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Validity of microrubri, instrument to measure the development of competences in mathematics

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Abstract. The article presents the validity and reliability of the MICRORUBRI instrument based on rubrics, with problems applied to engineering that allow analyzing situations in real context, as well as the generation, visualization of surfaces, planes and vectors; its objective is to evaluate the development of competences in vector calculus in students who are enrolled in undergraduate engineering programs in the Municipality of Cúcuta, Colombia. It follows a design of descriptive study of validation of multidimensional scales through factorial analysis, construct validity, and facial. The study population was students of undergraduate programs of engineering, administration and agricultural sciences with ages between 17 and 20 years in the city of Cúcuta, Colombia, constituted the sample by 500 students. Results: A scale of 35 items was obtained. The factor analysis revealed dimensions of pedagogical practice oriented to leadership, creative thinking, emotional satisfaction, independence, creative attitude, productivity, leadership competencies, motivation; internal consistency was adequate (Cronbach alpha $0.72 - 0.95$), global intraclass correlation coefficient of 0.97, average differences in sum of items -1.2 (SD: 7.5) and Kappa indexes higher than 0.9, shows high agreement among experts. Conclusion: MICRORUBRI is a valid and reliable instrument to evaluate the development of competences.

1. Introduction

In the real world, many common problems are modeled mathematically by functions of several variables. The man today, navigates in an infinite sea of information, which does not allow him to meditate or reflect on it or know it. The technological and scientific advances that required many years before, today occur in a few years, forcing him to modify their concepts continuously to adapt to changes in their environment, study, work and their individual and social life [1].

Microrubri, includes rubrics to evaluate the development of competences in engineering students who study vector calculus. With this the teacher guarantees that the explosion of scientific knowledge that a student encounters in situations of real life problems[2], progresses not only by elimination of the error, but also by the use of technology, mathematical software and the elaboration of programs and applications, this in them implies changes in their mental structures, but it enhances the formation for the generation of scientific knowledge, requires changes in the curricula of educational institutions, where science adheres to didactics, where intellectual knowledge and social capacity is constituted in an educational purpose, to teach knowledge through a reflexive response that reorients its practices linking the student in a 3D and 4D space-time and virtual reality, as a being with potentials, competences, abilities, that must exploit and associate what has been taught; it must know, characterize and evaluate all its potentialities.

The above reflects the need to integrate objective and subjective views, which allow understanding and evaluating the creative action of the student [2], as this could help government agencies to prioritize educational policies in innovation from learning, revealing the need to combine the dimensions that they are part of this one.

On the other hand, competences in science as a quality factor for programs and institutions is an important element to evaluate, in terms of dimensions according to models such as the multidimensional model of quality, which links indicators of creativity in performance (specific competences, critical reading), teaching, research (researchers, works, articles, patents), internationalization (co-authorship), presence and attraction, as well as an element to identify perceptions and value that youth give to creativity. Consider the context in which you study.

In this way, the problem has social, educational, innovation and knowledge generation and internationalization considerations, demanding an integral formulation that responds to needs around the development of creativity in young people. In that sense, [3] argued that there are not many validated instruments that measure the development potential of students in vector calculus, which makes the identification of outstanding young people a problem. To this end, an instrument is designed to analyze the development of skills in youth.

Validating the instrument will provide an answer to this problem, since generic scales allow the assessment of group attitudes in general, whereas specific scales allow determining the level of student development, analyzing a phenomenon, problem or other variables related to the creativity of the young students during the learning process. The use of different scales and questionnaires is useful to establish states, apply social policies, as well as the allocation of resources according to [1].

2. Methodology

The research follows a descriptive study of validation of an instrument. The actors are 500 young people between 17 and 20 years old students of differential calculus, differential equations and mechanical physics of academic programs offered by universities in the Municipality of San José de Cúcuta, Colombia. A multidimensional questionnaire was designed [4], analysis methodology disaggregated by dimensions. The instrument linked a main factor associated with Micro Teaching (5 items), a factor associated with teamwork (5 items); a third factor associated with motivation (5 items) measured on a scale of 5 points on the Likert scale, measured on a scale of 5 points, from 1 (completely unsatisfied) to 5 (completely satisfied). The goodness-of-fit index of the model was evaluated through the Hosmer-Lemeshow test [5], where values lower than 0.05 indicated poor adjustment of the model. The effects of multicollinearity, evaluated through coefficients of inflation factors of variance $VIF > 10$ [5], conditioning index $IC > 25$, dimension with load greater than 0.51, performing linear regression analysis following Popperian logic. Goodness-of-fit measures were used [6] chi-square (absence of significant significance reflects good global adjustment of data with the proposed relationships), SRMR (values below 0.05), CFI (values above 0.95), TLI (greater than 0.95), RMSEA (lower than 0.05). Asymptotically free estimation procedure (ADF) was used, not required multivariate normal distribution. The weighting of each dimension and indicator, according to the factorial analysis method, initially gives equal weight to each of the dimensions. A model was structured whose statistics considered to assess the adjustment of the structural model, were the goodness index of the adjustment made (AGFI), and the goodness of fit index (GFI), which measure the percentage of the variance and covariance matrix explained by the different equations of the structural model. The AGFI statistic considers the number of degrees of freedom in relation to the number of indicators that intervene. All hypothesis contrasts were bilateral, for $p < 0.05$.

