Working Toward the Successful Deployment of Post-graduate Research Students on University-Industry Collaborative R&D Projects

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1. Introduction

Against a background of increasing international competition and rapid technological change, governments are actively encouraging collaboration as a means of improving innovation efficiency and thereby enhancing wealth creation [1, 2]. Collaboration provides companies with the means by which to advance technologically, at lower cost and with less inherent risk [3, 4]. Collaboration also provides access to a greater breadth and depth of knowledge and technologies than would normally be possible through internal development. For universities the benefits of university-industry collaboration include additional public and private funding, opportunities to up-date teaching and case study material and a valuable source of industrially relevant as well as academically challenging research projects for research students [5-7].

However, these considerable potential benefits are often not realised in practice [3]. The major reason is that collaborations between, often diverse, organisations, need considerable management effort in order to be successful. Given the substantial investment (both public and private) currently being made in collaborative research activities, it is clearly important to ensure that collaborations are managed effectively, in order to maximise the benefit achieved from such activities. A particular source of problems are the cultural differences that exist between academia and industry and the correspondingly different outlooks of these two parties continue to present major challenges to those involved in such collaborations and to the ultimate success of collaborative R&D projects [7-9]. This paper will, in particular, concentrate on the effects that such cultural differences can have on the endeavours of post-graduate students working toward a research degree on university-industry collaborative R&D projects.

This work examines the evidence from case studies of collaborative R&D projects undertaken by Warwick Manufacturing Group (WMG), University of Warwick, England and its industrial partners, and presents guidelines for the management of post-graduate research in such situations. Warwick Manufacturing Group (WMG), University of Warwick has, since it's foundation in 1980, established a substantial involvement in collaborative research with industry. It was therefore considered that the Group provided an excellent opportunity for a study of management practice within collaborative projects involving academic and industrial partners.

2. The Influence of the "Cultural Gap" in University-Industry Collaboration

A major difficulty with regard to the successful and effective management of university-industry collaboration, is the influence of the perceived "cultural gap" between academia and industry and the detrimental effects that can result [7-15]:

- The academic culture of publishing research results in the open literature, versus a typical desire by industry to maintain data as proprietary in order to establish competitive advantage.
- A considerable difference in priorities is evident in that industry is often focused on near-term, applied research, leading rapidly to a new product in the market, compared to academic aspirations to longer term, more fundamental research, with the eventual realisation of an application. An inevitable time-frame conflict therefore also arises.
- A perception of university researchers by industry as having a *laissez-faire* approach to project managing research.
- Concern among academic researchers that collaborative research with industry will lack the flexibility to pursue unanticipated, but interesting and potentially valuable research directions.
- Conflict regarding the ownership of IPR arising from a partnership.

University-industry collaborations generally involve a range of different personnel in the day-to-day research activities, including a number of post-graduate and under-graduate students. This is to be expected given that one of academia's key aspirations regarding collaborative ventures is the provision of industrially relevant, "real world" research projects for students and the exposure of students to industry in preparation for their future careers. A recent report by the Business-Higher Education Forum (BHEF) [16] in the US has stated that, for this reason, *"graduate students can enhance or impede a collaboration, but they are almost always used"*. However, given that there is considerable evidence in the literature of significant problems arising from fundamental differences between academia and industry, it seems likely that such problems will ultimately affect students working on these joint research projects. The literature provides some examples that make specific reference to the role and experiences of students directly involved in university-industry collaborations.

2.1 The Effect of Cultural Differences on Research Students

Starbuck [17] offers some indications of the practical benefits that students can gain through exposure to this hybrid university-industry environment. For example, it is suggested that students should be involved in project meetings, both in the discussion of ideas and in helping to track progress made against action items and against the project's overall schedule. Students can also, toward the end of their projects, function as experts in the wider dissemination of information within the company, thus further smoothing the transition from student to potential corporate employee [16, 17]. But while this provides an important learning experience for the student, Starbuck [17] also warns that these "company activities" should not become "an onerous burden", thereby implying that such broadening activities should not detract unduly from the student's academic work. Though clearly not definitive evidence, BHEF [16] have found that it is not unusual for a student involved in industry sponsored research to take 6 months longer to complete a doctorate than would be the case in a purely academic effort.

