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Teaching and Assessing Supply Chain Modelling Modules in Higher Education

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Abstract: Teaching and assessing mathematical based modules represent a real challenge not only for lecturers but also for students. This research evaluates a selection of current teaching and assessment methods used in different modules taught in higher education within a logistics and supply chain management environment. This investigation aims to provide a framework that stresses continuous improvements in teaching and assessing logistics and supply chain modelling modules in higher education programmes. The conclusion summarises the key finding of this research and at the same time highlights key steps required for further research.

Keywords: Teaching Supply Chain Modelling, Practical and Computer-Based Assessment, Independent Learning

Introduction

IT IS WELL documented in the literature that management courses requiring some degree of mathematics and mathematical modelling present a challenge for teachers as well as for students (see for example Desai and Inman (1994), Curland and Fawcett (2001), Stevens and Palocsay (2004) and Nyman and Berry (2002)).

It has also been observed that students progressing further in the course realise the importance of quantitative based subjects due to their relevance and applicability in industry. It has been reported in the literature that students rank quantitative analysis based modules as “most valuable required course” when studying MBA curriculum (Carraway and Clyman, 1997).

A variety of teaching approaches have been developed and published in respect to the teaching of quantitative or mathematical based modules. The emphasis here is directly related to the application of mathematical modelling in a practical logistics and supply chain environment. Modelling, mathematical modelling in particular, develops a selection of analytical, problem solving skills for students as they have to identify problem situations, formulate a mathematical model for this, solve it in the most appropriate way as well as verify, validate and interpret the answers. Researchers (see for example Powell (2001) and Leon L. (2006)) reveal that even though mathematical modelling is considered to be one of the most important skills for students to learn, it is the most difficult and least - developed area in operational research/management science education due to the nature of the modelling process. Although Winston (1996) considers his course in simulation modelling successful, he states that “this course is not easy to teach”.

This research evaluates current teaching methods and approaches used in four different higher education modules within a logistics and supply chain management programme. All of these modules have as a base the use of mathematics in the form of mathematical modelling, operational research, operational management and simulations, most of which involve the

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use of computers. The evaluation will consider the suitability of teaching methods used to date and current assessment methods. Two of the modules considered are taught at an undergraduate level, the other two are taught at a Masters level. The first undergraduate module is taught at an intermediate level (students in year 2) in the form of logistics planning techniques and application. The average number of students taking this module every year is around 50. The second module considered is taught at an Honours degree level (students in year 4) and concentrates on supply chain modelling. The average number of students taking this module every year is around 15.

The remaining two modules are taught at Masters level. The Masters programme is a conversion programme where students from different backgrounds other than logistics form the cohort of the students. The average number of students taking these modules every year is around 15.

The evaluation is applied to all of these modules as they have common elements, topics and structure. The difference between them is the level at which each one of them is taught.

Challenges in Teaching and Assessment

The content covered within these modules is diverse and consists of topics such as linear programming, vehicle routing and scheduling, supply chain network design, forecasting, inventory control and simulation.

For the purpose of this research only three techniques are discussed in detail, the rest have similar teaching approaches (see Tipi, 2007). The techniques under review are linear programming, forecasting and inventory control methods. For the delivery of these subjects, a wide variety of teaching methods are employed. These include lectures followed by tutorials, case studies, videos, factory visits, practitioners as guest speakers, games and simulations. All these methods aim to create diversity in teaching and cope with students' learning styles and their expectations. Although all of these methods are considered relevant, not all of them are possible for each topic. Primarily lectures, tutorials, case studies and simulations are used; games, videos and factory visits are used infrequently.

Linear Programming

Linear programming is first presented to students in a lecture where the conceptual part includes the manual representation of a model. This is then followed with a tutorial where the same problem is than presented using a computer as practical application. For the manual solutions the use of mathematical algebra is imposed as well as the graphical solutions where appropriate. The manual solution is than validated by the use of computer based spreadsheet modelling using the Solver function from Microsoft Excel. Some of the examples used within class are complex and do not offer the flexibility of a manual solution. In this case only the spreadsheet computer based solution is considered. However, students are still required to understand and formulate the model of the real situation using algebraic equations before they have implemented this in the spreadsheets.

Grossman (2006) states that a vast majority of management science instructors agree that one of the main problems in teaching and learning mathematical modelling is to do with the low level of students or their fear of mathematics. He also relates that a vast majority of students struggle to formulate an unstructured model using equations, or algebraic notations.

Stevens and Palocsay (2004) note that students without a strong mathematical background frequently have difficulties formulating linear programming problems.