3. Results

Complete information was obtained on the evaluation of competences in vector calculation of 500 young students of academic programs of engineering, business administration, agrarian sciences. Among these groups, there were no significant differences according to age ($p = 0.493$), with a greater predominance of women among cases ($p = 0.02$). Real applications, emotional satisfaction, pedagogical practice

oriented to leadership, proposed problems, resources in the classroom, are more mentioned when asked about the five most influential in their satisfaction.

Goodness of fit indices show results $chi-squared = 47.29, DF = 0.48, p-value < 0.01$. $TLI = 0.985; CFI = 0.97; SRMR = 0.025; RMSEA = 0.025; 1.6 < VIF < 2.7$. The results show that there are no problems of multicollinearity; controlling bidirectional effects or influence of other variables, associative participation is not revealed as a predictor of dependent variables, then, participating in associations does not have statistically significant effects on creative learning, the model's adjustment measures reflect consistent results. In the application of the Hosmer-Lemeshow Test $p-value = 0.897$, it implies that what is observed is adjusted to what was expected, there is high proximity between real and theoretical values, then using the model and calculating predictions with it is correct, considering it as a calibration.

The Tukey non-additivity test confirmed the additivity of the scale $(p > 0.05)$, which showed internal consistency of 0.89 in productivity, internal consistency of 0.95 in independence, 0.91 in motivation, 0.95 in flexibility, 0.97 in competition; Satisfaction with their social integration and satisfaction, in the context, showed a relevant effect on applied learning. The consistency of the measurement shows that the scale works in a similar way under different conditions, depending on the same instrument, on the application time, on the measurement, on the subjects, on the interaction between these sources and on the random error. The internal consistency of the instrument shows that the items measure the same concept, in this case, learning, Cronbach's alpha of 0.96 shows that the scale is homogeneous. In the same way, when analyzing alpha by element, the items within the scale are complementary to each other, the scale is one-dimensional, it measures only concept. Likewise, alpha based on standardized elements 0.95 shows high homogeneity and reliability of the instrument. The level of covariation of the items between them and the number of items or parts that make up the test. Convergent validity by latent factors analytical reasoning $(alpha = 0.86, validity = 0.75)$, problem solving $(alpha = 0.9, validity = 0.96)$, motivation $(alpha = 0.86, validity = 0.82)$, emotional satisfaction $(alpha = 0.78, validity = 0.65)$, use of technologies $(alpha=0.86, validity=0.75)$, teamwork $(alpha = 0.9, validity = 0.86)$, communicative $(alpha = 0.77, validity = 0.7)$.

Minimum marginal reproducibility 0.92, effect of reagents that are distributed with extreme modal value. The scalability coefficient of 0.144 indicates a non-cumulative scale, showing the reproducibility of the instrument for joint decision-making of all the items by factor. The above shows that the instrument is stable, that is, the same results are obtained when using the instrument in similar conditions on different occasions and it is feasible to generalize results. In bi-directional combined effects model where the effects of people are random, and the effects of measures are fixed, the correlation coefficient is shown to be greater than 0.67, Fisher = 90.0, p-value equal to 0, showing acceptable reliability for single measures and high for average measurements. For equivalence, goodness of fit test model of parallel forms, chi-square of 43.6, variance 0.5; correlation 0.8523; reliability scale 0.998; reliability without bias 0.98 Correlation coefficients between type C classes using a coherence definition.

Construct validity analysis determines each coefficient of agreement between evaluators with level of agreement evaluators 1 and 2, 1 and 4, Kappa = 0.987, error 0.05 T = 14.5 p = 0; agreement level evaluators 2 and 3, 3 and 4, 4 and 5, 4 and 7 Kappa = 0.88, error 0.03 T = 12.8 p = 0. The Kappa value is statistically significant different from zero and considering valuation according to Landis and Koch [7] its Kappa value (0.95) suggests that the qualifications of the experts are very similar, there being a strong almost perfect agreement between them, that is to say a very good concordance force. It is concluded that the scale is valid. The factorial analysis showed seven dimensions, adequate internal consistency (cronbach alpha 0.85-0.9), average of the differences in the sum of items -1.5 (DS = 8.6), limits of agreement of Bland and Altman were -16.9 and 12.3. Significant correlations were found between the different tests that make up the instrument, which suggested the use of exploratory factor analysis also confirmed by the Bartlett sphericity test $(\chi2 = 915.9, df = 14, p = 0)$, Kayser index Meyer-Olkin (KMO = 0.879) for the detection of underlying dimensions, and to compare the factorial structure found with the study by Chaparro, Ortiz & Bruges [8].