While the work of Starbuck [17] provides sound guidance that can be used to enable students to gain significantly from collaborative experience, other writers warn of issues relating directly to the influence of industry, that can have an adverse affect on students. Randazzese [18] for example, raised concerns regarding industry's attitude toward collaborative research with universities. A survey of faculty members and affiliates of a collaborative research centre revealed that industry required applied research that was essentially short term and geared toward specific applications. The interpretation placed on these findings was that industry wanted research that could be transferred without the need to deploy considerable internal resource. As evidence in support of this conclusion, it was stated that this preference by industry had often lead to an inappropriate level of implementation work being carried out by students, thus jeopardising their education. Randazzese [18] also indicated that in such situations companies were left in a quandary when students graduated and began working for competitors.

Evidence of real benefits, though apparently rare, indicate that collaboration is worthy of the effort required to make it work. Balakrishnan [14] for example, reported on a particularly successful project where it is stated, the collaboration yielded under-graduate, masters and doctoral theses in engineering, management and operations research, whilst also exposing and enabling students to contribute to actual industry practice. The company involved gained in return, a number of tangible benefits including PC-based tools and predictive models, and a general awareness of relevant long-term issues in an environment dominated by short-term pressures. Other benefits of this project included the sponsorship of several six-month in-house internships and the decision to employ one particularly promising graduate.

The project, though successful, was not however without its problems. Students and academic staff found that the company was unwilling to contribute to the research as much as had been anticipated, and there were issues relating to conflicting goals among the "stakeholders", i.e., company representatives, academics staff and students. Further problem areas included differences in timescale expectations and a tendency for the company to change the priorities and direction of the project over its life, in an attempt to keep pace with changes in the market. Balakrishnan [14] observed that the differing goals and perspectives of practitioners and researchers can create tensions that impede project progress, to the detriment of the students concerned. Therefore, careful management of expectations on both sides is required.

While evidence relating directly to students involved in university-industry collaborations is sparse, the nature of the problems reported with this type of activity indicates that students are likely to be subject to some adverse effects. The potential impact that such problems could have on the education of students, particularly given that student research and recruitment opportunities are among the much vaunted benefits of collaboration, suggested that further study in this area was warranted. The case study research reported below considers university-industry collaborative projects primarily from the perspective of the post-graduate students engaged in them. By approaching collaboration from this little recognised perspective, this exploratory research has lead to the development of some preliminary guidelines designed to aid in the successful deployment of students on future collaborations.

3. Research Approach

This essentially exploratory line of research is a consequence of previous research work by the authors, aimed at developing an understanding of the key factors enabling effective management of university-industry collaborations. This previous research theme resulted in the development of a framework for the effective management of university-industry collaborations, providing a practitioners guide to enhancing the success of joint research activities. The work reported here subsequently developed from the discovery that, of the parties involved in joint research activities, post-graduate students in particular, can find their role within a university-industry collaboration especially problematic. Post-graduate researchers have a key role to play in research collaborations involving industry, but preliminary findings suggested that the contribution of student researchers was also an area which required particularly careful management.

This research brings together the results of a review of the published literature in the field of university-industry collaboration management and empirical evidence provided by five in-depth case studies. The majority of the joint research projects in which WMG are engaged at any one time involve the automotive and aerospace industries, and it was therefore logical to select cases within WMG's research portfolio with representation from those industries. Of the five cases, four were components of a larger research programme involving the automotive industry. These projects were therefore selected because they formed a natural multiple case study; the projects had a number of common characteristics, i.e., similar set-up (1 university plus several companies), similar collaboration agreement terms, and the projects shared a common timescale. These common characteristics provided natural boundaries for the study, limiting the extent of environmental variation. The fifth case study project, from the aerospace industry, also shared some of the important characteristics of the other four cases.

The collection of data for this research was carried out primarily through structured interviews with post-graduate students involved in the projects and other key participants (both industrial and academic), with supplementary evidence provided through project documentation, i.e., minutes of meetings and progress reports, and direct observation of project meetings. This research was conducted at a time when all five case study projects were well advanced – approximately 2 years into their 3 year duration. Since the projects were still active, the perceptions of those involved would be current, thus lessening the opportunity for important detail to be forgotten or for a loss of accuracy to occur in a person's memory of events.

The data collected was then analysed to identify factors and common themes across the five cases relevant to the aim of this research – gaining an insight into the personal experiences of the students and those working closely with them. Throughout this analysis, the findings were compared with evidence from the published literature in order to establish the relevance of this study beyond these specific cases.

