



## INFORMS Transactions on Education

Publication details, including instructions for authors and subscription information:  
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To cite this article:

Arnold Reisman, (2004) How can OR/MS Educators Benefit From Creating and Using Taxonomies?. INFORMS Transactions on Education 4(3):55-65. <https://doi.org/10.1287/ited.4.3.55>

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# How can OR/MS Educators Benefit From Creating and Using Taxonomies?

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## Abstract

After listing various approaches used over the years to teach OR/MS and quantitative methods and showing sample references for each, this paper suggests that taxonomies, combined with any other approach, can uniquely serve an important educational objective - showing the overall picture of the subject matter. The paper argues for using taxonomies in basic courses and in graduate education as they provide a framework in which the material to be taught, reviewed, or researched can be organized. When made explicit, the framework helps students organize knowledge gained in their own minds. Productivity Analysis (PA) is used to illustrate a taxonomy's educational potential. Lastly, for those interested in so enhancing their approach to teaching, a bibliography of publicly available taxonomies for various theoretic and applied OR/MS sub-disciplines is provided.

**Editor's note:** This is a pdf copy of an html document which resides at <http://ite.pubs.informs.org/Vol4No3/Reisman/> (Volume 4, Number 3, May 2004)

## 1. Introduction

In the beginning, the first formal educational program in Operations Research was inaugurated at the Naval Post Graduate School in 1951. It was taught by modeling real-world military operations "using the only text available - a declassified 1946 document by Morse and Kimball (1951)" (Schrady, 2001).

Over time at the introductory levels, we taught OR/MS, decision sciences and quantitative methods via *models*, we have used *case studies*, Bodily (1996); *problem-based learning* Boyle (1999); *cooperative learning* Magel (1998); *team learning*, Koppenhaver and Shrader (2003); *thematic assignments*, Grinde and Kammermeyer (2003); *expert systems* and *artificial intelligence* as learning tools Moore (1996) and Meyer, et al, (1999), Lester, et al (1997); *spreadsheets*, Plane (1994), Evans (2000), Winston (1996), Bell (2000); other *packaged software* such as SIMLIB, Huffman, J.B. (2001); *Web based simulation* Dessouky, et al (2001); *interactive tutorials* Aberson et al, (2002); *virtual factories* Dessouky, et al, (1998); *games and puzzles* Sniedovich, M. (2002); *computer aided games* Reisman et al, (1977, 1980); *industry-specific service-learning projects* and *critical thinking exercises* Cox, and Bobrowski (2003); *questioning strategies* Nadler and Chandon

(2003); *analogies* Martin, (2003). We incorporated *laboratory experiments* in undergraduate courses Martinez-Dawson, (2003); the *Ideals* approach to problem solving had been used for decades at both undergraduate and graduate levels by Nadler (1973) and with various degrees of success many of us have been involved in *team teaching* at one time or another.

Moreover we have used the *constructionist* approach in optimization type modeling and the *reductionist* approach in teaching regression and other statistical tools Lazaridis (1999).

We have tried using various combinations of the above approaches including, but certainly not limited to, incorporating *spreadsheets* into a *case-based* (MBA) quantitative methods as in Carraway, and Clyman (2000); *modeling and puzzles* as in Chlond and Toase (2002); and *spreadsheets, cases and project work* as in an OR capstone course, Armacost and Lowe (2003) and have offered *teaching management science summer faculty workshops*, in which many of the above teaching methods presumably were discussed Grossman (2001).

All of these approaches to teaching OR/MS when used individually or in any combination have their virtues

and their own unique shortcomings. None however provides the novice a global perspective on the subject discussed - often not even a clue. A good taxonomy<sup>(1)</sup> does precisely that and based on the author's own experience<sup>(2)</sup> does not take much class-time away from what the instructor wants or is curriculum-bound to teach Reisman (2004), irrespective of whether the subject being taught involves a theoretic domain e.g., queuing or inventory theory or an application area e.g., human resources planning. No matter which aspect of OR/MS is involved, taxonomies allow one to see and to show the big picture very effectively and very efficiently. They can be used to provide a framework in which the material to be taught can be organized. The framework, if made explicit to the students, helps them organize the material in their own minds, Liebman (1998), West, et al., (1991). Significantly, taxonomies can help in curriculum planning. However, when so used there is a significant danger that professors will try to cram all possible material into a single course. Information overload is a common problem in university courses and is detrimental to student learning. Perhaps for course planning purposes, there should be an added attribute of importance; that is, elements of the taxonomy could be color-coded to represent levels of importance with respect to the levels of the students and the purpose of the course.

