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ScienceDirect
Research Policy 36 (2007) 1239–1250
research policy
www.elsevier.com/locate/respol

# A view from the coal face: UK research student perceptions of successful and unsuccessful collaborative projects

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Received 1 August 2005; received in revised form 17 January 2007; accepted 19 April 2007
Available online 30 May 2007

**Abstract**

Studies of the effectiveness of collaborative research partnerships between industrial and academic institutions rarely focus on understanding success as perceived by those involved in the research activities. We explore the extent to which three classes of potential success factor are correlated with perceived collaborative research success; supervisor characteristics, project management characteristics, and communication characteristics. Findings are based on a questionnaire-based survey of 348 doctoral students supported by the UK Research Councils' Engineering Doctorate (EngD) and Co-operative Awards in Science & Engineering (CASE) schemes. Conclusions describe how the experience of collaboration as a process influences and how successful students consider the collaboration to be for themselves and the collaborating institutions.


*Keywords:* Collaborative research; Research students; Perceptions of success; CASE; EngD

## 1. Introduction

Contemporary approaches to knowledge and wealth generation stress the benefits of collaboration between disparate intellectual, professional, and sectoral actors (both individual and institutional). Accrued advantages from such collaboration include increasing the absorptive capacity of industrial sectors (Cohen and Levinthal, 1989) and improvements to the yield of company R&D activities (Zucker and Darby, 2000).

The industrial and commercial sectors have long recognised the value of such boundary spanning partnerships but more recently governance agencies have introduced specific funding and promotional schemes to encourage and facilitate research partnerships between universities and commercial or public sector organisations. Many of these involve the provision of funding from third parties; facilitating a range of types of research partnership varying in duration, intensity, and level of financial and other resources required to underpin them (AURIL, 1997). Indeed, non-academic institutions have been shown to be highly effective at exploiting the variety of available collaboration initiatives sponsored by government to accomplish a range of business and strategic objectives (Santoro and Chakrabarti, 2002). The university sector has also been pro-active in this regard, initiating thematic or disciplinary collaboration programmes and courting potential industrial partners through networking and marketing activities. For example, many universities have established industrial liaison offices to facilitate contacts with industry, in particular small and medium sized companies. The role that the various collaboration schemes have in stimulating or

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doi:10.1016/j.respol.2007.04.009

impeding relations between industry and academia was recently highlighted in a benchmarking study (Polt et al., 2001; OECD, 2002).

In the UK, the policy context is of fundamental importance to industry–science linkages (OECD, 2002). Significant emphasis on support for industry–academia collaboration can be traced back to the early 1990s as a result of a government White Paper on the UK's science and technology policy (HMSO, 1993) which set out policies designed to encourage closer contact and exchanges between the science and engineering base and industry. Consequently, UK innovation policies reflect a theoretical understanding of the innovation process at a particular time. Thus, some of the more established policies that encourage universities to commercialise their research reflect an older, linear model (characterised by a uni-directional transfer of knowledge from science to society) whereas recent initiatives take into account a more contemporary 'network' model where knowledge is seen to flow in many directions through a web of nodes and connections (Stewart, 1999).

Based on the assumption that there is a significant cultural divide between universities and (in particular craft-based) commercial companies, the UK government has concentrated on policies aimed at helping the two sides communicate more effectively by using people as 'agents of change' (Stewart, 1999). Examples of such 'people based partnership' schemes include the Teaching Company Scheme (now called Knowledge Transfer Partnerships), the Co-operative Awards in Science and Engineering (CASE), Engineering Doctorates (EngD), and Faraday Partnerships. These schemes facilitate knowledge flows between parties and therefore reflect the network model noted above. Recent comment on these initiatives (e.g. Lambert, 2003) has emphasised both the significance of knowledge exchange as part of the collaboration dividend, and the important role-played by research students in realising the benefits of cooperation.

Such new modes of knowledge creation and dissemination (*sensu* Gibbons et al., 1994) demand new modes of appraisal and evaluation. Consequently, research funders, researchers, and research exploiters have sought to identify practical and robust metrics which can be used to evaluate the level and effectiveness of university–industry relationships. Increasingly detailed measures (many based on statistical analysis of outputs) have been developed and large-scale surveys have been carried out, providing useful evidence of the continuing increase in and changing nature of university–industry interactions (e.g. Howells et al., 1998; OECD, 2002). These studies do not however represent the entire picture as they fail to map (for example) informal relationships, knowledge flows ('tacit' benefits) and the intellectual nature of relationships between industrialists and academics.