4. Discussion

4.1 The Influence of Prior Industrial Experience

In total eight post-graduate students had been assigned to the five case study projects examined. All eight students were registered for a doctoral degree. A key variable in the backgrounds of the students involved was the degree of work experience each had acquired prior to registering for their post-graduate degrees. The amount of prior industrial work experience ranged from none at all to 14 years. There was also a significant variation in the ages of the students; a gap of approximately 12 years between the youngest and oldest student.

Among the students studied a range of issues were identified which the students considered had been detrimental to the progress of their research, and had had a negative effect on their overall experience of collaboration with industry. Analysis of these problems (which are discussed more fully in Section 4.3) did not reveal a correlation between the nature and number of problems encountered by each student and individual levels of prior industrial experience. However, it was found that students with little or no prior industrial experience generally expressed a higher level of dissatisfaction and frustration than their more experienced counterparts.

On the basis of this evidence alone, it is difficult to draw any definitive conclusions regarding the influence of industrial experience on a student's personal experience of working collaboratively with industry. However, it would appear logical that students with prior industrial experience would be better able to relate to the perspectives and objectives of their industrial sponsors. This would thus facilitate communication and understanding, leading these students to, the perception at least, that they had more control over their research than those lacking this prior experience. Thus, it is tentatively suggested that a "cause" and "effect" relationship may exist between the prior industrial experience of the research student, combined with the cultural issues discussed in Section 4.3, and the outcome, i.e., the degree to which the student benefits from or is otherwise impeded in their pursuit of a doctorate in collaboration with industry.

4.2 Motivations & Expectations of Outcomes

It has already been seen from the literature that involvement in a collaborative research project with industry provides valuable opportunities for students. Such opportunities are important motivational factors and are therefore likely to influence a student's performance on a project and their perceptions of it. In order, therefore, to set their individual experiences in context, each student was asked at interview what they personally had hoped to gain from their involvement in the collaborative research project, beyond their overall objective of obtaining a doctorate. Responses to this question are summarised below:

- Opportunity to work on a "real world" problem that will be useful and relevant to industry
- Opportunity to innovate and progress technology in chosen field
- Gain experience of working with industry
- Establish contacts within industry (opportunities for jobs in the future)
- Opportunity to improve interpersonal skills
- Opportunity to benefit from the experience and expertise that industrialists bring to the research project

- Expand personal knowledge and experience
- Develop project management skills

These findings generally conform well with the perceived benefits of university-industry collaboration identified in the literature [6, 7, 9, 19]. Furthermore, the students generally conveyed the view that at least some of their expectations had been met and that the experience had been worthwhile overall. However, there was also evidence of significant issues arising in each of the case study projects as a result of the inevitable cultural differences between academia and industry. As the next section will show, these issues often had a significant impact on the students involved.

4.3 Cultural Issues & their Impacts

The literature has shown that while collaborations in general require particular management effort to ensure their success, university-industry collaborations are often still more problematic as a result of an inevitable difference in culture and perspective [3, 11, 12, 15]. Industry and academia measure the success of collaboration quite differently and inevitably perceptions of progress made, the perceived value of the outcomes and opinions regarding how a project should be planned and managed, differ substantially between the two parties. The deployment of students on such projects is logical given the manner in which success in academia is measured, e.g., number papers published, the generation of new knowledge, number of students successfully achieving research degrees. However, it is also logical to assume, given the opposing perspectives of academia and industry, that such students may experience difficulties as well as benefits as a result of such differences.

The literature offers some tentative evidence in this respect, but such issues are often merely mentioned as an interesting aside, or as a minor aspect of the overall findings of a wider topic of research. This research considered the role of post-graduate students in university-industry collaborations, and their experiences of it, in more depth in order to determine the extent and nature of any difficulties encountered. In interviews with the students involved in the five case study projects, the students were asked to consider the positive and negative aspects of their experience of pursuing their research in collaboration with industry. In particular, they were asked to consider the impact of this collaborative relationship on their research efforts. As a result a number of issues were raised and these are summarised below (Tables 1 & 2).

