Study Groups with Industry: What is the value?

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Executive Summary

Study groups with industry have been running for over fifty years, and starting with pioneering work in the UK now take place all over the world. They are a most effective means of knowledge exchange in many areas of mathematics. They also serve as a means of initiating long term collaborations between industry and academia. Furthermore they play an important role in the training and CPD of both PhD students and academics. In this report we will look both at the current activity related to Study Groups and will provide evidence for their impact by summarising the results of a recent survey of Study Group participants. It concludes with some recommendations for the future support of Study Groups in the UK. Case studies for some Study Group problems will be provided.

1. Overview

- Mathematical study Groups with industry have been operating in the UK since 1968. Originally founded in Oxford they are now an international activity with very many countries running similar activities.
- A study group is an **open** workshop in which academics, PhD students and companies work together as equals, usually for a week, and in particular without any form of NDA or IPR restriction, to share ideas freely, and to engage in very focused discussions. They are based on the premise that industry is a valuable source of interesting problems to stimulate new research and that in addition, the mathematical sciences can solve key industrial and societal challenges of economic and societal value.
- A typical such workshop will gather representatives from industry, academic mathematicians, graduate students, and postdoctoral fellows. Participants will work in teams, each of which studying a concrete problem submitted by a company or a public or quasi-public institution. At the end of the week the team makes a short presentation. This is followed a few months later by a report to the company.
- One of the goals of the study group is to provide companies and institutions with mathematical tools for solving problems.
- A study group also allows academics and students in the mathematical sciences (including data science, statistics, optimization, numerical analysis, mathematical finance, machine learning, etc.) to be exposed to, analyse and solve real-world problems. Through this they become familiar with, and up to date in, some of the latest problems and methods arising in industry.
- The workshops act as "incubators" of collaborations. The work initiated during the study groups typically leads to collaborations lasting several months or years, which can develop into major engagements between mathematicians and industry. In particular they play a vital role in establishing close relationships between academia and industry, and it is these relationships which lead to very effective future knowledge exchange.
- The research started at study groups often leads to long lasting and deep mathematical investigations.

- Study groups act as a vital source of training both for the students and the academics, they also provide a resource of problems which can be used in teaching at both undergraduate and postgraduate level. The resource of past study group reports is maintained on the Maths in Industry Information Service website[1].
- Study Groups form a very useful means of public engagement in mathematics. This is either directly, through media coverage of the event itself, or indirectly through (for example) public talks based on Study Group problems. An example being the Gresham lectures delivered by Prof Budd, or the public lectures by William Lee.
- In general study groups are a very important feature of the knowledge exchange activity of the UK mathematics community. They represent an area in which the UK is world leading. The recent Bond review – *the Era of Mathematic*s, an independent Review into KE in the Mathematical Sciences [2] has the following recommendation:

Recommendation 16: Resources for workshops with industry should be broadened and increased. In particular the Mathematical Study Groups with Industry should be expanded in scope.

2. Data collection mechanism

In this report we will provide evidence to substantiate all of the points made above. This evidence was collected by writing to participants of recent study groups from both academia and industry, asking them a series of questions about the impact of study groups on their work. Replies were received from 23 industrialists and 64 academics.

3. Current activity

3.1 The Study Group schedule

The UK study groups started in Oxford in 1968, and were based in Oxford every year until 1987. Since then they have been hosted every year by universities all over the UK, most recently in Cambridge in April 2019. The total attendance at Cambridge was 166. Participant breakdown :

- Academic (Lecturer, Reader, Professor): 43
- CDT Student: 41
- Industry/Public: 26
- Other PhD Student: 37
- University Staff: 7
- Postdoc: 12

[1] http://www.maths-in-industry.org/
[2] https://epsrc.ukri.org/newsevents/pubs/era-of-maths/

The previous study groups were held in Bath (2018), Warwick (2017), Durham (2016), Manchester (2015), and Oxford (2014). The next will be held at Leeds in 2020.

At present the UK hosts one week-long study group per year. This is typically attended by around 100 academics and PhD students, and between 8 and 10 companies. The academics are usually mathematicians, but can also include statisticians, engineers and physicists. The study group is organised by the host institution. However, there is a strong group of academics around the UK and beyond who regularly attend the groups and provide advice and support for them.

The week-long study group generally has a wide variety of mathematically based problems, depending on the companies who come. The problems are worked on by teams of around 10 academics in collaboration with the industrial partner. Usually each team will have a problem coordinator who is assigned in advance by the organisers to ensure that the team delivers a solution to the industry.

When the study groups started the problems were typically focused around mechanics, mathematical modelling and differential equations. However in the last 20 years there has been an explosive growth in the range of problems considered. The majority of the problems in recent study groups have been in areas such as data science, optimization, financial maths, and signal/image processing, although mechanics is still important.

