Pedagogy, Practice and Procedure (*The P 3 Project*) - Educating Engineering Managers: A Model for the Future

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ABSTRACT

Over the past two decades there has been much discussion about how to best educate Engineering Managers. Indeed, traditional Management Education within Business School Settings has been subjected to considerable criticism, with, some suggesting that traditional MBA programmes lack engineering context and application and thus fail to meet the needs of both employers and students. Conversely, others postulate that Business Schools provide graduate students with generic skills and transferable competencies and are thus exactly engineering managers *should* be educated. Looking critically at Engineering Management Education within an Engineering School, this paper suggests that graduate level Engineering Management Education needs to be led by Engineers who have experience in industry and who also are qualified in management. It introduces a model of organisational change developed specifically for an Engineering Education setting and considers how that model may be best applied to an Engineering Management Education setting.

Key words: RVS, Graduate Students, Engineering Management Education

1) INTRODUCTION

Set within a global workplace where professional engineers need to be multi-skilled practitioners able to work in multi-disciplinary teams , the matter of how to best educate those individuals who find themselves with managerial responsibility for major engineering projects is of great importance. Yet the question of how and where management training should be included within an engineer's career path is rarely discussed; with many professional engineers looking outside their employers' vocational offerings and beyond traditional university engineering education to access management training from graduate level Business Schools. Such business-centric education has been subjected to considerable criticism, with some suggesting that traditional MBA programmes lack engineering context and application and thus fail to meet the needs of both employers and students [1]. On the other hand some literature

suggests that Business Schools provide graduate students with generic management skills and transferable competencies and are therefore exactly what engineering managers *should* be accessing as an opportunity to broaden their thinking [2]. In looking at both sides of the argument, what is clear is that engineers who take on management responsibilities should be trained; and because most engineers do, at some time in their career, find themselves working at a management level, this training needs to be appropriate to an engineering context. Despite this, the question of how and when management training should be accessed by engineers, or what it should comprise in terms of practice, focus and theory, remains largely unanswered.

In seeking to explore this issue, this paper looks at engineering students' experiences and perceptions of a management module that is embedded into graduate level engineering education. The module, which provides students with key Project Management knowledge, theory and skills, has been carefully constructed around an approach to engineering education developed by the paper authors [3]. Termed the RVS Model of Engineering Education, the approach comprises three key concepts, Relationships, Variety and Synergy and is built around the concept of 'Synergetic Configuration'. The study upon which this paper is based critically discusses students' perceptions of the Project Management module that has been synergistically configured so as to encapsulate key engineering, managerial and educational requirements. The paper builds on previous studies to show how the RVS approach to engineering education can be a catalyst for educational change. In this case it is in teaching engineers about management, thus adding to key discussions in the area of management education for engineers.

2) BACKGROUND

In a pre-Brexit UK Government Report, Member of Parliament Vince Cable, who was at the time Secretary of State for Business, Innovation and Skills commented "*A strong British engineering sector is vital to the long term sustainability of our economic recovery, and increasing the supply of engineers is at the heart of this*" [4]. Indeed, both before and after Brexit, the importance of engineering to a thriving UK economy is frequently featured in the British press with arguments that 'engineering skills shortages' comprise a present and future threat to the success and security of the country being a favoured topic [5,6]. From a more global perspective, it is evident that much of the world acknowledges the important role that Professional Engineers play in both solving transnational problems and challenges including issues around: Sustainability and Sustainable Development: Political unrest, terrorism and war: Global warming and pollution: An aging infrastructure, and, as we move into the 21st Century: International cyber security and artificial intelligence [7].

Set against this challenging environment, the need for those managing engineering projects to be able to understand science and maths and to be in a position to solve engineering problems, whilst adopting sound managerial practices, has become increasingly important, with much debate focusing on the need to promote leadership and management skills within the engineering workforce [8,9]. Yet in many areas, engineering projects are managed by non-engineers who, whilst being 'professional managers' have little or no understanding of the underpinning engineering or scientific theories. At best this can result in financial and project mismanagement, whilst at its worst technical errors could result in loss of life and a damage to the environment. Hence the need to educate engineers with managerial skills is increasingly important. In seeking to address this, business and management modules have been introduced

into many graduate level engineering programmes. The P3 Project looked at one such module. It examines the issues around applying the RVS approach to management training for engineers so as to 'Synergistically Configure' the curriculum and in doing so promote pedagogy and practice within graduate engineering education.