Table 1 Positive Aspects of Pursuing Post-graduate Research in Collaboration with Industry

Positive Aspects of Collaborative Research
Industrialists have maintained a check on the industrial relevance of the research
Collaboration allowed for industrial relevance whilst maintaining the potential for doctorate level research
Learned considerably from expertise & experience provided by industrial partners
Research results have been published in journals (with consent of industrial partners)
Collaboration provided opportunities for valuable on-site visits and access to information which would not have otherwise been available

Table 2 Negative Aspects of Pursuing Post-graduate Research in Collaboration with Industry

Negative Aspects of Collaborative Research
Dynamic changes in project objectives to meet the ever changing needs of industry resulted in divergence of the doctorate work from that of the collaborative project
Industrialists expect researchers to deliver & do not always appreciate that researchers are often working with unknowns
Industrialists demand too many progress meetings, often not allowing enough time for much actual work to be carried out. Places a substantial burden on the researcher in terms of time spent writing progress reports.
Difficult to focus research adequately because of frequent changes in the project objectives instigated by the industrial partners
Industrial partners place too much emphasis on development rather than research which creates difficulties for post-graduate research – different expectations
Too much emphasis on obtaining quick results and not enough on ensuring that researchers have sufficiently developed the skills required to conduct the work
Companies lose interest & motivation very quickly when the research does not progress in the direction expected. Can become more difficult to obtain their help when this happens
Industrial partners can be extremely critical of publication of results in the public domain. Paper contents were heavily scrutinised leading to a significant delay in publication
Industrial partners were often slow in responding to requests for information or data – production issues take precedence over such requests, but researchers are still required to deliver on schedule
Industrialists have their own agenda & therefore researchers often have to carry out activities which are not directly relevant to their research

These findings were verified through evidence from interviews with academics involved in the case study projects, and through complementary evidence provided by project documents and observations made directly at project meetings. There was a substantial degree of agreement across the range of evidence available. Furthermore, some of the issues raised in the findings have already been identified in a more general context in the literature, i.e., problems experienced concerning publication and the issue of different timescale expectations (Section 2). For example, Balakrishnan [14] provided evidence of difficulties as a result of differing timescale expectations and an unwillingness by industrial sponsors to contribute as much to the collaboration as had been expected by the academics involved. Balakrishnan [14] also cited problems as a result of changes in project priorities and direction as a result of dynamic market pressures. Finally, Starbuck [10] warned against placing an "onerous burden" on research students with respect to their involvement in project management activities.

However, the findings also highlight issues that have not been raised before, issues far more specific to the role of the post-graduate student. For example, the problems raised by industry's urgency for results versus the need to ensure that researchers are properly trained in the skills required to conduct robust research. Similarly, the problems caused by divergence of the research pursued in the interests of the collaboration, from the (often narrow) field chosen for the pursuit of a doctorate, can place a significant strain on the researcher involved.

It should be noted however, that not all of the issues raised will necessarily have a negative impact on the researcher involved. For example, instances where researchers find that it is necessary for them to engage in activities that are not directly related to their doctorate research, can also have positive benefits. Clearly such activities can provide a valuable broadening experience which would enable researchers to appreciate the wider context and

implications of their work. In this way researchers may develop a more rounded perspective which will be valued by future industrial employers. Furthermore, Dawson [20] has shown that engaging in activities of limited relevance to the research, but which would be valued by industrial partners, can significantly increase the commitment, interest and motivation of the industrial partners, thus making them more receptive to the needs of the researchers.

Clearly any analysis of the above findings and subsequent solutions need also to take account of the perspectives of the industrial partners involved. Section 4.4 therefore explores the views of the industrial participants.

4.4 Perceptions & Expectations of Industrial Partners

The views of a number industrial partners across all five case study projects were obtained through interviews and the findings are summarised below (Tables 3 & 4). The views obtained provide some insights into industry's perception of the role of student researchers. Some more general insights were also gained into their views regarding both their own contributions and the university's contribution to the projects concerned.

Table 3 Views of Industrial Partners Regarding the Role of Student Researchers

Role of Research Students
Students are a particular problem because they have their own agenda – obtaining a doctorate
Researchers often lack experience and this can cause problems and delays
Students want to obtain their degrees, we want to obtain useful technology
The outcomes from the project were limited because the student was trying to get his doctorate & was not doing enough work on the project

Table 4 General Insights into the Contribution of Industrial & Academic Partners to the Collaborative Projects

General Insights
University's need to take away an idea & come back with a cost & time estimate for carrying out the work, as with industry
The project produced a lot of publishable work. Some of the work was confidential, but a lot of it should be available for public interest
Industrial partners have more difficulty obtaining information that the university expects & this occasionally causes friction, particularly when researchers are held up

It is evident from the views expressed in Table 3 that some of the industrial partners regarded work toward a doctorate as a distraction which interfered with the aims of the project. Clearly in some of the cases studied there was a failure to appreciate the potential value of work conducted by student researchers. The work of post-graduate students is intended to add value, and the implication that it does not is one which requires careful consideration. It should be noted however, that academics are not used to defending the *business* value of their work. Therefore, it could be argued that a failure by the academics to adequately communicate the benefits of post-graduate level research in terms that their industrial counterparts would appreciate, could be contributing to this problem.