As an example, the ten problems at the 2019 Cambridge Study Group were a mixture of data and modelling as follows:

1. Identification of changes in noisy spectra – to detect incipient problems in rotating equipment (Faraday Predictive)

2. Statistical Modelling and Pattern Recognition for Predicting Evolution of Temperature Forecasts (BP)

3. Uncertainty in Seismic Inverse Problems (BP)

4. Identifying Potential Hardening Techniques for Image Classifiers (Defence Science and Technology Laboratory)

5. Limits on Simultaneous Transmit and Receive (Defence Science and Technology Laboratory)

6. The Value of Information in Managing the Electricity System (National Grid)

7. Conditional Quantile Estimation using High-dimensional Time Series Data (Prudential)

8. Improving Weather Models for the Insurance Industry (Aviva)

9. Towards Managing Landscapes: How can we Interpret and Design Better Environmental Monitoring Surveys? (Syngenta)

10. Analysis of Shear Forces during Mash Disk Formation (PepsiCo)

More recently, in close collaboration with Innovate UK, there have been focused, three day study groups, concentrating on a particular area. Examples of these include study groups in agri-science, energy, and health. These three-day sessions are as follows:

- Uncertainty Quantification & Management in Manufacturing – Liverpool (2015)
- Agri-Food – Bath (2016)
- Uncertainty Quantification & Management in Manufacturing – Liverpool (2016)
- Energy Systems – Sussex (2018)
- Uncertainty Quantification & Management in Manufacturing – Liverpool (2017)
- Agri-Food – Edinburgh (2018)
- Energy Systems – Edinburgh (2018)
- Uncertainty Quantification & Management in Manufacturing – Warwick (2018)
- Clean Growth – Nottingham (2019)
- AI in Health & Care – Cardiff (2019)
- AI in Health & Care – Manchester (2019)

These three day Study Groups are seen as 'strategic' whereby gaps in engagement are large, upcoming pots of public R&D budget becoming available are driving the need to engage the mathematical sciences.

There are also Maths in Medicine and Maths in Plant Sciences Study Groups. The Alan Turing Institute organizes Data Study Groups. A further development has been one-day study group type workshops such as those as organised in Manchester (by Geoff Evatt) and Huddersfield (by William Lee). In Manchester, they tend to invite one company to present half a dozen problems, and then the 1-2 most promising problems are followed up as MSc projects.

3.2 Training

As well as the training which occurs during the study group itself (which is valuable for academics, students and industrialists), the study groups are supported by dedicated modelling camps for PhD students. Typically these last a week and the students on them work in teams to solve problems, which have come up at previous study groups. This is done under the supervision of experienced academics. The European Consortium for Mathematics in Industry (ECMI, of which the UK was one of the founding partners) has held an annual Modelling Week every year since 1988[3]. For the last few years, Oxford has hosted a Graduate Modelling Camp the week before the UK study group. Similar workshops are hosted by the ICMS, Edinburgh and MACSI, Limerick.

It is worth noting that the importance of PhD training in knowledge exchange by study groups has been recognized by a number of Centre for Doctoral Training (CDT) programmes. The Oxford InFoMM CDT requires that its students attend study groups both in the UK and overseas as part of their training programme. In Bath all of the students on the SAMBa CDT attend two *Integrative Think Tanks (ITTs)* at Bath per year. These are similar to study groups in that teams of students, academics and industrialists, work together on open industrial problems. However, they are much more focused around student training, and the outcome for each

[3] https://ecmiindmath.org/education/modelling-weeks/

student is a proposal for a PhD project with an industrial partner. The HetSys CDT at Warwick has built study groups into its industrial engagement strategy.

3.3 Finance.

The week long Study Groups aim to break even, however they do cost money to run. Funding comes via government (indirectly through the EPSRC support of CDT students or directly through Innovate UK), but mainly from direct company support and significant university in-kind support. Typically the charge for a large company is around £8500 to attend, with smaller costs for SMEs and (maybe no cost for) charities. Academics attend a study group for free, with accommodation and subsistence paid for. Direct costs arise from supporting their subsistence, plus the institutional costs of administration, logistics, promotion and of room hire. The total costs for running a Study Group are in the order of £50k-£60k depending on the number of problems considered. It is worth noting that academics give their time and expertise for free at a Study Group.

Further substantial costs arise from the time spent finding and pre-processing the (typically 8-10) problems, including company visits, contract negotiations, time spent writing the reports, time spent reporting to the company and time spent in follow up to the problems. Typically this work is done by 'technology translators' whose time has to be paid for.

Although the UK initiated week long study groups, it receives far less central support for them then many other countries. For example Study Groups in Ireland, the Netherlands and Canada all rely on substantial government grants.

The strategic, three-day Study Groups (which are shorter and have fewer problems) are mostly funded either by Innovate UK (indirectly through KTN) or by host organisations (or a combination of the two) where total costs do not exceed £12k.

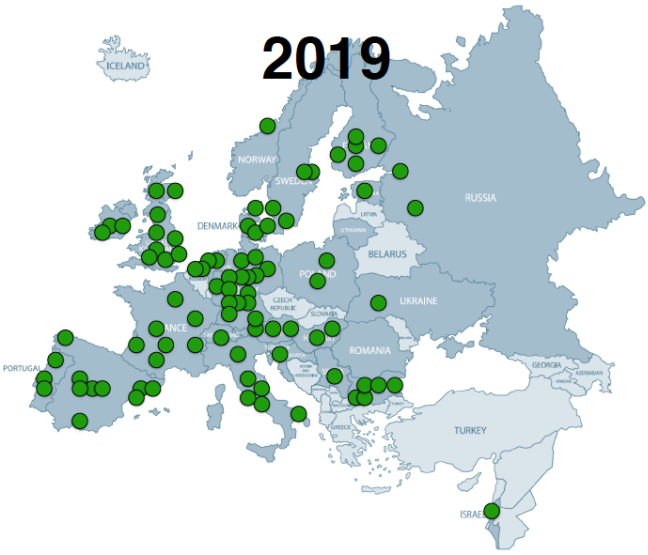
In addition, there has been a small amount of activity in Government departments paying to have their own Study Groups run in order to solve a number of their strategic challenges. The Ministry of Defence have run two with KTN on uncertainty visualization. In these cases, the entire costs have come from the MOD.

