

Project Management Methodology Requirements for use in Undergraduate Engineering Research Projects

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Abstract - This paper aims to determine the requirements placed on a project management methodology (PMM) designed to assist undergraduate engineering students to manage their research projects. The study makes extensive use of the available literature and draw upon preliminary data from surveys and structured interviews with undergraduate engineers as well as interviews with academic supervisors and module conveners for engineering research project courses. This working paper presents the research methodology and the results to date on the development of the methodology that aims to stimulate external feedback on the existing results and the methodology under development.

Keywords – engineering research management, project management methodology, undergraduate engineering projects

I. INTRODUCTION

Across all industrial sectors, project management has become an essential element in the successful delivery of engineering projects. Regardless of the industrial sector or project size, project management methods can be applied to improve the probability of meeting the project goals [1]. In the majority of undergraduate engineering courses, project based research is an integral component of their degree and often a requirement for professional accreditation [2,3]. Undergraduate engineers commonly approach the engineering aspects of project work with enthusiasm, but often only pay lip service to the project management requirements. The most obvious example of which is the use of Gantt charts. Rather than being developed as a useful tool to help achieve the project objectives they are constructed because they are required but are rarely used in practice [4]. The reasons behind this are complex; (and part of this study) but have been attributed to factors such as: high time table pressures, lack of reward for the appropriate use of project tools, lack of understanding and the feeling that it is additional work without offering significant benefits [5]. However, utilizing PMM are widely cited to enhance the probability of completing projects on time, within budget and to deliver the product to the satisfaction of all involved [1,6,7,8,9]. It should however, be noted that these conclusions are typically based on larger, more complex projects in a commercial environment, therefore further investigation is required before drawing direct parallels with undergraduate research projects [4].

The advantages of using a PMM have been expressed by a number of authors [1,9,10,11]. The following is a compilation of the various advantages:

- Clarifies project goals and objectives
- Work processes are more efficient and effective
- Greater flexibility and adaption of lesson learned from project to project
- Increased accuracy in planning, identifying and managing risk/challenges/complexity
- Assures a greater degree of standardisation
- Clear roles and responsibilities are identified, thus communication is enhanced
- Optimises deliverables and outputs
- Integration of tools, techniques and knowledge to improve present and future projects

The long term focus of this study is to develop a PMM customized to facilitate the successful delivery of undergraduate engineering research projects. This paper presents the research methodology and results to date. The main objectives of this paper are: (1) define what constitutes a PMM, (2) to understand the undergraduate engineering research environment, (3) to identify the requirements of a suitable PMM.

II. METHODOLOGY

Three methodologies were employed in this initial study: (1) review of existing academic and industrial literature, (2) student's survey and interviews were carried out prior to the completion of their formal project management training and their major engineering research projects, (3) interviews with academic project supervisors and engineering project module conveners.

All students surveyed and interviewed in this initial study, were from the University of Nottingham's Engineering faculty. A total of 66 year 3 undergraduate engineers were surveyed. As this was a preliminary study, thus the sample size may only represent a group of the entire population. The questionnaire (delivered on 21st January 2008) was designed to measure their level of fundamental knowledge and what they required from a project management methodology. Two types of interview (structured interviews and focus group) were carried out over a period of two weeks (3rd to 15th March 2008). The interviews were carried out at a scheduled time, recorded and transcribed (with the permission of the participants). The focus groups were conducted with

undergraduate engineers in order to clarify the results of the surveys and the requirements of a given PMM from the student's perspective. The following questions were posed to academic staff (n=2) and module conveners (n=3) to further understand the needs of undergraduate engineering students; (1) what are the problems faced by engineering students in managing their research projects (2) suggestions to elevate problems, (3) current practice, processes and the templates required as part of engineering undergraduate projects and (4) the effectiveness of implementing a PMM. In addition, the interviews with academic staff were used to understand the flow of work during an undergraduate engineering research project.

III. RESULTS

This part of the paper outlines the results obtained. The discussion is structured based on the objectives of the present study.

A. What constitutes a project management methodology?

Review of Academic literature

A PMM can be defined as: "an application of knowledge, skills, tools and techniques to meet or exceed the project requirements" [12], in other words, by using the correct methodology, a project manager can identify and minimize risks, costs and meet the project schedules. No PMM can be universally applied to manage all projects across the various sectors [1,13]. Therefore a range of methodologies exist although many are not fully developed and none fully meet the specific needs of undergraduate engineering research projects.