A large selection of quantitative methods, operational research and operational management books are made available to students. These cover linear programming (see for example Russell and Taylor (2006), Baker (2006), Curwin and Slater (2004), Winston (2004), Waller (2002)). Most of these books have specific chapters titled Linear Programming. Detailed explanations are given in problem formulation, manual representation as well as spreadsheet calculations. Students are referred to these books, and have to work through examples by themselves. Initially for students, working through such examples appears to be difficult as they are not familiar with the principles underpinning linear programming.

One of the main challenges for students is to formulate a mathematical model of a real logistics problem. Stevens and Palocsay (2004) use the translation approach when formulating a Linear programming problem. Meaningful words are used instead of algebraic notations. Their research showed that students have difficulties in verbally recognising model constraints and translating a verbal concept into the corresponding algebraic expression. Within the formulation of a linear programming problem, three main parts are required. These are the identification of variables, constraints and the objective function. To identify the three key elements students are faced with three main questions:

> 1. What are we trying to resolve? Or decide? – this corresponds to finding out the decision variables, 2. What is the objective? - this will correspond to the objective function and finally 3. Which are the constraints?

One of the difficulties encountered by students is related to the identification of problem variables. This is directly related to the understanding of the real case or problem formulation. Students are more comfortable to delve into providing the solution for the problem as soon as the variables, constraints and the objective function have been clearly identified.

A problem can be solved manually if it consists of a reduced number of variables, ideally two or three variables. As soon as the number of variables increases, it becomes more complicated to provide a manual solution, therefore a spreadsheet based approach has been used. This approach is preferred by students over the manual approach, although from a teaching point of view it is argued that a spreadsheet approach can not be taught in isolation as the model formulation directly translates into the spreadsheet approach. Presenting computer based spreadsheet models to students does not necessarily mean that they can translate a real situation into a model. Students need to be taught how to model first, before using computers.

Students argue that*: " Overall, I think the teaching methods used are relevant and useful to the study of the material. Particularly useful to me are the computer based applications used in the model, which is a vital skill to gain real work experiences."*

Students are positive about learning computer based models as they see these as skills which can be used in their future workplace. Leong and Cheong (2008) found that students relatively stronger in Excel skills are generally weaker in modelling and vice versa.

Increased attention is given in the literature to the use of spreadsheets for teaching mathematical modelling (see for example Olafsson (1998), Leon et al. (1996), Leon L. (2006), Winston (1996), Grossman (2006)). Their advantages are highlighted and some of the most important ones are to do with their increased use in industry and their availability. Other advantages are associated with their ease of use and manipulation. They are also easy to communicate as most people have access to some form of spreadsheet software. A manager can retrace the steps followed to generate the different outputs from the model in order to understand it and verify results.

Spreadsheet software and computers have become very powerful and they can support a relatively high level of complexity. One of the key drawbacks of spreadsheet models is due to the fact that complex logistics problems are not supported by the spreadsheet software due to their computation power. Therefore practitioners are looking to more commercial software with a base language such as C++.

It is considered essential that the concept behind understanding and building mathematical models is understood before approaching any dedicated software. The same principles apply in models comprehension and model structure regardless of the software used for generating the solution. Therefore the emphasis is to clearly develop understanding for the model built. The use of both manual and computer based approaches are there to support the solution and the validity of the model. Within many situations one method is not possible without the other.

As soon as the model is formulated and a solution is obtained there is the challenge of validating this solution. The teaching method used here is seen as no-solution approach.

Frequently appears that the main purpose for students approaching mathematical exercises is to generate “the right solution”, where the usual question is “have I got the right answer?”. The response in this case is that the answer is not initially provided until this has been validated. The argument behind this method comes from a practical situation, where by having to solve a real logistics problem in Industry “the right solution” is not available. Students are required to determine if the solution obtained is the right one by employing different means of validation. Using this approach it does take students beyond model build and model understanding, it takes them to model validation and solution validation. For example a solution becomes valid, when changes made to numerical values will determine the model to generate appropriate changes in the solution. Students find this technique very challenging. Although this approach is demanding and challenging for students, some of them are coming with encouraging arguments such as: “*I’ve enjoyed it. linear programming was fun…”*.

It is believed that the no-solution approach will better prepare students for understanding of problem formulation and for better decision making by considering the model validation.

Forecasting and Inventory Control

Forecasting and inventory control are two other topics in the teaching of quantitative methods in logistics and supply chain. Forecasting and inventory control models consist of totally different modelling concepts and structures compared to linear programming. Some students prefer one method over the other; others enjoyed all approaches. Compared with linear programming, forecasting does not require the same theoretical approach as the problems do not have variables, constraints and objective functions. In order to identify the best forecasting model, a different type of thinking is required. For forecasting, a selection of historical data is available. Students need to evaluate the model fit and error calculations. It is important how this data is manipulated and used in order to find the most appropriate model which generates the best forecast. The question then remains which is the best forecasting model?