Empirical studies evaluating the effectiveness of (specifically) industry–academia collaborations have tended to focus on issues of technology transfer (Siegel et al., 2003), knowledge transfer (Etzkowitz and Leydesdorff, 1997) the role of social networks (Davidson and Lamb, 2000), organizational factors (Mora-Valentin et al., 2004) and the promotion of collaboration within certain countries or regions (Nelson, 1993; Inzelt, 2004). More recently, attention has also focused on complementarities between expectations and the experience of collaboration (Tan et al., 2004). The field is also typified by studies of narrowly defined fields of research or technology (often via case studies), which consider the contribution of university research to knowledge production and studies which focus on specific objectives of interaction (particularly commercialisation activities) (Schartinger et al., 2002). Because of the wide range of collaboration types and outputs from these activities, it is perhaps understandable that no single metric is fully able to capture the whole range of benefits which accrue from industry–academia collaborations.

The reasons that many companies collaborate with universities are a lot broader than just the development of well defined new products. Access to a wider range of ideas, facilities, expertise and know how are all desirable features of collaborative endeavours. As knowledge transfer from universities to industry is a lot more complex than the undertaking of individual projects with specific results in mind, measurement of the outcome of such relationships is consequently problematic. The way the effectiveness of an industry–academia relationship is measured therefore depends on how 'success' or 'efficiency' is defined either by the investigating team or by the participants involved in collaboration (industrialists, academics and government), and on the type of relationship being observed. Measures of success which rely on tangible products can generate an incomplete picture of achievement and fail to capture many (experiential) outcomes which may influence future collaboration intents or behaviour. The challenges faced by those seeking empirically derived evidence of collaboration success in this field have been highlighted many times. The authors of the benchmarking project mentioned above (Polt et al., 2001) committed a good deal of space to expounding the difficulties of evaluating and measuring the effectiveness and efficiency of the various linkages between society and science for knowledge exchange and therefore innovation. Others have drawn attention to the informal nature of many of the artefacts of collaboration and the difficulties inherent in measuring flows of ideas, modified knowledge, opinions and attitudes, etc. which are the very lifeblood of intellectual interaction (e.g. Rahm et al., 2000).

## 2. Characteristics of successful and unsuccessful collaboration

Whilst the determinants of effective research collaboration across academic disciplines has been extensively addressed in recent years, ranging from descriptive accounts of collaboration (Jeffrey, 2003) to more expansive studies of large research teams (Hara et al., 2003), comparable explorations of industry–university collaboration are few. However, several sector specific studies have identified a range of candidate elements which have been seen to influence collaboration success. For example, Klein et al. (1992) identified relevance, patience, participation, value, and sharing as key influences on collaboration success in the petroleum industry. Reback et al. (2002), drawing on experiences from the research-praxis dynamic in drug dependency rehabilitation, found that forming equal partnerships, frequent bilateral communication, ensuring non-hierarchical relationships within teams, and agreeing appropriate dissemination routes were key factors in winning collaborations. Working in the field of management research, Amabile et al. (2001) considered three potential determinants of the success of such cross-profession collaborations: collaborative team characteristics, collaboration environment characteristics, and collaboration processes, their conclusions emphasised the role played by trust building, frequent communication, conflict resolution procedures, and socialising processes in the operations of successful collaborating teams.

Several authors have used both bibliometrics and surveys to study collaborative research activities (e.g. Wen and Kobayashi, 2001; Tijssen and Korevaar, 1997; Tijssen, 1998), although these rarely go beyond an assessment of effectiveness or efficiency in absolute terms to consider the characteristics of successful and unsuccessful collaboration. Our approach is, perhaps, of a different lineage in that we are primarily interested in perceived success from the perspective of those engaged in collaboration. Other enquiries in this tradition include those from Behrens and Gray (2001) and Lee (2000), who employed a 'simplified' measurement system termed 'behavioural outcomes'—that is the perceived benefits of collaboration to participants based on their experience of current or recent collaborative projects (e.g. degree of satisfaction). Barnes et al. (2002) also evaluated the success of collaborative projects on the basis of participants' perceptions—the value of the research outcomes to individual partners and how well their expectations had been met. They also used objective measures of innovation to balance these subjective measures, based on quantifiable outcomes such as the number of published journal papers, the number of patents filed and evidence of new product, process or technology developments. They justified their emphasis on the perceptions of the participants by noting that '*collaborative ventures are often perceived as failures despite some significant technological and/or tangible outcomes*' (Barnes et al., 2002, p. 273) and that such perceptions may influence the decision to collaborate in future. More recently still (and with particular import for the study reported here), Carayol (2003) studied science–industry collaboration by considering information from both academics and firms on organisational characteristics and aims, allowing the construction of a typology of collaboration.

Our terms of reference for the study reported here are relatively broad in that we are interested in collaborative research across application sectors. So, for example, we include collaborative research between universities and public sector organisations such as local authorities or charities. In broad terms the study seeks to enrich the current understanding of industry–university research collaboration by providing an empirically grounded characterisation of successful and unsuccessful projects from the perspective of research students. Studies of this type were recently encouraged by Bozeman and Corley (2004) who called for work to identify the 'predictors of successful collaboration'.

