Review of EPSRC Mathematical Sciences Taught Course Centres

The Engineering and Physical Sciences Research Council

Final Report

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1. Study Background and Approach

1.1 Background

An international review of UK Mathematical Sciences in 2004 said that while the UK PhD standard remained high, new PhDs from the UK usually have less breadth and experience than their peers from other countries. The review recommended that in order to keep UK PhDs competitive in the jobs market (particularly for academic positions where the jobs market is highly international), students needed to be given the opportunity to develop a greater breadth of knowledge as part of their PhD.

This was already happening at Cambridge University in terms of its Part III programme which is most simply described as a taught masters course in mathematics. Students from Cambridge take it as the last year of a four year course and obtain a BA/M Math. Students from outside Cambridge take it as a one year course and obtain the MASt (Master of Advanced Study) degree in Mathematics. Applicants for a mathematics PhD place at Cambridge are expected to demonstrate a standard of education comparable to the Part III programme.

EPSRC's response to the international review was to issue a call to establish Mathematical Sciences Taught Course Centres (TCCs) for PhD students. The rationale behind TCCs is that it is not practical or economically viable for (most) universities to provide their own taught course programme for PhD students. It makes sense for universities to 'pool' their subject expertise and to work together in delivering a taught course programme. EPSRC agreed to provide £2.9million funding over five years to 'pump-prime' the establishment of TCCs. Thereafter they were expected to be entirely funded by universities. All universities with EPSRC mathematical sciences PhD students (with the exception of Cambridge because of its Part III programme) were expected to participate in the TCC initiative.

In total six TCCs were established:

- The Academy for PhD Training in Statistics (APTS)
- The National Taught Course Centre in Operational Research (NATCOR)
- The London Taught Course Centre (LTCC)
- The Oxford-Led Taught Course Centre (Oxford-Led)
- The Scottish Mathematical Sciences Training Centre (SMSTC)
- Mathematics Access Grid Instruction and Collaboration (MAGIC)

Table 1.1 shows that the TCCs are not homogeneous. There are significant differences in terms of size and method of operation.

Table 1.1: Summary Information on TCCs

	EPSRC Grant (£)	Disciplines Covered	Size of Consortium	Training Delivery Approach
APTS	362,000	Statistics	9 'core' unis + 24 other unis (for 09/10).	Residential
NATCOR	241,000	Operational Research	6 unis	Residential
LTCC	422,847	Maths, Statistics	8 unis	Face-to-face lectures
Oxford-Led	626,232	Maths, Statistics	5 unis	Video conferencing using Access Grid Technology
SMSTC	377,910	Maths, Statistics	7 ''member' unis + 1 'associate' uni	Video conferencing using H.323 technology
MAGIC	853,839	Maths, Statistics	19 unis	Video conferencing using Access Grid Technology

TCCs are now in their fourth year so EPSRC wishes to review how successful the initiative has been in relation to its original aims. It also needs to review the sustainability of the initiative in terms of the future for TCCs after EPSRC funding comes to an end.

1.2 Study Objectives

The purpose of the study is to:

- Evaluate how well the initiative has met its objectives
- Examine the structure, organisation and management of the six TCCs
- Consider the various methods of course delivery and the technologies used
- Provide conclusions and recommendations for EPSRC and TCC Directors to take forward in the future.

The study has not assessed the quality of the training provision provided by the TCCs. The emphasis has been on reviewing the management, operation, impact and future of the TCC initiative.

1.3 Study Approach

The study has involved the following tasks:

- Desk research on TCCs
- Face-to-face consultations with TCC managers, staff and advisors
- A web survey of PhD students who have attended courses at TCCs
- A web survey of academic staff who supervise PhD students
- Research on other PhD TCC models.

Detailed reports from the face-to-face consultations with TCCs are provided in Appendix 1.

Information on the level and nature of response to the two web surveys is provided in Appendix 2. The survey questionnaires are provided in Appendices 3 and 4. In total, completed questionnaire returns were received from 230 PhD students and 158 supervisors. This is a good sample size and provides a robust basis for analysis. However, sample sizes are much smaller for individual TCCs as shown in Figures 1.1 and 1.2. (particularly for LTCC and SMSTC). Thus, although survey data for individual TCCs is presented in the report, it should be interpreted with caution and used only as a general guide of performance.

