Global Research in Higher Education
ISSN 2576-196X (Print) ISSN 2576-1951 (Online)
Vol. 3, No. 3, 2020
www.scholink.org/ojs/index.php/grhe

Original Paper

Numeracy and Environmental Skills with Indicators: Educational Micro-Assessment in University Students

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Received: August 9, 2020 Accepted: August 19, 2020 Online Published: September 7, 2020

doi:10.22158/grhe.v3n3p42 URL: http://dx.doi.org/10.22158/grhe.v3n3p42

Abstract

This study is an extension of a micro-assessment on educational advances that has developed in 2010, for valuate numerical and environmental skills. After ten years, it observe, in terminal biology students of UNAM-Iztacala, a very notable change in the recognition of terms in the sum of a polynomial, but for the fine skills -of the same students- in separation of two assembled materials present in the common waste, we don't observe a change or an improvement. This comparative study was carried out with forty participants. The effectiveness of formal and informal educational interventions, in the quest to seek a learning improvement, is evident.

Keywords

docimology, educational micro-assessment, numeracy, environmental education, and problem solving

1. Introduction

In April 2010, we carried out a comparative study with numerical and environmental skills, with terminal biology students from UNAM-Iztacala. For this purpose, we chose the use of two numerical and two environmental problems, of high, medium and high difficulty (Ruiz & Lupercio, 2011). These problems are described in the next section. In February 2020, after ten years had passed, we found it interesting to repeat the same observation with biology students similar to those of the previously described experience, with the purpose of observing, if with respect to the original results, it was possible to show a change in the last observation.

In the educational research setting, the application of extensive questionnaires is common (OECD, 2018), which include a large number of questions or problems to be solved (Bomboir, 1971; Bomboir, 1974; Flavell, 1976), however, an alternative modality is beginning to develop an educational evaluation (Díaz-Barriga & Hernández, 2002), based on reactive or problems with the character of indicators (Katic, Hmelo-Silver, & Weber, 2009; Tavernal & Peralta, 2009; Ruiz, Lupercio, & Bernal, 2015). These indicators should represent a high or medium difficulty in the initial observation (pre-test) with respect to the final observation (post-test), in order to obtain clear results (Ruiz, Lupercio, & Bernal, 2017; Ruiz, Lupercio, & Bernal, 2020).

This leads us to suggest the opening of a debate about the scope and limitations of the educational macro-evaluation and micro-evaluation models, where the former point towards a general and standardized measurement of educational progress and, the latter, more properly, to a more particular and detailed corroboration of educational topics of strategic value (INEE, 2016). In our opinion, both types of approach can and should be complementary.

This comparison at two different moments and after ten years, forced us to make a recognition of the curricular and institutional changes that occurred in the studied university, in order to find the possible causes of differences or not observable, in the results we obtained when examine biology students and the problems to be solved that we apply.

2. Curricular and Institutional Framework

A review of the curricular and institutional changes that had taken place both in the curriculum of the bachelor's degree in biology and in the institutional environmental performance was carried out, especially considering that the replication of the study carried out in 2010 included the evaluation in particular to two numerical and two environmental problems (differentiated dumping of waste). During this ten-year period, the bachelor's degree in biology restructured its curriculum, having a new curriculum that began in August 2016. In this, considering the mathematical deficiencies that students historically showed, a compulsory course was incorporated, which is called "Algebra workshop", with the same hours as a normal course, but without credit allocation, although it must be approved for the purposes of the degree, which is taught in the first semester. The objectives of this course is that students amicably review their essential mathematical knowledge, correct poor basic learning, as well as learning to make intelligent use of algorithms and mathematical procedures frequently used in biology (biology descriptive letter, 2016).

Also, since 2014, an institutional program called PROMIR was reconsidered, aimed at promoting good practices in the comprehensive management of urban solid waste generated at UNAM-Iztacala. The latter is based on giving some talks to new students, with the support of brochures and posters, to motivate them to participate in the responsible management of common waste generated on campus, inviting them to respect the nomenclature for the landfill of the waste indicated in the garbage containers (Ruiz, Lupercio, Muñoz, Torner, & Bernal, 2015). Both types of intervention did not exist in their current version, ten years ago. Although at UNAM-Iztacala, for 25 years there has been a more or less structured program, which has been promoting the recycling of waste materials and other pro-environmental actions (Ruiz & Lupercio, 2015). We point out this background, because it can be useful in explaining the results.

