Benchmarking the Content of Master's Degrees in Systems Engineering in 2013

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Abstract. This paper fills a gap in the literature by describing a benchmarking study of the knowledge taught in a sample of systems engineering degrees performed in October 2013. By describing the methodology, the development of the benchmarking criteria, and presenting the observations from the benchmarking study, the paper provides an example of the activities performed in the early stages of the Scientific Method. Since the study was performed to benchmark the Master of Defence Technology and Systems (MDTS) degree offered by the Temasek Defence Systems Institute (TDSI) in the National University of Singapore (NUS), the paper:

1. Highlights benchmarks of the MDTS degree against the sampled Masters' degrees.
2. Covers the first stage of the Scientific Method, in which observations are made, sorted and analysed before a hypothesis is developed.
3. Proposes criteria to be used for benchmarking degrees from other institutions.

Keywords: benchmarking; systems engineering education; postgraduate degrees, MDTS, TDSI.

1. Background

The purpose of this paper is two-fold.

1. To document the MDTS benchmarking study.
2. To provide an educational example of the stages of the early research in the Scientific Method that takes place prior to developing the hypothesis.

As part of its ongoing commitment to its sponsors to not only keep the Master of Defence Technology and Systems (MDTS) degree (TDSI, 2014) current but also make it the leading world-wide degree of its type, TDSI re-evaluated its curriculum on an annual basis from 2010 to 2013 using the process depicted in Figure 1 (Kasser, et al., 2004). The 2013 re-evaluation differed from the previous ones because it incorporated a study which benchmarked the MDTS degree against other Master's degrees in systems engineering based on college/university website descriptions of their Master's degree programs in systems engineering. This paper presents some of the observations from the study.

The benchmarking study performs the steps in the early stages of the Scientific Method before the hypothesis is developed; the Observe and Research blocks in Figure 2. The benchmarking study provides an example of the research process in the early stages of the Scientific Method which begins with observing the situation and gathering an initial sample of data from which to develop one or more hypotheses.

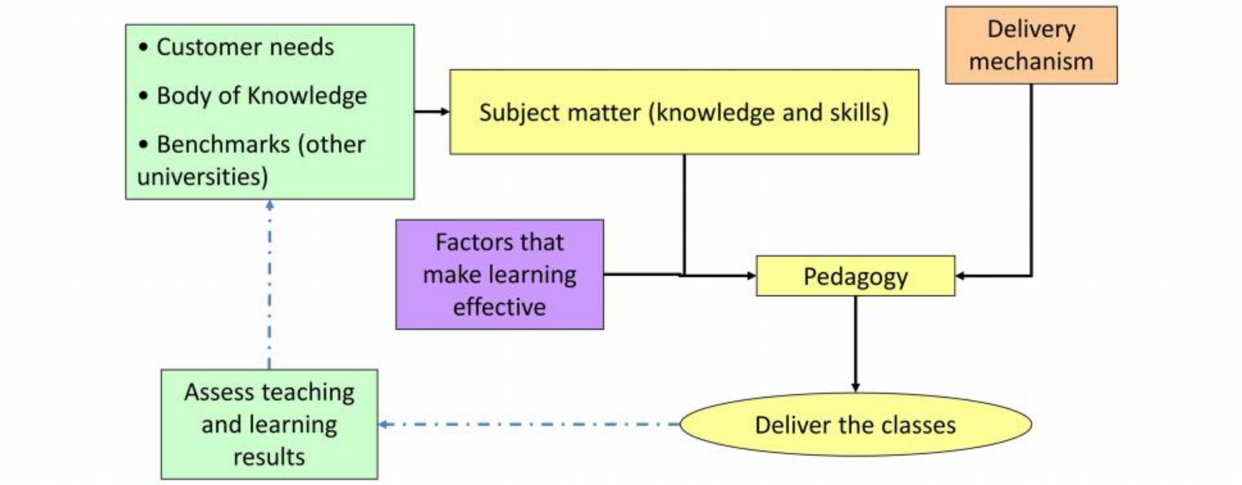

Figure 1 Process used for evaluating the MDTS degree

A search for "systems engineering graduate programs" on `http://www.graduateschools.com` showed that there were 213 Masters and 59 Doctorate programs in systems engineering world-wide in October 2013 (GradSchools.com, 2013).

