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Applications

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# Applications in Unusual Contexts in Engineering Mathematics: Students' Attitudes

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**Abstract**

This paper presents results of three studies on using an innovative pedagogical strategy in teaching mathematical modelling and applications to engineering students. The studies analyse engineering students' attitudes towards non-traditional for them contexts in teaching/learning of mathematical modelling and applications: environment, business and epidemics. The first study deals with using differential equations in the environment and ecology. The second study deals with using linear programming for maximizing profit and minimizing expenses for a company. The third study deals with using differential equations for making a prediction of a number of cases in an epidemic. Analysis of students' responses to questionnaires, their comments and attitudes towards the innovative approach in teaching are presented in the paper.

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**Introduction**

Many researchers and practitioners consider skills in mathematical modelling to be different from skills in mathematics. "Model building is an activity which students often find difficult and sometimes rather puzzling. The process of model building requires skills other than simply knowing the appropriate mathematics" (George, 1988). Some relationships between students' mathematical competencies and their skills in modelling were considered in (Galbraith & Haines, 1998) and in (Gruenwald & Schott, 2000). Obviously, there is a link between mathematical modelling and solving application problems. We support the view that solving application problems can be considered as a subset of the mathematical modelling process which can be described as "consisting of structuring, generating real world facts and data, mathematising, working mathematically and interpreting/validating (perhaps several times round the loop)" (Niss, Blum, and Galbraith, 2007, pp.9-10). Our perception of application problems again is similar to that expressed by Niss, Blum, and Galbraith (2007): "Standard applications: Typified by problems like finding the largest cylindrical parcel that can be shipped according to certain postal requirements, standard applications are characterised by the fact that the appropriate model is immediately at hand. Such problems can be solved without further regard to the nature of the given real world context. In our example, this context can be

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stripped away easily to expose a purely mathematical question about maximizing volumes of cylinders under prescribed constraints. So, the translation processes involved in solving standard applications are straightforward, that is, again, only a limited subset of the modelling cycle is needed (p.12)." An interesting question is how students in general and engineering students in particular react to the context of a modelling task. Do they value and learn modelling skills if the context is unusual for them? Can they rely on their past experience and common sense if the context is unfamiliar for them? Engineering students' attitudes towards environmental and ecological applications of mathematics were investigated in (Klymchuk et al, 2008). The role of entrepreneurship in engineering education was studied in (Gruenwald & Krause, 2006). In this paper we present the summary of the study by Klymchuk et al (2008) and two more studies dealing with unusual contexts for engineering students. We also discuss possible implementations for education of engineering students. We agree with Kadijevich who pointed out at an important aspect of doing even simple mathematical modelling activity regardless of the context by first-year undergraduate students: "Although through solving such … [simple modelling] … tasks students will not realise the examined nature of modelling, it is certain that mathematical knowledge will become alive for them and that they will begin

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to perceive mathematics as a human enterprise, which improves our lives" (Kadijevich, 1999).

## The First Study

The first study was conducted with 2 groups of students. The first group consisted of the first-year engineering students studying mathematics courses at Wismar University of Applied Sciences, Technology, Business and Design, Germany and Auckland University of Technology, New Zealand. The students did a project on ecological and environmental applications of mathematics. On the one hand, the context was not directly related to engineering. On the other hand, chances are that most of the graduates in engineering will be dealing with mathematical modelling of the environmental systems in one way or another in their future work because nearly every engineering activity has an impact on the environment. The total number of students who completed the project was 147 in both universities. The number of students who answered the anonymous questionnaire was 63 so the response rate was 43%. Participation in the study was voluntary. After completing the project the students were asked to answer the following two questions:

Question 1. Do you find the project to be practical?

Question 2. Do you find the project to be relevant and useful for your future career?

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A brief statistics and common students' comments are presented below.