3. Description of the Problems

The four problems, described below, have been tested and applied in various background reports, which have allowed us to verify their usefulness as effective indicators of performance, in numerical and environmental skills (Ruiz & Lupercio, 2011; Ruiz, Torner, Lupercio, & Bernal, 2015; Ruiz, 2015). This indication is particularly applicable, for rapid evaluations and with the items or problems that represent the greatest difficulty, in the initial observation (Ruiz, Lupercio, & Bernal, 2018).

Problems:

P (1): sum of a polynomial, which includes the help of a parenthesis, to make it easier for the performer to identify the terms of the sum. It should be noted that, in this operation, $3.2 + (4.4 \times 2) + 8$, the parentheses are mathematically unnecessary. The correct answer is 20. This problem, applied to university students, represents a minimal difficulty, mainly due to the help provided by the parentheses.

P (2): sum of a polynomial, which does not include the previous help, $2 + 3 \times 4 + 5$. The correct answer is 19. This problem, based on our historical references, represents a high difficulty in university students, which is explained by the general mistake of not identifying the terms in the sum of a polynomial. What is a remnant effect, due to their neglect, in the learning of elementary mathematics and that leads to making many more serious mistakes in other operations, such as, for example, in geometry, algebra and calculus (Alatorre, 2002; Alatorre, 2009). As a mere reminder, we refer that the "term", represents in all serial or polynomial operations ($a + b + c + ...$) the independent computations or values, in numerical or algebraic connotation, that are separated by sum or subtraction. It is a fundamental concept (Larousse mathematics dictionary, 2018; Miles, 1999) for the correct execution of algorithms and in advanced mathematical reasoning (Matheracy).

C: differentiated discharge of an aluminum can with a plastic straw, inserted inside, which constitutes an occasional assembly with two pieces of different material, present in the common garbage. The success is only granted by placing the aluminum can, separated from the plastic straw, in an exclusive container for "metal". In the case of an occasional assembly, this problem represents a medium difficulty in university students. The mistakes are generally due to the inadvertence on the part of the participant in the separation of the second object, by not attending to the indications for the differentiated discharge requested. The failure is due to neglect and not ignorance of the materials.

B: differentiated discharge of a glass bottle with a plastic screw cap, which constitutes a structural assembly, with two different material wastes, present in the common garbage. The success is only granted by placing the glass bottle, separated from the plastic screw cap, in an exclusive container for "glass". Being a structural assembly, where both components of different material are part of the same container, it represents a high difficulty with university students. As in what was stated in the previous problem, the failure is due to neglect and not ignorance of the materials.

4. Method in a Comparative Study

4.1 Objectives

1) Replicate a comparative study published in 2011, with numerical and environmental examples, with a similar sample of the same students, in order to observe if there are differences.

2) Finding the possible causes that explain the significant and insignificant differences, both numerically and environmentally.

4.2 Hypothesis

"A noticeable change in the frequency of successes observed in solving a problem can only be attributed to a specific and systematic educational intervention".

4.3 Subjects and Procedure

Both the historical reference and the replica made were carried out with forty terminal biology students from UNAM-Iztacala, where they were informed of the intention of this exercise and, where their consent was requested, to participate voluntarily. The numerical problems were applied in a group session and the environmental problems in a cabinet (simulator for the differentiated discharge of waste) arranged for individualized observation, without communication between the participants. In the latter case, the response options are exclusive containers for: metal, plastic, glass, writing paper/cardboard and everything else.

Both the numerical and environmental problems are accompanied by another ten contextual questions related to the respective themes.

5. Results

Figure 1 shows the results observed in 2010 and 2020, with the four aforementioned problems, where the successes are presented separately, as well as the coincidence between them, separating the numerical and the environmental.

