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Why Mathematics Is Essential In Biomedical Sciences Degree?

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Abstract

Improvement of mathematical education and motivation of students in the mathematics' area is needed. What can be done? We introduce some ideas to generate the student's interest for mathematics, because they often present difficulties in appreciating the relevance of mathematics and its role in the health sciences. We consider that a cornerstone in the strategy to attract the students' interest is linking the mathematics with real biomedical situations. We proceed in the following manner: We first present a real biomedical situation to produce interest and to generate curiosity. Second, we ask thought-provoking questions to students as: Which is the biomedical problem presented? Which is my knowledge on this situation? What could I do to solve this biomedical situation? Do I need some new mathematical concepts and procedures? Thereupon, the teacher explains the mathematical concepts necessary to solve the case presented, providing definitions, properties and tools for graphical display and/or mathematical calculations. In this learning methodology, ICTs were cornerstones for reaching the proposed competences. Furthermore, ICTs can also be used in the evaluative task in its two possible aspects: formative and for obtaining a qualification. Comments from students about this new mathematics teaching method indicate that the use of real biomedical case studies kept the lessons in mathematics interesting.

Keywords: Mathematics program, biomedical sciences, competences, ICT;

1. Introduction

Progress in post-genomic biomedicine requires the effective collaboration of scientists from different disciplines, combining distinct knowledge from biology, mathematics, and medicine. Students from the Biomedical Sciences degree at the University of Barcelona will be a new generation of postgraduate researchers in this field. Therefore, it is necessary to improve mathematics education and to motivate the student in the mathematics' area. This new approach of teaching mathematics has to be in accordance to the new EHES (European High Education System)

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frame and based on competences. Furthermore, in this learning methodology, ICTs have to be cornerstones for reaching the proposed competences.
Biomedical Sciences degree at the University of Barcelona was introduced in September 2009 and it was essential to have the mathematics subject in the first course. As previously explained, a traditional course would be easy for a classical teacher, but this approach was considered not convenient for the new students of this degree. It was assumed that mathematics had to be interesting for biomedical students, giving them a general view of its usefulness. Furthermore, it was considered that the proposed biomedical problems would be an interesting way to introduce mathematical concepts and procedures to the students. The main aim of this communication is to present the program that was developed for the mathematics subject and some of the biomedical examples used to introduce and explain each lesson.

2. Biomedical situations and program

The program is organized in six main blocks: Functions, successions and series, integration, difference equations, differential equations and matrices. However, in the first day of class the subject is introduced by indicating the utility of mathematics in our common life, commenting on police TV series such as "Numbers", where mathematics are used to solve criminal cases, and finally showing interviews of several distinguished biomedical researchers explaining its importance (for example, Professors C. Cordón-Cardo and I. Daubechies). Finally, many biomedical examples that can be dealt with mathematics are presented (the quality of a diagnosis test or the genetic frequency variation after a number of generations considering mutation and back-mutation).

2.1. Functions

It is easy to find functions that describe biomedical situations such as cardiac rhythm or tumour growing rate (Gentry, 1978; Arenas, 2010; White, 2010). This topic is focused in remaining the basic concepts related to functions, since students have acquired the principal knowledge in high school (continuity, derivability, extrema, and graphical representation). These basic concepts will be useful in introducing the following new topics. One possible motivating example (Arenas, 2010) could be: the biomass of *Saccharomyces cerevisiae* increases approximately according to the logistic curve: $y = \frac{M}{1+ce^{-rMt}}$. The questions presented are: in which instant the function has its greatest rate of increase? In a given instant, which is the relation between the growth rate with the biomass in this moment? The students have to analyse this function and prove the following relation $y' = r(M-y)y$. In a given moment, the growth rate is directly proportional to the biomass in that moment and the difference between the maximum sustainable population and the current size. The students keep this information in a Microsoft Word table. This information will allow with the solving other similar cases, although more complex, for example in the field of differential equations. Finally, the approximation of a collection of data points to a function, and functions with two variables are also explained with examples.

2.2. Successions and series

To introduce this topic, one of the examples that we use is the frequency change of the mutant allele for retinoblastoma along different generations (Arenas, 2010). On the example, the evolution of this frequency depends on the initial frequency, mutation rate and reproductive rate in the affected individuals. The mathematical concepts of successions and series can be developed from this example. The variation of the total drug amount along consecutive days can also be useful as exercises of this block (Gentry, 1978).

2.3. Integration

A classic topic of integration in biomedical sciences is the computation of areas, for instance, the surface of cancer cells in a histological slide (Arenas, 2010). However, recent technological advances, such as measuring with a computerized microscope, have substituted the previous procedures. There are other biomedical situations where integration is also useful. For example, in the evaluation of a diagnostic test based on ROC (Receiver Operator Characteristic) curve analysis, integration is needed (Arenas, 2010). The curve illustrates the trade-off between the false positive rates and true positive rates. The area under the ROC curve indicates the accuracy of the diagnostic test.

2.4. Difference equations

To introduce this block the following example is presented: a bacteria population which doubles its size every generation, but a known number of cells are lost in each generation due to sampling by the researcher to motorize the culture (Gentry, 1978; White, 2010). The question presented to the students is: which is the size at each generation if the initial number of individuals is known? Thus, with this example it is possible to develop the difference equation topic and additionally relate it to the successions lesson that was previously explained.

2.5. Differential equations

For presenting this topic, we use a model of spread of epidemics (Gentry, 1978). It is possible to assume that the speed of an infection is directly proportional to number of affected (I) and susceptible (S) individuals. Assuming that the population has a finite size ($N=I+S$), the question presented to the students is: how many individuals will be infected in a given moment? With this example it is possible to the retrieve the logistic function previously studied in first block. Thus, the student has to learn the relationships between all mathematical concepts introduced. Other interesting examples of differential equations include the blood dynamics in the heart or the result of a reversible monomolecular reaction. Finally, a more complex epidemiological situation can be presented to the students: let's suppose that in our population we still have a number of affected (I) and susceptible (S) individuals. However, it is possible to consider a number of recovered individuals (R). Thus, this situation needs a different mathematical approach: matrices, eigenvalues and eigenvectors. For this reason, block 6 was added to the course's program.

2.6. Matrices

Although this topic is linked to the previous one, matrices are also needed for other biomedical situations. A presented example included a matrix of data in which the n rows correspond to genes and the q columns to the tissue samples measured on patients. The idea is to transform this matrix in a visual two dimensional representation. Thus, the mathematical procedures needed are introduced to our students.

3. Conclusions

In summary, our aim is that our students understand the mathematical concepts and how to use them in the biomedical situations, not to focus in a mere mechanical mathematical calculation. Although this aspect is also needed, we minimize it by using *Maxima* program. This is free software available to the students. The results obtained with our methodology are very satisfactory, because a large proportion of our students pass the evaluation (about 85%). Furthermore, their comments on the course development are very positive.

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