Nevertheless, it was evident throughout the case studies that, despite a stated intention to pursue longer term research through these collaborations, the industrial partners were still very much influenced by short term considerations. A finding supported by Randazzese [18]. Certainly there was a marked tendency to concentrate on the shorter term goals of the

research at the expense of areas requiring more in-depth, and therefore longer term investigation. This offers a viable explanation for their attitude toward the student researchers. It also indicates that where such short-term considerations have a strong influence on a collaboration there are likely to be detrimental effects on any student researchers involved.

Among the more general insights obtained was an acceptance that industrial partners are sometimes unable to provide important information in a timely manner, again because of the influence of issues likely to have a more immediate impact on the company. While this may sometimes be avoidable, it is likely to be a feature of this type of co-operation and should therefore be taken into consideration during project planning. Related to this, the view that universities should provide a cost and time estimate for the work proposed provides an important indicator of a key issue which often causes unnecessary problems in university-industry collaborations. Universities have not traditionally been noted for their attention to project planning, management and progress monitoring. While it is often the case that an industrial partner will assume responsibility for overall project management, the university partner will generally have responsibility for conducting much of the research work, and should therefore contribute to planning and monitoring activities. Where a university partner fails to institute good planning and progress monitoring, industrial partners will tend to draw their own conclusions as to how long key elements of the work are likely to take. Since their expectations are often optimistic, industrial partners are often disappointed by evidence of actual progress and therefore develop a negative perception of the project and their academic counterparts. Certainly there was evidence in these case studies indicating that project planning and progress monitoring was not as rigorously applied as many of the industrial partners would have liked.

The foregoing discussion has consistently revealed a large degree of commonality between the case study findings and the published literature. However, while other writers have clearly highlighted similar problems, none have offered a comprehensive solution to these very important issues which are currently limiting the degree of benefit available to students undertaking this particular route to obtaining their research degrees. Furthermore, since it is evident that this type of collaborative activity is continuing to increase and be positively encouraged by governments, there is an urgent need for a coherent and substantial solution to these issues. The foundations of such a solution are discussed in Section 5.

5. A Potential Solution

While a number of workers have described similar problems with regard to the deployment of post-graduate students, as yet no comprehensive solutions have been put forward. Starbuck [10] offers some robust, but basic guidance, and a thorough review of the literature has revealed no coherent framework that can be employed to ensure, not only the welfare of the students involved, but also the maximising of the value of their contribution to academic and industrial partners alike. The foundations for a potential solution may lie in the work of Roussel, Saad & Erickson [21] on the strategic planning and management of an organisation's R&D activities.

The framework developed by Roussel *et al* [21] considers all R&D activities within an organisation as a portfolio of projects. Each project has a number of characteristics relating to, for example, the type of research being undertaken, time to completion, probability of success and its competitive potential. Using these characteristics Roussel *et al* applied a

mapping technique to position projects relative to each other and thus determine whether the company has a good balance of, for example, technologies which will be commercialisable within 2 years, versus technologies which will only mature in around 6 years time. The value of Roussel's approach is that it takes a holistic view of all these activities and ensures that the company has a short, medium and long term strategy regarding the development of new technologies. Using Roussel's mapping techniques organisations can ensure that developing technologies will continue to feed into new products for the company over a period of the next 10 years. Clearly while this process has been developed with a very different application in mind, a similar approach could be adopted for the management of R&D collaborations involving post-graduate students. Roussel *et al* [21] classified R&D into three types (Table 5).