Students are faced again with the no-solution approach. There is no one best solution that is given to them. They have to use appropriate arguments to justify the solution found.

This approach appears to be challenging and frustrating at times, when the students do not have the final result given to them. Developing the argument behind the method is much more relevant than working towards an imaginary best solution. The beauty of the argument is that there isn't a "best solution". This depends very much on the context of the problem. Students should select the method which best optimises the overall outcome.

A comment from a year 4 student is that "*the module should contain more mathematical investigations and applications including checking of the results*". The same student relates that "*this is the module that is the most important in logistics*." Although it appears that this student does not have a fear of mathematics, he still requests the "*checking of the results*". The fear is not related to mathematics it is coming from not knowing if he did the right thing or not. Therefore the fear is related to the process of learning, when the student is at the evaluation stage. Results are given to students, but they are given in the form of a selection, whereby they have to justify which one is the best answer through "in class" discussions.

There are many forecasting models available for students to choose from such as linear regression, moving average, single exponential smoothing, double exponential smoothing and triple exponential smoothing. These models have their individual variations, such as the selection of the smoothing coefficient, the selection of the moving average coefficient and so on. After the method and the coefficient selection have been made, the error calculation needs to take place. There are four or five different methods for errors calculations which need to be selected and used. Great complexity appears in the model selection structure, after which students are faced with the mathematical models for each method, all of which could have complex mathematical equations.

It is difficult for students to embrace the complexity of the models, as well as the complexity of model's structure and the approach used for a solution. Due to model complexity manual calculations are not possible, therefore a spreadsheet approach is used.

To get students familiar with model equations, they are asked to manually insert the equations into a spreadsheet and build their own templates to find the best forecasting method and solution.

The idea that there is flexibility in taking a business decision is a difficult concept for students to comprehend. The models are there to guide in taking this decision and not there to impose a decision. The final solution obtained in forecasting does not have to be the final decision taken by the management team. This needs to be justified and adjusted in the context of the problem.

Students have commented that the content of this part of their course was too mathematical, whilst others said they would prefer more in depth analysis: "*Sometime it becomes too mathematical. I would rather stop at double exponential smoothing, and be able to use it rather than pushing on for triple and Box Jenkins*." "*Most of the modules used in forecasting and regression should be studied in more detail*."

Where some students would like more in depth understanding, there are others who see these types of techniques as: "*difficult and unnecessarily complicated*."

The teaching of inventory control models followed the forecasting. Within logistics these two aspects are very close together and critical for an inventory planner role.

The same approach was used for the inventory part of the module, whereby spreadsheet examples were developed with the students. Areas of concern were monitored such as model complexity, mathematical structure and model approach.

At this stage, students became familiar with all the differences between models. They embraced the inventory part better than the forecasting topic, where particularly students in year 4 and at Masters level were very complimentary about this part:

> "*Inventory control was well covered"; "overall the module content in inventory control is thorough. The delivery was excellent as it was explained in simple and easy to understand format*."

Learning inventory control models, therefore, is seen by students as a real skill for their future career:

> Techniques covered in these modules "*seem to be relevant with forecasting and inventory control being very valuable later on in my future career", "hopefully demand forecasting and inventory control will help me in my future career as I hope to work in retail logistics*."
>
> Overall, the techniques presented are design to encourage independent, autonomous learning and critical thinking and prepare students for their future career.

Assessment Techniques

Assessment techniques used for these modules are also critical tools for encouraging student lateral thinking and independent learning.

For the second year undergraduate group the summative assessment consisted of two forms: coursework and a computer based exam. The coursework had exercises and the students had to solve and discuss final results. The examination was in the form of an open book computer based exam whereby the students were allowed to take in any material they might need. Although it is argued in Monaghan et al. (2009) that timed written examinations are not really suited for assessing problem solving, there is an argument here that there are situations within an industrial context, especially in the logistics and supply chain area, where a solution to a problem requires a timed answer. Within this context managers need to have the right skills in place to produce or obtain an answer to a given problem. The aim of the open book examination is looking to encourage students to prepare for this exam in advance by being able to apply problem solving skills to a set of issues within a time limit window.

