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Operationalising operations research

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ABSTRACT: Operations research is perceived to be demising as a decision support tool in industry. However, this is not actually true, as the relevancy and interdisciplinary nature of operations research makes it an indispensable part of operations management. What rather should be asked is how operations research is introduced and taught to undergraduate industrial engineering students. The results of a semester project at the University of Pretoria, Pretoria, South Africa, indicate that the assessment process does, indeed, guide and enhance the learning experience. This article reports on a case where a project was used to address relevancy issues of industrial engineering practitioners of operations research. A rubric was used as assessment tool in order to guide learners in terms of required competence.

INTRODUCTION

In order to understand the need for different approaches to facilitate learning at the undergraduate level, it is important to understand the *operational* intention of operations research. It is just as important to appreciate the perception of industry that operations research is a dying tool in the decision support process, as well as the reasons leading to the perceptions that operations research is not being practised as intended.

However, this fostering of competence does not only happen within an engineering context, it also has to keep track with developments in the educational field.

CONTEXT

The South African Qualifications Authority (SAQA) Act (58 of '95) dictates an outcome-focused educational approach for South Africa. The prime focus should be on acquired competence on the part of the learner. This competence should not be viewed in a confined sense. Vital, generic skills have been identified and listed as Critical Cross-field Outcomes [1]. The Engineers Council of South Africa responded by contextualising these outcomes into the engineering realm where they are known as ECSA outcomes.

A new approach was called for to ensure a process that has all of the elements to provide such an encompassing learning experience. After all, rote learning and memorisation is insufficient. Indeed, it has been stated that *Pure knowledge is worthless. Skills and ideas are everything* [2].

The practical reality within which this research has been taking place is a four-year tutored Bachelors degree at the University of Pretoria, Pretoria, South Africa. Students ranged in age from 23 to 55, and all studied full-time. As adult learners, they tended to prefer active, independent and experience-based learning activities [3]. Additional motivational value was thus gained by shaping the context of their learning experience to coincide with their learning preferences [4].

The misconception of some students that only a percentage of accuracy is necessary in order to pass was also addressed by clearly stated assessment criteria that indicated levels of acceptable performance. Forcing students to identify and solve real life problems, where half an answer did not measure up to the desired requirements, supported this. An assessment instrument was needed that would be clear and practical, yet still left room for creativity and innovation on the side of the learners.

HOW RELEVANT IS OPERATIONS RESEARCH?

Rardin defines operations research as the study of how to form mathematical models of complex engineering and management problems [5]. The definition also addresses the importance of analysing such models in order to gain insight about possible solutions to the identified problems. Taha emphasises mathematical modelling as a cornerstone of operations research but states that, although the mathematical solution provides a basis for decision-making, intangible factors (such as human behaviour) must be accounted for before a final decision can be reached [6].

Operations research is taught at numerous engineering and management faculties at the tertiary level, but acceptance of the optimisation techniques are often questioned at the shop-floor level in industry. Leinbach and Stansfield addressed numerous complaints from the operational level with regard to Industrial Engineering (IE) professionals [7]. Many industrial engineers have lost touch with the *action* in companies and spend a lot of time on complicated models where the assumptions are so

plentiful that it is impossible for anyone to challenge the validity of these models over time.

In discussing the denouement of operations research, Ackoff has identified three major effects on the practice of operations research as a result of academics' obsession with techniques [8]. First, problematic situations are frequently sourced, selected and distorted so as to favour the application of a specific technique. A second effect is the diluted application of techniques as a result of the techniques being introduced to diverse professionals with little background of the fundamentals of operations research. The third, and probably the most detrimental, effect is the classification of operations research as an isolated discipline, as opposed to the original interdisciplinary characteristic of operations research.

GOALS AND DESIGN OF A SEMESTER PROJECT

Undergraduate Module

The second of three modules in operations research in the Department of Industrial Engineering at the University of Pretoria extends on students' knowledge of optimisation by introducing integer and dynamic programming. The focus of the module is on modelling problem situations and interpreting results – as opposed to simply applying optimisation techniques to solve problems. Figure 1 indicates a typical operations research process and shows modelling and interpretation (inferring) within the context of the process.

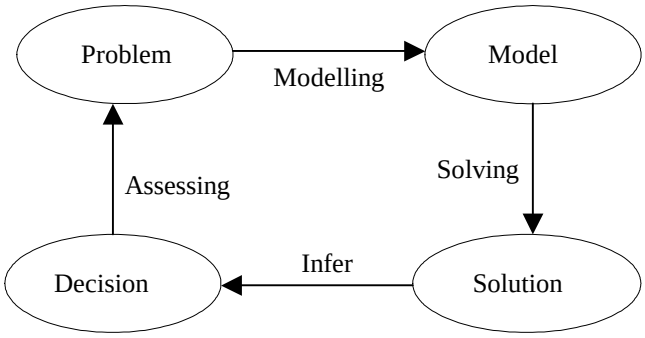

Figure 1: Operations research process.

Industry is often unaware of what the actual problems are, or what information is needed, in order to solve problems. The emphasis of this module aims to introduce students to actual problems, as opposed to giving a problem with all of the relevant information to students.

Students are required to write up a case study of their choice for a semester group project. Although Voss, Tsikriktsis and Frohlich comprehensively cover case research in the operations management domain, students were allowed to use a combination of actual and artificial data due to time limitations [9].

Outcomes Defined for the Project

In order to ensure that students appreciated the relevance and practical significance of operations research, specific ECSA outcomes were identified and communicated at the start of the project using a rubric, as indicated in Figure 2.

Rubrics are recommended in those situations that have a stronger focus on learning than on grading, as rubrics not only guide towards the desired standard, but also assist in developing reflective practice and self-evaluation. Where applied competence is called for, rubrics are a critical and vital link between assessment and instruction. Described standards operationalise quality in the minds of lecturers and students [10].