Table 5 Characteristics of Three Types of R&D (after Roussel *et al* [21])

Type of R&D	Description	Probability of Technical Success	Time to Completion	Competitive Potential
Incremental	The clever exploitation of existing scientific & engineering knowledge in new ways	Very high, typically 40-80%	Short, typically 6-24 months	Modest, but necessary
Radical	Creation of knowledge new to the company & possibly new to the world for a specific business objective	In the early stages modest, typically 20-40%	Mid-term, typically 2-7 years	Large
Fundamental	Creation of knowledge new to the company & new to the world to broaden & deepen the company's understanding of a particular area of science or engineering	In early stages difficult to assess	Long, typically 4-10 years or more	Large

Roussel *et al* [21] used these characteristics and other elements in order to position corporate R&D projects relative to each other in the corporate portfolio. However, while whole projects can be classified in this way, frequently projects will contain elements that range from *incremental* to *fundamental* and it is therefore proposed that collaborative R&D projects could be broken down into areas according to how well they fit the criteria for *incremental*, *radical* or *fundamental* R&D. By taking this approach, a potential solution emerges to the issue of how to deploy post-graduate students more effectively.

5.1 Effective Resource Deployment

A potential solution would involve using this classification process as a means of deploying resource within the collaboration more effectively. While it is common in collaborative projects to assign the majority of the research activities to post-graduate students (doctorate students in the cases examined here), there are many areas of this type of project that are not likely to contribute usefully to their research. Too much involvement in such activities is likely to severely hinder their primary goal of achieving a research degree and yet if they do not deliver on such activities the industrial partners often become frustrated by the lack of progress.

In any collaboration there are likely to be other personnel available, e.g., skilled technical staff and engineers with an, at least peripheral interest, in the research. Furthermore, the industrial partners may also be able to draw upon skilled personnel from within their own organisations to perform, or at least assist, with some areas of the project. This would constitute a truly collaborative situation in which learning and ideas are genuinely shared. Therefore, by dividing a project into components which are essentially *radical* or *fundamental* research (and therefore longer term) and separating them from elements which are more of an *incremental* nature (and therefore shorter term), post-graduate students can be more readily assigned to work which will be better suited to the requirements of their degree. Doctorate students, by definition are required to generate new knowledge and should therefore be assigned areas of the project which hold the greatest potential for *radical* and *fundamental* research, while engineers, experienced technicians and industrial partner personnel can usefully contribute toward research of a more *incremental* and applied nature.

It should be noted that the literature and evidence collected through the case studies reported here, have shown that industrial partners can be reluctant to contribute to any significant extent to the actual research work. It is therefore important at the outset of a new collaboration to establish very clearly the roles and responsibilities that each and every member of that collaboration (industrial and academic) have with regard to the research work and to ensure that the degree of effort and resource required in the completion of each element of the project is made very clear. Aside from that, where there is a risk of delay to activities (particularly those activities requiring input from industrial partners), then this possibility should be built into project plans, and adequate contingency plans should be developed to enable the project to progress in other directions, if necessary.

By directing and managing resources in this way, it should also be possible to schedule some short-term deliverables from the *incremental* areas of the research and thus satisfy industrial partners that some tangible outcomes will occur in a timescale that is acceptable to them. Progress reporting on these shorter term activities would be the responsibility of those conducting this work, thus relieving some of the short-term pressures on doctorate students with more long-term research to pursue. However, it remains important for doctorate students in this position to plan and manage their research to a schedule that is both realistic (given the requirements of doctorate research) and acceptable to all partners. But by careful management of the expectations of the industrial partners regarding the *radical/fundamental* elements of the research and the implied longer timescales involved, it should be possible for doctorate students to report progress less frequently and at intervals when a significant amount of progress (worthy of reporting) has been made.

However, such judicious research planning and management of expectations, does not relieve doctorate students of the responsibility for conveying their results in a manner that will be appreciated by all the key stakeholders to a collaboration. As has already been emphasised, academics have tended to overlook the importance of explaining the *business* value of their research. This is a situation which must change if industry-university collaborations are to succeed. The ability to adapt the presentation of research findings to suit the "audience", i.e., emphasising the academic findings in the presence of academics, whilst equally addressing the business implications for industrial stakeholders, should therefore be considered a necessary part of a research student's training.

5.2 Good Practice in Collaboration Management

The above solution is a tentative suggestion for a way forward, specifically designed with post-graduate students in mind. However, from a broader perspective, good practice in the management of collaborations will serve to enhance the success of such ventures for all involved. A considerable body of work is available in the literature relating to the identification of a wide range of success factors, factors which if present in a collaboration can increase the probability of a collaboration being perceived as a success by its partners. Detailed discussion of these success factors is beyond the scope of this paper and interested readers are referred to Barnes, Pashby & Gibbons [22] for a discussion of the success factors and the development of a comprehensive model of good practice based upon them.