- **Introducing Synergetic Configuration: An Approach to Engineering Education developed by Engineering Educators *for* Engineering Education.**

Synergetic Configuration is defined as "*the requirement that university level Engineering Education should equip students with the technical capabilities required by industry, whilst providing them with a sound theoretical knowledge base, within a supportive curriculum in which 'softer skills' are embedded alongside technical competencies and independent learning is the norm*". Grounded in the findings of previous studies and published work by the paper authors, Synergetic Configuration has emerged out of a new model of Engineering Education developed by the paper authors, the RVS Approach to Engineering Education [3]. Synergistically synthesizing three distinctive concepts, Relationships, Variety and Synergy, and developed with the intention of promoting Scholarship in Engineering Education, the model has been specifically developed so as to overcome the linguistic and conceptual barriers many engineering educators encounter when trying to engage with pedagogic theory. As such it has helped to facilitate change in an environment that typically struggles to adopt new ideas quickly and holistically [10].

In considering how to promote Scholarship in Engineering Education the paper authors turned to the work of Boyer [11] who argued that there are four separate, but overlapping, areas of Scholarship (Discovery, Integration, Application and Teaching). Each of these four areas was considered in the development of the RVS Approach from an Engineering Education perspective. Synthesized with the three different concepts that make up the RVS approach, the foundational use of Scholarship as an educational ideology resulted in a theoretically grounded and academically relevant pedagogy specifically aimed at those working in Engineering Education.

From an Engineering Education perspective, the first area of Scholarship, that of Discovery, is encapsulated by the pursuance of knowledge which underpins engineering pedagogy and research. Following on from this the Scholarship of Integration is evident within an Engineering Education context when considering the inter-connectivity across different engineering disciplines, particularly when taking account of the vital role engineers play in society. Within the RVS approach the Scholarship of Integration encourages learners and teachers to seek answers beyond traditional disciplinary boundaries in a manner that is *imaginative*, *interdisciplinary, interpretive* (and) *integrative* (Boyer, p 21). The third area of Scholarship, Application, represents the fundamental basis of much engineering education, indicative of the fact that engineering is an applied discipline and as such requires the acquisition *and* application of knowledge, competencies, skills and contextual insight. The final area of Scholarship, Teaching, represents the fundamental purpose of the model, which is to provide an easily adaptable, scholarly approach to engineering education. In bringing together three distinctive concepts of Relationships, Variety and Synergy the paper authors have produced a useful and useable model which has been tested over a number of years. The P3 Project aimed to take this testing one stage further and set out to critique how proactive synergetic configuration of pedagogy, practice and procedure within different elements of a graduate level engineering management programme can act to promote a positive learning experience at graduate level.

3) THE P 3 PROJECT METHODOLOGY

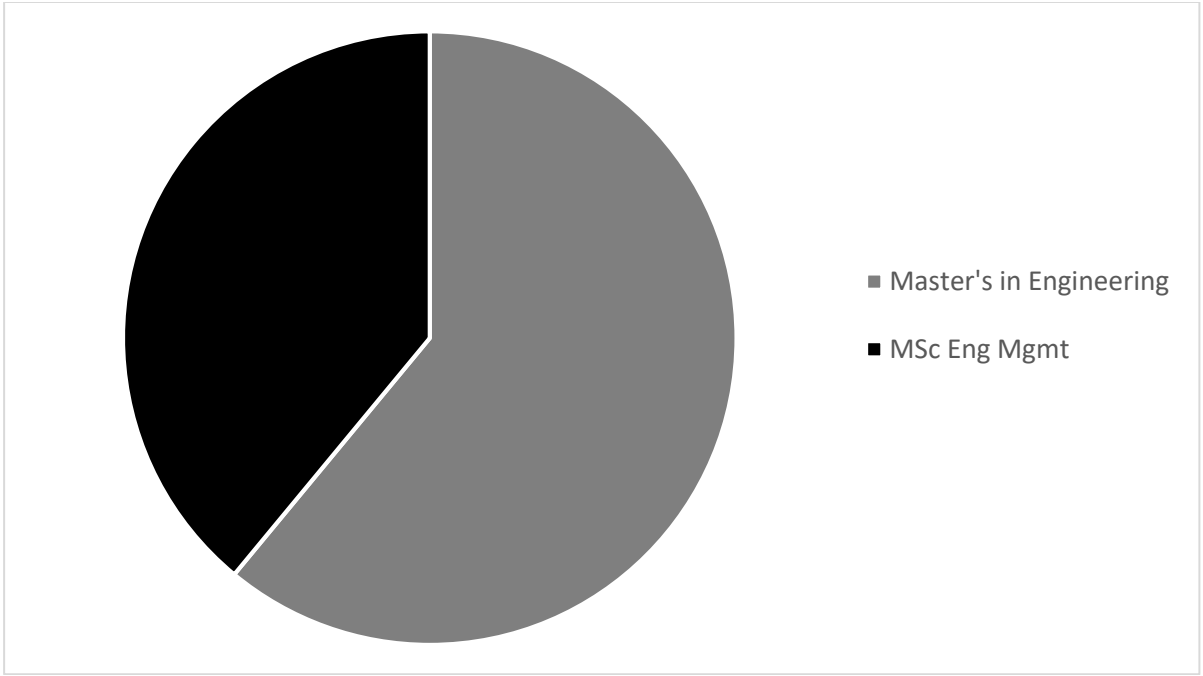
To achieve this aim, an Action Research Approach [12] was adopted in which the project leaders set out to answer the question *"How can pedagogy, practice and procedure be improved through the application of the RVS model of engineering education at graduate level?"* A small exploratory study was conducted focusing on pedagogy and practice within an Engineering School based in the UK. A survey tool was developed and administered to a cohort of 80 engineering students studying Engineering Project Management. The response rate was 75% (61 students). The survey itself was divided into three main themes, each one relating to the key concepts of the RVS approach to engineering education: Relationships, Variety & Synergy. Each of the concepts aligns with one of the three areas upon which the P^3 study was focused: Practice (Relationships): Pedagogy (Variety): Procedure (Synergy).