The literature on the scholarship of teaching and learning systems engineering (e.g. (Asbjornsen and Hamann, 2000; van Peppen and van der Ploeg, 2000; Sage, 2000; Brown and Scherer, 2000; Thissen, 1997; Jain and Verma, 2007; Rashmi, et al., 2007)) focuses on the nature of the knowledge that should be taught; the requirements. There does not appear to have been a survey of what is actually being taught, namely the content of the various Master's programs in systems engineering (the compliance to the requirements).

2. Methodology

Since the secondary purpose of the paper is to provide an educational example of the early stages of research in the Scientific Method that takes place prior to formulating the hypothesis, the aspects of the methodology used for the study documented in this paper cover the following sub-steps included in the 'Observe' and 'Research' blocks of Figure 2.

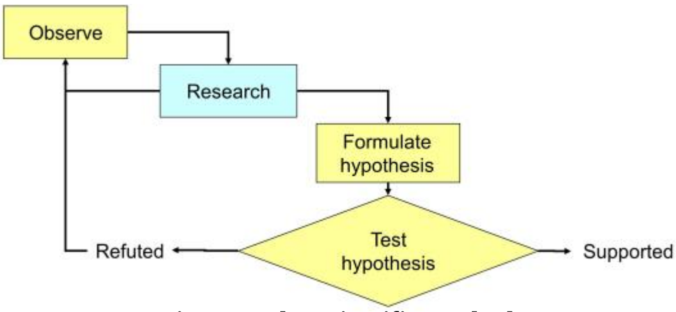

Figure 2 The Scientific Method

1. Select the sample.
2. Determine the benchmarking criteria.
3. Document the observations of each degree using the criteria.
4. Analyse the resulting data.
5. Summarise the observations.
6. Point out areas for further research including formulating the appropriate hypothesis.

3. Selecting the sample

Sample selection took place in two stages. The first stage identified the initial sample to be the ten degrees offered by the institutions exhibiting at the 23rd Annual Symposium of the International Council on Systems Engineering (INCOSE) in Philadelphia in June 2013 since:

Table 1 Sampled degrees

	Degree	Institution
1	MEng in Systems Engineering	Penn State University (Malvern, PA)
2	MEng in Systems Engineering	Stevens Institute of Technology (Hoboken, NJ)
3	MSc in Systems Engineering	Missouri University of Science and Technology (Rolla, MO)
4	MSc (Major in Systems Engineering)	Southern Methodist University (Dallas, TX)
5	MSc in Systems Engineering	University of Maryland – Institute for Systems Research (College park, MD)
6	MSc in Systems Engineering	Worcester Polytechnic Institute (Worcester, MA)
7	MSc in Industrial and Systems Engineering (MISE)	University of Michigan (Dearborn, MI)
8	MISE	University of Southern California – Viterbi School of Engineering (Los Angeles, CA)
9	Professional Master's in Applied Systems Engineering	Georgia Tech (Atlanta, GA)
10	MSc in Engineering and Management	MIT System Design and Management Program (Boston, MA)

1. Prior research had indicated that there did not seem to be a comparable degree in Defence Systems.
2. The degrees sampled shown in Table 1 represent a variety of types of degrees, although all exhibitors were from American (USA) institutions.

The second stage began with a quick review of the different degree titles and the wide range of courses offered in the degree, providing an indication as to the reason why benchmarking studies of the contents of degrees had not been previously performed, namely:

- The courses offered covered different aspects of systems engineering and domains in which systems engineering was practiced, with some similarities and lots of differences.
- The amount of granularity in the on-line published course descriptions also differed widely, ranging from a single paragraph to a detailed course description of the sessions.
- Required courses in some degrees were electives in others.
- Master's entrance criteria, such as previous engineering or science degree, weren't always indicated.
- Some degree offerings appear to be developed around their local industry's needs as expected.

These findings produced a need to find a reference set of criteria to be able make comparisons between the degrees. Consequently, the decision was made to:

1. Only focus on the required courses for each degree.
2. Develop a set of benchmarking criteria that would provide a reference against which to evaluate all the degrees as well as the MDTS degree. These criteria could also subsequently be used if the research was extended to cover additional degrees.
3. Make the evaluation based on the wording in the information contained on the degree website.