## 2. Illustrative example:

With outsourcing being a major practice in all sectors (including government) of developed economies, productivity is becoming a major strategic or policy issue in the Century-XXI global economy. At the same time there are many calls for the OR/MS education and research community to increase its relevance to the real world<sup>(3)</sup> In industry, commerce, the non governmental organizations (NGOs) and the public sec-

tors, usage of the subject matter currently dominating OR/MS education, e.g., optimization, simulation, decision analysis, or project management, etc., are but a few of the means to the end of improving productivity. So, let us imagine that we were given the challenge to design a unique course, curriculum or program dealing *comprehensively* with PA. A number of questions would surface immediately. One might be what topics should be included? This might lead to the question of what is the scope of PA? Which in turn might lead to who is involved in PA? Is it just managers? Clearly not! Engineers, economists, accountants, social scientists, policy formulators, and others have an interest in PA. Do they have differing approaches to PA? You bet they do. Is PA concerned with efficiency? It is to some. What about others? Well, they worry about issues of effectiveness. Does efficiency mean technical efficiency? It does for some. What about others? Some are concerned with allocative efficiency, others with economic (cost) efficiency. Is PA performed on the individual worker, shop-floor, company/institution, industry, sector, or cross sector levels? All of the above. Are PA measures absolute or relative? Yes and Yes. Are they objective or subjective? Yes and Yes. Are they theoretical or empirical? Yes and Yes. Unidimensional or multidimensional? Yes and Yes. Ratios, indices, econometric models, data envelopment analysis or stochastic frontier approaches? All of the above.

At this point we might realize that more heads are better than one or two; so a panel or group of knowledgeable people might be organized and called in to participate in a *brainstorming* session. This session might result in a number of ideas which when analyzed can be organized into a taxonomy. And so it came about that Figure 1 was created<sup>(4)</sup>.

<sup>(1)</sup> See Reisman (1992) for a more general discussion of the usefulness of taxonomies.

<sup>(2)</sup> The author has used taxonomies in his teaching starting with the (1962) publication of the Reisman and Buffa article. Over the years this approach was incorporated into teaching MBA quantitative methods and systems analysis courses, undergraduate courses in managerial and engineering economics as well as research methods seminars for PhD students in operations research and in industrial engineering. The introduction and discussion of a taxonomy and its usefulness in any given course typically does not take up more than four hours of lecture time. At best, it should be introduced early in the course so that the students have a context for all that follows. Moreover when introducing a significantly new or major topic the instructor should reinforce the context by referring to the taxonomy presented.

<sup>(3)</sup> Hall, and Hess (1978); Horner, (2003); Blumstein (1987); Abbott, (1988); Corbett, and Van Wassenhove (1993); Cooper and McAllister (1999); Grossman, (2001); Geoffrion, (1992); Pierskalla, (1987); Powell, (1998); White (1991). And, there are many more.

<sup>(4)</sup> Figure 1 resulted from an impromptu brainstorming session at the end of a faculty seminar on meta research conducted by this author at the Industrial Engineering and Management faculty, Istanbul Technical University, during the 2002-2003 academic year. Said Gattoufi contributed to its refinement. For a taxonomically formatted pros-and-cons discussion of state-of-the-art productivity measurement research, see Singh et al, (2000)

**A TAXONOMY FOR PRODUCTIVITY ANALYSIS**

1. Productivity Analysis
  - 1.1. Effectiveness Analysis
    - 1.1.1. Cost/Effectiveness
    - 1.1.2. Cost /Benefit
  - 1.2. Efficiency Analysis
    - 1.2.1. Technical Efficiency
    - 1.2.2. Allocative Efficiency
    - 1.2.3. Economic (Cost) Efficiency
2. Relativity of Measurement
  - 2.1. Absolute Measures
  - 2.2. Relative Measures
3. Objectivity of the Productivity Analysis
  - 3.1. Subjective
    - 3.1.1. Individual
      - 3.1.1.1. Expert
      - 3.1.1.2. Non expert
    - 3.1.2. Group
      - 3.1.2.1. Experts
      - 3.1.2.2. Non experts
      - 3.1.2.3. Both
  - 3.2. Objective
4. Organizational Level for the Analysis
  - 4.1. Unit level
    - 4.1.1. Individual
    - 4.1.2. As part of an Organization
    - 4.1.3. As part of a Sector
    - 4.1.4. As Part of a Cross-Sectoral grouping
  - 4.2. Organization Level
    - 4.2.1. As part of an Organization
    - 4.2.2. As part of a Sector
    - 4.2.3. As Part of a Cross-Sectoral grouping
  - 4.3. Sector Level
    - 4.3.1. Individual
    - 4.3.2. As Part of a Cross-Sectoral grouping
    - 4.3.3. Cross Sector Level
  - 4.4. Nation
  - 4.5. Cross-nation
5. Domain
  - 5.1. Engineering
    - 5.1.1. Design
    - 5.1.2. Production
    - 5.1.3. Operations
  - 5.2. Management
    - 5.2.1. Finance
    - 5.2.2. Marketing
    - 5.2.3. Human resources
  - 5.3. Economics
    - 5.3.1. Macroeconomics
    - 5.3.2. Microeconomics
  - 5.4. Political Science
  - 5.5. Anthropology
    - 5.5.1. Social
    - 5.5.2. Cultural
6. Models
  - 6.1. Econometric, or parametric
  - 6.2. Nonparametric
  - 6.3. Single input – Single output
  - 6.4. Multi input – Multi output
  - 6.5. Single period
  - 6.6. Multi period
  - 6.7. Deterministic
  - 6.8. Stochastic
    - 6.8.1 Stationary
    - 6.8.2 Non-stationary