3.4 International activity

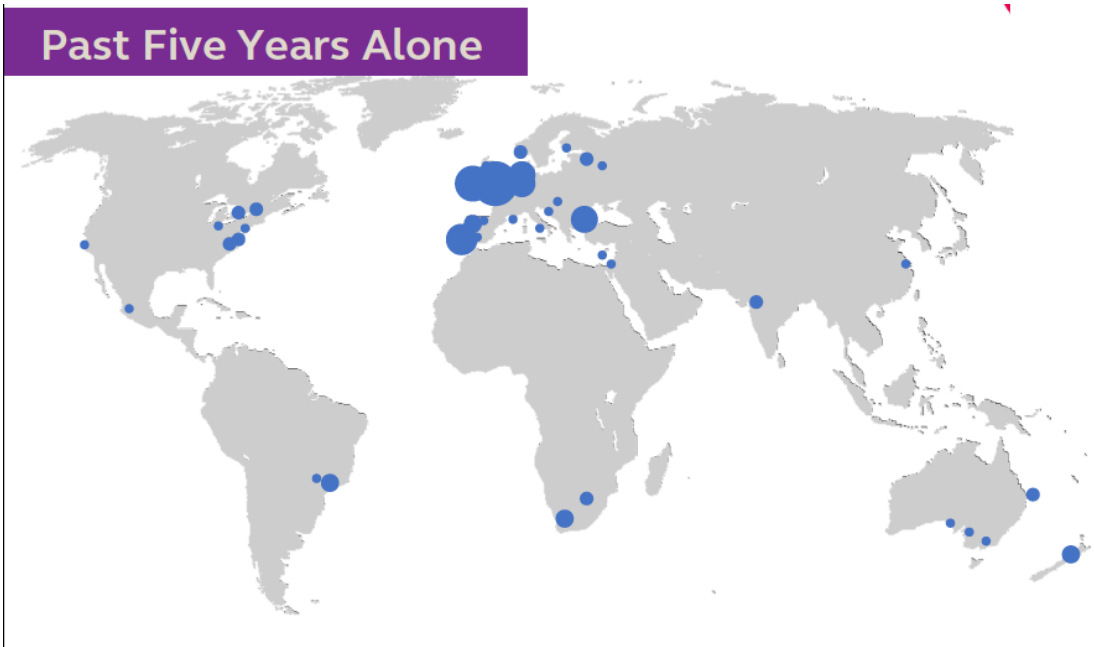
Inspired by the UK, Study Groups now take place all over the world. The UK is part of a broader network of European Study Groups (ESGI) which has a degree of central coordination and is closely linked to the European Consortium for Mathematics in Industry (ECMI). ESGI workshops are organized regularly across the whole of Europe. There are now long established annual study groups in the Netherlands, Denmark and Ireland, with new countries running study groups every year. In 2019 alone there are study groups in Holland, UK, Spain, Estonia, Austria, Lithuania, Portugal, Denmark and the Basque Country. From 2015-2019, the UK-coordinated EU-funded Mathematics for Industry Network supported the establishment of study groups in new countries, and has written a handbook on how to organise a study group[4].

[4] https://mi-network.org/resources/handbook-for-running-a-sustainable-european-study-groups-with-industry

Locations for European Study Groups up to 2019 are shown below:



Study groups or similar are also run in many other countries including Australia, New Zealand, China, USA, Canada, Japan, India, South Africa, and Brazil. UK academics, experienced in the UK study groups, played a major role in setting these up, and frequently attend them Recent international activity is summarized below.



3.5 Case Study: The Canadian Study Groups

PIMS (the Canadian institute based in Western Canada) started organizing study groups (called International Problem Solving Workshops or IPSWs) twenty years ago[5]. In Toronto the Fields Institute also organizes problem solving workshops, as does the University of Montreal (CRM). The CRM, the FI, and PIMS take turns organizing "national" workshops. The recent Montreal study group in August 2019 addressed the following nine problems:

1. *Improving a taxonomy through Natural Language Processing*
2. *Adapting regulations for an automated reading system*
3. *Constrained demand forecast (Air Canada)*
4. *Flight Spill Detection (Air Canada)*
5. *Optimizing the design of a loyalty program (Aeroplan, Air Canada)*
6. *Segmenting and smoothing territories in the context of non-life insurance (Desjardins GAG)*
7. *Prioritizing abnormal situations automatically in the context of fraudulent claims (The Co-operators, Insurance and Financial Services)*
8. *Development of a mathematical framework to represent a 2D/3D smooth structure (National Research Council)*
9. *Automatically identifying patterns and novel behaviours in the radio-frequency environment at DRAO (National Research Council)*