This paper uses descriptive statistics only at this stage in an attempt to gain some insight into students' background and experiences. The reasons for this is reflective both of the small sample size, and of the fact that the study aims to directly impact practice. The next stage of the work will be to conduct in-depth interviews with students studying engineering management.

- **P^3 Project Sample**

The sampling field comprised a cohort of 80 students studying either an MSc in Engineering Management or an MSc / MEng in a range of different engineering subjects, including Chemical Engineering, Design Engineering, Mechanical Engineering and Computing Science amongst others. The respondents were divided into two main groups as shown below in Figure 1. Just under two-thirds of the cohort were enrolled on a technical MSc / MEng Programme, with the rest, all graduate engineers, studying for an MSc in an Engineering Management related discipline.

Figure 1: Programme of Study: Percentage of Sample (*N = 61)*



In looking closely at the demographic makeup of the respondents it was noted that just under a quarter of the sample were female; this is typical of the School of Engineering in which the study was conducted

Figure 2: Demographic Breakdown of Sample: Gender

Gender	*N*	%
Male	47	77
Female	14	23
Total	61	100

In considering the issues around engineers in management, one of the key variables which emerged out of the literature related to individual work experiences, particularly when considering graduate engineers. Figure 3 shows that the majority of the sample had undertaken a period of paid internship as part of their undergraduate training. This figure, which for the UK is quite high, is indicative of the School of Engineering & Applied Science in which the study occurred, whereby all undergraduates are strongly encouraged to participate in a year-long formal work experience. This is usually paid and is, where possible, at graduate level.

Figure 3: Sample work experience

Work Experience	%
Undergraduate internship	54
Part-time work whilst studying	9
Engineering management role	8
Engineer	5
Consultant Engineer	2
Other	7
None	15
Total	**100**

4) THE STUDY FINDINGS

This section focuses on the study findings. It is divided into three sections, each one looking at a different area explored in the P^3 Study.

- **Exploring relational issues in engineering management education**

The first part of the study focused upon the importance of developing a practice-based approach to teaching that encourages positive work-study relationships amongst the cohorts. The importance of relationships in education is discussed elsewhere [3] and is viewed as particularly important for engineers who, upon graduating, may soon find themselves responsible for managing teams of people from a wide-range of backgrounds and disciplines with different levels of knowledge and understanding.
The Project Management module was carefully constructed so as to encapsulate the main theoretical and practical issues around Project Management. Human relations is key to this, and thus the assessment requires high levels of cross-cohort collaboration and communication. The student-focused approach adopted by the module lecturer represents an important part of learning as the students are encouraged to view the lecturer's interactions with them as a role model in terms of how to manage disparate groups and situations. In total, seven relational-practice focused question-statements were asked. Whilst a five point Likert scale was used in all of the questions, the

differentiation between the levels of agreement and disagreement was not valid; hence the 'agree and strongly agree' data (denoted as A) and 'disagree and strongly disagree' data (denoted as DA) are merged together. This provides a clearer picture of the students' perspectives. The numbers of those students who either agreed or disagreed with the statements is given below.