*Figure 1:*

With a draft taxonomy in hand the next step is its validation. In the words of Vogel and Weterbe (1984):

The key to taxonomy effectiveness rests on criteria of comprehensiveness, parsimony and usefulness. Obviously, to be effective, a taxonomy must represent the full spectrum of the research [subject domain] chosen for categorization. Thus, comprehensiveness is a necessary condition for effectiveness. It is, however, not sufficient. To further be effective, a taxonomy should be parsimonious. It should not include unnecessary categories. Finally, to be considered effective, the taxonomy should be robust and generally useful. The categories should be reasonably if not mutually exclusive, i.e., non-overlapping, reasonably distinct, meaningful, commonplace, and descriptive to allow utilization by a wide variety of interested persons.

Next, does the "taxonomy represent the full spectrum of the research or subject domain chosen for categorization"? To answer this question it is necessary to seek out a number of very diverse papers from the open literature of the field and apply the classification procedure<sup>(5)</sup>. This will either validate the taxonomy's comprehensiveness as well as its parsimony or indicate a need for some modification. This may involve adding attributes and/or combining some existing ones.

After a few such iterations the taxonomy is ready to go - at least it is for the a-priori assumed boundaries of the field's domain.

Having a satisfactory taxonomy allows one to return to the design of a curriculum for the intended unique course, or program dealing *comprehensively* with PA. The taxonomy of Figure 1 gives us the blue print or the specs for topics to be covered. Conversely, any existing program of study can be evaluated for comprehensiveness of its PA-specific content coverage using the taxonomy of Figure 1.

If a comprehensive textbook or even an encyclopedia on PA is to be written, then the taxonomy of Figure 1 delineates the topics to be covered.

If a doctoral student is to be examined for his or her knowledge of PA, then the taxonomy of Figure 1 gives the student a context of what to prepare for and the examiner a menu of leads to be pursued.

When the above doctoral student does a comprehensive literature review of PA literature for his dissertation, then the taxonomy of Figure 1 gives us the blue print or the specs for topics to be covered as had been done in a number of PhD dissertations, most recently

<sup>(5)</sup> In some areas of OR/MS it is possible to find pre-existing taxonomies. These often are fairly coarse in granularity or concern only a subset of the domain being addressed. By all means they should be used in making make sure that the newly established framework is robust enough to subsume each and all. Such was indeed the case in validating the taxonomies of Reisman (2004), Reisman et al., (2003) and Capari et al (2004)

by Dr. Gattoufi in *Data Envelopment Analysis* (DEA). The result apart from his technical contribution, has been no fewer than four published papers, Gattoufi et al, (2004a, 2004b, 2004c, and 2004d).

When the same doctoral student wants to find a research topic in PA for his or her dissertation, a comprehensive literature search and classification of the extant papers based on the taxonomy of Figure 1 will identify voids in the literature and hence, potential topics to work on, Reisman (1988, 1989, and 1992). It is worth reinforcing the fact that a topic so identified is easier to defend as a contribution.

At the graduate level, literature reviews are playing an increasingly important role in social and therefore OR/MS scientists' definition of knowledge (Cooper, 1988, 1998). "Integrative reviews are clearly the most useful reviews as they show the similarities and the differences between the individual contributions" (Cooper, 1984) and if based on a taxonomic framework they can be used to identify voids in the domain of knowledge under consideration (Reisman, 1988, 1989, and 1992).

For example, in an integrative literature review it may be noted that a DEA based model allowing for "data uncertainty" (as recent extensions do) applied to a bank's branches to study human resources' utilization at any point in time (single period), would be classified using the Figure 1, taxonomy as: **1.2.2/2.2/3.2/4.1.2/5.2.3/ 6.2/6.4/6.5/6.8.1** However when the very same model is applied to compare human resources' utilization in all private versus all state owned commercial banks in a given country it is then classified as: **1.2.2/2.2/3.2/4.1.3, 4.4/5.2.3/ 6.2/6.4/6.8.1** If applied to a cross-country analysis of commercial **4.5** merely replaces the **4.4** part of the code designation. No taxonomy dealing only with PA models would pick up such major differences in application.