A letter of support from Prof Odile Marcotte who organizes the Montreal Study Groups is included as an appendix to this report. To quote from this letter:

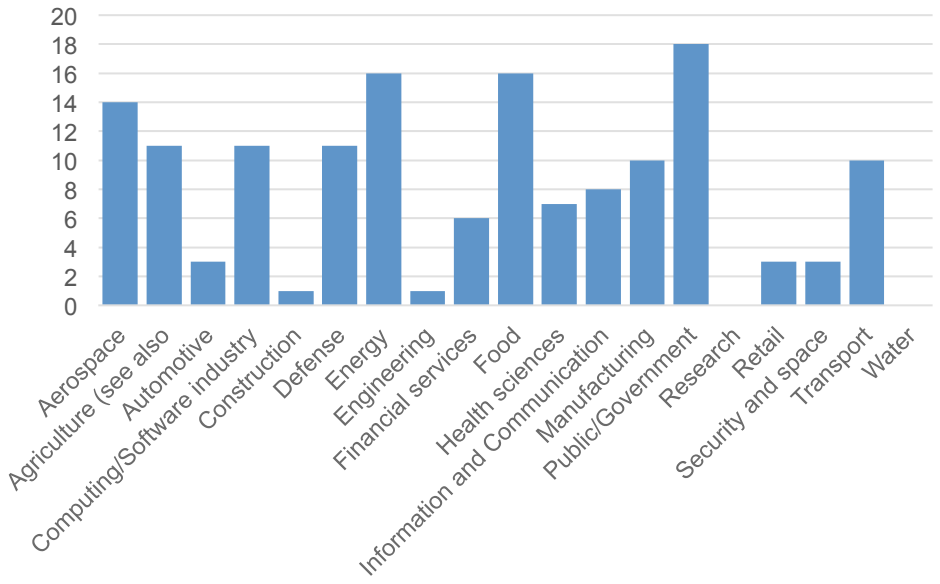
"The flexibility of study groups is probably one of the hallmarks of the British sprit and has ensured the spread of the study group model across the world."

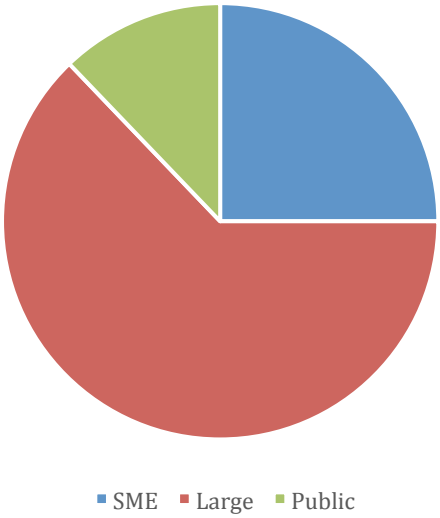
[5] see www.pims.math.ca/industrial.

4. Impact of Study Groups on (UK) industry

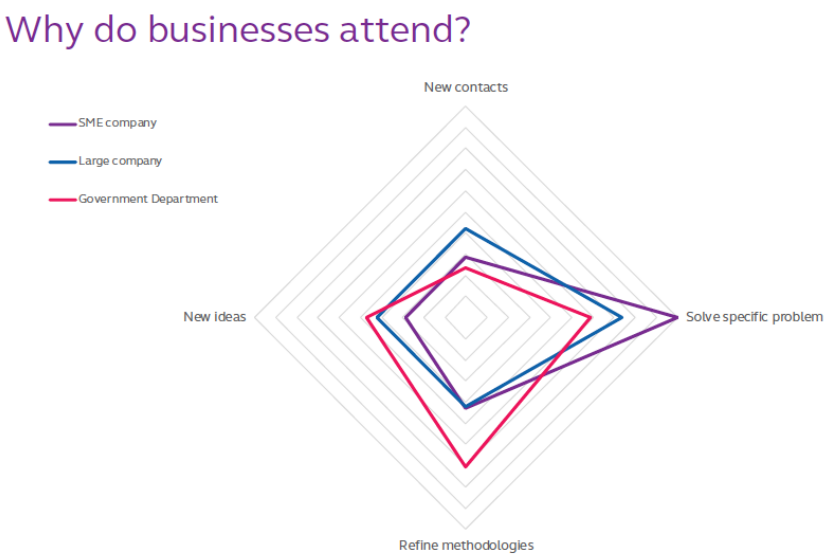
4.1 Who attends and why?

Since 2000, 160 companies from a wide range of different areas and sizes have attended UK Study Groups. The breakdown is given by the following figure:





In the survey we conducted together with Innovate UK, 23 companies replied. These showed that they regarded the study groups as successful both to solve problems, save money and also to develop new contacts. It was notable that many of the companies had attended several study groups. This is a summary of the various responses to the questions asked:



Repeat Business: 80% of the companies surveyed have taken part in 1 study group, 15% in 2-4 and 4% in over 5.

