Comments on the Quantitative Reasoning Report

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Abstract

We analyze the Report "La Interpretación y la Comprensión: Elementos Fundamentales del Razonamiento Cuantitativo" ("the **Report**") prepared by Group 4 of the ACE/Kellogg Project to Reconceptualize the Baccalaureate degree at the University of Puerto Rico, Río Piedras. It is shown that the **Report**, which studied quantitative competencies, has serious flaws in its assumptions, its research methodology, and, therefore, its conclusions and recommendations.

The **Report** is also analyzed within the context of the proposed reform of the Baccalaureate. The final document of the Academic Senate concerning this reform, *Un Nuevo Bachillerato para el Recinto de Río Piedras* [17] ("the **Senate Document**"), is shown to contain important omissions and contradictions. Studies of students and graduates, carried out by the Office of Academic Planning, are analyzed and found to be inconsistent with claims in the **Senate Document**. It is concluded that insufficient justification has been provided for proceeding with reform of the Baccalaureate degree in the manner envisioned and, in particular, with the **Report**'s recommendations concerning the teaching of quantitative reasoning.

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1 Background

In 1995 the Academic Senate of the University of Puerto Rico, Río Piedras Campus initiated a project to "reconceptualize" the baccalaureate degree. This initiative was identified for support by the ACE/Kellogg Project on Leadership and Institutional Transformation, which is funded by the W.K. Kellogg Foundation. Initially the reconceptualization process focused upon:

i. strengthening of the teaching-learning processes,

ii. strengthening of linguistic competencies, and

iii. strengthening of academic support systems for students.

In 1998 it was decided to add

iv. strengthening of quantitative reasoning skills across the curriculum.

One result of this project was the creation of a "Center for Academic Excellence" and the appointment of resident professors in the areas of quantitative and linguistic competencies. In February 2001, the report *La Interpretación y la Comprensión: Elementos Fundamentales del Razonamiento Cuantitativo* ("the **Report**") was received by the Mathematics Department. According to an American Council of Education (ACE) document [1]

> "Another key to the success (of the ACE project at the UPR) has been the careful **selection** of participants according to their capacity for teamwork. The one task force that has had the most difficulties in producing results is precisely the one in which **selection criteria** were not strictly followed." (Emphasis added).

Thus the UPR "task force" on quantitative reasoning skills appears to have been *selected* using the rather narrow criterion of *capacity for teamwork*. How exactly was this capacity measured? Were any other criteria taken into account? The **Report**'s clear ideological bias in favor of constructivism is the predictable result of this selection. Accordingly, it is necessary to treat with great caution the conclusions and recommendations of this "task force".

It is shown in the sections that follow that the **Report** has serious flaws in its assumptions, its research methodology, and, therefore, its conclusions and recommendations. Given the already deplorable state of mathematics education in Puerto Rico, the policies recommended in the **Report** could have disastrous consequences.

The following is an analysis of this report.

2 Analysis of the Report

Comments are organized following the **Report**'s four parts.

2.1 Report – Part I. Introduction

The definition of quantitative reasoning (p. 3) that sets the tone for the rest of the **Report** is incoherent, making rational discussion difficult. The so-called quantitative reasoning skills referred to on pages 3 to 6 of the **Report** (fracciones, porcientos, álgebra, representaciones gráficas . . .) actually comprise a very small subset of the syllabi of some of the mathematics courses listed on page 34 of the **Report**. In many countries, such topics are included in the mathematics curriculum somewhere between the 6th and 8th grades.

Quantitative and mathematical reasoning are treated in the **Report** almost as if they were interchangeable. A careful reading of the Graduate's Profile as spelled out in the Bachelor's Reconceptualization Project (*Proyecto de Reconceptualización del Bachillerato*) suggests that the revised curriculum expects the graduate to master more than just quantitative reasoning skills. For example, included in the Profile's requirements are the following:

3. Posea el conocimiento en las artes y las ciencias que le permita reflexionar críticamente sobre la naturaleza, la sociedad y el ser humano, así como sobre las tradiciones culturales de la humanidad.
4. Valore, critique y renueve el conocimiento, y las destrezas necesarias para obtener, manejar y evaluar la información, de manera que pueda contribuir a la producción de nuevo conocimiento.
6. Conozca profunda y ampliamente por lo menos un campo, disciplina o área de estudios.
7. Cultive la imaginación, creatividad e iniciativa y desarrolle la aptitud emprendedora que lo capaciten para realizar proyectos de investigación, creación y aplicación del conocimiento en iniciativas de alcance económico, social y cultural.
10. Domine las competencias de razonamiento cuantitativo necesarias para desempeñarse adecuadamente en el manejo de la información matemática y estadística.