Whilst the survey reported here does not set out to validate a particular model of collaboration (although see Woods et al., 2004; Nye, 2004 for examples), we are able to say something about the characteristics of successful and (perhaps more significantly) unsuccessful collaborative research activities. Specifically, we explore the extent to which three classes of factor are correlated with perceived collaborative research success; supervisor characteristics, project management characteristics, and communication characteristics.

A series of scoping interviews ($N = 16$) were conducted with research funders and research managers to identify a list of factors relevant to each class. This group of respondents included programme managers from the UK Research Councils as well as industrial liaison departments and technology transfer units based at several UK universities. The results of this scoping study comprise factors which might be correlated with successful collaborative projects. Each factor (as pre-

Table 1
Factors observed by research funders and managers to influence collaboration success

| Class of factor | Component factors | Direction of influence on project success |
|---|---|---|
| Supervision | i. Collaborating partners have worked together before | Previous collaboration promotes success |
| | ii. Extent to which supervisors understand the work | Greater understanding of student's work promotes success |
| | iii. Enthusiasm of supervisors for the project | Greater enthusiasm promotes success |
| | iv. Compatibility of supervisors' disciplinary backgrounds | Better compatibility promotes success |
| | v. Differences of opinion between supervisors cause problems | Fewer differences of opinion promote success |
| Project management | i. Restrictiveness of project management/supervision | Restrictive project management threatens success |
| | ii. Gantt chart or list of deliverables for project requested | Agreement on a project timetable or deliverables list promotes success |
| | iii. Problems encountered with project timescales | Success promoted by fewer problems with timescales |
| | iv. Changed project objectives/research methods | Consistent project objectives promote success |
| | v. Partner providing most leadership | Greater industrial involvement promotes success |
| | vi. Partner coordinating/managing relationship | Greater industrial involvement promotes success |
| | vii. Personnel changes in coordination group | Success promoted by few personnel changes |
| | viii. Collaboration agreement in force | Existence of collaboration agreement promotes success |
| | ix. Asked to sign confidentiality agreement | Existence of confidentiality agreement promotes success |
| Communication | i. Frequency of joint project meetings held | More frequent project meetings promotes success |
| | ii. Communication problems between students and supervisors | Success promoted by few communication problems between student and supervisors |
| | iii. Communication problems between partners | Success promoted by few problems between supervisors |
| | iv. Quality of communication over time | Success promoted by increasing quality of communication |

sented in Table 1) can be considered a proposition about a determinant of success to be explored in the main survey.

The factors identified through the scoping study correspond well with best practice elements for the effective organisation and management of university–industry research partnerships identified elsewhere in the literature:

- Mutual trust and good personal relationships that develop over time (Schartinger et al., 2002; Rappert et al., 1999; Senker et al., 1998).
- Good project management (e.g. progress monitoring, effective communication) (Starbuck, 2001; AURIL, 1997).
- Mutual understanding and appreciation of motivations, interests and needs (Brannock and Denny, 1998; Konecny et al., 1995).
- Clearly specified objectives and expectations (e.g. Barnes et al., 2002; Burnham, 1997).
- Frequent, clear and open communication and feedback (BHEF, 2001; AURIL, 1997; NAS, 1997).
- Commitment and continuity of both partners—helped by mutual goals and benefits (Barnes et al., 2002).
- Close alignment of expertise and interests of collaborating parties (Molina et al., 1997).
- Agreements on project roles and responsibilities and publication issues (BHEF, 2001; Starbuck, 2001).

In addition, in order to extend the range of factors under consideration, we investigated a number of factors which do not fall within the classes reported in Table 1; perceived success as a function of (i) research funding body, (ii) size of collaborating organisation, (iii) proportion of time spent by the student with the collaborating organisation, and (iv) the age of the student.

## 3. Study method

Our approach to studying the characteristics of successful and unsuccessful collaboration conforms with the 'reflexive' approaches noted above by focusing on PhD students' perspectives of the experience of collaborative research. Our sample population comprised UK students studying for Doctorate degrees under two forms of funding; (a) the Engineering Doctorate (EngD) scheme, and (b) the Co-operative Awards in Science & Engineering (CASE) scheme. Both schemes provide funding for research students who work on projects jointly supervised by an academic and an industrial or public sector organisation.

The opinions and perceptions of those people actually working on collaborative research projects (as opposed to those managing or supervising such initiatives) are under-represented in the literature. Despite this, the effects of differences in the priorities and perspectives of academia and industry have been evidenced through the experiences of doctorate students involved in collaborative projects (Barnes et al., 2002). The students in our response group are at the 'coal-face' of collaborative research, exposed to the day-to-day detail of research practice, and well positioned to assess both the accomplishments and failings of collaboration. Because they are typically brought in to the project after funding has been secured, their perceptions and opinions (which are primarily formed by the functional performance of the research activity itself) will be untainted by the history of the industry–academic relationship. We do not claim any priviledged or better insight from a focus on research student perceptions. Concerns about response rate and quality dictated against the inclusion of industrial and academic supervisors in the survey. Our findings provide a complementary view to other recent studies by reporting how a relatively independent but closely involved third party experiences and judges the collaborative process.