For more advanced students in year 4 and at Masters level the coursework assessment consisted of an open case study. Students had to develop their own global supply chain case study based on a real or fictitious company. They also had to identify key problem areas within the case and use operational techniques presented in the class to solve problems. This assignment was meant to develop students' ability to search for a complex case study which not only developed their lateral thinking but also enhanced their research skills. The purpose was to help students identify key problems, their links and implications for the good operation of a supply chain, and associate a solution with each problem. To solve problems along a supply chain different techniques are required such as: network distribution (which involved the use of linear programming) to product development (which requires forecasting), to stock segmentation (which requires inventory control), to transport problems (which requires planning and scheduling) and so on. As presented earlier each of these techniques has a different approach and each requires different models and modelling skills to solve the problem at hand.

This particular assignment aimed to cater for different learning styles, by not restricting the case study and by allowing students to develop their creativity.

Masters students confirmed that the assignment was very challenging but rewarding in the end. *"This assignment over stretched my problem-solving skills. It was not a straight forward assignment. From a scale of 1 to 10, where 1=lowest and 10=highest, I think it was a 10, which implies a difficult assignment. I found it useful as a challenging exercise designed to test my intellect as an MSc student. While I admit it was a difficult assignment, I must say that I felt relieved when I finally "cracked the nest" and finished it."*

An assignment which clearly stretches students' knowledge and expectations, which leaves them with the felling of achievement is clearly rewarding not only for the students but for their lecturer as well.

Other students went further and stated that*: "in fact the assignment gave me a strong support in understanding the different modelling techniques used in the supply chain and put me on the right track to evaluate what others have written about certain models."*

"The coursework was really helpful in establishing the understanding of different models and methodologies. It also assisted in the gaining of an overall view of the application and versatility of modelling techniques in solving supply chain problems."

While Masters students find this coursework approach challenging and rewording, undergraduate students considered that a set case study is more appropriate for them. One said: *"The student is not totally confident when allowing a huge freedom in the choice of the assignment. The assignment could be seen as a choice to explore new techniques not studied in the lectures. The student is not certain about what is exactly expected in this assignment."* The student at this level was not totally confident to go outside his normal style and explore new approaches to learning. Although he recognised the opportunities for exploring techniques which were not considered before, he was looking for a clear structure in its approach, without "too much freedom".

Other year 4 undergraduate students revealed that the assignment *"was very open but allowed freedom to explore their own supply chain in depth. This allowed an evaluation of all topics which was good revision".*

The open case study coursework has generated a different case study from each student. This clearly reduced the chance of communicating findings before submitting the coursework and reduced the chances of copied or plagiarised work. There have been no cases where a similar approach has been taken in solving a problem and completing the coursework. There are more similarities in seeking a solution when a set case study is provided especially for a coursework assessment. This issue is easily resolved by an open case study for a coursework assessment.

For this type of analysis more data is required to evaluate if the technique used for the coursework is appropriate for year 4 students, since it appears that the technique used for this coursework is better valued by the Masters students.

Conclusion

Students taking the modules at undergraduate level especially in year 2 come in with very different motivational level for studying a quantitative subject. They also have different mathematical and computer skills as well as varying levels of understanding of logistics. There is the constant challenge to pace the material taught at the right level so that the students with strong mathematical and computer skills will not get bored, and so the weaker students can keep up with the rest of the class. To engage the entire class a hands on computer based approach is used during tutorial sessions accompanied by detailed discussions especially for the no-solution approach. The new method used in teaching for the no-solution approach proved to be challenging for students at first. This has been embraced by students later on in the course. The motivational level increases as students realise that this type of module will provide modelling skills appreciated by their future employer.

It is concluded from the above that as a teaching approach it is considered important to insist on model formulation, model and modelling understanding, no-solution approach and models validation and verification. Although the topics and modelling skills required are different, the consistency in teaching methods has proved to be a benefit for achieving good results in assignments and examinations as well as providing the confidence for students to continue to use these skills in their future careers.

The open case study coursework assessment method appears to be very challenging but at the same time rewarding, where students have the opportunity to challenge themselves in different way.

Overall, it can be argued that most of the modelling techniques used at all levels required different teaching approaches, each with their specific detailed complexity. Goffin (1998) also relates that one of the challenges of teaching Operational Management (OM) modules is trying to get structure to a course consisting of lots of diverse tools and techniques. This point is also observed in this research, as the complexity of modelling methods required in the logistics area imply different teaching tools for each one. This challenges not only the lecturer in order to find the best methods which fit most students learning styles, but also the students who need to change and adapt their learning accordingly in a very short time in order to assimilate the entire material.

This paper has indicated that although students find the modelling area challenging and too mathematical for them, at the end of the teaching period they can see the relevance and the importance of it in practice. Therefore the analysis of student perception could be considered as a relevant performance measure in assessing student's learning.

It should be noted here that what makes the delivery of these modules successful is the diversity of tools and approaches which together contribute to the student learning of logistics as well as their integration with other modules within the course and their links with the practical application.

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