It is unlikely that the kind of quantitative reasoning competencies supported by the **Report** will on their own be sufficient to advance the above goals. In order for students to compete successfully in a challenging era of globalization, training in mathematics is essential. It is precisely mathematical education, as opposed to quantitative reasoning, which trains the brain and enables students to think and reason correctly whatever their discipline. It is the lack/non-existence of good prior **mathematical** training which is responsible in the first place for the current dearth of quantitative skills. Mathematical reasoning should not be equated with quantitative reasoning.

According to Kleinfeld [9], a University of Iowa Mathematics professor,

> "The power of mathematics is abstraction. [. . .] Pure reasoning with symbols in place of arbitrary numbers lets one prove things that are true independent of a particular choice of numbers." "Without the proper definition, things are difficult. With good definition, they are simple and clear."

H. Wu [22], a mathematician at the University of California, Berkeley, points out that

> "an over-emphasis on real-world applications robs mathematics of its coherence and internal structure." "When an educational document consistently presents mathematics as a toolshed instead of the edifice that it is, its wholesale revision is overdue."

It goes without saying that these remarks are even more relevant in the sciences. The current situation is far from satisfactory. The Strategic Plan conceives of the University of Puerto Rico as developing into a Research Institution. If the University is to compete successfully at an international level in a *broad spectrum* of scientific endeavors a higher level of mathematical training than is currently required will be needed. A student can currently graduate in biology with only a single calculus course and a single statistics course. While this minimum level of mathematical preparation may be adequate to equip the student for certain careers in biology and the health sciences, it is clearly insufficient preparation for many areas of biological research such as mathematical population dynamics, DNA combinatorics and topology, etc. A similar situation is evident in chemistry. Classification of molecular species is based on algebra and combinatorics. The study of spectra depends on group theory. Analysis of chemical reaction rates often requires a knowledge of differential equations. Unfortunately, however, it is common to find students using tables of group representations without knowing even a single theorem from group theory and discussing wave functions without knowing the definition of a probability density.

Thus, although the existing mathematical preparation may be adequate for certain purposes, the failure to require students to take additional mathematics courses limits their opportunities to a small part of the scientific spectrum. In other areas the situation is the same. In computer science, a proper understanding of, say, fractal image compression is based upon the mathematical discipline of topology. Management science applications such as critical path analysis and linear programming require knowledge of discrete mathematics and graph theory. In order to do *nontrivial* applications students first of all need a good basis in mathematics. Only then can they have the basis to choose wisely among the ocean of possible applications.

2.2 Report – Part II. Analysis of the Current Situation

The four-page Part II, "Analysis of the Current Situation," (!) states the need to build a firmer basis of "quantitative reasoning." It points out that the students' academic achievement is below the Department of Education's goals. It mentions some "studies" of professors' perceptions about the students' difficulties in the area which agree with "research" on the subject (p. 7). Without establishing the difference between perceptions and substantiated research, the **Report** concludes that studies show that "lots of the traditional approaches used in classrooms and in curriculum design are not effective in achieving the objectives of quantitative reasoning. They may even hinder the achievement of these objectives" (p. 8, our translation). Which traditional approaches? Which effectiveness criteria? Which objectives? How exactly do they hinder these?

As part of the "analysis" two workshops sponsored by the Center for Academic Excellence were held to "meet the worries about teaching and obtain the input of professors" (p. 8, our translation). No information is offered as to their effectiveness, how and which input was obtained, how many professors participated, which courses they teach, their experience, etc. Also "analyzed" were the mathematics or statistics requisites of the Campus programs, as well as the syllabi and grades of students in the first mathematics or statistics requirement of various programs. The reader is referred to Exhibits 1 and 2 of the **Report**. Far from being an analysis, Exhibit 1 shows what could be obtained from program catalogues (i.e., just the mathematics or statistics requirement for the program; except for one case, no course descriptions are provided). The one-page Exhibit 2 presents a table of failure percentages (1995–1997) for six of the courses included in Exhibit 1.[1] Can this be construed as an "analysis"?

2.3 Report – Part III. Findings and Interpretation

The third part is no more specific. It leaves unanswered most of the questions already raised, while introducing new ones. Part III is divided into the three "findings" from the studies conducted. Section III.A. indicates that there is a "general displeasure" ("descontento general") among professors regarding students' performance on tasks that require quantitative reasoning (p. 9). Table 1 (p. 10) shows the grades of a sample of students taking a second mathematics course after MATE 3001, a remedial course. No conclusion is drawn from the table or comparisons with other options considered, except from pointing out that in another group of those who took MATE 3023 as first course (with no remedial), 40% failed or withdrew. The method of assigning students to MATE 3001 is not explained. Usually students who take MATE 3023 directly have higher college board scores so this would not be a good control group. The Table is "explained" focusing on failures or withdrawals (p. 11). The same Table, however, also shows that 51% of the students who took the remedial passed MATE 3023 (21, or 37%, with A or B; 26, or 46%, with A, B, or C), and that three students went on to MATE 3018, MATE 3132, MATE 3171 (probably refers to MATE 3151), and earned A in these courses. This other interpretation was omitted.[2]