Figure 4: Relational (Practice focused) Questions

In thinking about the Project Management module the following applies…	**A**	**DA**
The group work in this module has enabled me to build some close friendships	**47**	**11**
The group work has provided the opportunity for me to develop my communication skills	**53**	**4**
The fieldtrip has provided the opportunity for me to get to know my classmates better	**48**	**10**
I have found the module lecturer approachable throughout	**54**	**2**
I found it difficult to work in a group	**20**	**39**
The opportunity to gain feedback in stages has helped me develop my understanding of PM	**49**	**6**
The class visit by a Project Manager helped me appreciate the real world PM context	**55**	**1**

- **The Importance of Variety in Pedagogy**

Having examined the issues around relationships in teaching and learning practice, the survey then turned to the question of variety in pedagogy. In seeking to expose students' to a range of different scenarios and situations the module leader aimed to provide an interesting and relevant learning experience. One of the key aspects of the Project Management module is the manner in which management of engineering projects has changed over time. This is contextualised by a fieldtrip to a heritage site in which students are encouraged to look at the different socio-economic, engineering and political issues associated with project management from the end of the 18th Century through to modern-day practice. The location used for the field trip is part of a UNESCO World Heritage Site. The site is Cromford Mill and it is considered to be the first factory established anywhere in the world [13]. The questions asked in this section therefore focused both on classroom activities but also included a look at students' perceptions of the value of the fieldtrip. Figure 5 presents the 7 question statements asked and the data is again disaggregated into 'Agree' (A) and 'Disagree' (DA).

Figure 5: Variety in Pedagogy Questions

In thinking about the Project Management module the following applies…	**A**	**DA**
The different learning and teaching approaches used in the module made the lectures more interesting	**57**	**0**
The different learning and teaching approaches used in the module made the content more understandable	**56**	**1**
The use of case-studies has helped me appreciate the range of practical project management issues	**55**	**2**
The class discussions have been valuable in helping me understand the main issues	**50**	**6**
The lectures provided the foundational knowledge necessary to study the subject independently	**57**	**4**
The visit to Cromford Mill was interesting in helping me understand the concept of industrial heritage.	**50**	**6**
The presentation at Cromford Mill was useful in helping me comprehend some of the practical issues associated with PM	**60**	**1**

- **The importance of Synergy in Pedagogic Practice**

The final area explored by the survey related to the manner in which the module leader had purposefully and synergistically aligned all aspects of learning and teaching. Figure 6 provides an overview of the disaggregated data relating to the 10 questions posed.

Figure 6: Synergy in Pedagogic Practice Questions

In thinking about the Project Management module the following applies…	A	DA
The module content is relevant to modern day engineering	60	1
The module content is applicable to the coursework	60	1
The group work in the module is good preparation for work	57	4
The real life case-studies helped me understand the theory	53	8
The visit to Cromford Mill helped me gain a wider perspective on PM	46	9
The visit to Cromford Mill has given me an insight into the importance of heritage within contemporary society	51	7
The visit to Cromford Mill brought PM to life	51	10
The module learning outcomes have been achieved	60	1
The assessment is appropriate for developing my PM skills	58	3
The module content is relevant for a career in industry	59	2