In addition, a number of studies revealed that PMM are often under used, wrongly used, are unusable or simply over-sold [1,14]. It follows that these issues would be amplified if a methodology designed for a different environment was directly applied to undergraduate engineering research projects. It is widely agreed that the use of a suitable PMM increases the likelihood of project success [1,7,9]. However, this condition only applies if the project manager understands the nature of the project and is able to 'reshape and scale' the methodology the project.

There is no universal agreement as to what constitutes a complete PMM. It is definitely not merely a series of templates, forms and checklists [15], although it will typically contain these. PMM also identify specific approaches to managing each aspect of the project in the form of general and sector specific procedures, rules and regulations which sets the standards to ensure quality and control [6,9]. PMM also provides a means of identifying the risks and opportunities associated with the product. In a broader sense a methodology include a wide range of knowledge areas, and a set of tools and techniques for supporting and managing projects [7,9].

Effective methodologies are those that can be tailored to the specific environment and that can be adapted to the dynamic nature of projects and stakeholder demands. Thus, an effective methodology must be flexible, yet it should provide a guideline which leverages on both best practice and past experience to ensure the project goals are achieved. In addition, the methodology must be scalable to cope with various project sizes. In fact, it should help the project team to clearly understand the scope of their work, what to accomplish, and how to accomplish it using the tools and techniques available within the methodology [1]. It is impractical to develop a new methodology for each new project within an organisation. However, in the adoption and use of a methodology; it should be easily customizable to any project within a given environment [1,13,16]. Thus, the key is to develop a methodology specifically for the specific organization and type of project but which is also dynamic, flexible and adaptive facilitating easy tailoring to a given project.

Review of Existing Methodologies

PMM have been classified into two categories [1,9,15,17]; project management methodologies (that provide a high-level framework of the project) and application development methodologies (which provide details on project design and development). The most apparent difference between these two classes is that application development methodologies have a strong focus on system testing, which is not covered in project management methodologies. The confusion within the published literatures and by project practitioners as to what constitutes a methodology is understandable as opinions vary widely. As a consequence the authors of this paper have classified PMM into three different groups, the degree of specificity increasing from the first to the last:

- best practices and standards
- sector specific methodologies
- organization specific methodologies

Those in the first group are frequently called methodologies; however, they are better described as "best practices" as they lack the organizational specific nature that constitutes one of the fundamental characteristics of a true methodology identified above. These best practices are extremely valuable sources of information for the development of a new methodology, particularly as they commonly comprise the syllabus of many project management training courses. The primary materials in this group include: the project management institutes (PMI) body of knowledge (PMBOK), the Association of Project Managers Body of Knowledge (APMBOK) and Project in Controlled Environment Version 2 (PRINCE2). PRINCE2 provides a more process oriented approach than PMBOK, identifying the

necessary techniques; however, it still cannot be directly applied. A number of prominent authors support the view that these are not methodologies; rather they are considered to be encyclopaedias of best practices [17,18].

The next group is the sector specific methodologies. Among the various industrial sectors, the construction sector makes the most frequent reference to PMM [19, 20,21,22]. However, PMM in the information technology sector are rapidly gaining popularity [21]. Common software development based methodologies (e.g. Agile, SCRUM, RAD) are heavily used in the market [1,9,17].

The last group of methodologies, organization specific methodologies, includes in-house customized methodologies designed specifically to meet the organizational strategy and structure. Many organizations redesign PMM for the specific needs of the organization. For example, Microsoft has successfully designed, deployed and operated their well-integrated methodology known as Microsoft Solution Framework (MSF). The MSF consists of multiple components; foundational principles, models or disciplines, key concepts, proven practices, and recommendations. Each of these components can be used individually or collectively to suit any size and complexities of project in a flexible and scalable manner [23].

IBM similarly has its own effective PMM for the implementation and delivery of projects called the Rational Unified Process (RUP). The RUP is an iterative and adaptable process framework that was created based on Boehm spiral model. It is based on six key principles for business-driven development; adapt the process, balance stakeholders' priorities, collaborate across teams, demonstrate value iteratively, elevate the level of abstraction, and focus continuously on quality (ABCDEF) [24].