However, basing an evaluation on wording from websites meant that:

- The benchmark information was limited to what the institution website communicated it was teaching, not necessarily what it was actually teaching in October 2013.

- There was an assumption that the website wording used by each institution emphasized the aspects of the degree the institution thought were important. For example, if the term 'systems thinking' did not show up in a course description, the assumption was that it wasn't being taught. The validity of the assumption is questionable and undeterminable without further research since the curricula given on the websites are seldom scrupulously followed. Many times they are outdated. Furthermore, the instructor usually has the flexibility to change around the content, sometimes dependent on the background of the students and their need and/or to meet local stakeholder need. Sometimes a complete course is changed or swapped because the right instructor is not available.
- Due to the variation in the depth of course descriptions, the depth of topic coverage was difficult to determine, however, the missing data may just be masked and the topic may really be present in the course offering.
- Interpretation of data was subjective, likely due to cognitive bias. Although both authors performed the assessment independently, they produced the same categorization except in a few cases; and it is still possible that meanings of terminology may have been misinterpreted.
- The early findings were good enough for the benchmarking study and development of a hypothesis.

In academic research, the hypothesis would be developed and further data would then be obtained to test the hypothesis in the next stage of the Scientific Method. Recognising that the sample size of 10 was small (a subset of wider, more global offerings), a quick search of the websites of a number of other degrees by a number of other institutions in the USA, the UK and Australia, showed that the limited sample was indeed representative of the varieties of systems engineering degrees offered.

4. Determine the benchmarking criteria

The sponsors of the MDTS degree want a degree in Defence Technology Systems not a degree in systems engineering. It is expected that sponsors of degrees in other institutions would want degrees that focused on their areas of interest, which would shape the content of what would be taught. Systems engineering covers a broad area of knowledge and each degree is constrained by circumstances covering a subset of that knowledge, customized for sponsors and customers. Determining if the content of an Academic-Off-The-Shelf (AOTS) degree meets the requirements of a specific sponsor is a complex problem. Given the wide disparity between the degrees and the required courses in the small sample, comparing each of the degrees against each other posed a problem; an external reference was needed. Consequently, the following set of benchmarking criteria was developed to provide a standard set of perspectives from which to observe the content for each of the degrees.

1. Types of knowledge taught in the required courses discussed in Section 4.1.
2. The ability to understand, solve, and manage technological problems (Wicklein, et al., 2009) discussed in Section 4.2.
3. The Hitchins-Kasser-Massie Framework (HKMF) discussed in Section 4.3.
4. The Competency Model Maturity Framework (CMMF) discussed in Section 4.4.
5. Two systems engineering paradigms discussed in Section 4.5.

Note this set of criteria was developed to benchmark the MDTS degree. Other criteria may need to be developed for other benchmarking purposes.

4.1. *Types of knowledge taught in the required courses*

This criterion (Kasser and Arnold, 2014) was developed using the *Generic* Holistic Thinking Perspective (HTP) (Kasser, 2013) from the similarity between systems engineering and mathematics, namely they are both enabling disciplines used for solving different types of problems in other disciplines. The criterion applies the *Continuum* HTP to differentiate between three notional types of systems engineering (Kasser and Arnold, 2014):

Table 2. The HKM Framework (HKMF) for Systems Engineering

Layer of Systems Engineering \ Phase in the Life Cycle		Needs identification	Requirements	Design	Construction	Unit testing	Integration & testing	O&M, upgrading	Disposal
Socio-economic	5								
Supply Chain	4								
Business	3								
System	2								
Product	1								
		A	B	C	D	E	F	G	H

1. ***Pure systems engineering*** which includes cognitive skills such as systems thinking, critical thinking, problem formulation/ solving, and decision-making.
2. ***Applied systems engineering*** which includes the activities performed in the workplace such as requirements elucidation and elucidation in general, systems architecting, Verification and Validation (V&V), systems integration, engineering, the 'ilities, etc.
3. ***Domain systems engineering*** pertains to fields such as aerospace, transportation and defence, which provides depth (several courses in a single domain), or breadth (courses in several domains) or some mixture which aids in contextual formulation by the learner and reinforcement of the application concepts.