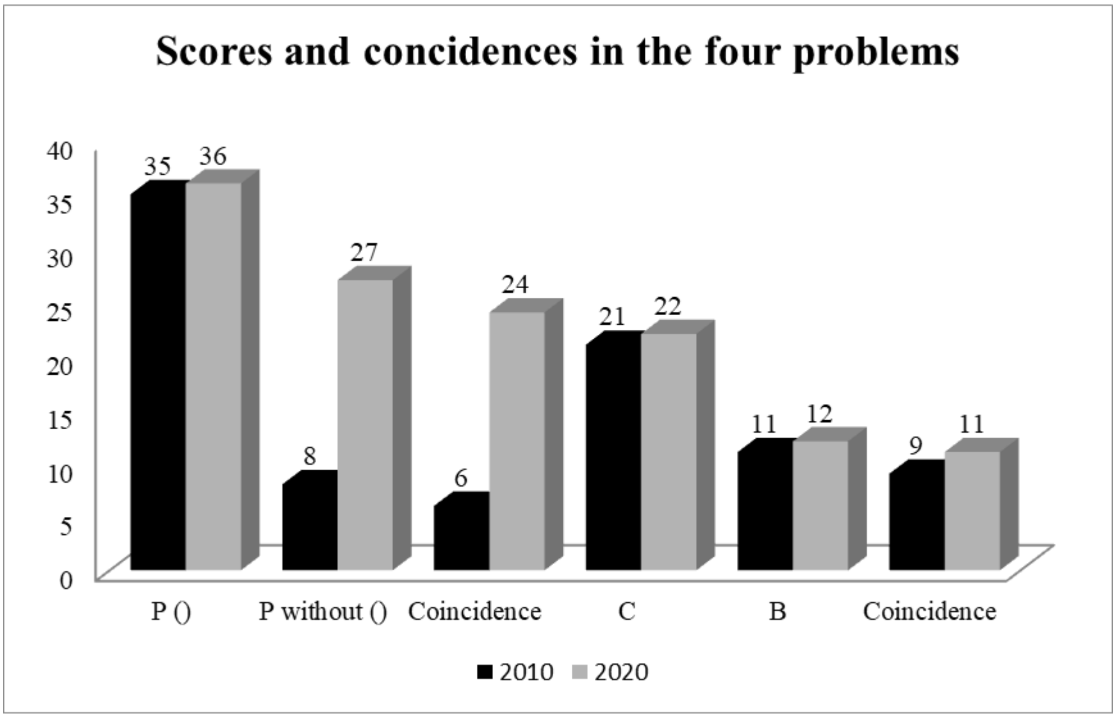

Figure 1. Results of the Problems Applied

In these results, an extremely notable change can only be observed in the span of ten years, in the successes obtained by the participants of this replicated study, in the resolution of the sum of a polynomial without the help of a parenthesis (Note 1) and, consequently, also in the respective coincidence between the two sums (where the first one represents practically no difficulty, both in 2010 and 2020). Regarding the environmental ability evaluated, no change was registered, which generally occurs in the measurement of fine ability in the dumping of wastes, even in higher education institutions that have well-structured programs for the management of urban solid waste, but without attending to the acquisition of environmental knowledge and skills in the student community (Ruiz & Lupercio, 2013; Ruiz, Lupercio, & Bernal, 2018).

6. Discussion

Here it is worth analyzing and looking for an explanation to two aspects that are observed in our results, the reason for the remarkable change -with the incidence of successes- in one of the numerical problems and, also, the null improvement in the problems of differentiated waste disposal that we examine, taking into consideration the span of ten years, elapsed from the previous observation (2010) and the current one (2020). It seems to be clear that the "Algebra Workshop" (a formal curricular course), has had a relevant role in the remedial improvement of basic mathematical knowledge, where the sum of a polynomial, without any help or clue given to the participant, it is an effective indicator. In the case of the PROMIR program, which constitutes the institutional policy for the management of urban solid waste, with informal interventions and without any curricular involvement, based on the measurement of fine ability for the differentiated dumping of waste, with waste presented in assembly, no change was observed. This leads us to propose considering the advisability that in the same institution, the tasks of pro-environmental promotion, begin to be treated in a similar way, to what has been done with the "Algebra Workshop", or in other words, a kind of "Workshop on good pro-environmental practices" can be structured, which is more or less formal in nature and with a well-organized pedagogical approach, which could be taught in the first semester, not only of a degree in biology, but of all the degrees and postgraduate courses taught at UNAM-Iztacala.

Although the referred "Algebra Workshop" does not solve all the learning of basic mathematical knowledge (where we detect that the term concept, most terminal biology students, although they intuitively understand it functionally, do not understand it in its definition or formal characterization), this course does contribute in a substantive way to improve the essential mathematical skills -beyond just the numerical one- of biology students, since we found in a complementary investigation (carried out in 2019), in which we evaluated the items contextual numerically and we compare it with a group of first-year students, where in a battery with ten items such as hand-operations, mental calculation, valuation of decimal numbers, roots and powers, among other problems (Ruiz & Lupercio, 2013; Ruiz, Lupercio, & Bernal, 2020), both groups of students (initial and terminal), obtained on average grades higher than 9.