Such issues are of at least equal importance to those discussed above with specific regard to the role of post-graduate student researchers. Consideration of good practice in the setting up and managing of a collaborative venture will significantly enhance the experience of university-industry collaboration for all involved, and thus immediately provide a more favourable environment within which post-graduate students can conduct their research, whilst at the same time benefiting from the broadening experience provided through close contact with industry.

6. Conclusions

Instances of university-industry collaboration continue to grow in developed economies across the world, encouraged by government policy aimed at harnessing the benefits, i.e., increased industrial competitiveness and academic research with greater industrial relevance. However, inevitable differences in culture and perspective between academia and industry has presented a major obstacle to realising the full benefits of collaboration, and there is evidence that post-graduate students can encounter particular difficulties as they work toward attaining research degrees in projects where there is considerable industrial influence.

This work has examined five cases of university-industry R&D collaborations involving post-graduate student researchers, in order to better understand the benefits and the problems of pursuing a research degree in this environment. The findings showed that despite some valuable benefits, there were also significant problems, relating directly to the very different needs and expectations of industrial partners. The problems included:

- Difficulties focusing the research because of frequent changes in the priorities and objectives of the project. These changes in objective were often instigated by the industrial partners as a result of dynamic changes in the market
- Too much emphasis placed on short term deliverables and developmental work rather than on longer term research
- Industrial partners are often slow to deliver their contribution to the research, e.g., provision of essential data, information and equipment. Industrial partners also tend not to contribute as much to the research as originally anticipated by their academic counterparts
- Placing an onerous burden on students with respect to the frequency of progress meetings and progress reporting, to the extent that there was little opportunity to carry out a substantial amount of work between meetings
- A tendency for industrial partners to dismiss doctorate level research as a non-value adding activity and therefore a distraction from the “real objectives” of the project

This research has lead to the proposal of a potential solution designed specifically to aid in the effective deployment of post-graduate research students on collaborative projects with industry. The solution, based on the work of Roussel *et al* [21] begins by classifying the key elements of an R&D project as *incremental*, *radical* or *fundamental* research. This classification can then be used to determine the most effective deployment of project resources – doctorate students would pursue radical and fundamental research over an appropriate timescale, while other personnel such as technicians, engineers and industrial participants would concentrate on the incremental and therefore shorter term elements.

However, while this solution should significantly enhance the effective deployment of post-graduate researchers, it is noted that the application of good practice in collaboration management will enhance the experience of university-industry collaboration for all involved, and therefore of itself, greatly improve the environment in which post-graduate researchers pursue their research. The combined use of the solution suggested here and recommendations for effective collaboration management should enable post-graduate researchers to attain their research degrees whilst still benefiting from the broadening experience of working closely with industry.

7. Suggestions for Further Work

The research reported here, while informative, is still largely exploratory in nature. Further in-depth case studies are recommended to further elaborate on the difficulties experienced as a result of pursuing research in this environment. In particular, the case studies reported here and the evidence presented in the literature offer a mere snap-shot in time. As such, it is not possible to establish which of the issues raised, ultimately presented the most significant difficulty to student researchers over the overall duration of their research. By eliciting their views at one specific point in time, the students are as likely to remember their most recent problem as to remember the problems which had hindered their progress over an extended period. Therefore, a longer term (longitudinal) study, recording the progress of post-graduate students throughout their degree registration is now required to develop an understanding of the issues in greater depth.

In addition, it is recommended that since the cases studies examined here were all based within Warwick Manufacturing Group, University of Warwick, other exploratory case studies need to be carried out within other institutions, as well as with other industries, in order to establish the wider applicability of these findings. The degree of commonality between findings in the literature and the case study results presented here, indicate tentative evidence for the wider generalisability of the findings, but this needs to be more extensively tested.

Finally, the solution developed here is, at this point, tentative and requires further development and testing. It is therefore recommended that the solution be further developed with particular concentration on how it could best be implemented. The solution should initially be tested through consultation with academics and industrialists experienced in university-industry collaboration, and modified accordingly. It should then be tested through implementation in new university-industry collaborations, with the effects monitored closely throughout the duration of each collaboration.

8. References

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