CONCEPTIONS ABOUT PROBABILITY AND ACCURACY IN ARGENTINE STUDENTS WHO START A CAREER IN ENGINEERING

Mónica Giuliano, Ignacio Nemirovsky, Sonia Concari, Silvia Pérez,
Marcelo Alvarez, and Aldo Sacerdoti
Universidad Nacional de la Matanza. Argentina
monicagiuliano@yahoo.com.ar

Previous misconceptions about science may cause difficulties in the interpretation of scientific models. A Likert scale test was made and presented to part of the population in order to find out beliefs about science and technology that students who wanted to have a degree in engineering at Universidad Nacional de La Matanza had. Principal components analysis was performed to identify the testees' profile. We show the results referring to the beliefs and conceptions about probability, margin for error, accuracy, certainty, truth and validity. Although most of the people who answered the survey acknowledged the presence of probability in the results of a physical experiment, they also gave it accuracy *and truth* values *which are not inherent. It is also remarkable that only a very low percentage has a posture that is coherent with the scientific vision of the terms.*

INTRODUCTION

Several papers have shown that misconceptions and erroneous beliefs about science and technology bring about misinterpretations of scientific models (Aikenhead *et al.* 1987, Aikenhead *et al.*, 1992; Azcárate *et al*., 1998). Students who start studying Engineering at Universidad Nacional de La Matanza (UNLa M) show very little scientific and technologic knowledge at the moment they enter the university. Quantitative and qualitative analyses were made in order to make a test with the results of the answers students gave in the test (Alvarez *et al*., 204; Sacerdoti *et al*., 2004). We present the results concerning the students' conceptions and beliefs about probability, margin for error, accuracy, certainty, truth and validity.

With the release of "Curriculum and Evaluation Standards for School Mathematics" (NCTM 1989), it is proposed that primary and secondary school students have to study probability, and also explore situations actively, experimenting and simulating probability models. In Argentina the study of probability has been included on the curricula from General Basic Education (EGB) to Polimodal since the Federal Law of Education was passed. But as Batanero (2002) argues, most schools do not deal with statistics owing to the length of the syllabuses. Thus, students start university without the expected knowledge of the subject.

Another aspect Fischein (1975) pointed out is the exclusive deterministic nature that the mathematics curriculum has had up to some years ago, and the need to show students how to face facts more realistically: "In our contemporary world, scientific education cannot be merely reduced to a certain, deterministic interpretation of events. An efficient scientific culture demands an education in statistic and probabilistic thought." The same idea can be applied to the teaching of Physics, when there is an abuse of the explanation of deterministic models, such as Newton's, ignoring in many cases the uncertainty of experimental results and the differentiation between model and reality (Gilbert *et al*., 1998). On the other hand, the fact that some phenomena we want to model have results that depend on chance rather than on a deterministic nature, makes it necessary to use probabilistic models.

METHODS

With the aim of building an instrument to find out beliefs and conceptions of students who could start studying Engineering at UNLaM, 103 phrases were chosen from a first test with open ended questions. 199 students were asked to mark their agreement with each of the open ended questions, in a 1 – 5 scale. The students were picked at random among those who started to study Physics I in careers in Engineering at UNLaM. In order to reduce the number of phrases and integrate them on a new multidimensional scale, principal component analysis (PCA) with Varimax rotation was used, thus allowing us to choose those phrases which showed the greatest variety of answers, associating those representing the same idea in the same component.

Afterwards, these phrases were analysed with the aim of looking for testees' profiles. As for the application of PCA, validity requirements were verified: KMO (Kaiser-Meyer-Olkin measure of sample adequacy) and Bartlett test. The following conditions were observed to select the number of components: (Hair *et al*., 1999) **a.** to choose the components corresponding to self-values higher than 1; **b.** to include in each component items with factor loadings higher than 0.4 and high communality; **c.** to admit the items which are theoretically coherent with the component in which it is found, and **d.** to consider the number of components necessary to explain a minimum percentage of 60% of the total difference.