We infer, that this "Algebra Workshop", is more involved in the development of intermediate mathematical skills (Matheracy), which will be studied in other new research. It seems to us that something very similar could be expected if, with pro-environmental tasks, such a workshop could be structured. It is time to recognize that the pro-environmental promotion tasks -given how difficult, complicated and complex they are in practice- demand a more serious and demanding educational treatment. Alone talks and voluntary altruism (basically supported by publicity interventions or institutional propaganda) do not seem to generate significant learning with community significance.

7. Conclusions

The problems used as indicators of educational progress did prove to be effective and reliable, including in the recognition of fine differences. Likewise, the comparison of formal and informal intervention strategies, commonly used in higher education institutions, allowed visualizing the relative results of both intervention models, in the recording of results in the four problems that we examined, with the improvement in the numerical ability of high difficulty and, likewise, the stagnation or absence of improvement in the fine ability to separate wastes, in this case presented in assemblies, from wastes present in common garbage. This type of rapid evaluations, systematically applied, can help to identify both good educational practices, as well as less successful ones, to provide better and meaningful learning, at all school levels.

It was shown that this rapid modality of the evaluation of educational progress, supported by the resolution of problems that serve as effective indicators, constitutes an extremely useful resource for the measurement of learning, without the need to apply a battery of reagents extensive and strenuous. The key to this is having a collection of reagents -really appropriate- to carry out an exploration of this nature, both for its application in the field of natural, social, humanities and civic knowledge, among other topics. The cost involved, in terms of time, money and effort, can be considerably reduced, obtaining a well-weighted and reliable result.

Acknowledgments

This research was carried out with the financing of the Program of Support for Research Projects and Technological Innovation of UNAM, PAPIIT: IN310719. Thanks to the other members of the project: Carlos Enrique Palacios (biologist), Eduardo Rodríguez Sierra (pedagogue) and José Antonio Melo (psychologist) who actively participated in carrying out of this research. Likewise, the editorial support given by Michelle Ruiz Valdes (Master in International Cooperation) and Adriana Hernández García (grant holder of the PAPIIT project) is recognized.

References

Alatorre, S. (2002). *Efectos temáticos del efecto remanente de las matemáticas escolares, en Algunos problemas matemáticos en México, A. de la Peña (Compilador) Siglo XXI Editores* (pp. 51-112). México.

Alatorre, S. (2011). Numeralismo: Un asunto que incumbe a todo el mundo (Sí, también a usted a quien las matemáticas lo aturden). *Revista Mexicana de investigación Educativa, 16*(50), 961-986.

Bomboir, A. (1971). *Pedagogía correctiva*. Ediciones Morata, Madrid.

Bomboir, A. (1974). *La docimología problemática de la evaluación*. Morata, Madrid.

Carta descriptiva de la materia: Taller de álgebra. (2016). *Licenciatura en biología, Facultad de Estudios Superiores Iztacala, UNAM*. Retrieved from https://biologia.iztacala.unam.mx/plan2034/obligatorias/1112_algebra.pdf

Díaz-Barriga, F., & Hernández, R. G. (2002). Constructivismo y evaluación psicoeducativa. Cap. 8 en Estrategias docentes para un aprendizaje significativo. In *Una interpretación constructivista*. McGraw-Hill, México.

Flavell, J. (1976). Metacognitive aspects of problem solving. In L. B. Resnick (Ed.), The nature of intelligence (pp. 231-235). Hillsdale, Nueva Jersey: Lawrence Erlbarum Associates.

INEE. (2016). *Consideraciones conceptuales y metodológicas para la elaboración de indicadores de proceso y resultado*. Cuarta Etapa. México: Autor. Retrieved from https://www.inee.edu.mx/wp-content/uploads/2019/04/5.-Gu%C3%ADa-para-el-desarrollo-PEEME_cuarta-etapa.pdf

Katic, E. K., Hmelo-Silver, C. E., & Weber, K. H. (2009). Material mediation: Tools and representations supporting collaborative problem-solving discourse. *International Journal of Teaching and Learning in Higher Education*, *21*(1), 13-24.