The EngD programme is operated by the UK Engineering & Physical Sciences Research Council (EPSRC) and comprises a 4-year postgraduate studentship focused on commercially relevant research and including an MBA component. The EngD was first introduced in 1992 in response to the needs of industry and demand for more industrially relevant qualifications coming from students (EPSRC, 2002). EngD students (known as 'research engineers') are expected to spend around 75% of their time working directly with the collaborating company. The project (or a portfolio of projects) is designed by an academic institution and a co-operating company (or, indeed, companies), who jointly supervise the studentship.

The CASE scheme is supported by five UK Research Councils.[1] Most CASE projects are also designed and supervised by both an academic institution and a collaborating organisation. Some CASE projects are defined only by the non-academic partner who then selects the academic partner, and then both partners select and supervise the student (e.g. EPSRC Industrial CASE). CASE students are usually working towards PhDs and, to qualify, they need to spend at least 3 months of their 3-year project (except for part-time students) working in a non-academic setting with the collaborating organisation. The 'industrial' partner can be any organisation from the public or private sector, including charities, local authorities, and research council institutions or laboratories. Both the EngD and CASE schemes offer students the opportunity to undertake a research project with both practical and theoretical aspects and to gain experience of working in both industrial and academic environments. Although many students on these schemes may be working alongside other researchers, their specific project would typically involve only themselves and their two supervisors.

An Internet based invitation-only questionnaire was selected as the elicitation vehicle for the study. Primary considerations influencing this choice were; ease and speed of questionnaire completion and return, size of sample population which made an interview based survey impractical, level of response group computer literacy, and ability to automate much of the response coding. Potential difficulties raised by this form of survey deployment include low response rates (Cook et al., 2000) privacy and confidentiality (Cho and LaRose, 1999) and respondents feeling imposed upon or burdened by the request to participate (Crawford et al., 2001). Engaging authoritative institutions and individuals in survey dissemination (see below) and adhering to the tenets of ethical survey research practice (including transparency of process, informed consent, and data protection) enabled the potential impact of these issues to be minimized. Further guidance on sampling and questionnaire design was adopted from Dillman (2000). The questionnaire was piloted with a small group of EngD students (as representative of both EngD and CASE respondents) in order to both test the relevance of the survey agenda and evaluate the quality of questionnaire design. One minor change to the structure of the questionnaire was required following the pilot but the factors identified by the research managers and funders (see Table 1) proved to be robust in terms of the respondents' ability to understand the questions and provide meaningful answers. Following piloting, an HTML template of the questionnaire was created and loaded on to a server. Completed questionnaires were forwarded from the server to the survey team by email.

Permission to distribute a request to EngD and CASE students to participate in the survey was sought from five of the UK Research Councils (EPSRC, BBSRC, PPARC, NERC & ESRC) and fifteen Engineering Doctorate Centres. Permission was granted by all 5 Research Councils and by 13 of the 15 EngD Centres. Data acquisition occurred between December 2003 and January 2004. A total of 348 questionnaires containing valid responses were returned of which 64 were from EngD students and 284 from CASE students. Because some of the EngD centres and individual supervisors took responsibility for

[1] EPSRC, PPARC (Particle Physics & Astronomy Research Council), NERC (Natural Environment Research Council), BBSRC (Biotechnology & Biological Sciences Research Council) and ESRC (Economic & Social Research Council).

Table 2
Factors related to supervisory issues

| Variable description | Measure | Results | |
|---|---|---|---|
| | | Successful projects ($N=30$) | Unsuccessful projects ($N=30$) |
| Collaborating partners have worked together before | Percent | Yes: 83.3%, no: 13.3% | Yes: 36.7%, no: 53.3% |
| Extent to which supervisors understand the work | Mode[a] | Ind. supervisor: 5 (73.3%), acad. supervisor: 5 (93.3%) | Ind. supervisor: 2 (43.3%), acad. supervisor: 5 (43.3%) |
| Enthusiasm of supervisors | Mode[a] | Ind. supervisor: 5 (80%), acad. supervisor: 5 (83.3%) | Ind. supervisor: 1 (30%), acad. supervisor: 4 (40%) |
| Compatibility of supervisors' disciplinary backgrounds | Mode[a] | 5 (63.3%[b] | 3 (33.3%) |
| Differences between supervisors cause problems | Percent | Yes: 13.3%, no: 76.7% | Yes: 60%, no: 23.3% |

[a] Scale ranged from 1 (not at all) to 5 (very much).
[b] No responses <3.

distributing information about the study to their students, the response rate for the survey is difficult to quantify. Based on the assumptions that (a) EngD centres that did not specify the number of registered EngD students have as many registered students as the average for all those centres that did provide figures, and (b) that only one in two CASE supervisors approached forwarded the questionnaire to their students, we conjecture that the response rate was 26%. The CASE responses came from 59 different academic institutions and just over 170 different industrial or non-academic organisations. The EngD responses reflected 10 different academic institutions and over 50 different collaborating organisations. Results were coded, stored and analysed using a standard statistical analysis package (SPSS, V.11).