Using these criteria, at the beginning 22 main components were obtained (Giuliano *et al*., 2005), among which three referred to the character of validity of scientific knowledge, including terms such as probability, margin for error, accuracy, certainty, truth value, validity in the context of science of a specific physical phenomenon. These three components grouped nine phrases from the original 103, and were used to analyse conceptions in the testees.

RESULTS

PCA was performed over the sub-group of the 9 phrases (see Appendix I), and three equivalent components were found which satisfactorily passed the requisites of validity. Each component explains more of the 17% of the total difference, and the whole explains 56%, moreover, each was interpreted in the light of the phrases they were made of. Table I shows the resulting components.

Component	Interpretation	% Var. Explicate
Comp 1	It is possible to know with a certain probability or margin for error the exact location of the place a missile will hit.	20.4
Comp 2	It is possible to know certainly and accurately the exact location of the place a missile will hit.	17.7
Comp 3	Affirmations of science cannot be defined as true nor be formulated as completely accurate.	17.5

Table I: Interpretation of the resulting components and % of the explained difference

The tipicity index was estimated for each one of these components, as an average of the phrases it was made of pondered by its factor loading. The typical quality of each component was considered in an ordinal way grouping the values in three equal intervals classified as disagreement, indifference and agreement. The results are shown in Figure 1.

As can bee seen in Figure 1, approximately half of the responses are in the indifference area for all three components. In component 1 a high percentage of agreement with the probabilistic idea can be seen, although most of them also agree with the idea of certainty, and this implies ambiguity in the interpretation of the concepts. The equal distribution of agreement and disagreement in both components 2 and 3 should not be taken as similar interpretations seeing that with the method of building of the components their co-relationship is low. This implies that it is not the same testees who do not agree or disagree with both factors.

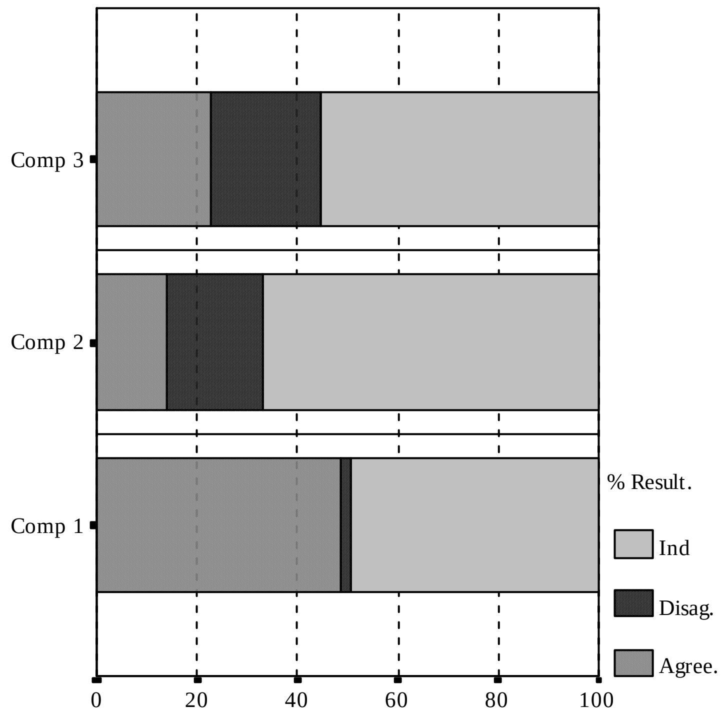

Figure 1: Percentage of responses in agreement, disagreement and indifference in each component

The combinations of answers within factors show diverse postures distributed among all possible combinations of these three components, showing that only 10% of the testees show a posture which is scientifically adequate, i.e., agrees with components 1 and 3 and disagrees with 2. Nine % of the testees admits probability and certainty in scientific phenomena, i.e. agrees with component 1 and disagrees with component 3, while only 16% agrees with both components.

CONCLUSION

It is worrying to note that students show diverse interpretations of terms such as probability and accuracy and that these do not coincide with the scientific meaning of the terms.