Sections III.B. and C. criticize the "traditional approaches" and defend the constructivist view and the use of "new technologies." In doing this, the **Report** draws a misleading dichotomy that trivializes mathematics and the way it is and should be taught.[3] The traditional approach, it claims, involves "solving exercises (mechanically)" and "not problems (analytically)" (p. 11). It adds that solving a problem "is understood as looking for a rule that brings about the correct answer, frequently without first analyzing the context and the situation" (p. 11, our translation). Reality is just the opposite. "The essential and characterizing properties of mathematics, which enable it *when properly taught*, to make

[1] Recall that in 1995 the University of Puerto Rico changed the formula for computing the admission index known as the IGS. This led to an increased enrollment in the UPR. College board mathematics scores and results on the Natural Science admission exam indicated that the majority of the extra enrollment had deficiencies in mathematics. The effect of that change on students' performance in mathematics and statistics courses is not discussed in the **Report**.

[2] In any case, given the large fluctuations in pass rates from section to section, the sample size is too small to draw conclusions without a much more careful analysis.

[3] A review of the **Report**'s Bibliography reveals the following: Out of 72 items, 55 are from publications in education or psychology (including six from some of the authors of the **Report**). Of the remaining 17, 14 deal with statistics or the teaching of statistics. Mathematics sources are underrepresented.

unique and indispensable contributions to the education of all youth, are that it is exact, abstract and logically structured" (Allen [2]). A glance at the syllabi of Mathematics courses reveals that topics like proof and mathematical induction, as opposed to inductive reasoning, play an essential role. As Wu [21] points out,

> "The truth is that in mathematics, skills and understanding are completely intertwined. In most cases, the precision and fluency in the execution of the skills are the requisite vehicles to convey the conceptual understanding. There is not "conceptual understanding" and "problem-solving skill" on the one hand and "basic skills" on the other. Nor can one acquire the former without the latter."

While good research examines the merits of various approaches, the **Report** selectively includes only the "studies" that support its constructive ideological framework and omits the wide body of research that support the opposite and alternative views. For example, Anderson, Reder, & Simon [3], a Nobel Prize winner, make the following comments on constructivism:

> "It is not the case that learning is totally tied to a specific context. [. . .] In fact, there are many demonstrations of learning that transfers across contexts and of failures to find any context specificity in the learning." "Knowledge does not have to be taught in the precise context in which it will be used, and grave inefficiencies in transfer can result from tying knowledge too tightly to specific, narrow contexts." "Representation and degree of practice are critical for determining the transfer from one task to another, and transfer varies from one domain to another as a function of the number of symbolic components that are shared." "What is important is what cognitive processes a problem evokes and not what real-world trappings it might have." "When students cannot construct the knowledge for themselves, they need some instruction. There is very little positive evidence for discovery learning and it is often inferior. In particular, it may be costly in time, and when the search is lengthy or unsuccessful, motivation commonly flags." "To argue for radical constructivism seems to us to engender deep contradictions. Radical constructivists cannot argue for any particular agenda if they deny a consensus as to values. The very act of arguing for a position is to engage in a value-loaded instructional behavior. It would seem that radical constructivists should present us with data about the consequences of various educational alternatives and allow us to construct our own interpretations. (But data beyond anecdotes are rare in such constructivist writings.)"

Other serious criticisms of constructivism have been made by Grossen [6], Kozloff [11], Matthews [13], Carnine [4], Thomas [18], and Jennings [8]. Although some constructivist ideas are true (for example, that students are not just passive learners and that they have an interest in understanding themselves and their world), unquestioningly accepting all of its tenets is unwarranted.[4] Overlooked in the **Report**, for instance, are criticisms of the

[4]In the United States and elsewhere this discussion has reached a wide audience. Articles in the **New York Times**, the **Wall Street Journal** and the **San Francisco Chronicle**, among others, report of widespread parental protests against the new math, MathLand, Connected Mathematics, and other projects inspired on constructivism (Hartocollis, [7]; Saunders, [15]; "Math wars," 2000).

writings of Piaget and Vygotsky, two pioneers of constructivism. Many studies question their methodology and the validity of their conclusions. Also overlooked are the results of Project Follow Through,[5] as well as the criticisms of the National Council of Teachers of Mathematics' (NCTM) Standards which has been correlated to lower mathematics skills. In the United States, the worst impact has been on Hispanics and blacks. For an evaluation of the NCTM Standards, see Wu [22], [21], Carnine [4], Schommer [16], and articles in the Web site `http://mathematicallycorrect.com/`. A report of the Council of the London Mathematical Society (quoted by Wu, [22]) on similar changes in the United Kingdom points out that, "we can look forward to a generation of students with:

- i a serious lack of essential technical facility—the ability to undertake numerical and algebraic calculation with fluency and accuracy;
- ii a marked decline in analytic powers when faced with simple problems requiring more than one step;
- iii a changed perception of what mathematics is—in particular of the essential place within it of precision and proof.

