs' model of constructive alignment

Biggs' theory argues that the key to thinking about how to teach is to base this thinking on what is previously known [10]. Under this premise, learning is the result of its constructive activity so that teaching is effective when it supports appropriate activities to achieve curricular objectives, thus stimulating students to adopt a deep approach to learning. The SOLO taxonomy describes that when learning a new subject, understanding goes through a quantitative phase, from the one to the multi-structural, which involves discovering more and more data and relationships between them. The taxonomy consists of five levels: (i) pre-structural, (ii) one-structural, (iii) multi-structural, (iv) relational and (v) extended abstract.
2.2. Teaching and learning geometry in university education

Geometry is the subject through which the student studies geometric shapes and structures, and learns to analyze their characteristics and relationships. At the same time geometry points out spatial visualization as an important aspect of geometric thinking, not to mention the construction of geometric models and spatial reasoning as a way of describing the environment, all of which constitutes an important tool in solving problems, whether in geometry or in other areas of mathematics or general knowledge [11]. However, from the vision of the current state of geometry teaching in the world, it can be deduced that although it is taken into account within the university curricular systems, and in spite of the efforts of university communications to direct it, in practice there are weaknesses and deficiencies, which are reflected in the deficiencies of high school students when they enter into college. [12], there are several studies that justify the reasons for these difficulties, among them the way in which it is taught in teacher training, with a formal focus, overloaded with structuralism, abstraction and fragmentation of knowledge. It is evident that this form of teaching, acquired by teachers, tends to be reproduced in classrooms, and generates a scarce understanding of geometric concepts and processes in students. Geometry has had a progressive loss of its formative position in the mathematics field in several countries of the world. As a consequence, "the training of teachers (primary, secondary and technical) must be reviewed, and through successive repercussions, higher education must be reorganized" [13].

3. Methodology

The investigative process is assumed from the definition of science, the author [14] defines it: "it is the set of knowledge that is organized in a systematic way from observation, experimentation and reasoning within specific areas". Given the rigor of scientific research, the paradigm of quantitative research was considered. As far as the quantitative paradigm, [15] points out that "the statistical method is fundamental, both for the construction and application of relevant procedures and for the evaluation of the reliability and validity of the tests carried out and the results obtained". The design is non-experimental, which is defined by [16] as: "that which is carried out without deliberately manipulating any variable".

Likewise [17], defines non-experimental quantitative research as: "research that is carried out without deliberately manipulating variables". What we do in non-experimental research is to observe phenomena as they occur in their natural context, in order to analyze them. Within the variables that are not manipulated, we find the reasoning styles of the students in question, and therefore, the type of non-experimental design selected is trans-sectional or transversal. In the case of the present research, after validation, the test was applied to the students and analyzed at the same time as it was being developed. Likewise, the non-experimental research carried out is trans-sectional of a descriptive type.

The level of research is descriptive. According to [18], "descriptive research seeks to obtain information about a phenomenon or process in order to describe its implications without much interest in knowing the origin or causes of the situation." Therefore, its intention is to record and describe what the surveyed or interviewed people think, so that the data obtained can reflect the facts that occur [19]. Indicates that "field research allows to establish the interaction between objects and the reality of the field situation, to observe and collect data directly from (reality in) the natural situation".

The population consisted of students who passed geometry I and geometry II during semester 2017-b at the university. The exact size of this group was 32 students between the ages of 21 and 41 of different genders. Since the population is small, the entire population was taken as a sample for the study [20], considers that "the census sample is the portion that represents the entire population"; we felt that it was necessary to use a test constructed with open ended questions for this research, in order to gather the information required, so the answers could be evaluated from the so the answers could be evaluated from the taxonomy SOLO. For its construction, the ideas that [21] presents with the notion of super items and that are related to the evaluation in light of the taxonomy SOLO were applied. The criteria for assigning a level were assumed by the researcher. For its construction, the ideas that [21]
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The technique known as "expert judgement" was used to determine the validity of the instrument. When a researcher applies a test, scale, inventory or any other measuring instrument to a person, reliability is relevant in the test-test strategy which consists of applying the same instrument to the same sample of subjects at least two different times [22]. Points out that there is no single criterion as to what should be the appropriate time lapse between the first and the second application. If the correlation between the results of the different applications is very similar, the instrument is considered reliable. In the case of the present investigation, the instrument was applied in two moments, resulting in a correlation coefficient of 0.85, considered high, which is equivalent to saying that the test applied is highly reliable, in terms of the stability of the scores over time.