Classifying the degrees was difficult before creating this criterion. Once sorted by the three types of knowledge taught in the required courses it was easy to observe that degrees had different mixtures of pure systems engineering, applied systems engineering and domain systems engineering.

4.2. *The ability to understand, solve, and manage technological problems*

This criterion is based on the five top aspects of the engineering design process that best equip secondary students to understand, solve, and manage technological problems (Wicklein, et al., 2009) which are:

1. Understanding that there may be multiple solutions to a problem/requirement.
2. Effective oral communications.
3. Ability to communicate graphically and pictorially.
4. Ability to handle open-ended/ill-defined problems.
5. Ability to perform systems thinking.

This criterion was less evident in the communicated course content, as was expected due to their skill-based nature.

4.3. *The Hitchins-Kasser-Massie Framework (HKMF)*

The Hitchins-Kasser-Massie Framework (HKMF) (Kasser, et al., 2001) which plots the product layer of complexity and process (lifecycle) state on different axes as shown in Table 2 was developed when trying to develop the requirements for what should be taught (the knowledge) in post-graduate coursework at the University of South Australia.

4.4. *The Competency Model Maturity Framework (CMMF)*

A number of different competency models have been proposed for systems engineering. Several of these had been studied and were found to be wanting for various reasons which resulted in a proposed Competency Model Maturity Framework (CMMF) (Kasser, et al., 2013). The cognitive skills section of the CMMF:

- Traces back to discussions of the abilities needed to identify the problem and conceptualize the solution in the literature on innovation (Gordon G. et al., 1974; Gharajedaghi, 1999).
- Includes and exceeds the ability to understand, manage, and solve technological problems (Wicklein, et al., 2009).
- Goes beyond systems thinking to critical thinking and holistic thinking; in particular, by using the *Generic* and *Continuum* HTPs which are critical for problem formulation and problem solving and differentiating between four of the five types[1] of systems engineers (Kasser, et al., 2009) as shown in Table 3 which is based on both Gharajedaghi (Gharajedaghi, 1999) and Gordon et al. (Gordon G. et al., 1974).

Table 3. Factors conducive to innovation

Ability to find similarities among objects which seem to be different *Generic* perspective	**High**	Problem solvers **(Type III)**	Innovators **(Type V)**
	Low	Imitators, Doers **(Type II)**	Problem formulators **(Type IV)**
"Ability to find" generally comes mainly from application of *Generic* and *Continuum* HTPs		**Low**	**High**
		Ability to find differences among objects which seem to be similar *Continuum* perspective	

4.5. *Two systems engineering paradigms*

These criteria are based on earlier research into the nature of systems engineering which identified two sets of concurrent paradigms:

1. The 'A' and 'B' system engineering paradigms (Kasser, 2012).
2. The problem-based and process-based paradigms.

4.5.1. *The 'A' and 'B' paradigms*

The 'A' paradigm begins with the systems engineering activities performed in column 'A' (Needs Identification state) in the HKMF shown in Table 2. The 'B' paradigm begins with the activities performed in column 'B' (Requirements state) in the HKMF, and is a result of the devolution of systems engineering in the US Department of Defense (DOD) (Kasser and Hitchins, 2012).

4.5.2. *The Problem-based and Process-based paradigms*

Some systems engineers, particularly members of INCOSE and the US DOD, are process-focused (Lake, 1994; Haskins, 2011). The Problem Paradigm can be traced back at least as far as 1980 (Gooding, 1980). Systems engineers in the Problem Paradigm focus on the problem and identifying the best solution available given the constraints at the time (Hitchins, 2007). Some of these systems engineers also address carrying out that process to realize the solution system (Bahill and Gissing, 1998).

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[1] Type I, not shown in the figure is the beginner.

Table 4. Types of knowledge taught in the required courses

Degree/Knowledge	1 MESE	2 MESE	3 MScSE	4 MScSE	5 MScSE	6 MScSE	7 MISE	8 MISE	9 PMAS	10 MScEM	11 MDTS
Pure systems engineering	0.50	0	0	0.10	0	0	0.10	0	0.25	0.09	0.10
Applied systems engineering	0.42	0.40	0.50	0.80	0.40	0.60	0	0	0.55	0.22	0.40
Domain systems	0	0	0	0	0	0	0.10	0	0	0	0.30
Management	0.08	0.10	0.10	0	0.20	0.20	0.10	0.20	0.10	0.31	0
Total	**1.00**	**0.50**	**0.60**	**0.90**	**0.60**	**0.80**	**0.30**	**0.20**	**0.90**	**0.62**	**0.80**

5. Document the observations of each degree by the criteria

This section documents the observations of the 10 Master's degrees based on the contents of their websites by the benchmarking criteria discussed in Section 4 and the MDTS degree. The following approach was used to create the numerical data in the summary tables.