Some of the "truths about the NCTM Standards," according to Quirk [14], are that "it is talking about history and sociology, not math" and that "it wants to substitute calculator skills for the logical and abstract thinking skills that can only be learned through the mathematical disciplines of algebra and plane geometry." He adds that, unlike NCTM thinking, "most of math is not impacted by calculators and computers" and that "recognizing patterns depends on remembered math facts."

The **Report** states that to apply mathematics and statistics, "a set of attitudes and competencies are needed that go beyond the knowledge of mathematics and statistics" (p. 13, our translation). But there is a mutually reinforcing relationship between attitudes and competencies and knowledge. We come to appreciate more certain bodies of knowledge the better we know them. The **Report** adds that these "attitudes and competencies" are developed in the long term, not just in a course; "this is why it is important to integrate the competencies of quantitative reasoning throughout the curriculum" (p. 13). What is there to integrate when there is a vacuum? What is there to integrate if students lack basic mathematical knowledge? Mathematical thought is trivialized once it is reduced to a list of applications and examples.

The **Report** also points out that "new technologies" (the calculator included!) "free" the students from computations and, therefore, allow their attention to be "focused on interpretation and evaluation" (p. 15). How exactly does this follow? No one denies that

[5] Project Follow Through, a longitudinal study funded by the United States government in more than 180 US schools (kindergarten through third grade) representing 51 school districts, demonstrated that the traditional Direct Instruction method was most effective when compared to the other models tested, some of which were based on constructivist views. Students in the Direct Instruction groups performed better on both academic and affective (self-concept) measures. The Project, which cost almost a billion dollars and ran from 1968 to 1976 (Follow Through continued until 1995 as a federal service program), collected yearly data on around 10000 students. Later evaluation of 1000 graduates of the Direct Instruction groups showed that, in their senior year of high school, their performance was still better than their counterparts'. For details on Project Follow Through, see Grossen [6], Watkins [19], and Carnine [4].

"new technologies" can be quite useful in teaching and learning. Yet, are the students' brains limited and compartmentalized in such a way that if they are too busy "computing" they will not be able to fully interpret and evaluate?[6] And, once freed from computations, will they necessarily be focused on interpretation and evaluation? Aren't these interconnected processes? Doesn't computation help in evaluation and interpretation? Aren't students freer the more confident they feel deriving formulas and knowing how results are obtained? (without adding the enslaving effect of power outages, weak batteries, devices gone awry or left at home, etc.) To use a computer correctly to solve mathematical problems first requires a certain level of mathematical sophistication. The type of abstract thinking required cannot be taught by computers.[7]

2.4 Report – Part IV. Proposals

Part IV remarks that there should be a "continuous dialogue" with the academic community regarding the quantitative reasoning component changes and that the **Report**'s proposals are the result of such a dialogue (p. 17). However, the Mathematics professors, a major constituency in this issue, were not formally consulted or widely involved in the process. The "proposed model" is based on a series of general "findings", most of which are obvious ("quantitative competencies are fundamental in our daily and professional lives"; "students' needs vary") and could justify a number of other recommendations different from the **Report**'s.

The **Report** supports the list of competencies needed to meet the quantitative reasoning component's goals by its own definition of the concept and "other university requirements such as Alverno College's" (p. 18). Why was this College—an independent, four-year liberal arts college for women with an enrollment of approximately 1900 students (quite different from the University of Puerto Rico!)—selected? What criteria were used in this selection? Was it, perhaps, because most universities—in the United States and elsewhere—favor a different model? What are the requirements of these other institutions? Do the above two reasons support the list of "competencies"?

Among its additional recommendations, the **Report** suggests considering alternatives to the Introductory course in each area, including another course that covers subjects that allow students to see the need, richness and limitations of quantitative analysis "from different perspectives" (p. 26). It is unclear what such a course would be like since no syllabi or further information is provided. It adds that the Introductory course "could also be substituted" by workshops, tutorials or laboratories associated to an experience of quantitative analysis in a course of different content.[8] It states that any of the alternatives should give the students the

[6] In a recent Calculus class I asked my students to simplify $(0.1)^5$. Of 12 second and third year natural science majors only two could provide a correct answer. Some suggested $(0.1)^5 = 0.1$; others that $(0.1)^5 = .11111$. Many students cannot sum the points on their exams without the use of a calculator. This lack of skill is partly the result of excessive reliance on calculators in the high school and a failure to teach the traditional algorithms. The situation is hardly likely to be corrected by replacing basic Math courses by yet more calculator labs, modules in **quantitative competencies**, training in the Internet, etc.

[7] "Calculation and technology need to be accompanied by understanding" (Kleinfeld, [9]. For more on the subject see Koblitz [10] and Quirk [14]).