Half of the testees do not have definite postures regarding the phrases under discussion, what represents a high percentage considering their simplicity. This sample, taken among a group of students interested in studying Engineering, reveals a poor knowledge of the topics analysed. It is feared that major deficiencies may be found in students who have finished the secondary school and have different interests.

It is highly important in our role of teachers at the basic level of engineering to acknowledge the deficiencies our students may have in order to help them to improve, taking into account that similar words may carry different meaning to teachers and students. The teaching of physics at any level should take into account modelling and probability. It is advisable to do activities which aim at surpassing ingenuous beliefs about deterministic models apart from including probabilistic models as from pre-university levels, not only in Maths but also in Physics.

ACKNOWLEDGMENTS

This paper has been made within the following projects: PICT 04-13646-BID 1201/OC-A and C054 UNLaM. A special thanks goes to Sonia Concari (Universidad Nacional del Litoral) for making helpful suggestions and corrections.

REFERENCES

Aikenhead, G. S., Fleming, R. W. and Ryan. (1987). A. High school graduates beliefs about science, technology and society I. Methods and issues in monitoring students. *Science Education*, 71(2), pp.145-161.

Aikenhead, G. S. and Ryan, A. (1992). The development of a new instrument: Views on Science–Technology. *Society (VOSTS) en Science Education*, 76(5), 477-491.

Alvarez, M., Giuliano, M., Nemirovsky, I., Pérez, S., Romero, C., Sacerdoti, A., Santorsola, M. V. and Vázquez, S. (2004). El análisis multivariado ACP como método para agrupar concepciones sobre la naturaleza de la ciencia en alumnos de ingeniería. SIEF 7, La Pampa.

Azcárate, P., Cardeñoso, J. M. and Porlán, R. (1998). Concepciones de Futuros profesores de primaria sobre la noción de aleatoriedad. *Revista Enseñanza de la Ciencias*, 16(1), 85-97.

Batanero, C. (2002). Los retos de la cultura estadística. *Jornadas Interamericanas de Enseñanza de la Estadística*, Conferencia inaugural, Buenos Aires.

Fischbein. (1975). *TheIintuitive Sources of Probabilistic Thinking in Children*. Dordrecht: Reidel

Gilbert, J., Boulter, C. and Rutherford, M. (1998). Model in explanations (Part 2). *International Journal of Science Education*, 20(2), 187-203.

Giuliano, M., Pérez, S., Álvarez, M., Nemirovsky, I. and Sacerdoti, A. Análisis estadístico de actitudes tecno-científicas de alumnos que ingresan a carreras de Ingeniería. Memorias de REF XIV, Reunión Nacional de Educación en Física, Octubre de 2005, Bariloche.

Hair, Anderson, Tatham, and Black. (1999). *Análisis Multivariante* (5th edition). Madrid: Prentice Hall Iberia.

NCTM. (1989). Curriculum and evaluation standards for school mathematics. Reston, VA: Author.

NCTM. (1991). *Estándares Curriculares y de Evaluación para la Educación Matemática*. Sevilla: Sociedad Thales (traducción española del original publicado en 1989 por la National Council of Teachers of Mathematics).

Sacerdoti, A. and Giuliano, M. (2004). La Probabilidad como medida de la información. Memorias *IV Conferencia* Argentina de Educación Matemática, Buenos Aires.

APPENDIX I

	PCA was performed over the sub-group of the following phrases
P 1	La ciencia puede decir si algo es valido o invalido
P 2	Las afirmaciones de la ciencia no pueden definirse como verdaderas.
P 3	La ciencia no puede formular nada con total certeza.
P 4	Es posible conocer con certeza la ubicación del lugar de impacto de un misil
P 5	Es posible conocer con exactitud la ubicación del lugar de impacto de un misil
P 6	Es posible conocer con cierto margen de error la ubicación del lugar de impacto de un misil
P 7	Es posible conocer con cierta probabilidad la ubicación del lugar de impacto de un misil
P 8	las teorías científicas cambian conforme se descubre que son incorrectas (o no tan correctas).
P 9	Las teorías científicas cambian, porque otros científicos pueden encontrar errores entonces se reúnen y lo exponen a sus colegas y discuten su veracidad.