4.2 What was the value of the study groups

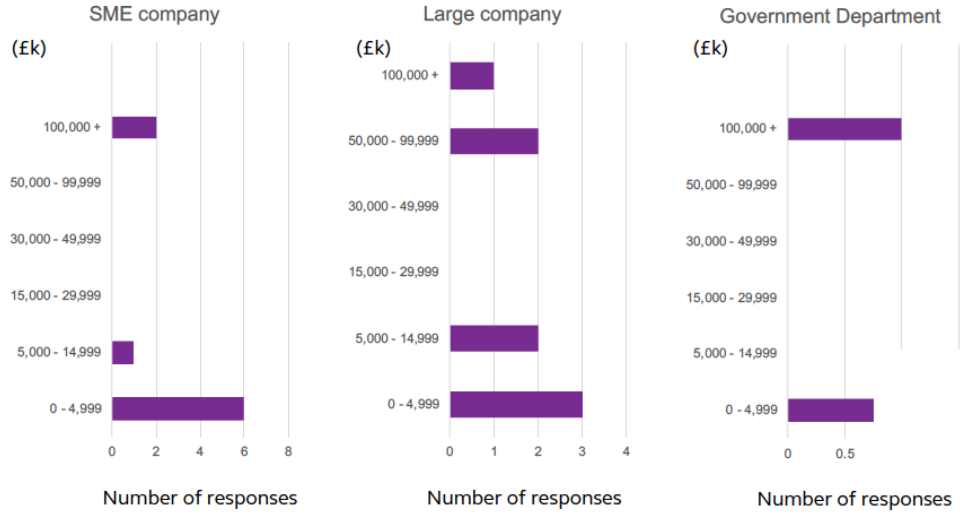
Did the Study Group achieve its objectives?

80% of the SMEs said YES, as did 100% of the Large companies and 67% of the government departments.

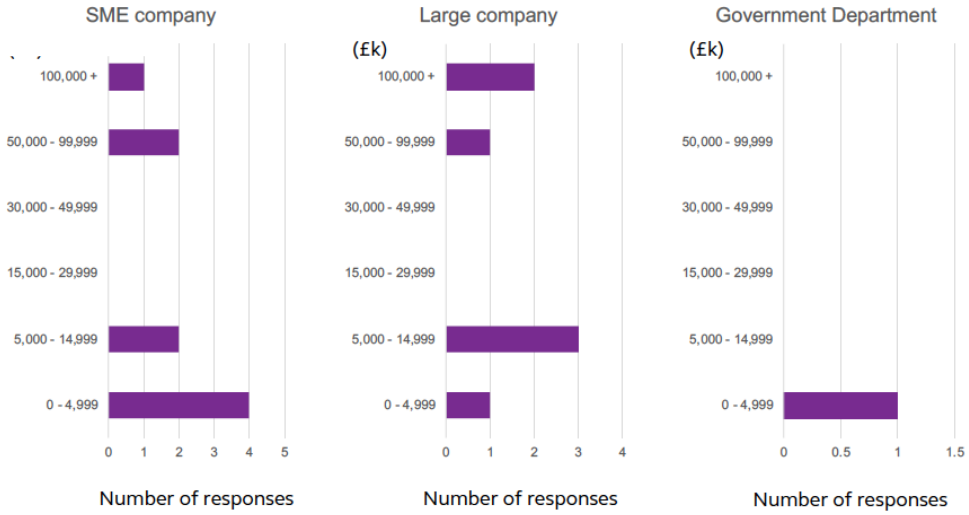
When asked in comparison to other Knowledge Exchange mechanisms whether Study Groups provide good value for time and money?

95% of the participants said that they were.

Estimate value of time saved (£k)

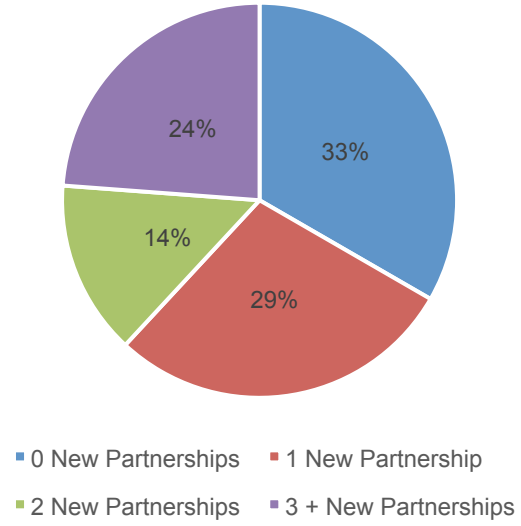


Estimate value of new projects (£k)



The data above shows that the study groups both save time and money for the companies and also generate new projects for both small and large companies.

For the companies contacted, there was also evidence that the Study Groups had led to new partnerships and jobs:



4.3 Some quotes from the company responses:

The study group enabled a company staff member and his company supervisor to make contact with the leading academic (and after the study group several other leading academics) in the field of uncertainty quantification and emulation. This in turn influenced several company people (of the order of 10), including senior managers, to modify projects. To quantify the actual value of new products is dependent on rather many assumptions. However, it is very clear that the study group enabled interactions with several academics that would otherwise have been too difficult and expensive to organise without the help of the study group. The study group mechanism is a unique method of facilitating consultancy and academic interaction that provides benefits lasting many years after the study group. This happened to me as a result of study groups that I attended from 1973-2008 during my industrial career, and I am still collaborating with students and academics that I met while attending many of these study groups. Long may study groups continue and flourish.