## 4. Results

The findings from the survey are presented in two forms. We have no particular model of the determinants of collaborative success to validate and neither are we responding to any broader theoretical framework which posits a specific role for research students in the collaboration process. Rather, our intention is to illustrate the extent to which factors deemed by research funders and managers to characterise successful and unsuccessful collaboration are correlated with success as viewed from the perspective of research students.

In order to conduct such an analysis, we need to be able to distinguish between 'successful' and 'unsuccessful' projects (Tables 2–4, below). The responses to three questions asking the students to indicate on a five point Likert scale how successful they considered their project to be from their own, their academic supervisor's and their industrial supervisor's perspective were summed, providing a measure of overall success with a maximum value of 15. In order to generate sub-sets of the data for comparative analysis which reflects the extremes of project success, the thirty projects which received the maximum success score possible (a total score of 15) were selected for further analysis. As only two cases exhibited the lowest possible total score (3), a

Table 3
Factors related to project management issues

| Variable description | Measure | Results | |
|---|---|---|---|
| | | Successful projects ($N=30$) | Unsuccessful projects ($N=30$) |
| Restrictiveness of project management | Mode[a] | Mode: 2 (36.7%) | Mode: 1 (40%) |
| Gantt chart or list of deliverables for project requested | Percent | Yes: 53.3%, no: 26.7% | Yes: 40%, no: 50% |
| Encountered problems with project timescales | Percent | Yes: 10%, no: 73.3% | Yes: 60%, no: 26.7% |
| Changed project objectives/research methods | Percent | Yes: 47%, no: 51.4% | Yes: 66.7%, no: 30% |
| Partner providing most leadership | Percent | Academic: 70%, equal: 20%, industrial: 10% | Academic: 76.7%, equal: 10%, industrial: 13.3% |
| Partner coordinating/managing relationship | Percent | Academic: 33.3 %, both: 56.7%, industrial: 6.7% | Academic: 70%, both: 23.3%, industrial: 6.7% |
| Personnel changes in coordination group | Percent | Yes: 10 %, no: 80% | Yes: 33.3%, no: 63.3% |
| Collaboration agreement in force | Percent | Yes: 26.7%, no: 16.7% | Yes: 33.3%, no: 26.7% |
| Asked to sign confidentiality agreement | Percent | Yes: 60%, no: 40% | Yes: 40%, no: 36.7% |

[a] Scale ranged from 1 (not at all) to 5 (very).

Table 4
Factors related to communication issues

| Variable | Measure | Results | |
|---|---|---|---|
| | | Successful projects ($N=30$) | Unsuccessful projects ($N=30$) |
| Frequency of joint project meetings held | Percent | <Once a year: 6.7%, once a year: 26.7%, quarterly: 53.3%, once a month: 6.7%, >once a month: 6.7% | <Once a year: 16.7%, once a year: 40%, quarterly: 36.7%, once a month: 6.7%, >once a month: 0.0% |
| Communication problems with supervisors | Percent | Yes: 10%, no: 90% | Yes: 66.7%, no: 26.7% |
| Communication problems between partners | Percent | Yes: 3.3%, no: 90% | Yes: 40%, no: 36.7% |
| Quality of communication over time | Percent | Improved: 90%, worsened: 0% | Improved: 23.3%, worsened: 36.7% |

comparably sized data set of unsuccessful projects was constructed by adding cases with the next lowest total scores (5, 6, and 7).[2] This approach ensures that we have a comparable number of cases available for each group of projects. It also means that, in selecting the most successful thirty cases and the most unsuccessful thirty cases out of a total of 348 cases (17.2% of total cases) there is sufficient distinction between our two groups. A sample size of 30 provides a balance between ensuring a clear distinction between successful and unsuccessful cases and retaining the relevance of the Central Limit Theorem to our analysis and thereby precluding any need to revise confidence intervals.

Table 2 shows how successful and unsuccessful projects are characterised by supervisory factors. A large proportion of successful cases involve partners who have worked together before, supervisors who both have a very good understanding of the work and have very high enthusiasm for the project. However, unsuccessful projects are poorly correlated with a lack of enthusiasm or understanding on the part of the academic supervisor. This disparity in the weight of evidence about contributing factors for successful and unsuccessful projects is also apparent in the case of the compatibility of supervisors backgrounds. Here, successful projects are clearly characterised by high levels of compatibility whilst unsuccessful projects are not exemplified by particularly low levels of compatibility.