Based on the authors' findings, organization specific methodologies are being adopted in academic institutions. For example, the University of Cornell's project management methodology (CPMM) [25], adopted from Princeton University, and the University of Tasmania's methodology [10] adapted from the Tasmanian Government Project Management Guidelines. While in other universities, PMM are adopted for administrative, information and technology services, for example the University of Sydney [26], University of Michigan [27] and University of South Carolina [28].

B. Project Management in an Undergraduate Engineering Research Environment

Despite the relative simplicity of undergraduate engineering research projects they still often contain many elements of commercial projects, for example they have stakeholders, specific deliverables, interact with external and internal suppliers, have to operate within, and interact with organizational systems. In addition, students encounter many challenging issues during the project. Given the increasing exposure to project based learning in many leading institutions [4,19,29] undergraduate

engineering students are increasingly asked to lead, manage, plan and execute projects. However, according to Mengel [5] and the authors own observations, undergraduates typically lack life and work experiences. Consequently, they need to be exposed to the processes, structures, tools and techniques of project management if they are to contribute to or lead projects effectively.

In the University of Nottingham 3rd year engineering programmes, students are required to carry out both group and individual projects. These projects enable students to put into practice the academic and practical skills they have learned in other modules as well as to develop softer skills and gain exposure to project management. Engineering courses typically require students to plan, execute and report on their progress both to their immediate supervisor and often to a wider audience. Relatively, few engineering programmes include a single compulsory course dedicated to project management [30, 31] however, most receive some project management training as part of other modules.

Based on the structured interviews, the major concerns of engineering undergraduates' was lack of skills and experiences needed to carry out their research projects. Participants also agreed undergraduates' lack project management knowledge which minimizes their opportunity to make the most of the tools and techniques. The results indicated that 64% of respondents make limited use of the tools and techniques. A significant number of respondents were not aware of tools such as Gantt chart (47%), network diagram (71%) and project management software tools (80%). Academic staff and module course conveners agreed that the majority (95%) of students do submit their schedule plan, but do not use them to track the progress of their projects. In addition both the academic staff and students agreed that any PMM should minimize complexity and administration to improve the probability of it being accepted [1].

One of the objectives of this paper is to develop a roadmap for the work flow of a generic undergraduate engineering project. The roadmap was developed from the surveys, interviews, focus groups and from reviewing the engineering project guidance notes from a number of public and private universities [e.g.32-35]. Fig.1. presents a generalized perspective of the processes that students undergo during the lifecycle of a typical undergraduate engineering research project. The process starts with the selection and approval of the project. Students then develop either a formal or informal project proposal in conjunction with their individual supervisors; the proposal should at least detail the following to ensure clarity and that expectations are aligned:

- introduction and background of the research
- research aims and objectives
- deliverables and outcome of the research
- proposed / breakdown of research activities
- high level schedule
- resource plan

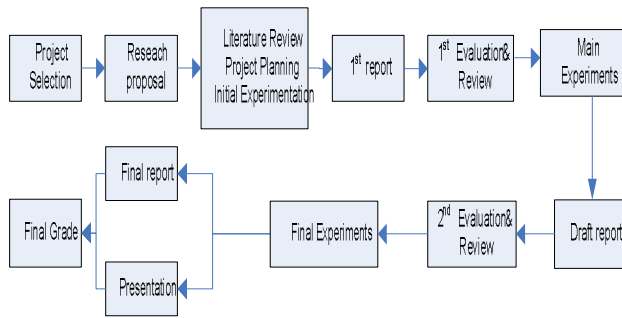


Fig. 1. Generic roadmap for engineering undergraduate research projects

The students then proceed with their literature review, project planning, and begin their experimentation. The project progress is assessed at a number of key points during the year and through regular meetings with their project supervisors. The project is closed by the submission of the final report and the presentation. As with all technical disciplines, students are required to maintain a scientific log book of their progress. It follows that any PMM for engineering undergraduates should utilise the logbook and the inherent systems surrounding it for reporting on the project progress.

C. Requirements of a Project Management Research Methodology

This section aims to define the requirements of a project management methodology for use in managing undergraduate engineering research projects. The results from the literature review, survey and interviews have been grouped into four categories below.