Larousse: Diccionario esencial de matemáticas (pp. 361-362). (2018). CDMX, México.

Miles, D. (1999). Algebra vocabulary as an important factor in Algebra achievement. *Focus on Learning Problems in Mathematics*, *21*(2), 37-47.

OECD (Organisation for Economic Co-operation and Development). (2018). *Programme for International Student Assesement (PISA) Results from PISA 2018 for Mexico*. Retrieved from https://files.eric.ed.gov/fulltext/EJ1183972.pdf

Ruiz, C. (2012). Pocos más muchos. *Contexto sociocultural al hacer cuentas en Ciencia y Desarrollo*, *38*(257), 30-31.

Ruiz, C. (2015). Hacia una comprobación experimental de la zona de desarrollo próximo de Vigotsky. *CIENCIA ergo-sum*, [S.l.], *22*(2), 167-171.

Ruiz, C. Y., & Lupercio, A. (2011). Separar para reciclar: ¿sabemos hacerlo? *Revista Ciencia y Desarrollo*, *237*(251), 20-27.

Ruiz, C. Y., & Lupercio, A. (2013). *La utilidad de los paréntesis en la enseñanza de las matemáticas, en Ciencias* (No. 107-108, julio 2012-febrero 2013, pp. 148-153).

Ruiz, C. Y., & Lupercio, A. (2015). Auditoría ambiental participativa sobre manejo de RSU en dos universidades mexicanas: Prospección preliminar. *Memoria del primer encuentro académico sobre manejo de residuos en universidades*. México: UAM Azcapotzalco.

Ruiz, C., & Lupercio, A. (2013). Habilidad fina para el vertido detallista de desechos con y sin intervención propedéutica en universitarios: Microevaluación en educación ambiental Revista. *Intercontinental de Psicología y Educación*, *15*(2), 155-170.

Ruiz, C., Lupercio, A., & Bernal, T. (2018). Evaluación diagnóstica para el análisis de programas de manejo integral de residuos sólidos urbanos en dos universidades mexicanas. *CIENCIA Ergo-Sum*, *25*(3). https://doi.org/10.30878/ces.v25n3a12

Ruiz, C., Lupercio, A., Muñoz, J., Torner, F., & Bernal, T. (2015). Residuos sólidos urbanos: Normatividad y cumplimiento de metas. *Derecho Ambiental y Ecología*, *68*(12), 92-96.

Ruiz, C., Torner, F., Lupercio, A. Y., & Bernal, T. (2015). Auditoría ambiental participativa. *Cartilla de RSU, Ciencia y Desarrollo*, *41*(275), 34-35.

Ruiz-Hernández, C., Lupercio, A., & Bernal, T. (2020). A Zone of Proximal Development Process in the Selective Disposal of Urban Solid Waste: Problem Solving with Two Assembled Materials. *Education Journal*, *9*(2), 48-51. https://doi.org/10.11648/j.edu.20200902.13

Ruiz-Hernández, C., Lupercio-Lozano, A. D., & Bernal-Gonzalez, T. A. (2015). The Scope and Limitations of Brief Interventions for Remedial Education: An Experimental Approach in a Numeracy Case. *International Journal of Secondary Education*, *3*(4), 32-36. https://doi.org/10.11648/j.ijsedu.20150304.12

Ruiz-Hernández, C., Lupercio-Lozano, A. D., & Bernal-Gonzalez, T. A. (2017). Towards an Experimental Verification of Vygotsky's Zone of Proximal Development: A Docimological Approach. *Education Journal*, *6*(1), 47-50. https://doi.org/10.11648/j.edu.20170601.16

Ruiz-Hernández, C., Lupercio-Lozano, A. D., Bernal-Gonzalez, T. A., & Torner-Morales, F. J. (2017). Basis for the Analysis of Plans for the Comprehensive Management of Municipal Solid Waste: A Collaborative Assessment in Two Mexican Universities. *Environment and Sustainability*, *1*(3), 85-89.

Tavernal, A. Y., & Peralta, O. (2009). Dificultades de aprendizaje. Evaluación dinámica como herramienta diagnóstica. *Revista Intercontinental de Psicología y Educación*, *11*(2), 113-139.

Note

Note 1. This difference reaches a statistical confidence level of 99.9% in a two-tailed Student's t-test (40 + 40 - 2 = 78 degrees of freedom); this same significant difference is also present in the coincidences for this same problem.