Table 3 illustrates how successful and unsuccessful projects compare with regard to project management factors. The restrictiveness of project management arrangements appears inconsequential as a distinguishing characteristic, as does the existence of a GANTT chart or list of project deliverables, the existence of a collaboration or confidentiality agreement, and changes to project objectives or methods. A lack of problems with project timescales however does appear to characterise successful projects. However, it is factors related to the project coordination team itself which exhibit the strongest association with project success. In particular, consistency of coordination group personnel reflects positively on project success. In terms of which collaborator takes the lead in coordination or leadership, the findings are less clear with academic partner dominance being equally associated with successful and unsuccessful projects.

The extent to which communication factors characterise successful and unsuccessful projects is presented in Table 4. The key indicators in this class for successful projects are (i) no communication problems between supervisors, (ii) no communication problems between student and supervisors and an improvement in the quality of communication over time. Frequency of joint project meetings is low for unsuccessful project where over half of projects have such gatherings once a year or less frequently.

We next consider the significance of correlations between those factors listed in Tables 2–4 (above) and perceived overall success of the project. Our analysis of these relationships (in Tables 5–9) draws on all valid responses to the survey ($N=348$), and not only the most and least successful cases. This analysis uses a $t$-test to evaluate whether there is a significant difference in the perceived influence of a specific factor in more and less successful projects (Table 5). Significant results ($p<0.05$) can be interpreted as evidence that the assessed factor is correlated with perceived overall success of the project. The cut off value used to demarcate the more and less successful projects was the median value of the overall score for perceived project success.

We next turn to those data which relate to the perceived success of collaborative research projects for different Research Councils (Table 6). As noted above, these bodies are broadly reflective of distinctions

[2] Each student represents one unique questionnaire return and one unique case (research project).

Table 5
Strength of correlation between supervisory, project management, and communication factors and perceived success of collaboration ($N = 348$)

| Factor | $p$ value[a] |
|---|---|
| Supervisory factors | |
| Collaborating partners have worked together before | 0.00 |
| Extent to which supervisors understand the work | 0.01 |
| Enthusiasm of supervisors | 0.00 |
| Compatibility of supervisors' disciplinary backgrounds | 0.00 |
| Differences between supervisors cause problems | 0.36 |
| Project management factors | |
| Restrictiveness of project management | 0.05 |
| Gantt chart or list of deliverables for project requested | 0.00 |
| Encountered problems with project timescales | 0.00 |
| Changed project objectives/research methods | 0.34 |
| Partner providing most leadership | 0.92 |
| Partner coordinating/managing relationship | 0.73 |
| Personnel changes in coordination group | 0.22 |
| Collaboration agreement in force | 0.14 |
| Asked to sign confidentiality agreement | 0.94 |
| Communication factors | |
| Frequency of joint project meetings held | 0.01 |
| Communication problems with supervisors | 0.00 |
| Communication problems between partners | 0.00 |
| Quality of communication over time | 0.42 |

[a] Details of the direction of the observed relationships can be found in Tables 2–4.

Table 6
Mean overall success scores and standard deviation by research council

| Research council | $N$ | Success score (S.D.) |
|---|---|---|
| NERC | 72 | 11.47 (2.21) |
| PPARC | 16 | 11.06 (2.14) |
| BBSRC | 86 | 10.80 (2.47) |
| ESRC | 61 | 10.70 (2.17) |
| EPSRC | 109 | 10.54 (2.44) |

Table 7
Mean overall success score and standard deviation scores by size of non-academic partner for each research council

| Research council | Size of non-academic collaborator | | |
|---|---|---|---|
| | Small ($N = 40$) | Medium ($N = 48$) | Large ($N = 253$) |
| EPSRC | 9.67 (2.82) | 11.88 (1.72) | 10.57 (2.39) |
| ESRC | 9.86 (1.86) | 10.00 (2.37) | 11.19 (1.99) |
| NERC | 10.44 (2.16) | 11.44 (1.94) | 11.75 (2.15) |
| PPARC | – | 10.67 (1.52) | 11.15 (2.30) |
| BBSRC | 10.33 (1.00) | 11.09 (3.04) | 10.89 (2.48) |

Table 8
Mean overall success score and standard deviation by the proportion of time the student spends with the non-academic partner

| Time spend working at industry (%) | $N$ | Overall score (S.D.) |
|---|---|---|
| >25 | 257 | 10.77 (2.37) |
| 25 | 31 | 11.39 (2.39) |
| 50 | 14 | 11.71 (1.97) |
| 75 | 1 | 14.00 (–) |
| <75 | 38 | 10.58 (2.38) |

between different areas of scientific endeavour. Five of the eight currently operating Research Councils were included in the survey.

