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Publication date:
2016

Document Version
Peer reviewed version

PAPER TEMPLATE

DIFFICULTIES IN MATHEMATICS EXPERIENCED BY STUDENTS IN A TRANS-DISCIPLINARY ENGINEERING STUDY

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This paper discusses difficulties in mathematics experienced by students in the Media Technology program of the Aalborg University Copenhagen, Denmark. The Media Technology program is an example of a trans-disciplinary engineering study, where mathematics is used in fields such as computer graphics, image and audio processing, analysis of experimental data, and physical interface design. Data comes from three diagnostic tests, which were distributed in three consecutive years to a total of 231 students in the beginning of the fifth semester of bachelor. These tests contained questions on basic trigonometry, linear algebra (matrices, systems of linear equations, linear transformations) and 2D/3D geometry (equations of lines/planes, vectors, dot and cross product). In this paper, we present common difficulties observed during these tests in an attempt to sketch a profile of trans-disciplinary engineering students in mathematics.

INTRODUCTION

Over the past years, a number of engineering programs have arisen that transcend the division between technical, scientific and art-related disciplines. In relation to mathematics education, this new development has created new modes of application for mathematics and a new type of engineering students. These students are less technically oriented compared to traditional engineering students and they use mathematics as building blocks in various digital products and creative expressions. Little is known about the emerging field of mathematics education in such trans-disciplinary engineering studies. The literature has yet to discuss how different and media-oriented modes of application influence the students' conception of mathematics.

This paper discusses difficulties in mathematics experienced by students in the Media Technology program of the Aalborg University Copenhagen, Denmark. The Media Technology program is an example of a trans-disciplinary engineering study, where mathematics is used in fields such as computer graphics, image and audio processing, analysis of experimental data, and physical interface design.

STUDIES IN ENGINEERING MATHEMATICS

The profile of engineering students has been widely investigated. Morgan investigated the problem of the lack of mathematical expertise by engineering students (A. Morgan, 1990). In order to identify areas of difficulty, he designed a multiple-choice diagnostic mathematics test, which was taken by first year engineering students over a period of five years. He was able to identify certain areas of mathematics which appear to be difficult to a large proportion of students and common errors made by students in certain topic areas. He concluded that engineering students often have difficulties with understanding the mathematical concepts due to their inability to perform deductive reasoning. Finally, he proposed a reconsideration of the teaching methods in order to produce conceptual understanding, not just mechanical skills with standard problems, and a new curriculum that will cover only the essential topics in context.

Maull and Berry developed a questionnaire to elicit engineering student concept images attached to key mathematical concepts (Maull & Berry, 2000). They collected responses from over 200 students in the schools of mathematics and engineering and the results suggested that engineering and mathematics students do have different concept images, and in particular that engineering students gradually adopt mathematical ideas into their engineering knowledge in a way that makes sense to them. They also found that although engineering students appear to regard themselves as visual people, they seem to prefer verbal representations of mathematical concepts, while in mechanics problems they preferred the pictorial ones.

Bingolbali et al. explored mechanical engineering students' conceptions of and preferences for conceptions of the derivative, and their views on mathematics (Bingolbali, Monaghan, & Roper, 2007). They employed pre-, post- and delayed post-tests and a preference test, they conducted interviews with students and they performed an analysis of calculus courses. Moreover, they used data from mathematics students to make comparisons with engineering students. Their results indicated that engineering student conceptions of and preferences for the derivative develop in the direction of the rate of change aspects while those of mathematics students develop in the direction of tangent aspects, and confirmed that the engineering student sees mathematics as a tool, and therefore wishes to see the application side as part of the course.

Other researchers focused on engineering students' mathematical background. Such studies acknowledged that there is increasing academic diversity among the student population and this diversity was found to cause difficulties in disciplines such as engineering (Mustoe, 2002; Roberts, 2002). Morgan, who investigated anecdotal evidence that physics and mathematics A-levels are not sufficient for undergraduate physics and engineering courses, stated in his report: '…a lack of fluency in mathematics was an obstacle to students achieving their full potential in the long term, and … affected their department's ability to deliver an optimal programme of study' (B. Morgan, 2011). Moreover, he found that there is a common belief among students and academics that studying further mathematics should be made a requirement of studying engineering.