Question 1. Practical? Yes – 48%. Selected students' comments were: "The models describe the real world", "A good way of increasing students interest in the subject", "It was so helpful for my other subjects", "I didn't realize modelling is used for fishing quotas. It also helped me realize the effects of sneaky illegal fishing (which most of us have done)". Question 1. Practical? No – 52%. Selected students' comments were: "It is not possible to calculate the nature", "It did give a practical situation but you bearly think about that at all when doing the assignment".

Question 2. Relevant for your career? Yes – 35%**.** Selected students' comments were: "Mathematics is the base needed to go into the Engineering World, so it will help a lot", "In engineering, we will be dealing with these kind of situations", "We are more motivated to solve such real problems than working with dry examples", "Everything you learn is bound to be beneficial at some point".

Question 2. Relevant for your career? No – 65% . Selected students' comments were: "I don't see how it relates to mechanical or electrical engineering" (most common comment), "I don't compute formulas, I have to calculate beams…".

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The second group consisted of a mixture of year 2-5 engineering students studying the experimental course Mathematical Modelling of Survival and Sustainability at Wismar University. The students solved a number of ecological and environmental models in their individual and group projects among models in other contexts. After completing the course the students were asked to answer the question “Do you think this course is suitable for engineering students and if so, why?” There were 25 students in the course. The response rate was 100%. Participation in the study was voluntary. All 25 students answered ‘Yes’ to the above question. The main two reasons were:

- Improving knowledge in mathematics, Matlab and mathematical modelling that is useful for engineering – 23 (92%). Typical students’ comments were: “You consolidate your mathematical knowledge”, “Raise knowledge about differential equations and especially how to build them”, “Increasing skills in Matlab”, “In my opinion many problems or predictions in the ‘engineering world’ could be handled/solved with the techniques that you can learn here”, “Because you learned how to put some problems into a mathematical system”, “To see new ways (models)”, “In the course you can better make a statement for normal problems about

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the life", "Because I could improve my understanding for differential equations", "The mathematical models all around us and the true way for an engineer is to understand how a model from the nature reacts if you change one parameter".

- Practical and interesting – 10 (40%). Typical students' comments were: "To get practical problems", "It is very important to use practical part in the course as it is done here to help students to understand what are they going to do in their future jobs", "Of course it deals not with typically engineering problems but after all it was an interesting subject", "Engineering students can apply their knowledge and broaden their horizon", "It is nice to see we can use differential equations in other areas", "I think that every subject which has a lot of practical things is very useful. This mathematical course was very useful for me and I think, that in our university everyone must study mathematics in this way".

There was a big difference between the students' responses in the two groups about the relevance of the suggested context of applications. Only 35% of the students in group 1 (first-year students) indicated that the environment/ecology context is relevant for their future career whereas 100% of the students in group 2 (year 2-5 students) commented that the course was suitable for engineering students. One of the reasons for such a

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difference might be the difference in maturity. Another reason might be the difference in students' mathematics background. It was reflected in the exam performance. The pass rate of the first-year students in their maths courses was around 50%. The pass rate of the year 2-5 students in the modelling course was 100%. Moreover, all 25 students from the second group received excellent or very good final grades. From informal talks to the students of the second group we received a strong indication that their enthusiasm and positive attitudes towards the course significantly contributed to their high performance in the course and very positive attitudes towards the unusual contexts. They were mature enough to value the new knowledge in mathematics and modelling they received from the course that can be applied in engineering (92%). They also enjoyed the practicality of the course that enhanced their problem solving skills (40%).