[8] This is already happening—with disastrous consequences. In a document of the Chemistry Department written for the "Taller de Prequímica" in summer 2001, the parabola $y = x^2$ is incorrectly drawn with clear

opportunity to achieve five competencies (p. 26), which are actually a subset of the previous list (pp. 19–20). Missing from these five are, among others, the logical thinking and the formulation of arguments that a mathematics foundation provides. Research justifying those alternatives should have been provided.

Finally, the **Report** questions the existence of remedial courses. It points out that there is "no evidence to show that remedial courses improve substantially the students' success in the course that follows" (p. 27, our translation). Some studies contradict this. For example, the **Report** ignores studies that conclude that remedial courses lower the number of students leaving school without a degree (University of Wisconsin System, Durhams [5]). Another study at West Chester University [20] showed that students with SAT Math scores of 530 or below tended to do better in university level mathematics courses once they had completed the remedial math course. It does incredible damage to students to pass to the next higher level when they have not mastered the previous level.[9] Endless cycles of failure are caused as witnessed by the transcripts of hundreds of students. The elimination of remedial courses contradicts the university's mission to educate and hurts the most those that are already disadvantaged.

The **Report** provides two additional reasons to support the elimination of remedial courses: they do not meet students' individual needs and they mainly teach techniques not always taught "in context" (p. 27). Neither of these are inherent features of a remedial course. That is, a remedial course can be individualized if supplemented by tutorials, accompanied by diagnostic tools, etc. The **Report** itself acknowledges that the tutorials offered by the Mathematics Department have benefited students (p. 24). It is better to reinforce and improve existing programs. Besides, nothing rules out applications from a remedial course, once students know basic concepts and techniques which should have been mastered in previous schooling. It is hard to imagine how "in context" teaching can be when some students do not know how to divide by ten or multiply by zero, as has been our actual experience. Neither is dividing the remedial course (MATH 3001 in our case) into small modules the solution. Usually students who have trouble with such things as fractions and percentages have so many other mathematical problems that a few modules are unlikely to help the situation. In addition, modules at this level give the false idea to the student that mathematics is

non-zero slope at the origin and one half missing. A graph of the logarithm function is shown passing through the origin instead of approaching negative infinity from the right! and the canonical hyperbola $xy = 1$ is drawn with an incorrect vertical asymptote. These errors have serious chemical as well as mathematical consequences: the potential function of a harmonic oscillator is parabolic; *ph*, a measure of acidity, is defined as the logarithm to the base 10 of the reciprocal of the hydrogen ion concentration; the perfect gas law yields a hyperbolic relationship between pressure and volume for fixed temperature, etc. The text of this document whose purported aim is to teach graphing and interpolation is almost total nonsense, the authors having no clear understanding of what constitutes a proper mathematical definition. The fact that this can happen in a quantitative area like Chemistry should be a warning as to what could very well happen if, as suggested by the **Report**, introductory mathematics courses are "substituted by workshops, tutorials or laboratories associated to an experience of quantitative analysis in a course of different content." It is essential that those who teach mathematics be properly trained in the area.

[9] The California State University System recognizes this. **All** students entering the CSU system are expected to take three years of college preparatory course-work in mathematics, while a fourth year of Precalculus is recommended. Students failing the entry level placement exam are required to take remedial course-work. In 1998 the number of students requiring remediation in mathematics increased to well over 50%.

somehow separated into lots of different independent compartments rather than being a way of thinking. Students need a coherent course with a solid mathematical content—not just a bit of this and a bit of that. Important courses should not be eliminated without substantial reasons.

Among the administrative issues that the **Report** briefly covers, it recommends that a *Grupo Interfacultativo* that started as part of the ACE/Kellogg Project be institutionalized. This Group would be coordinated by the Dean of Academic Affairs and would recommend university policy on quantitative competencies, support its implementation and its evaluation, as well as the exchange of professors from different areas. This adds yet another level to the University's bureaucracy. In the absence of rigorous criteria as to its composition (including criteria for the selection of its members), its objectives, and its functions, this group could very well end up hindering, rather than enhancing, the mathematical education of our students. We should, indeed, encourage the exchange of ideas between faculties and departments. However, when this exchange is meant to *recommend university policy*, many questions arise, including the implications on the role of Faculty and Department Curriculum Committees.

2.5 Summary

We can summarize the **Report**'s main flaws as follows:

1. Lack of precise definitions.
2. Terms which have different definitions are used interchangeably.
3. Insufficient evidence (i.e., research-based literature, scientific research) to support its recommendations.
4. Lack of evaluation of the "studies" mentioned; no discussion as to their limitations.
5. Insufficient distinction between opinions, perceptions, anecdotal evidence, and substantiated research.
6. Omission of studies that question or contradict some of its assumptions, conclusions, and recommendations.
7. Questionable interpretation of some of the data presented.
8. Lack of supporting materials to back its claims (such as syllabi, questionnaires used, data from workshops and focal groups, etc.)
9. Lack of examination of curricula of universities that excel as teaching and research institutions in the United States and other countries.
10. Lack of full consideration of all of the items of the Graduate's Profile that have implications on the design and implementation of the mathematical training of students.
11. No consideration of the impact of its recommendations on the University's status as a research institution, as well as an institution with a wide variety of graduate programs.