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In application of subscales, categories are associated in a 5×2 hierarchical model, with indicators of analytical reasoning by identifying and separating the parts of a whole, appropriating the concepts of domain, range, traces, surfaces, contours and level surfaces; problem solving, with sub-scale in kinematics, electromagnetism, thermodynamics, hydraulics, recognizes the situation, identifies relevant information, organizes it and uses it to solve the problem; quantitative literacy; develops the ability of interpretation and mental manipulation of data, graphics, tables, among others, to give explanation or solution to problem situations; communicative to develop assertive oral expression to manifest and support their points of view; use of information and communication technologies; and teamwork by interacting critically and efficiently in work groups. The structural model (Figure 1) presented appropriate adjustment levels ($AGFI = 0.94, GFI = 0.961$, Bollen's $IFI = 0.94, Qui = 972, df = 62, p < 0.001, CFI = 0.853, NFI = 0.907, RMSEA = 0.070$) Totalized standardized effects of associative participation on 95% CI lower coefficient superior satisfaction with institution and pedagogical focus 0.04, satisfaction with activities that encourage development of skills 0.31, satisfaction with their social context 0.18, satisfaction with their emotional resources 0.11; VdeCramer 0.16.

The square root of the mean quadratic error (RMSEA), shows that both the point estimate and the confidence interval confirm a high degree of adjustment of the estimated model to the data. The results suggested a stable structure of eight factors: Microteaching, pedagogical practice, emotional satisfaction, creative attitude, productivity, independence, leadership competencies and motivation. Regarding facial validity, the suitability of the content according to Secolsky [9], shows an instrument that complies with parameters of clarity ($CI = 0.85$), precision ($CI = 0.935$) and comprehension ($CI = 0.937$). In this way each item complies with the criterion of the category, is written in an exact way, easy to understand, allows to interpret and understand its meaning.
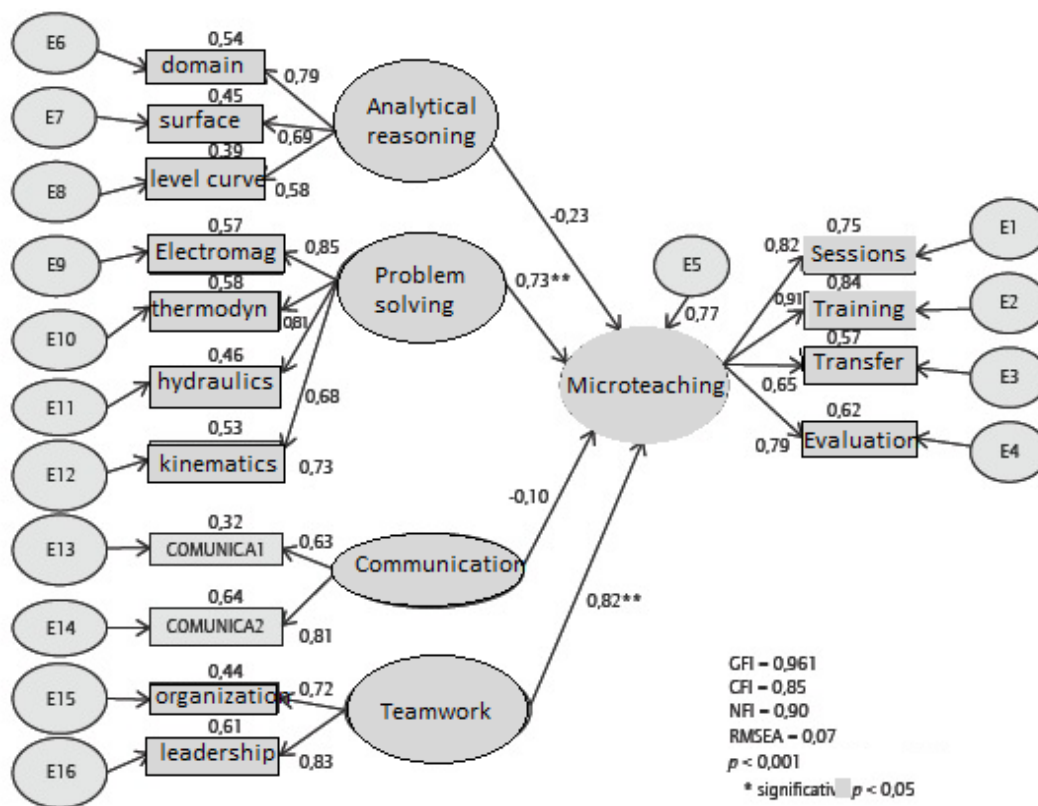

Figure 1. Structural model.