## The Second Study

The second study was conducted with 2 groups of engineering students – Bachelor and Masters – studying Operations Research course at Wismar University. The students studied a variety of linear programming models dealing with maximizing profit and minimizing expenses. On the one hand, the (business) context of the course was not directly related to engineering. On the other hand, chances are that most of the graduates

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in engineering will be dealing with mathematical modelling of optimization problems in one way or another in their future work because nearly every engineering activity has commercial implications. The course did not require any special knowledge from economics or business studies. It was based on a spreadsheet modelling and had many real practical applications from the business world. Excel was used as the main program being a standard for small businesses and the chosen program of the course textbook. Apart from using the Excel Solver tool the students learnt many useful Excel functions thus mastering their spreadsheet modelling skills. There was much attention put into enhancing students' generic mathematical modelling skills while doing sensitivity analysis and discussing assumptions and limitations of each model. After completing the course the students were asked to answer the question "Do you think this course is suitable for engineering students and if so, why?"

There were 16 students in the first group. All 16 students answered "Yes" giving the following reasons:

- Benefit for the future work - 15 (94%). The typical students comments were: "Because in all jobs in engineering you must maximize the profit and minimize the cost", "Companies want engineers who are trained in financial questions of small

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companies", "It is also useful for independent engineers to optimize their own profit", "In small firms engineers are responsible for calculating the costs and make sure the company makes profit. And also in bigger firms engineers are used for management positions thus a basic idea of business and optimization is very useful", "To know how to maximize the profit is very important for me. This could be a help for us if we have our own firm later on".

- Enhancing the skills in Excel - 7 (44%). The typical students comments were: "It is good to know how Excel works", "It is very good because the skill to handle Excel is very useful. We use Excel very often in our mechanical engineering", "To learn to work with Excel and to use its 'hidden' functions".

There were 17 students in the second group. All 17 students answered "Yes" giving the following reasons:

- Benefit for the future work - 8 (47%) The typical students comments were: "Students learn to fix problems in a way that is quite often used in 'real life' business", "It is good for me to know how to optimize a problem and it will make my chances bigger

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on employment market", "It is very suitable because it teaches to implement the problem which is similar with the problem in a company".

- Enhancing the skills in Excel - 10 (59%). The typical students comments were: "This course shows me new ways to work with Excel and solve mathematical problems", "Excel is software that almost every company owns. For that reason it is quite useful to know this program very well", "Learning basics and extended applications in Excel".

All 33 students in both groups indicated that the course was suitable to engineering students. They appreciated the practical nature of the models, the opportunity to enhance their problem solving, modelling and computer skills. Bachelor students saw more benefits from the course for their future job than Masters students: 94% versus 47%. One of the reasons for this difference could be that some Masters students were planning to do PhD study so the relevance of the course to their employment was not a priority at that stage.

## The Third Study

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The majority of the participants in the third study were first-year engineering students from Wismar University with several second and third-year students majoring in applied mathematics from Auckland University of Technology. 90 questionnaires were distributed over 2009 and 2010. 48 responses were received so the response rate was 53%. It was a self-selected sample. The study was about differences in prediction from 3 familiar models (linear, exponential and logistic) in an unfamiliar context – an epidemic of an infectious disease. One of the questions in the questionnaire was about students' attitudes towards the unusual context: "Are you interested in learning more about epidemic modelling and possibly doing research projects in this area (e.g. modelling of the spread of swine flu)? Why?" The students' answers are below.

Yes – 4. An interesting topic (4), important for the science on viruses (2). No – 39. Not my area of interest (18), lack of time (8), this is only making panic (3), don't see the point to play with numbers or equations which are not correct (2), it is going to have too many factors and the predictions may not be that reliable (1), not enough knowledge in mathematics (1).

Very few students (9%) reported that they were interested in doing a research project in epidemic modelling. However, in spite of the unfamiliar context most of the students did

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very well in answering the other questions from the questionnaire – on the reasons for differences in predictions from the three models and the ways of improving the accuracy of the predictions as it was reported in (Narayanan, 2009).

## Implications for Education

The majority of engineering students participated in the three studies valued practical aspects of application problems in spite of the non-traditional contexts. They also valued problem solving and modelling skills they learnt that could be applied to problems in an engineering context. This was more the case for more mature students. The main lesson for us as lecturers was: students' feedback should be taken into account when designing curricula for their study.

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