Figure 1.1 Total Number of Student Respondents by TCC

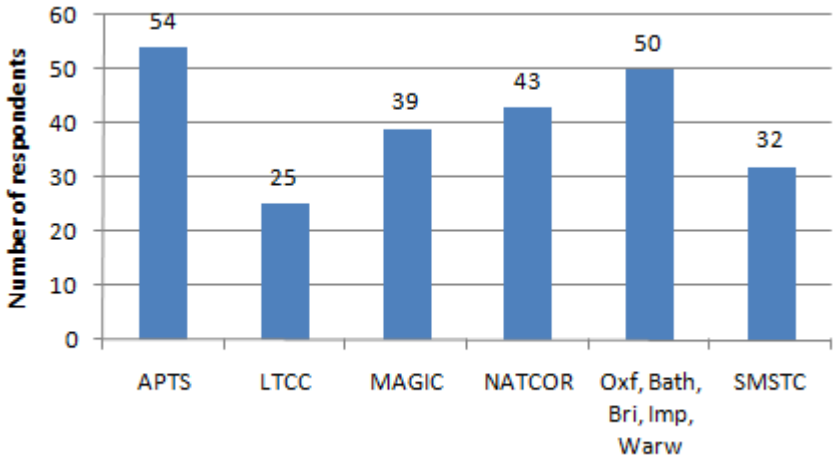
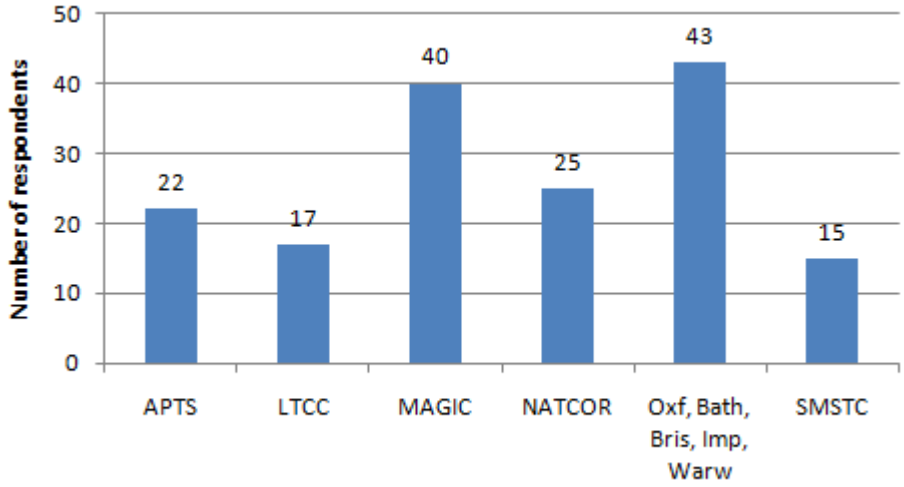


Figure 1.2 Total Number of Supervisor Respondents by TCC



1.4 Report Structure

The rest of this report is structured as follows:

- **Section 2** reviews the organisation and management of TCCs (including delivery methods and technology used).
- **Section 3** evaluates how well the initiative has met its objectives.
- **Section 4** considers the future sustainability of TCCs.
- **Section 5** considers other PhD TCC models.
- **Section 6** presents conclusions and recommendations.

2. The Organisation and Management of TCCs

The key features of TCCs are summarised in a matrix which can be found in Appendix 5. This section highlights key issues and presents information from the surveys relating to these issues.

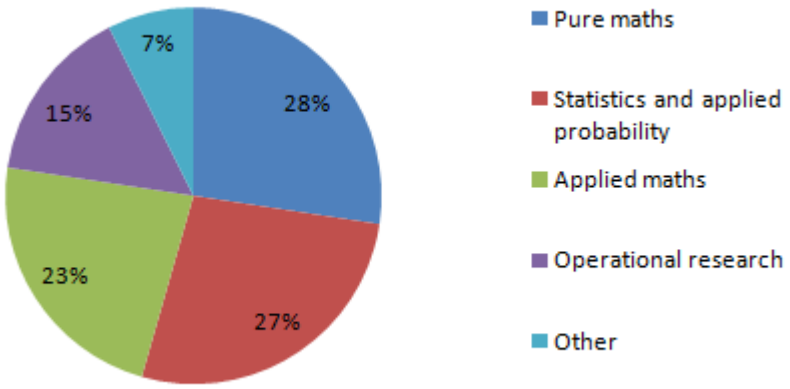
2.1 Overview

The review shows clearly that TCCs are very much a partnership between EPSRC and participating universities. EPSRC investment of £2.9million over 5 years in the TCC initiative is more than matched by £4million investment over 5 years from universities. EPSRC funding has therefore secured significant leverage from the university sector.

The TCCs are being used by Mathematical Sciences PhD students as a whole, not only PhD students funded by EPSRC. The percentage of students using TCCs who are funded by EPSRC ranges from 57% at the Oxford-Led TCC to 37% at NATCOR and SMSTC.

All the TCCs are also open to non-Mathematical Sciences PhD students. Information from the student survey suggests that the majority of students using TCCs are undertaking Mathematical Sciences PhDs but there is a small minority (7%) who are studying other subjects.