4. Discussion

Through Microrubri thematic was oriented into functions of several variables, domain and range, function graphs, level curves, level surfaces, functions in context, partial derivatives, geometric and physical interpretation, derivatives of higher order, chain derivation, implicit derivation, change ratio problems, gradient, directional derivative, direction of maximum growth, extreme values of a function, global and local maximum and minimum, problems of maximum and minimum application. Also, applications in conduction design, heat transfer, optimization in costs and sizing of storage rooms subject to restrictions. Its implementation improved communication between peers, fostered empathy with the teacher and teamwork. The methodology based on micro-teaching, using the rubrics allows to detect previous errors in the student when solving real problems, decreases the fear to request advice, improves attention processes, and the time in the classroom is more effective, therefore, they make corrections immediately when observing the development of activities. Cognitive aspects of improvement were observed in the geometric and physical understanding of the concept of variation and derivative, the student manages to generalize in R^n, thus transcends his thought from the plane to space, this leads to improve demonstrative processes; In the same way, the support of the production in the classroom improves the mathematical language, communicating the student mathematically. There was improvement in analytical reasoning, appropriation of concepts, problem solving, quantitative literacy, the ability to manipulate and interpret mental representations, develops assertive oral expression to express and sustain their points of view, encourages the use of the information and the communication.

Criteria of efficiency, effectiveness, innovation, successful methodology are mentioned by the students when evaluating microrubri. Faced with the work of the teacher acquires a greater commitment to guide the young, does not also allow improvisation. Like Freire [10], the use of the word rate was strange, and the teacher clarifies its meaning in the context of Differential Calculus. Educator and educator "The subject who teaches learns and the subject who learns teaches" [10]. The teacher proposes a problematizing situation, in a scenario in which the concept for learning takes place, with the purpose of expanding language and applying thought to learning through teamwork. For there to be interaction, the teacher integrates himself into the life of man and investigates his language, his activity, is thought and the context in which the concept for learning is evident. Take note of the different meanings, submit to consideration and by consensus accept the position that the rate of change is "the variation of one variable with respect to another" and occurs in the context of Mechanical Physics.

This position is shared by the teacher, who broadens the spectrum of situations in which it applies. Education occurs in a process of communication and conscious dialogue and with discernment, contrary to banking education. Likewise, as suggested by Harf [11], the idea of strategy induces a range of possibilities where the creativity of the teacher consists of making a good diagnosis of the group's skills to those who will guide, the contents and the context of selection of those strategies that at that moment and for that group are the most indicated. The strategy is determined as such in the planning, staging and constitutive dynamization of the pedagogical and didactic processes before, during and after the class. Several authors argue for the need for conceptual change to be accompanied by an associated methodological change [12]. It is reasonable to affirm that the findings agree with the idea that the instructions in the classroom, immersed in the production factor, acquire functions that cannot be interpreted limitation as discriminative [13], but these can be classified functionally in terms of their effects in the acquisition of effective executions and their transfer to applicable, novel situations such as intelligent and creative performance. The empirical validity of such polyfunctionality of the instructions, considers factors associated in the participants as their linguistic development, critical aspects in the instructional control, as well as the characteristics of the procedure of which they are part [14]. Similarly, as noted by Atchley, Strayer [2], it is important to understand the influences of experimenting on nature and using technology in creative problem solving. Contrary to the point made by Yan, et, al. [15] Age did not influence the development of competences in vectoral calculus. Triangulation of information shows subcategories creativity as innovation motivation [16], expectation of affection like the manifest by Martínez, Vergel, Zafra [17], arising emotions as an element within the educational process; linked to teachers, concerned that the young person generates ideas and achieves a learning for life.

5. Conclusions

Mircrorubri is a reliable instrument for the context of engineering programs, Colombia, scale with dimensions of analytical reasoning, problem solving, communication, teamwork, has validity and adequate consistency to measure the development of skills in vector calculation. Microrubri fostered social and critical dialogue and practices in the context of youth, where the formation of perceptions about innovation projects is influenced by the pedagogical practices of teachers and motivation. The methodology based on micro-teaching, using the rubrics allows to detect previous errors in the student when solving real problems, improves attention processes, and the time in the classroom is more effective, therefore, cognitive aspects of improvement were observed in the geometric and physical understanding of the concept of variation and derivative, whit indicators of analytical reasoning by identifying and separating the parts of a whole, appropriating the concepts of domain, range, traces, surfaces, contours and level surfaces; problem solve, with sub-scale in kinematics, electromagnetism, thermodynamics, hydraulics; develops the ability of interpretation and mental manipulation of data, graphics, tables; the student develop assertive oral expression to manifest and support their points of view by interacting critically and efficiently in work groups.

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