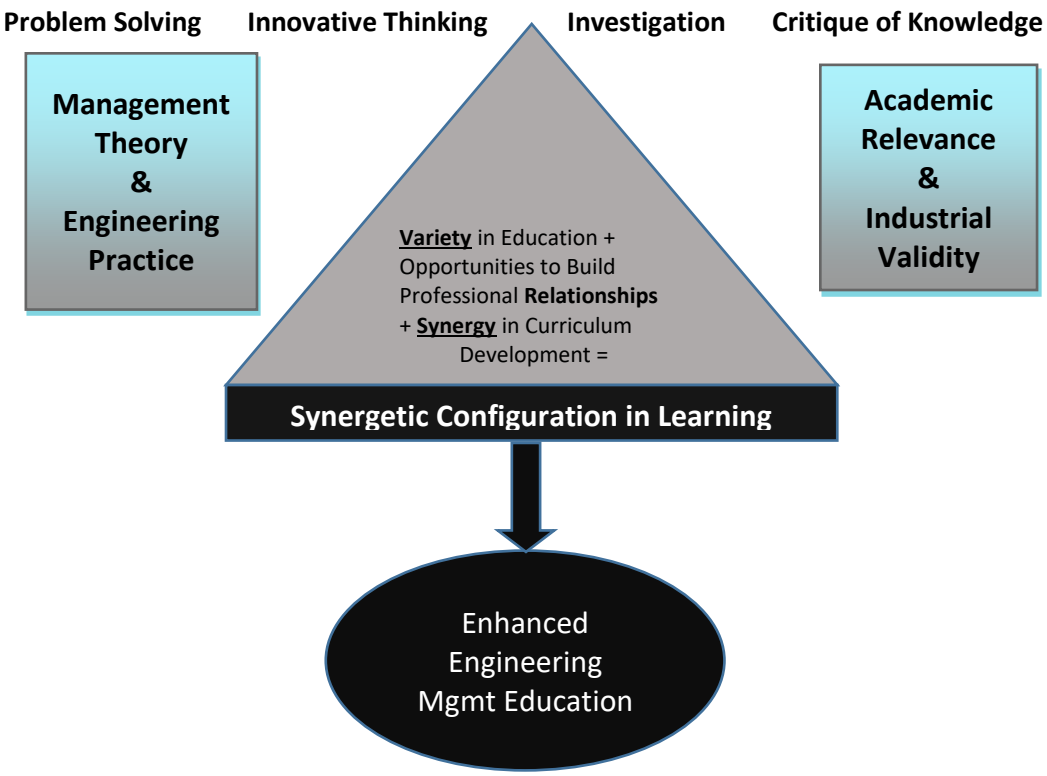
5) DISCUSSION

Based upon the emergent research findings, a conceptual framework was developed. Depicted overleaf in Figure 7, the framework highlights the centrality of the main three concepts of the RVS formula [3]. In further developing this approach, the paper authors drew upon a meta-analysis of the findings of *a priori* educational research studies they were directly responsible for leading; the largest one of which examined the experiences of around 1,000 undergraduate students and found that the most important driver of student success is a ‘sense of belonging’ [14,15].

An important facet of belonging, learning and professional *Relationships* represent a key part of student success. Whilst some colleagues appear to believe that students’ professional relationships have little or nothing to do with engineering education, the fact is that following graduation, personal and professional networks are often key to success in engineering and management roles. Thus, in educating engineering managers, there is a clear need to identify mechanisms by which ‘networking’ and ‘communicating’ may be taught and assessed.

The second component of the RVS formula, *Variety* applies directly to innovative engineering education **and** practice. In engineering management education, the concept of *variety* requires educators to take account of students’ individual learning preferences and styles, whilst factoring in their differing demographic, professional and educational backgrounds [16,17,18]. Additionally, it is also important that educators consider the future different disciplinary settings that the students, once they are employed as engineering managers, will be working in.

Figure 7: Emergent Conceptual Framework: Synergetic Configuration in Engineering Management Education



The final component of the RVS formula, *Synergy* needs to be applied at all levels of learning. In an engineering management module this means purposefully constructing learning experiences that synthesize and synergize engineering contexts and problems with real-life management tools and approaches. In applying a formulaic approach, the application of the RVS approach results in Synergetic Configuration and leads to enhanced student experiences, retention and success. The link between the quality of learning and teaching and student success is reflected in the literature [19,20], with much of the contemporary academic debate built upon the concept of Scholarship proposed by Boyer [11,21]. In educating engineering managers the application of the RVS approach to pedagogic practice means that each distinctive strand of scholarship is considered to be central to student success.

6) CONCLUSIONS

As engineering teachers, we are confronted with the challenge of engaging a diverse student body in a discipline that is multi-faceted with the aim of preparing them for future employment. Often, when speaking to alumni, the role they fulfil after graduation is more reliant on the life skills they have developed during their university education rather than the technical content of the programmes they have been studying. This is reflected in the literature and often discussed as skills development [22].

Courses such as the one described here, expose students to authentic settings with real problems and issues that need addressing. Whilst engaging with the learning context as an interested and knowledgeable observer, students quickly begin to appreciate the multiplicity of opportunities a career in engineering can offer.

In conclusion, too often, the need for accreditation, study of discipline content and traditional pedagogy frame the learning environment. Certainly innovation in learning and teaching through active approaches and industry engagement are welcome, but perhaps now is the time to move the debate forward and start to consider our students as taking an 'engineering role' rather than being an 'engineer' on graduation [23]. Clearly more work needs to be done in analysing this data and exploring the subject further, but now is certainly the time to challenge the status quo.

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