These projects form part of a sustained effort to develop R&D skills within the company. This portfolio of skills is an essential requirement when developing joint ventures. As such, the impact on the company can only be measured over all group activities.

Study group was very useful in providing ideas and areas for further research in an early stage internal research project. This may eventual lead to new products / projects but difficult to say at this early stage.

Broadly useful exercise, providing useful challenge to internal company thinking about an area; the study group demonstrated new avenues to take that would lead to improved efficiency and more impactful internal research and trials.

This led to a T-TRIG project in 2018 and we have started a new business, still early stage, but has the potential to reduce aviation fuel burn by up to 1% and save millions of tonnes of C02 production.

The experience of attending and participating in a study group has contributed to CPD by developing an undertaking of using mathematical analysis to solve engineering problems.

The cost to industry is small, and if the problems are well-posed they get bang for buck.

Had to run with existing model I was developing because Study Group, though offering interesting ideas, did not really offer an alternative that I could implement within budget. This may be because project was presented by three people and requirement had not been specified well enough.

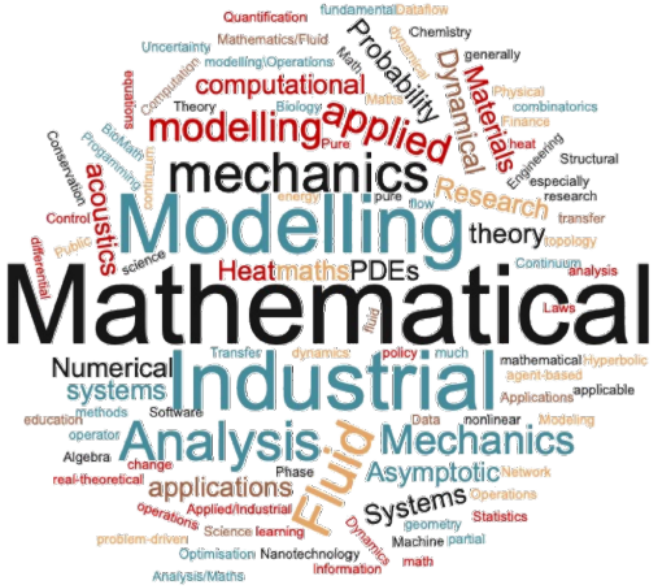
Contact with University of Edinburgh and others opens potential for future development of the Maths Model.

5. Impact on UK researchers

UK research mathematicians from a wide variety of backgrounds attend study groups. In general they are faced in a study group with the challenge of working on new problems, outside of their comfort zone. This automatically means that they learn new mathematical skills, and gain new ideas. The study groups also teach skills associated with team working, collaboration, presentation and working to tight deadlines.

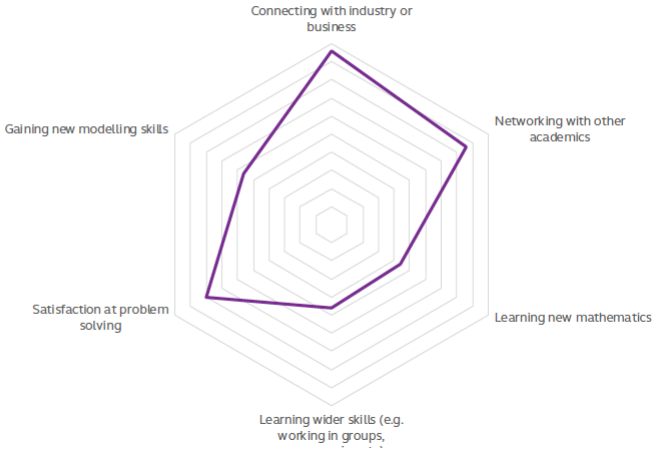
5.1 Who attends and why?

In the survey we conducted, 63 researchers who had attended study groups responded. The research areas of these were very diverse as can be seen below. This is reflected in the diversity of problems that now come to study groups.



Researchers attend for a variety of reasons. From the survey results. It is interesting that as well as the benefits of connecting with industry and academics, many attend for the sheer satisfaction of solving problems. This is not unreasonable given that they are mathematicians. Certainly study groups have a major benefit of stimulating an interest in knowledge exchange through problem solving in both students and experienced academics. All of the academics consulted felt that Study Groups were good value for money.

Why do researchers attend?



5.2 Follow up from study groups

Many of the researchers said that the Study Groups had led directly to follow up projects. The majority of these were PhD projects. Numbers varied, with 50% of the respondents reporting between 1 and 3 such projects, and one listing 10. It was also notable that 50% of the study groups led to direct consultancy projects.

5.3 Impact on mathematics

In the survey of 64 academics, 46 journal papers were easily identified as coming directly from study group problems. These enriched journals as varied as: New. J. Phys.,J. Appl. Math., J. Eng. Math., J. of Colloid & Interface Science, Appl. Phys. Lett., J. Optics, Phys. Fluids, Simulation Modelling Practice & Theory, SIAM Review, SIAM Applied Maths, Phys. Rev. E., J. Nonlin. Mech., Discrete Cont. Dyn-B., Sports Engineering, and topics as varied as: rotor dynamics, crystals, machine learning, vortex dynamics, material science, PDEs, ODEs, network theory, signal processing, inverse problems, environmental science, chemical engineering, rheology, non smooth dynamics, uncertainty quantification, and financial maths.