On the other hand, when the same real-world situations are addressed using models of parametric statistics **6.2** will be replaced by **6.1** and **2.1** will typically replace the **2.2** in the above classifications.

This way of classifying extant literature in any give OR/MS subject area is computer friendly. This allows

for quickly culling out any desired subset of the literature and as is shown in Reisman et al, (2003) in many ways is superior to relying on *key words*.

Taxonomies for OR/MS subject matter can take on alternative formats. This is discussed in Reisman (1992) and can be seen by perusing the publicly available taxonomies listed in the Appendix. However, the format adopted for Figure 1, lends itself to being transformed into rows of a table where the columns can take on various attributes. These attributes could represent the importance of the row-item to some pre-specified course or curriculum. A column may be dedicated to citing seminal contributions/papers; the most recent contributions; the off-the-shelf software that can best handle the model/methodology so identified; Websites dedicated to the subject matter such as the UK based (DEA Website<sup>(6)</sup>) is for *DEA*; research networks such as *PARN*, the Danish based (moa@sam.sdu.dk) worldwide research network is for *Productivity Analysis*; business cases; or real-world applications involving the row methodology. Clearly, the latter can be subdivided into applications within the public versus the private sector and, the private sector may in turn, be subdivided into manufacturing versus services and so on. It may specify the number of teaching hours to be dedicated, or the lecture dates, for the subject. In a team-taught course it may specify the lead teacher for each segment. Similarly, in a graduate seminar it may specify the name of the participant who will lead the discussion. It may reflect an evaluation of the adequacy of coverage in the existing literature or anything else that is dictated by a specific need.

For illustrative and any other purposes the reader may have, Figure 1, was entered into a spreadsheet (Figure 1.xls<sup>(7)</sup>). The *importance* of each row's subject to each of two types of courses e.g., an undergraduate business course and a *Graduate OR course in Productivity Analysis* was color-coded<sup>6</sup>. Clearly, the prioritization shown reflects this author's opinion and should not be otherwise considered.

No taxonomy, no matter how well conceived, should ever be considered as final. Rather, it should be thought of as a stepping-stone to more comprehensive, more discriminating, more parsimonious, and/or more

<sup>(6)</sup> <http://www.deazone.com>

<sup>(7)</sup> <http://ite.pubs.informs.org/Vol4No3/Reisman/Figure1.xls>

manageable classifications of the subject. It should not be treated as binding or constraining the definition and/or scope of the field of knowledge it addresses. As the subject emerges, either in depth or in breadth, the taxonomic work must follow. In the best of circumstances taxonomies lead to such expansions and/or extensions. There is no better example of the above admonitions than the *Periodic Table of Chemical Elements*, Mendeleev (1889). It has no equal as an aid to educating neophytes yet it has guided chemical research for well over a century. However, at various developmental stages in chemistry the Table had to be reviewed and revised. This process, it is safe to say, is still ongoing. So it is and should be for any domain of knowledge circumscribed by a given taxonomy.

### 3. Concluding remarks:

In a call for shifting the established OR/MS paradigm, Thom Saaty (1998) raised the issue of creativity as "a pressing need" by saying:

"[W]e are better at *deductive* "creativity," by which I mean the ability to face a new application instance to which we might bring to bear past knowledge of similar situations. What I am calling for is *inductive* creativity, which looks at all experience and attempts to induce from it a description of the larger system from which the problem instances flow."

Creating taxonomies requires inductive creativity. Once created, a taxonomy provides a description of the "larger system" referred to above. Not many OR/MS courses provide students the "inductive creativity" experience called for by Saaty. Involving students in creating and validating a taxonomy for some subject of concern to OR/MS might provide a means to that end.

Most instructors use very crude taxonomies like linear vs. nonlinear, deterministic vs. stochastic, hard vs. soft problem or data, single facility vs. multiple facility, discrete vs. continuous, deterministic vs. stochastic, single vs. multiple objectives etc. The only taxonomy accepted more or less universally is the (Kendall notation) queueing taxonomy.

Lastly, advantages of using taxonomies in the teaching of OR/MS and quantitative methods are generic even though this paper based most of its arguments on a productivity analysis example. The *Appendix* lists several publicly available taxonomies for various theoretic and applied areas of OR/MS. Try using one or two in your teaching, in your research, or in proposal

writing. You may even wish to create one to serve your needs. Best wishes. If you have any questions send a quick message to: Reisman@cs.com. Alternatively, you may wish to enrich this paper by citing additional methodologies used to teach OR/MS, or suggest other publicly available taxonomies. Do not hesitate to send me such inputs.

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