Knowledge Level

The survey results indicated that at the start of the project students lacked the knowledge and experience to effectively conduct research projects, these knowledge gaps include:

- A lack of project management skills
- Initially students do not understand the full scope of the project
- A lack of research experience to appreciate the challenges they will face during the project

Similar issue were noted from the focus group interviews. Participants highlighted problems in relation to ‘unrealistic’ project scope based on their work load and current knowledge level. However, according to Barron [29], the creation of a near-realistic project environment is necessary for student’s development.

Interestingly, the results obtained from questionnaires clearly indicate that students, at least at an intuitive level, understand some of the basic project management concepts even before their formal project management

training. An example of this knowledge can be seen by reviewing the answer following to the following statements:

- “a project is a task with objectives to be accomplished”, 25 respondents strongly agreed.
- “stakeholder interest is a key success factor in project management”, 33 neutral and 33 agreed
- “scope, time, and budget are the main constraints in project”, 32 agree, 25 strongly agreed
- “effective communication is essential in project management”, 29 agree, 30 strongly agreed.

Application of tools and techniques

The literature reviewed indicated that all PMM contain tools and techniques to help manage all aspects of the project. The survey results clarified by the focus groups indicated the majority of student’s lack of awareness of project management tools and techniques as reflected by the neutral responses:

- “Gantt charts are useful in group projects”, 38 neutral, 16 agreed and 5 strongly agreed
- “Critical path analysis is a useful analysis technique”, 51 neutral, 8 agreed and 3 strongly agreed
- “project charter is a document that formalizes the start of a project”, 48 neutral, and 13 agreed
- “stakeholder analysis is very important at the initial phase of a project”, 38 neutral, 23 agreed and 1 strongly agreed
- “work breakdown structure is an important project management tool”, 28 neutral, 26 agreed and 8 strongly agreed.

Interviews with academic staff and module course conveners were used to clarify these issues. At this stage of the student’s course the only tool that they are required to use in project work is a Gantt chart. In addition, most of the tools are not considered necessary to reflect the learning outcomes of their engineering research projects.

Reflections on project management learning

Three open-ended questions on the need to learn project management, the benefits and their own opinion of project management were listed. The following responses were compiled and summarized in Table 1. The majority of responses were positive on the benefits of using project management methods as well as appreciating the advantages they offered. Previous results suggested a knowledge gap, thus it would seem appropriate to include an element of training in any given methodology.

TABLE I
STUDENTS' REFLECTIONS ON LEARNING PROJECT
MANAGEMENT

Questions	Reflections
1. Why do you want to learn project management?	- To apply skills into coursework - For effective organization of task and work load - Enable creation of network through communication - Carry out task in an organized manner - To be apply project methodologies
2. How will it benefit you?	- Provide knowledge in future career - Able to apply project methodology in different situation - To lead and manage team - Improve communication skills - Achieve successful project execution
3. How would you describe/define project management?	- Able to achieve all objectives and goals in the given constraints - A method, tools, skills to manage projects - Accomplishment of project objectives through a step by step stage

V. DISCUSSION

The methodologies reviewed have some commonality in terms of processes, procedures, tools and deliverables. In this section, the requirements of a PMM for use in undergraduate engineering research projects will be developed. The requirements placed on a PMM are not clearly defined in the literature; however, the following list has been compiled from the available literature, results from the surveys, interviews and focus groups:

- Principles, processes, guidelines and practices of project management [23,24]
- Organisation, governmental and sector specific Standards and regulations [1,6,9,15,17]
- Technology elements required [23,24]
- Tools and Techniques [1,18,36]
- Must be specific to the organisation but customisable to individual projects [1,13,16,23]
- Scalable and allow adaption to project size [1,23]
- Facilitates the identification and management of risks and opportunity
- Model of work flow of typical project[1,15,17,36]
- Facilitate the early clarification of the goals and scope of the project
- Systems must be in place to promote organizational learning [23]

VI. CONCLUSION

This study aimed to assess the capability of engineering undergraduates to manage their research project. The investigation highlighted a number of issues. From the data obtained there are several factors which limit success, these include; heavy coursework, poor time management, lack of knowledge and skills to gauge

research scope and the selection and application of project management tools and techniques. The above discussion on results and literatures will provide a stronger evidence on the yet to be implemented project methodology. In general, through data collected, there are significant positive reactions from both project supervisors and undergraduates on the methodology.

The next phase of study will include creation of the project methodology framework, documentation and an initial prototype of the system for use in managing undergraduate research project.

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