Whilst it is difficult to asses the long term impact of Study Groups on the development of mathematics, it is certainly true that work on problems arising in them they have led directly to the development of such areas as free boundary problems, non-smooth dynamical systems, exponential asymptotics, and financial mathematics for example.

The reports of the problems examined at Study Groups, which are maintained on the MIIS archive [6] provide a valuable source of teaching examples for both undergraduate and post graduate courses, and contain nearly 700 reports.

5.4 Quotes from the academics

What works well

Don't know about other mechanisms, but the Study Group seems like a perfect opportunity for collaboration

[6] http://www.maths-in-industry.org/miis/view/studygroups/

It's a very good format for making initial contact.

Study groups provide the perfect environment for trying out new ideas with minimal risk and at low cost

The format is excellent, very dense schedule with little distractions. If anything, I'd involve to a greater extent the academics in pitching some challenges to industry as well - not only the other way around.

Study Groups are usually the most productive meetings I attend in terms of the high density of mathematical ideas and results exchanged.

I find the five-day focused format very helpful; it gives enough time to get to grips with a problem and make some mathematical progress (often on multiple fronts with a suitably large team working on the problem), without being too overwhelming. Something that maybe could be improved is to follow the Australian/NZ model of getting a lay summary of the progress made at the study group completed as well as a technical report. I think the current UK systems for getting the technical report finished promptly are useful, but it may be even better for the companies if a two-page lay report is required after a week or two.

In a very short space of time, strong collaborations are often formed. I think it's a very effective use of time.

In my own career, I have found Study Groups perfect vehicles for making contacts in companies or in other branches of academia that would be much harder to set up via a consultancy or other similar mechanism. Sometimes it's not just the work accomplished during a study group but the connections made (both with non-mathematicians and with other mathematicians) that are useful, and I know that such connections and opportunities to work with people have served me very well in my career to date.

Study Groups will form a key part of the industrial engagement strategy of the newly established HetSys CDT (warwick.ac.uk/HetSys).

Giving PhD students the opportunity to experience problems generated by industry.

In theory study groups allow for substantive collaboration between academia and industry, hard to see an alternative to them.

The friendly environment is very conducive to enjoyable collaboration. I think leadership should be encouraged more. I think having KTN people around to encourage engagement is always good; more people like them please!

It is a unique possibility to gain new knowledge about practical applications of mathematics in short time and stimulating atmosphere

The openness of the meeting and the collaborative working that means that ideas are generated swiftly and effectively. Sometimes management of company expectation by the organisers hasn't been great.

I like the flexibility of the working groups and how you can closely work with academics even as a PhD student

Access to industrialists and understanding how they think

For mathematicians, best insight in what real-life problems are; for "society", what is mathematics.

There are two things I liked about the last study group: engagement with other academics and realisation that I lack certain skills, e.g., in programming.

Format is very well adapted for pump-priming future PhD project ideas

The most useful aspect of the study group is the opportunity to network and converse with people and companies that one would not ordinarily meet.

I am happy to learn about what are industries trying to solve currently. Knowing that the proposed solutions help gave a sense of satisfaction and contentment.

(Quote from South Africa) My experience covers study groups in 4 countries. Each does it differently. I think the format of the Australian groups is good (especially each problem having designated moderators so that the information does not get lost and the report gets written), but that is appropriate for Australia. In South Africa, there is a strong educational element, with small numbers of academics and greater numbers of PhD students. Generally I find the format of all to be pretty good – most people can adapt to the local structure.

For me there are few down sides. I use it for networking, getting new problems, improving my own knowledge/modelling and informing my teaching. It is also educational on how to deal with people from Industry who may have a greatly different perspective on why they are there! They introduce Industry who may not otherwise realize the value of Mathematics to its utility, they assist in teaching academics and students to deal with REAL industry and people and provide a source of interesting problems. In most cases, I am sure that Industry leave the study group feeling very positive about the interaction, and in the Australian context a number of problem have been "solved", especially those involving optimization of some process or other, i.e. operations research type problems.

What can be improved

I find the mini study groups organised by KTN much more focused and effective in knowledge exchange than the conventional 5 day ones

We need to find a systematic way for follow ups

Need be more organised, otherwise those well established in a field can take over the study group sessions with little to give to the younger students.

It can feel like 1 week is too short to make real progress on problems.

Opportunities for deep conversations between academics and industry are few and far between. When the value of the time of study group participants on all sides is taken into account, the multiplier effect of the money spent organising study groups is large. That's before the value of the problems that are occasionally solved is taken into account.

6. General comments and recommendations

Most of the academics and industrialists comment very positively on the openness of the study groups, and the effectiveness of friendly and stimulating collaboration over the 5 (or 3) days of the study group.

The variety of the five day workshops means that all those involved are very likely to meet new problems in new areas and to work with new academics and industrialists. One week is considered by some to be the minimum time to make progress on a problem.