12. Insufficient input from mathematics professors and researchers.

13. Failure to consider the administrative and budgetary issues.

We conclude with a quote from the **Report** itself (p. 21). In a section which advocates teaching quantitative reasoning within the context of courses which use such reasoning, supported by modules, laboratories, workshops, etc., the **Report** quotes Cobb as saying:

> *[Plato's] curriculum began the education of the future philosopher kings with a decade of mathematics, as a foundation for reasoning, but followed that decade with another devoted to the subjects—more difficult in Plato's estimation—that brought pure reasoning into contact with the real world.*

This quote seriously undermines the recommendation made on page 26 of the **Report** that introductory mathematics courses be "substituted by workshops, tutorials or laboratories associated to an experience of quantitative analysis in a course of different content." Plato, who was not a pure constructivist, clearly recognized the importance of mathematics.[10] A sound mathematical basis is necessary if any meaningful integration is to be attained. Real applications require this basis. Moreover, mathematical training is important for training the mind, independently of any applications. A true Reconceptualization of the Bachelor should reinforce, and not weaken, the foundation for reasoning that mathematics uniquely builds.

3 Quantitative Literacy and Reform of the Baccalaureate

As mentioned in the introduction, the **Report** arose out of the project to "reconceptualize" the Baccalaureate degree supported by the ACE/Kellogg Project on Leadership and Institutional Transformation. Thus a proper analysis of the **Report** is incomplete without some reference to its place in the context of this more general scheme. The final report of the Academic Senate concerning the reform of the Baccalaureate *Un Nuevo Bachillerato para el Recinto de Río Piedras* [17] was approved (by the Senate) in May 2001. The following is a brief analysis of this report, henceforth referred to as the **Senate Document**.

3.1 Analysis of the Senate Document

It is well known (and moreover true), that there are profound and complex problems at all levels of the educational system in Puerto Rico. The situation in the high schools is catastrophic. Many students arriving at the universities have (through no fault of their own) huge gaps in their academic preparation which require extensive remediation. This is especially true in languages and mathematics. Concomitant with this situation, there is a pressing need to reform many aspects of the baccalaureate degree. However, because of the serious and almost irreversible consequences of mistaken policies, proposers of radical change should proceed with due caution. In particular, at least an objective and rigorous analysis

[10] In fact it is said that above the door of Plato's Academy was written: *Let no man who does not know geometry enter here.*

of the problems and the proposed solutions should be provided. In professional fields like medicine it would be unthinkable to introduce a new drug without very careful field testing, particularly if there is an existing one with a proven track record. Likewise, in education, a curricular structure which has served generations of students well should only be replaced if an alternative system is, after careful scrutiny, expected to be undeniably superior. As in medicine, mistakes in education have widespread and potentially fatal consequences.

Unfortunately, the **Senate Document** [17] provides meagre justification for the reforms it advocates. It contains:

no field studies,

no review of the relevant literature,

no analysis of the studies of alumni and undergraduate students,

no analysis of whether and how the proposed changes achieve the **Senate Document**'s recommended Graduate's Profile,

no studies of distinguished universities,

no studies of similar restructurings in other institutions,

no explanation as to why current change mechanisms (e.g. Departmental and Faculty Curriculum Committees, procedures for the creation of new programs, etc.) are inadequate,

no reference to studies which question its philosophical basis of constructivism as well as many of its other assumptions,

and of primordial importance,

no section explaining and justifying the need to reconceptualize the baccalaureate.

In the next two sections we examine two studies which contain findings which contradict some of the suppositions of the **Senate Document**:

1. *Perfil del Estudiante de Bachillerato y Percepción Estudiantil del Bachillerato (1998)*, Office of Academic Planning, University of Puerto Rico, Río Piedras.

2. *Estudio de Egresados del Bachillerato (2001)*, Office of Academic Planning, University of Puerto Rico, Río Piedras.

For some strange reason, the **Senate Document** contains no reference to the results of the first study although, as noted on page iv of the **Senate Document**'s section "Transfondo," it was actually commissioned from the Office of Academic Planning by the Senate's Special Committee for the Reconceptualization of the Baccalaureate! Moreover, included among the collaborators of the Reconceptualization Project in Appendix 1, is a list of five persons who worked on the "perfil del estudiante de bachillerato y estudio de percepciones, bajo la Oficina de Planificación Académica".