This paper aims at sketching a profile for students in trans-disciplinary engineering studies. In this regard, it discusses student difficulties in mathematics that were observed during three consecutive years (2013-2015) in the Media Technology department. Data comes from three diagnostic tests (each every year), which were distributed to in total 231 students in the beginning of the fifth semester of bachelor. In their fifth semester, Media Technology students attend the 'Computer Graphics Rendering' and 'Computer Graphics Programming' courses, which require knowledge on basic trigonometry, linear algebra (matrices, systems of linear equations, linear transformations) and 2D/3D geometry (equations of lines/planes, vectors, dot and cross product), which are taught during the second semester of bachelor. The diagnostic tests contained questions on these topics, and the students who failed them had to attend a mathematics workshop of three four-hour sessions. In 2013, we employed a pen and paper test containing five exercises, while in the next two years we converted the test to a 24 multiple-choice question quiz in Moodle due to the large increase in student intake. The passing criterion in all cases was a score of at least 67%. The diagnostic test pass rate was 28.3% in 2013, 47% in 2014, and 38.1% in 2015. Based on student answers, we present in the following section the difficulties experienced by students taking these tests.

DIFFICULTIES EXPERIENCED BY MEDIA TECHNOLOGY STUDENTS

Many researchers have attempted to describe and categorize difficulties and errors in mathematics (Borasi, 1987; Maxwell, 2006). In the following, we categorize common difficulties in mathematics experienced by Media Technology students according to the topics examined during the diagnostic tests[1].

The diagnostic tests contained exercises on basic matrix operations and systems of linear equations (applied for investigating intersections of geometrical constructions in 3D). However, knowledge of basic algebra was also required in questions of all topics. It was observed that many Media Technology students lack such basic algebra knowledge. For instance, they failed to properly distribute parentheses and they "lost" or failed to add parentheses, when needed. In matrices, many students failed to correctly multiply two matrices. As an example, in the question "$[1\ 4] \cdot \begin{bmatrix} 6 \\ 2 \end{bmatrix}$ is equal to:" the majority of students answered [14]. This question had actually the lowest success rate among the 24 questions of the diagnostic test.

In trigonometry, we have observed that many students do not understand the difference between degrees and radians, and they assume that all angles are described in degrees. Moreover, we have noticed that they have difficulties in interpreting powers of trigonometric functions and they confuse them with the notation of the inverse trigonometric notation. When asked to calculate an angle between two vectors, many students after calculating the cosine of this angle did not use the inverse trigonometric function to find the actual angle because they failed to see the difference between these two entities.

In geometry, one of the most challenging questions was the following:

"The angle between the x-axis and the vector a = i + j (where i and j are the unit vectors on x- and y-axis respectively) is equal to: a. π/2 b. π/8 c. π/6 d. π/4"

There were students who could solve this question because they could not recall what the unit vectors on x- and y-direction are. Moreover, many students were unable to use the cosine definition in order to calculate the requested angle. Regarding basic definitions, many students could not remember how the parametric equation of a line is defined. Finally, we have also confirmed that like many other students they had difficulties in conceptualizing objects in 3-dimensional geometry (Gutiérrez, 1992).

Apart from difficulties in the aforementioned topics, it has been observed that many Media Technology students lack knowledge in arithmetic. While attempting to calculate the vector between two points, many students got wrong answers because they failed to perform correctly arithmetic operations with negative numbers. The same applies also for the calculation of the cross product of two 3D vectors. Moreover, we noticed that division and multiplication by zero can be also challenging for these students. Finally, the majority of students experience difficulties with

[1] Due to the limit of four pages, difficulties are described very briefly and without referring to statistical data available on the frequency of these difficulties

operations with fractions. The question “If cos(a) = 12/13, sin(b) = 4/5 and sin(a), cos(b) > 0, then sin (a - b) equals to: a. 56/65 b. 72/65 c. –16/65 d. –33/65” had the second lowest success rate among the questions of the diagnostic test because students failed to correctly perform the fraction multiplications and subtractions required.

Finally, there were students who had difficulties with mathematical notation. Challenging topics were for example square roots, exponents and the order of operations.

DISCUSSION AND CONCLUSION

The data presented in this paper indicate that the Media Technology students lack basic skills in mathematics. Arithmetic such as addition and multiplication of fractions or operations involving negative numbers can be quite challenging for such students. The same applies to exponents and factorizing in algebra. The lack of these basic skills significantly weakened the mathematical performance of these students, but it may also impede students from developing conceptual understanding of mathematics since skills and understanding are intertwined, as other researchers have proposed (Wu, 1999).

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