1. The number of required and elective courses in the degree was determined.
2. The percentage of the degree represented by a required course was calculated. For example, if there were 10 courses in a degree, six of which were required and four of which were electives, the required courses contributed to 60% of the total courses.
3. If the topic was not mentioned at all in the course material on the website, the score was 0.
4. The rows Table 4 to Table 9 contain the criteria and the columns contain the degrees. The numeric results are the associated assessments of the degrees against the criteria. In Table 4 to Table 9 the number of the column is the same number as the column number in Table 1. Note that 11 is the MDTS degree, which was included to assess direction for the four annual upgrades of the MDTS degree.
5. Table 4 to Table 9 contain percentages for that degree against each criterion discussed in Section 4.1 to 4.5. If a required course was deemed to meet part of the criteria, then the course was awarded a fractional percentage. For example, if a breadth course covered part of a criterion, it received partial credit, namely if 50% of a breadth course (already 10%) looked like it met a criterion, the course was awarded 0.05 (0.10*0.5).

5.1. *Types of knowledge taught in the required courses*

The knowledge content of the required courses was sorted by the three types of knowledge identified in Section 4.1 and are shown in Table 4. Since a management course of some kind was required in many of the degrees, management content was singled out and added to Table 4.

The observations indicate that:

- All of the degrees required a mixture of pure and applied systems engineering except the MISE degrees offered by Degree 9. Degree 9 does not require any pure systems engineering courses but does require two management courses For example, for degree 1:
  - The 0.25 for degree 1 indicates that 25% of the coursework is in pure system engineering.
  - The total of 0.90 represents that 90% of the required coursework is in pure, applied, domain systems engineering and project management leaving 10% for electives.
- Except for Degree 4, the focus is on applied systems engineering more than on pure systems engineering, even when management is defined as its own type of knowledge.

Table 5. Observations of the ability to understand, manage, and solve technological problems

The five top aspects of the ability to …	1 MESE	2 MESE	3 MScSE	4 MScSE	5 MScSE	6 MScSE	7 MISE	8 MISE	9 PMAS	10 MScEM	11 MDTS
1. Multiple solutions to a problem/ requirement	0	0	0	0	0	0	0	0	0	0	HT
2. Oral communications	0	0	0	0	0	0	0	0	0	0	HT
3. Graphical/pictorial communication	0	0	0	0	0	0	0	0	0	0	HT
4. Ability to handle open-ended/ill-defined problems	0	0	0	0	0	0	0	0	0	0	HT
5. Systems thinking	0	0	0.01	0	0	0	0	0	0	0	HT

5.2. *The ability to understand, manage, and solve technological problems*

The observations against the 'ability to understand, manage, and solve technological problems (Wicklein, et al., 2009) criterion discussed in Section 4.2 are summarized in Table 5.

The five top aspects of the ability to understand, manage, and solve technological problems indicate that the terminology used in the course descriptions on the websites imply that systems thinking is not communicated as being taught, except for a small part of one course in 3. This observation is most likely invalid, since this level of detail may actually be taught as an undercurrent of the course dependent on the instructor. Since the MDTS program is used as a reference, the ability to understand, manage, and solve technological problems is covered in the MDTS course on Holistic Thinking (HT) even though it is not mentioned in the course description.

5.3. *The Hitchins-Kasser-Massie Framework (HKMF)*

The observations by the 'Hitchins Layer' criterion discussed in Section 4.3 are summarized in Table 6 and Table 7 and show that:

- All degrees focus on Layer 2, the system layer, with a few moving up into Layer 3, the business Layer.
- Degree 2 has coverage in all five layers.