3.1.1 Perfil del Estudiante de Bachillerato (1998)

The following findings are based on the most frequent responses of the 661 students who answered the questionnaire:

- A majority of students expressed satisfaction concerning a variety of academic and non-academic aspects of life at the Río Piedras Campus. The categories in which the greatest degree of satisfaction was observed have to do with **curricular** matters—course content and level of complexity of courses—as well as with the general university environment.

- A majority of students stated a preference for the offering of basic courses during the first year of studies and in the Faculty of General Studies. They also preferred to "**leave unchanged**" the components of the Bachelor's degree.

- The majority of students recommended that the amount of practice and participatory discussion courses be increased. Although this seems to coincide with assertions in the **Senate Document**, a majority of students actually recommended that the number of laboratory courses be left unchanged. In fact, a greater percentage of students were in favor of **not** changing the number of laboratory courses than in increasing the number of participatory discussion courses. Moreover 46.3% wanted to "leave unchanged" the number of lecture based courses (a higher percentage than those who recommended reducing them; in fact, some 21.3% recommended an increase).

- The majority of students expressed satisfaction with their university experience in matters related to personal, academic and professional development.

- Contrary to what the reader of the **Senate Document** would infer, the majority of students either agreed or partially agreed with the existing curricular sequence, the integration between different disciplines and the balance between theoretical and practical components. Furthermore, some 52.1% stated that they were in partial or total agreement with the flexibility of the program and only 38.4% were in disagreement. It would be pertinent to ask which recommendations this latter group of students would make concerning this matter given that the majority of students express satisfaction with the current curricular structure.

3.1.2 Estudio de Egresados del Bachillerato (2001)

The following findings are based on the most frequent responses of the 1580 graduates who answered the questionnaire:

1. "Excessive number of credits" is not the factor which causes many students to take 9 or more semesters to complete their degree. On the contrary, the data suggest personal reasons or deficiency in the orientation and registration processes.

2. The majority of graduates recommended that the total number of credits in each of the following categories remain **unchanged**:

   Total credits

   Credits in the concentration

   Credits required by the faculty

   Credits in free electives and interdisciplinary courses.

3. The majority of graduates expressed satisfaction with **curricular** (course content, academic quality) and **teaching** aspects (interest of the professors in the teaching process) both of the concentration and of faculty requirements.

4. The majority of graduates expressed satisfaction with the integration of learning with personal experience.

5. The main positive factors were curricular and teaching; the worst were registration and orientation processes.

6. Finally, the majority of graduates considered that the academic preparation at the Río Piedras Campus has prepared them well ("excellent/good") for further studies as well as to compete in the labor market.

In conclusion, neither of these studies support a restructuring of the Baccalaureate as proposed in the **Senate Document**.

3.1.3 Some contradictions of the Senate Document

The **Senate Document** contains many contradictions. The following is a partial list.

- It claims to promote flexibility yet at the same time it imposes limits on the number of credits of each curricular component and on the total number of credits. This inflexibility ignores the characteristic requirements and particulars of each program. Some programs, because of their professional or technical nature, accreditation requirements, and/or students' academic background, may require more than 140 credits.[11] This is particularly true in areas such as mathematics and computer science where the quantity of core material is relatively large and, at the same time, student preparation in the high school is poor.[12] Consequently, much of the class time of courses in these areas is spent teaching material which should have been, but unfortunately is not, covered in high school.

  The claim to greater variety and flexibility is also contradicted by the **Senate Document** that requires institutional policy to be determined by Committees on Skills.

[11] It is interesting to note that the original Baccalaureate in Business Administration at the University of Puerto Rico which started in 1926, required 154–158 credits including mainly professional courses, one year of algebra, one year of geometry, and additional courses in commercial mathematics. The final year consisted of a supervised internship in some company.

[12] The current Baccalaureate degree in Mathematics does not even include a course in the Foundations of Mathematics. Such a course is essential to prepare students for all further courses in Mathematics and Computer Science and in most universities is taught in the first year (if not in high school). In the absence of such a course, the appalling failure rates in Abstract Algebra, Linear Algebra, Advanced Calculus, as well as in many Computer Science courses, can well be expected to continue. Nor are there any courses in the extremely important area of Discrete Mathematics. The single Advanced Calculus course in the current degree does not even provide time to cover integration theory. Thus the degree is already inadequate and it is difficult to see how reducing the number of credits will improve this situation. A University of Puerto Rico graduate who has taken only the specified courses is not ready to enter any good graduate program in Mathematics. This is evidenced by the fact that almost no student could pass the placement exam of the new graduate program in Mathematics.