The weighted outcomes indicate that the emphasis of the project is on identifying a real-world case and modelling the case in a comprehensive manner by identifying decision variables, expressing case objectives and addressing constraints. Students should not unnecessarily overcomplicate the case to the extent of not being able to solve the basic problem.

So as to address the relevancy perception of industry, student groups had to identify their own cases and thoroughly understand the problem, or the opportunity for improvement. Problem characteristics then had to be modelled comprehensively without losing contact with the actual problem environment.

FINDINGS

Research Project Contribution

The choice of case studies indicated that the explicit assessment criteria, with its respective weights, thoroughly guided student groups in the correct direction. Learner feedback emphasised the suggestions of Luckett and Sutherland to establish good linkages between assessment, learning and personal development through, *inter alia*, allowing students some element of choice and encouraging self-assessment and reflection [11]. Cases represented a multitude of non-traditional applications, of which a few are briefly discussed.

One student group assisted a game farmer in deciding on an optimal capital expenditure plan. The farmer had a budget constraint on animal acquisition; he had to fulfil tourists' perception of animal diversity, as well as take the carrying capacity of the farm, in terms of vegetation types and quantity, into account. The student group researched the actual problem environment in terms of grazing utilisation for a multitude of species, reproduction rates and expected market conditions. The result was decision support that resulted in an optimal solution reached by only spending 68% of the capital and earning in excess of 22% on the capital investment.

Another group identified unique market etiquette in the international uncut diamond market through a dynamic programming model. The company they investigated sell a predetermined number of diamond units at three distinct international venues. The number of diamond units allocated to each venue is not determined and should be indicated by the model, given the probability of achieving specific prices at each of the auctions.

Other cases included, but are not limited to, route optimisation for the Department of Education to determine zones and routes in order to deliver grade 12 examination papers to schools on time; newspaper vendor placement to achieve maximum exposure to the economically active public travelling by car; and timetable scheduling in the School of Engineering at the University of Pretoria.

DISCUSSION

The most important finding was that students at the undergraduate level appreciate the relevancy of operations research. This agrees with literature that states that the understanding of a problem is as important as the solution. However, it also contrasts with literature in that practitioners (students) were not required to spend an excessive amount of time to establish representative models of real-world problems. The research supports Dick in that words are the common currency for much discussion, but that numbers do offer advantages when available [12].

In this environment, where recollection and initial understanding is but the beginning of a process that leads to the solution of a particular problem, assessment that is linked to clearly defined criteria proactively guides learners towards levels of acceptable performance.

IMPLICATIONS

The introduction of operations research to undergraduate students as a decision support tool should include reference to pitfalls in using such tools. These pitfalls include:

- The time required to find solutions often exceeds the life (in time) of the actual solution.
- Modelling of an obvious problem that could have been solved using mere common sense.
- Manipulation of a problem to suit the application of a specific solution algorithm or technique.

The cited problems support the fact that operations research is as much an art that is developed through experience as it is a science. The introduction of rubrics as an assessment tool in operations research explicitly states the required outcomes and leads students to identify and appreciate the wide field of operations research applications. The consequential continuous self-evaluation further fosters critical and reflective practice.

This answers the relevancy question of operations research at both tertiary education and industry levels: management do require quantitative decision support that could lead to impressive yields, while students embark on a continuous learning experience that involves problem identification, appreciation and solving.

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ECSA Outcome	Outcome Description	Weight (%)	Not Competent (0)	Working towards Competence (1)	Competent (2)	Exceeded Competence (3)
2.1	Identity a real-world case	20	The case group identified was elementary. It was neither original, nor did it integrate different modelling techniques.	A typical text-book problem with little indication of integration between various modelling techniques.	A relevant case indicating the use of different techniques to address different case problems/ issues.	An original and innovative case with global relevance but with local application.
2.2 2.3	Formulate and model a real-world problem, or opportunity for improvement, mathematically using linear (continuous or interger), or dynamic programming tools. Identify and quantify model objectives and constraints using knowledge of the physical world.	25	Unstructured use of decision variables. Unrealistic approach to quantifying the objective function, constraints, and/or other parameters.	The decision variables are adequately defined and the data used is comprehensive and relevant to the case identified.	Decision variables are adequately defined and the data used is comprehensive and relevant to the case identified.	Decision variables are thoroughly defined with the minimum variables to represent the complete case. The group quantified constraints innovatively to address complex issues.
2.5	Using appropriate methods and/or tools, such as Microsoft *Excel* or *LINGO*, to solve an optimisation problem.	10	The group did not attempt to solve the case at hand.	The group attempted to solve the case, but did not represent the mathematical model due to, for example, over-simplification.	The case was solved, but it is unclear how the results will be interpreted.	The group solved the case, and interpreted the results realistically and preferably innovatively.
2.6	Communicate the scope of the case clearly. Present the mathematical model in the correct and generic structure.	20	It is not clear what the scope of the case is and there is no structure to the representation.	Although the scope of the case is understood, the formal structure does not resemble the described case.	The case is clearly defined, and corresponds with the formal representation.	The group defined and motivated the case clearly with a subtle balance between detail and background. The model repre-sents the case with great accuracy.
2.6	Communicate and motivate the choice of case study and the intent of the group professionally.	10	The group seems unclear of their objective and *modus operandi.*	The group represented their case, but cannot motivate the significance of the case, nor justify their choice of modelling approach.	The case is represented adequately, with all group members aware of the significance of the case and the methodology used.	The case was thoroughly motivated. The approach to modelling and solving the case was well-considered.

Figure 2: Rubrics for the operations research project.