The observations of the 'Lifecycle State' criterion discussed in Section 4.3 are summarized in

Table 6. Lifecycle State

Lifecycle State		1 MESE	2 MESE	3 MScSE	4 MScSE	5 MScSE	6 MScSE	7 MISE	8 MISE	9 PMAS	10 MScEM	11 MDTS
A.	Needs Identification	0	0	0.10	0	0	0	0	0.	0.31	0	0.20
B.	Requirements	0.17	0.10	0.23	0.10	0.10	0	0	0.01	0.01	0.01	*
C.	Design/Architecting	0.17	0.10	0.23	0.10	0.05	0	0	0.11	0.06	0.11	*
D.	Subsystem Construction	0	0	0	0	0	0	0	0	0.01	0	*
E.	Subsystem testing	0	0	0	0	0	0	0	0	0.01	0	*
F.	Integration & Testing	0	0.10	0.03	0.10	0.10	0	0	0.12	0.01	0.12	*
G.	Operations	0	0	0	0	0	0	0	0	0	0	*
H.	Disposal	0	0	0	0	0	0	0	0	0	0	*

Table 7. Hitchins Layer

Hitchins Layer		1 MESE	2 MESE	3 MScSE	4 MScSE	5 MScSE	6 MScSE	7 MISE	8 MISE	9 PMAS	10 MScEM	11 MDTS
5.	Socio-economic	0	0	0	0	0	0	0	0	0	0.06	0
4.	Supply chain	0	0	0	0	0	0	0	0	0	0.19	0
3.	Business	0	0	0.10	0	0	0.10	0	0	0.10	0.06	0.10
2.	System	0.17	0.50	0.50	0.30	0.40	0.50	0.20	0.10	0,80	0.19	0.50
1.	Product	0	0	0	0	0	0	0	0.10	0	0.13	0.20

Table 6 and show that there is:

- Little if any coverage of the critical Needs Identification State except for Degree 2.
- Little if any coverage of the Systems Integration and Testing States in more than half of the sample.
- Barely a mention of the Subsystem Construction and Subsystem Testing States even though
- this is where the systems engineers have to ensure that the subsystems comply with system specifications and the Technical Performance Measures (TPM) are monitored.

Since this was an exercise to benchmark the MDTS degree, an asterisk '*' character was inserted into the result tables when a topic was covered in the MDTS program and was not mentioned in the MDTS course material, exposing a communication gap. It is assumed that the similar gaps exist in the other degrees on their websites.

5.4. *The Competency Model Maturity Framework (CMMF)*

The observations by the 'sections of the CMMF'(Kasser, et al., 2013) criterion discussed in Section

Table 8. CMMF

	1 MESE	2 MESE	3 MScSE	4 MScSE	5 MScSE	6 MScSE	7 MISE	8 MISE	9 PMAS	10 MScEM	11 MDTS
Knowledge											
Systems engineering (pure)	0.20	0.09	0	0.50	0.10	0	0	0.10	0	0	0.10
Systems engineering (applied)	0.60	0.22	0.50	0.42	0.80	0.40	0.40	0	0	0.60	0.40
Problem domain	0	0	0	0	0	0	0	0	0	0	0.30
Implementation domain	0	0	0	0.08	0	0	0	0	0	0	0
Solution domain	0	0	0	0	0	0	0	0	0	0	0.30
Cognitive characteristics											
System/holistic thinking	0	0	0.02	0	0	0	0	0	0	0	0.10
Critical thinking	0	0	0	0.02	0	0	0	0	0	0	0.02
Problem formulation	0.02	0	0	0.02	0	0	0	0	0	0	0.01
Problem solving	0.10	0	0	0.08	0	0	0	0	0	0	0.05
Typical Individual traits											
Leadership	0.10	0	0	0	0	0	0	0	0	0	0
Management	0.10	0.31	0.20	0.08	0	0.10	0.20	0.10	0	0.20	0
Communications	0	0.03	0	0	0	0	0	0	0.20	0	*
Ethics	0	0	0	0	0	0	0	0	0	0	*

Table 9. System engineering paradigms

Paradigm	**1 MESE**	**2 MESE**	**3 MScSE**	**4 MScSE**	**5 MScSE**	**6 MScSE**	**7 MISE**	**8 MISE**	**9 PMAS**	**10 MScEM**	**11 MDTS**
Paradigm (‘A’/’B’)	‘B’	‘B’	‘B’	‘B’	-	‘B’	‘B’	‘B’	‘A’	‘B’	‘A’
Process (S)/Problem (B)	B	S	S	S	-	S	S	S	S	B	B

4.4 are summarized in Table 8 and show that none of the degrees mentioned ethics in their course descriptions.