Projects in the field of the Natural Environment have the highest 'success' means compared to those funded by the other Research Councils. Those in the Engineering & Physical sciences have the lowest ratings in terms of 'personal', 'academic' and 'overall' 'success. The success mean for the industrial side in Engineering is however higher compared to those in the Biotechnology & Biological sciences and the Economic & Social fields.

The data also allow us to consider relative success as a function of the size of commercial or public sector organisation involved in the collaboration (Table 7). Here, the 'success' means for the student, the academic side and the overall success mean are lowest in projects with small engineering firms, agreeing with Stewart's (1999) comments on the difficulties these firms face in collaborations. The 'success' means for the industrial side are lower in projects with small companies within social sciences (ESRC) and biotechnology (BBSRC). Projects with large companies within the physics (PPARC), environmental science (NERC) and social science (ESRC) sectors are more successful, whereas within the engineering (EPSRC) and biotechnology (BBSRC) sectors, collaborations with medium sized companies have higher success.

Perceived project success as a function of proportion of time spent with the collaborating partner is shown in

Table 9
Mean success score and standard deviation by student age group

| Student age range | $N$ | Success score (S.D.) |
|---|---|---|
| 21–25 | 213 | 10.78 (2.37) |
| 26–30 | 78 | 10.96 (2.24) |
| 31–35 | 27 | 10.78 (2.00) |
| 36–40 | 14 | 11.29 (3.12) |
| 41–45 | 8 | 11.50 (3.02) |
| 46–50 | 3 | 11.00 (2.00) |
| 51–55 | 2 | 11.00 (1.41) |

Table 8. Ignoring the values for '75%' which involves only one case, the 'success' mean is highest where the student spends 50% of their time at industry. Interestingly the success mean for the academic side is lowest where the student spends more than 75% of their time at industry and the mean for the industrial side is lowest where the student spends less than 25% of their time at industry.

Finally, we consider the relationship between student age and success of collaborative research. The data presented in Table 9 compares the 'success' means by student age group; no dominant patterns can be seen here but looking at the 'overall' 'success' means, it seems that in general, the means are slightly higher for students who are over 35 years old.

## 5. Discussion

In reporting a picture of research collaboration from the perspective of research students, we are clearly at the mercy of subjective observations and impressions. However, research funders are increasingly turning to 'softer' measures in their attempts to enhance existing research performance metrics so that the intangible benefits of collaboration can be assessed (Carayannis, 2004). In this context, surveys such as that reported above can provide evidence to both diagnose successful models of collaboration and identify the perceived benefits which accrue from collaborative actions.

The survey results allow us to contrast anticipated influences on collaborative success with the experiences of researchers themselves. The evidence confirms that aspects of all three classes of factor considered are indeed correlated with perceived project success. However, those relating to Project Management issues are perhaps less strongly associated with success than those relating to Supervision and Communication. That many of the Project Management factors considered influential by research managers and funders should be uncorrelated with perceived project success is perhaps surprising. Of the three classes of factor explored in this study, Project Management offers most scope for formalised planning and direction of a research activity. Whilst there are other benefits to strong Project Management (as characterised by, *inter alia*, the existence of formal agreements and consistent project objectives), the evidence from this study cautions against over-reliance on Project Management as a driver for success.

Supervisory factors which significantly correlate with perceived project success include collaborating supervisors who have worked together before, have compatible disciplinary backgrounds and demonstrate enthusiasm. These results (particularly the first two) are doubtless intuitively commensurate with many researchers' experiences. Despite this, funding bodies are unlikely to either emphasise such factors in calls for proposals, or explicitly apply them as criteria for project selection. Neither are proposers requested to specify how they will overcome such social and professional relationship issues. Is there an assumption here that the profession of scientist or researcher engenders the ability amongst all its practitioners to reach out across disciplinary and social spaces to collaborate? The popular (and often deliberately reinforced) image of the profession in the public's mind is often quite the contrary. Consequently, the observation made by Saussois (2001) that research funders and managers should do more to support students through the 'socialisation phase' of collaborative relationships may well be just as pertinent to more senior researchers.

Although nine project management factors were considered in the study, only two appear to be related to project success; the existence of a Gantt chart or list of deliverables for the project, and difficulties with project timescales. There is relatively little empirically derived information in the literature on these aspect of collaboration; the little that is available being based on experiences in the USA (e.g. BHEF, 2001; GUIRR, 1999). Planning and managing collaborative research is, in many respects, no different from coordinating any other multi-institutional, task based endeavour. The vagaries of changes in personal and institutional circumstances, and the inherently indeterminate nature of research as a pursuit, will intrude on the best laid plans. Such disruptions cannot be anticipated in detail but their potential can be acknowledged and their impact mitigated through common understandings and contingency planning. Given the particular viewpoint recorded in this study, Starbuck's (2001) suggestion that students should be involved, where possible, in project planning and in setting up agreements on objectives, timelines, confidentiality, etc. has merit.