No reasons are evoked for the creation of committees to set university policy concerning "quantitative" and other skills. Also, in the absence of sound selection criteria a very grave danger exists that policy in such fundamental areas will be dictated by persons who are not fully expert in the corresponding material or who are motivated by ideological concerns rather than well-grounded evidence.[13]

Whereas a great deal of flexibility in choice of courses is given to the student it seems that some Faculties do not have much confidence in the students' ability to make good decisions. For example, **in addition to** the existing orientation processes, the Natural Sciences Faculty has felt it necessary to introduce an Orientation Seminar. This seminar, as evidenced by its content, presupposes that the students may not be equipped to make even the most elementary decisions. Specific objectives of this seminar include:

– Identify the location and the purpose of essential services such as academic and personal advice, economic aid, registrar, etc.
– Make adequate use of documents such as the academic calendar, course schedules, student handbook, course catalogue, etc.
– Make adequate use of support centers and university facilities.
– Visit his/her academic advisor to make a plan of study, etc.

The criteria for passing this seminar course include written reports such as *student calendar to take courses [sic] and carry out all admission processes related to their area of interest.* (Our translation). Thus this seminar assumes that incoming natural science students (even with the support of the existing orientation programs and faculty advisors) do not even know how to **read** a calendar, course schedules, curriculum requirement sheets, admission procedures, organization charts, etc. Can such students correctly choose the course sequence which leads, say, to a proper understanding of an area such as electromagnetism?

- The Reconceptualization Project claims to pursue integration of the curricula but fails to mention how this will be achieved.

[13] There is evidence that this is already happening. At the Center for Academic Excellence, "Resident Professors" of Linguistic and Quantitative Skills have been appointed. Were these positions advertised to the academic community? What were the selection criteria? What effort was made to find the most suitably qualified candidates?

At a recent workshop of the Center for Academic Excellence entitled "Development of Thinking Skills for Life via Mathematics" the speaker (a member of the Committee on Quantitative Skills) presented a disparaging viewpoint of traditional Mathematics Courses. The inevitable PowerPoint presentation included a slide which read as follows:

> Question to Graduates of Humanities, Social Sciences or Education
> How would you describe the Mathematics component of your university education?
> The answer would **probably** be: *I completed my requirement.*
> What do you remember of the course?
> The answer would **probably** be: *I made a C in the course.*

Thus lack of evidence is replaced by opinion and anecdote! Evidently, no attempt was made to find students' real opinions. Other slides made similar pejorative remarks about so-called "traditional" mathematics.

- The Reconceptualization Project places great emphasis on the concept of a “Comunidad de Aprendizaje.” Yet, the **Senate Document** was approved **before** the faculties had been able to review and discuss its final version. This version differs substantially in a number of major aspects from that circulated previously (for instance, the proposed curricular structure, the creation of Skills Committees, the absence of a section explaining the reasons to “reconceptualize,” among others). Thus, the Senators voted without having the input of the faculties they are supposed to represent. Moreover, the Senate approved this version in spite of the fact that it was aware that a considerable number of professors (more than 10% of the faculty body) had signed a letter to the Rector requesting a faculty meeting to discuss the Reconceptualization Project. A “comunidad de aprendizaje” calls for the widespread exchange, debate, and deliberation of ideas; not the lack thereof.

- The Reconceptualization Project fails to adequately address important budgetary, administrative, and implementation issues that are essential for the evaluation of any proposal. Certificación 93-113 of the Academic Senate requires that these be discussed in case of program revisions. (Some of the many questions that are left unanswered: class sizes, transfer and convalidation procedures, prerequisites, etc.)

3.2 Summary

The Reconceptualization Project has serious repercussions for the future of our University. It impacts not only the curricula of the Baccalaureate but also its structure and philosophy, not to mention the associated academic and administrative processes. It will have an impact on future generations of students and, therefore, on society at large. In this section we have shown that the **Senate Document** which prescribes this Reconceptualization suffers from many of the same deficiencies in its assumptions, research methodology, and, therefore, in its conclusions and recommendations as does the report on quantitative reasoning. No serious analysis is provided for the restructuring of the Bachelor’s degree in the manner proposed.

True reform should proceed carefully on the basis of all the evidence and take into account proven models. Students are not guinea pigs for the testing of the latest educational fads.

4 Concluding Remarks

Part 2 of this document shows that there exists no justification for implementing the recommendations on quantitative reasoning contained in the **Report**. Part 3 indicates that the Bachelor’s Reconceptualization Project is also seriously flawed. It contains many contradictions and is inadequately supported by the evidence presented in the corresponding **Senate Document**. Since this document is the instrument which outlines the details and philosophy of the Reconceptualization and creates the concomitant bureaucratic mechanisms (committees on skills, etc.) which will formulate policy, its implementation should be put on hold until the deficiencies herein remarked are addressed. Our analysis has pointed out the clear danger in proceeding with a Reform which is not properly justified. Meanwhile, we should use the momentum that the Reconceptualization process has brought about as an opportunity to engage in a productive dialogue which proves our commitment to improving higher education in Puerto Rico. This is a unique opportunity to build an institution of excellence and, thereby, make a significant and enduring contribution to our society. It is hoped that the remarks in this paper will contribute to this endeavor.

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