5.5. *The ‘A’ and ‘B’ systems engineering paradigms*

The observations by the ‘systems engineering paradigms’ criterion discussed in Section 4.5 are summarized in Table 9 and show that the majority of the degrees follow the ‘B’ paradigm and are also process-paradigm-focused. Since the ‘B’ paradigm skips the Needs Identification State and starts in column ‘B’ of the HKMF, this observation explains why communicated coverage of the Needs Identification State of the HKMF discussed in Section 5.3 appears to be lacking. The ‘-‘entries for Degree 7 indicate that the authors could not decide which paradigm applied to the degree.

6. Analyse the resulting data

By using the benchmarking criteria, the knowledge taught in the modules of the MDTS program could be compared with the knowledge taught in the required courses in the sampled degrees. The MDTS is part of a dual degree program in which the students receive two Master’s degrees. They spend six months at NUS working towards the MDTS degree and then spend an additional twelve months at the Naval Postgraduate School (NPS) in Monterey, California working towards a second Master’s degree.

The study showed that as far as the MDTS degree was concerned:

- The MDTS was teaching a mixture of all three types of systems engineering as shown in Table 4 (10% pure systems engineering, 10% applied systems engineering and 30% Defence domain systems engineering) and none in management.
- There were some desirable applied systems and domain topics missing but there was no place to fit them in. However, the focus of the MDTS degree is Defence Systems, and since the MDTS is part of a dual degree, some of the applied systems engineering courses could be replaced by additional Defence domain systems courses since the applied systems engineering courses can be provided by the other degree.

7. Other observations

Other observations from the MDTS benchmarking study showed that in general:

- Different degrees teach different things as do degrees with the same name of the degree.
- One can get a MISE without a single required course on systems engineering if one picks the right institution and electives.
- Knowledge topics are bundled into courses in various ways.

- There are numerous differences in knowledge content in various degrees, which may be due to local sponsor's requirements or the lack of any requirements for bundling the knowledge into a master's degree.
- The focus of the coursework seems to be on:
    - Cookbook solutions (Type II) rather than on reasoning (Type V).
    - Processes (take one and apply it) instead of creating one to fit the specific situation.
- While the use of wording on a website does not provide in-depth information for a serious academic study, it does provide enough information for the preliminary research and for benchmarking the MDTS degree, which, after all, was the purpose of the study.
- The sampled and other institutions may want to adjust the wording on their websites to describe the knowledge they actually teach as well as the skills they encourage the students to develop.
- The benchmarking criteria demonstrated the need for answers to the follow-on questions, "what are the right topics to teach?" and "is the knowledge being taught in the right way" by different sponsors and institutions in the manner of the CMMF? It is easy to see which applied systems engineering courses might better fit the needs of systems engineers working in a specific state of the System Development Process (SDP) via the HKMF.
- The mixture of pure, applied and domain systems engineering can be adjusted to fit the needs of the local sponsor.
- Websites communicate to the world what systems engineering is and in effect are laying the ground work for what the world perceives systems engineering to be.
- Judging by the sample, on-line degrees are a popular offering in addition to classroom learning.
- Electives, in some cases, could radically affect the knowledge perspective for degrees with the same or similar title.

8. Further research

This study served its purpose of benchmarking the MDTS degree. Further research might investigate the pedagogy as well as the content including:

1. Develop one or more hypothesis and collect more detailed and accurate information representative of what is actually being taught, using traditional tools such as interviews and surveys, to test those hypotheses, after the latest institution website data has been gathered.
2. Developing a hypothesis appropriate for further research from the findings of this preliminary research.
3. Repeating the survey with a much wider sample possibly comparing the different content in different subsets of degrees such as a MISE.
4. Performing an additional survey of Master's degrees in Engineering Management and the degree of overlap in the knowledge taught in those degrees and the systems engineering degrees, given the overlap between project management and systems engineering management in the workplace.
5. Examining the follow-on question "what are the right topics to teach?"
6. Evaluating the Graduate Reference Curriculum for Systems Engineering (GRCSE®) against the benchmarks discussed in Section 4.
7. Examining the pedagogy of systems engineering courses to address the question "is the knowledge being taught in the most effective way?"