In terms of communication factors, the noteworthy elements are the frequency of meetings and communication problems both between collaborating partners and between students and supervisors. The importance of frequent contact between collaborating partners has been emphasised recurrently in both the research literature and prescriptive documents. For example, Dodgson (2000) points out that tacit knowledge exchange is not easily transferred unless there is frequent, effective and continuous communication. However, we would brand our findings on communication problems with a health warning. Communication between student and supervisors and amongst supervisors is likely to significantly undermine student satisfaction with, and confidence in, the research degree process. Project success then becomes conflated with research degree success. The potential for such associations is, of course, present across many elements of this and other studies. However, it is, we feel, particularly relevant to this class of success factors.

Our findings also indicate that collaborative success is less easy to achieve with small organisations than with larger ones. This result is consistent across type of collaborating institution (if we assume that each of the five Research Councils included in the study are broadly representative of collaborating sectors). The perceived success of collaborations funded by the NERC is consistently higher as a function of size of non-academic partner than that for the other councils, whilst EPSRC funded collaborations perform particularly poorly in relationships which involve small or large sized non-academic partners. Indeed, this trend in sector variance is reflected in other measures where students funded by NERC and EPSRC rate the overall success of the projects highest and lowest respectively compared with those from other councils.

The results which relate perceived success of a collaboration with time spent with the non-academic partner, suggest that longer residence correlates with higher success; although beyond the 50% mark, the results are ambiguous. Finally, if we ignore the last two student age categories (46–50 and 51–55) which contain two and three responses respectively, student age is positively correlated with perceived success of the collaboration. Older students are more likely to have had previous workplace experience and would thereby not be overwhelmed by exposure to a non-academic professional environment.

## 6. Conclusions

Prescriptive policy advice is always difficult to formulate from such a time and perspective constrained snapshot of opinion and practice. We are all too aware of the limitations of the style of enquiry and reporting we have adopted for this study. Research on the experiential dimension of research collaboration is, however, poorly reported compared with other metrics and we make no apologies for focusing on characterisation and illustration rather than substantiation or verification.

In conducting this study we have distinguished between three classes of factor; supervision, project management, and communication. In all three cases, perceived success is correlated not with factors which describe the formal structure of collaboration, but with factors that portray the experience of working together. Mitigation measures to meet these potential pitfalls are difficult to build into project proposals as they are typically emergent features of the collaborative process itself. For example, the enthusiasm of supervisors, problems with project timescales, and communication problems between or with supervisors are unlikely to feature in a project proposal and yet are clearly associated with perceived project success. Frequent project meetings (also found to correlate with success) is one possible strategy to cope with such social relationship challenges to effective collaboration. Whilst early recognition of communication and project timescale problems allows remedial action to be undertaken, we are perplexed by the question of who is to inform the collaborating partners that the process is going awry! Research students are well (best?) placed to monitor collaboration and identify problems, but they often have poor professional standing in the relationship and therefore do not have the legitimacy or remit to diagnose and advise. Collaboration is, by its very nature, a high risk mode of research. High risk and potentially high reward, for all parties; for science, society, and the individuals involved. Those engaged in research understand this (or are perhaps more at liberty to understand it) better than those wishing to measure research outcomes. 'Success' accrues to many stakeholders in many ways and our selection of research students to provide a measure of success needs to be balanced by comparative results from other perspectives (academics, industrial supervisors, research funders, etc.).

And it is with respect to 'perspective' that we would offer one final insight from our study. Much of the voluminous contemporary debate regarding the design and management of collaboration implicitly views the process as something to be engineered, manipulated, and somehow optimized. As a social process (a perspective often adopted by researchers considering purely academic collaboration), the personal experience of research collaboration is necessarily imperfect, noisy, messy, and ultimately one of mixed emotions and outcomes, thereby constraining the impact of interventions based on a 'best model' prescription. The tension between formal project management structures and the informal web of relationships and contingent actions which make up a collaborative venture are evident throughout the study reported above. Formality provides ambition, focus, efficiency, audit, whilst the informal engenders flexibility and independence. It is perhaps unsurprising that, irrespective of the measure used, some collaborative projects perform poorly. Those who seek to enhance the utility of collaboration may well be better served by research which identifies acceptable reasons for, and levels of failure, rather than research which specifies ideal models for success.

## Acknowledgements

The authors gratefully acknowledge financial support from the UK Engineering and Physical Sciences Research Council and the collaboration of all those who responded to the survey. We would also like to thank Brian McIntosh and two anonymous reviewers for their comments on earlier drafts of the paper.

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