The down side of the five day workshops is that they can be too broad for some participants. So it is essential that they are run alongside more focused three day workshops such as those organized by the KTN.

It is certainly the case that more resources need to be put into both the preparation for, and the follow up to, the study groups. Notably the Smith Institute and Innovate UK have been very helpful in doing this, both in identifying problems and companies, and providing 'technology translators' (knowledge exchange staff) to help during with the problems and the reports. As mentioned earlier, the use of such technology translators involves significant extra cost in running the Study Group and following up the work afterwards.

However the Study Groups could benefit from a more formal structure to do this, with a dedicated secretariat and more technology translators. For example, in the Netherlands they have recently used central funding to hire a coordinator who aims to obtain follow-up projects from companies after they have participated in a study group. They also produce "popular" reports suitable for a general audience as well as the technical ones[7], and maintain a national website with the last 20 years of study groups listed.

Certainly systematic follow up is important to make sure that the full benefit of a Study Group, in delivering long lasting relationships between academia and industry, is properly realized. At the moment this is largely left to the organizer of each Study Group, and thus is not as systematic as it could be.

Organising a Study Group is hard work (we speak from experience), made (much) harder in the UK by the need for them to be largely self financing. It is notable that in other countries study groups and their equivalents, get much more central support. Such support would make it much easier for Study Groups to engage with SMEs and Charities, thus broadening the range of problems studied, and crucially, to maximize the chance of follow up (and long term) projects with industry.

[7] https://www.swi-wiskunde.nl/proceedings/

7. Some case studies

We give below some case studies of the outcomes related to recent study group problems. These show both the way that work developed on one problem, and also how these problems led to further, multi faceted, long term activity.

Case Study 1

In 2017 a three day agricultural study group was hosted by the IMI at Bath in close partnership with Innovate UK. One of the problems worked on during this study group was brought by Mondelez and looked at modeling the effects of climate change on cocoa production in Ghana. A report on this was written up. This project was then developed through an LWEC grant and an MSc project and through journal publications. It is now being worked on by a PhD student at Bath. This work was reported in the Gresham Lecture 'How Much Maths Can You Eat' by Chris Budd [8].

At a follow up agricultural study group at the ICMS a similar problem was brought by Tropicana looking at the effects of climate variation on orange production in Florida. Using the earlier report as a basis, substantial progress was made on this problem.

Tropicana is one of the companies owned by PepsiCo. Motivated in part by the success on the problem above, PepsiCo brought two problems to the Bath Study Group in 2018. The follow up to these problems has led to two contracts between PepsiCo and Bath IMI, an MSc project at Bath, an ITT at Bath, a further problem posed by PepsiCo at the Cambridge Study Group and a one-day workshop at the University of Huddersfield, and ongoing collaborations between PepsiCo and many of the academics who attended the Bath Study Group, with a paper in preparation.

A press release led to further publicity of the PepsiCo problem[9]

"Study groups like this one in Bath are a wonderful opportunity to get the best brains working on your problem in a focused collaborative way, getting initial results in just five days.

"Working in this way brings together expertise from a variety of fields with different perspectives on the problem, so the resulting mix is more than just a sum of its parts.

"Over the five days, the delegates take the challenge, redefine the problem and focus on solving it. Study groups like the ESGI can really help build a better product and equipment that will help improve the productivity of processes in the long term.

"I would definitely recommend that other businesses get involved in these workshops."

Stacie Tibos, PepsiCo

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[8] https://www.youtube.com/watch?v=GplDsuHnVXI

[9] https://www.bath.ac.uk/announcements/how-number-crunching-can-optimise-crisp-frying/

Case Study 2

In 2007 Airbus came to the Study Group at Bath and brought the problem of shimmy in the undercarriage of aircraft. One of the PhD students who worked on this problem during the week, so impressed the Airbus team that he was offered (and took) a job with them shortly afterwards. The problem itself was then developed as a research project at the Department of Engineering Mathematics at Bristol. This led to a series of papers, and PhD projects with Airbus, on the application of non-smooth dynamical systems to aircraft undercarriage design. One of the PhD projects at Bristol was undertaken part time by the original poser of the problem from Airbus. This work has also been adopted as an evaluation tool for new designs within Airbus.

"The Study Group provided us with two main outcomes. The immediate outcome was the discovery of the network of people, who were interested in the topic area and were looking to take the study forward. As a result, we setup a 3-year research associateship at the University of Bristol, to extend the study. The by-product is that our relationships, between the University of Bristol and Airbus, are further strengthened."

Sanjiv Sharma, Airbus

Case Study 3

AstraZeneca's involvement in a Study Group looking at Improved Drug Discovery Through Better Machine Learning Models. Ola Engkvist, Associate Director, Discovery Sciences Computational Chemistry R&D brought the challenge to a group of eager mathematical and statistical research scientists at the University of Warwick. The researchers explored novel descriptors to describe the candidate chemical structures, and a comparison between a number of machine learning algorithms.

"It was a great experience and we were exposed to a lot of new and interesting ideas" Dr Engkvist said of the activity directly resulted in two PhD Students being sponsored through the new HetSys CDT.

CJB, MB, MB, JJ, September 2019