9. Summary

This paper:

1. Provided an educational example of the early research in the Scientific Method that takes place prior to developing the hypothesis.
2. Described most of a benchmarking study of the knowledge taught in a sample of systems engineering degrees performed in October 2013. The paper described the methodology, the development of the benchmarking criteria and presented the observations from the benchmarking study.

Since the study was performed to benchmark the MDTS degree offered by the TDSI in the NUS, and not as an academic research project, the paper:

1. Did not rank the sampled degrees against each other as the authors believe there is need for choices of knowledge gained in acquiring a Systems Engineering Master's degree.
2. Benchmarked the MDTS degree against the sampled Masters' degrees.
3. Only covered the first stages of the Scientific Method, namely, making observations and collecting data as shown in the 'Observe' and 'Research' blocks of Figure 2.

10. Conclusions

The conclusions in this paper are that the benchmarking study:

1. Indicated that the MDTS degree, in its context of being a dual degree, should drop three of the four applied systems engineering courses and replace them with three additional Defence domain systems courses. The applied systems engineering course that covers what systems engineers do in each state of the SDP should be retained to provide the context for the Domain courses.
2. Contained an effective methodology for the preliminary research activities in early stages of the Scientific Method for educational purposes and is worth publishing to provide an educational example and as a reading in one of the pure systems engineering courses.
3. Provided an effective basis for further research into the content of degrees in systems engineering.
4. Developed a useful set of benchmarking criteria for the knowledge content of degrees.

11. Biographies

Joseph Kasser has been a practicing systems engineer for more than 40 years and an academic for about 18 years. He is a Fellow of the Institution of Engineering and Technology (IET), a Fellow of the Institution of Engineers (Singapore), an INCOSE Fellow, the author of "*Perceptions of Systems engineering*", "*Holistic thinking: creating innovative solutions to complex problems*", "*A Framework for Understanding Systems Engineering*" and "*Applying Total Quality Management to Systems Engineering*", and many INCOSE symposia papers. He is a recipient of NASA's Manned Space Flight Awareness Award (Silver Snoopy) for quality and technical excellence for performing and directing systems engineering and other awards. He holds a Doctor of Science in Engineering Management from The George Washington University. He is a Certified Manager and holds a Certified Membership of the Association for Learning Technology (CMALT). He also started and served as the inaugural president of INCOSE Australia and served as a Region VI Representative to the INCOSE Member Board. He has performed and directed systems engineering in the UK, USA, Israel and Australia. He gave up his positions as a Deputy Director and DSTO Associate Research Professor at the Systems Engineering and Evaluation Centre at the University of South Australia in early 2007 to move to the UK to develop the world's first immersion course in systems engineering as a Leverhulme Visiting Professor at Cranfield University. He is currently a Visiting Associate Professor at the National University of Singapore.

Eileen P. Arnold, Fellow of INCOSE, has 35+ years of experience as an electrical engineer, software engineer, and systems engineer. She recently retired from her position as a Principal Systems Engineer at United Technologies Corporation (UTC) Aerospace Systems, Electric Systems. Her career spans aircraft avionics and electrical systems on commercial and Business/Regional jets, management, CMMI leadership, weapons systems (Future Combat Systems of Systems), and Lifecycle Management (LCM) across multiple sites improving the effectiveness of the organization.

Arnold is the recipient of the Minnesota Federation of Engineering, Science and Technical Societies (MFESTS) Charles W. Britzius Distinguished Engineer Award. She holds credentials as an INCOSE certified Expert Systems Engineering Professional with a Department of Defense Acquisition extension (ESEP-Acq) and is a PMI Certified Project Management Professional (PMP).

Arnold has been an active INCOSE volunteer and author since 1996, holding a variety of INCOSE and IEEE local chapter, corporate and international level leadership positions. She is currently a past member of the INCOSE Board of Directors, a past Chair of the INCOSE Competency Working Group (WG), a member of the PMI-INCOSE Alliance WG and one of the leaders of the INCOSE North Star Chapter.

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