4. Analysis of results

The following space is dedicated to the presentation, analysis and interpretation of the results found. The questionnaire was applied to thirty-two students: first, the same content to the informed consent. Second, the same one to the demographic data. Third and last, the same of the twelve open and developmental questions, with problematic situations from which the super-items emerged, providing a first approximation according to the levels of response foreseen in the table of operations of the variable the super-items were carefully written and adjusted to the contents developed in the geometry courses of the mathematics specialty, and presented sequentially, increasing progressively according to the levels of structural complexity of John Biggs for resolution.

4.1. Specific objective 1

To identify reasoning styles in students by establishing levels of structural complexity. All students who answered correctly are taken into account, 93.75% reached a lower or superficial cognitive level, and the remaining 6.25% reached the deep or superior cognitive level. The results obtained for each dimension or level are presented in the following Table 1:

| Variable | Dimension | Item | Result | Percentage |
|----------|-----------|------|--------|------------|
| Styles of reasoning according to John Biggs' SOLO* | Pre-structural | 1, 2, 3 incorrect | 4 | 12.50% |
| | One-structural | 1, 2, 3, 8 correct | 16 | 50.00% |
| | Multi-structural | 4, 5, 6 | 10 | 31.25% |
| | Relational | 7, 9, 10 | 2 | 6.25% |
| | Extended abstract | 11, 12 and 7, if you determine the coordinates of the point equidistant from the vertices | 0 | 0.00% |

* Prepared by the authors with the results of the test

Regarding the pre-structural dimension, it can be observed that 12.5% obtained this style of reasoning according to John Biggs' SOLO. Important evidence, which was not expected to occur, since the knowledge to answer the questions 1, 2 and 3 are basic, even less if the student answered incorrectly to questions that do not require a greater level of understanding besides using irrelevant information. Consequently, it is considered sufficient to mention that there are still students in the first level of reasoning called pre-structural. Since the objective is to identify the reasoning styles in students using the levels of structural complexity of John Biggs' SOLO taxonomy, and in this case, the first level is being analyzed. As for the uni-structural dimension, it is evident, observing the results,
that most of the students obtained this level of reasoning, since they were able to answer correctly the total of questions 1, 2, 3, and 8 of the test, reaching 50% of the respondents. In the multi-structural dimension, 31.25% of the total correct answers belonging to this dimension were obtained (questions 4, 5 and 6), which represents 31.25% of the population. In the relational dimension, it was also observed that very few respondents managed to reach this level. Only 6.25% of the surveyed population. Finally, in the dimension extended abstract occurred that no student was able to answer correctly at least one of the questions posed for this style, and what is more serious, he did not try to answer any of them. These study results show that the students' level of reasoning becomes superficial with respect to the area of geometry. This situation is alarming, since this area of geometry is fundamental in the curriculum; it influences considerably the formative aspect of their own activity, favoring the discernment and spatial reasoning of the students, their intuitive reasoning and their methods of analysis.

4.2. Specific objective 2
To characterize the profiles in each of the reasoning styles found at the university. To achieve this objective, the results were analyzed in two phases:

First phase of the second specific objective: the students’ demographic data were combined with the answers to the questions posed. Firstly, the database was constructed; secondly, the percentages of correct, incorrect and non-response answers were calculated; finally, the following tables and figures were constructed showing the results according to each demographic variable. As for gender, it is observed that the results do not represent significant differences between men and women, both, men and women, have a greater dominion in the first dimension, the one-structural, and decreases that knowledge until it becomes completely null in the abstract dimension. It is evident that sex is not a determining variable in the effective acquisition of mathematical reasoning styles.

Results of the second phase of the second specific objective. Pre-structural profile: a student without basic knowledge of geometry who knows his or her limitations, who tries to respond and in some cases, succeeds correctly, but who requires personalized attention that allows him or her to overcome this difficulty. The reasoning profiles: one-structural, multi-structural, relational and extended abstract, during this second phase, the procedure developed by the students for the solution of the problems posed at each level was observed and analyzed. The hierarchy of cognitive levels according to John Biggs' SOLO, presented below, was taken into account:

Profile of the union: Students with basic knowledge of geometry able to identify how to solve the problem and perform the corresponding simple procedure to answer the questions posed. They handle the basic concept of geometric figures and apply precise information in the use of geometric elements. They only manage to carry out informal demonstrations. Multi-structural profile: they reached a total of 10 students representing 31.25%. It is significant and alarming, since it is considered a deficient level of reasoning for students who, on average, are more than halfway through their professional careers. Relational profile: for the level of relational reasoning according to the taxonomy of John Biggs, it is important to point out that not all the questions posed to measure this style are answered correctly; however, they achieve at least one of them, indicating that if motivation is increased and didactic strategies are established, this level or style of reasoning can be easily reached. Abstract profile: a null development is evident in the abstract level, which infers then that the student with the knowledge that he handles is not able to solve more complex problems nor to apply them in diverse contexts.

4.3. Specific objective 3
To compare John Biggs' reasoning styles with the learning obtained in the students. Based on the characteristics presented in Table 2 according to John Biggs Structured of SOLO, students are placed at a lower and superficial level of reasoning. Although it is a fact that students learn differently, the poor geometric preparation in students of the specialty of mathematics is very noticeable. It is evident that the problem is generalized; consequently, it is not possible to blame the student only. Also, the
educational practice lacks innovative didactic actions that facilitate the acquisition of a coherent, pertinent, useful learning, that is to say, a significant learning. It is important to emphasize that levels of reasoning are not innate, they are learned, and that is, they must be developed through a didactic way in the classroom.

Table 2. Styles of geometric reasoning according to John Biggs in mathematics students, at UPEL-“Instituto Pedagógico Rural Gervasio Rubio (IPRGR)” 2017.

| Pre-structural | One-structural | Multi-structural | Relational | Extended abstract |
|----------------|---------------|------------------|------------|-------------------|
| In level, it was reached by four students who did not answer correctly the first questions, for which it was only necessary to know definitions. | This level was reached by sixteen students, who made use of concepts to give answers to the first four questions. | This level was reached by ten students, who made use of definitions and characteristics necessary to answer the questions posed. | This level was reached by two students, who made use of definitions and properties, which they managed to link in order to answer the questions. | This level was not reached by any student, so it can be inferred that there is a deficient level of reasoning. |
| In this case, because of the results obtained, the students were placed in the levels called Construction of R. Duval and Analysis of V. Hile. | In this case, because of the results obtained, the students would be placed in the levels called Visualization, both by R. Duval and V. Hile. | In this case, the students would be located in the levels called construction of R. Duval and formal deduction of V. Hile. | This level, compared to the models of R. Duval and V. Hile, coincides with the levels Reasoning and Rigour. | |

5. Conclusions
The reasoning style of the students was identified characterizing their structural complexity. In function of this variable, it was possible to determine that the majority of the students are located in the first three levels of reasoning. It means that the students, according to theory, present a basic and superficial style of reasoning, and their learning is characterized by the mastery of basic geometric concepts such as: definition of triangles, sides, angles, vertices, and those that express a more advanced level identify the triangle as a geometric figure and the different types at the most.

The students' level of reasoning handles a clearly superficial knowledge as soon as it reaches the second level, from these results, which only focus on the operability of geometric knowledge management, derives the need to investigate what other variables can influence this poor mathematical development of students. It is important to carry out studies on the levels of demand in academic performance. The characteristics of the educational process carried out include: pensum, didactic strategies, clarity in the professional profile of both the graduate and the professor of the specialty of mathematics.

The development of the reasoning style is a multidimensional problem that not only concerns the performance and commitment of the student, but it is a set of variables that must be given in a coordinated and coherent manner, so that the student can effectively develop these styles of reasoning, which in no case are innate; they are learned from a didactic practice of high educational quality.
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