Figure 2.1: Discipline of PhD Students Using TCCs



Many TCCs prioritise EPSRC funded PhD students when allocating places on courses in recognition of the financial assistance provided by EPSRC. It will be important to ensure that EPSRC funded PhD students continue to be prioritised after EPSRC funding ends.

TCCs generally do not charge PhD students to attend courses. The only exceptions are as follows:

– APTS charges EPSRC PhD students a £120 registration fee per APTS week. Non EPSRC PhD students also pay a £120 registration fee and have to pay for travel and accommodation costs as well (these are reimbursed for EPSRC students).

- NATCOR charges EPSRC PhD students a £70 registration fee per NATCOR week. Non EPSRC PhD students also pay a £70 registration fee and have to pay for travel and accommodation costs as well (these are reimbursed for EPSRC students).
- SMSTC charges students from outside the mathematical/statistical departments of the member universities £100/stream. There is also a one-off £250 registration fee for non-member university video-conference sites used by students.

The average number of PhD students using TCCs is 748 per annum. . The average number of EPSRC funded PhD students using TCCs cannot be estimated since this information is not collected by the MAGIC TCC. Excluding MAGIC, the average number of EPSRC funded PhD students using TCCs is 234 per annum.

The TCCs focus on different types of students:

- The **APTS** residential programme is focussed on **first year PhD students**. There are 8 modules which are delivered through 4 (individual) weeks of residential training. Each module comprises 10.5 hours lectures.
- The **NATCOR** residential programme is similar to APTS. There are 5 modules delivered through 5 (individual) weeks of residential training). Each module comprises 20 hours lectures. The main difference with APTS is that the training is delivered over a two year cycle and therefore focuses on **first and second year PhD Students**.
- The **SMSTC** delivers 8 modules ('streams') per annum. Each module comprises 20 x 2 hour lectures. The focus is on **first year PhD students** but open to other PhD students as well.
- The **MAGIC TCC** provides circa 30 courses per annum. These are a mix of 10 and 20 hour courses. The focus is on **first year PhD students** but open to other PhD students as well.
- The **LTCC** provides 15 basic courses per annum focussed on first year students and 15 advanced courses per annum focussed on second and third year students (30 courses in total). Each course comprises 10 hours lectures. **Thus, the focus is on all PhD students**.
- The **Oxford-Led TCC** provides 25 courses per annum. Each course comprises 20 hours lectures. **The focus is on all PhD students**.

2.2 Organisation of Training

2.2.1 Requirement for PhD Students to Undertake Taught Course Training

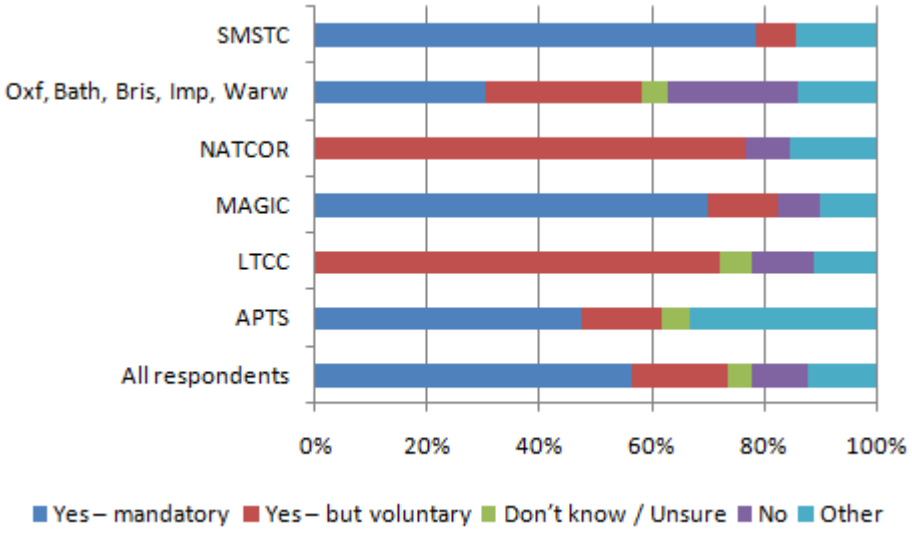
There is no 'mandatory' TCC requirement for PhD students at participating universities to undertake a specified amount of taught course training. However in the case of **SMSTC**, there is a strong expectation at TCC level that first year PhD students in participating universities will complete 3 streams (120 hours) of taught course provision. Exceptions are made for APTS participating students and highly qualified PhD students such as Masters' graduates and some overseas students. In such cases approval can be granted for taking one or two streams only. The **MAGIC** TCC also has a strong expectation that first year PhD students at participating universities should complete 80-100 hours of taught course training.

Otherwise, the requirements for taught course training tend to be specified at the level of university departments (bottom-up approach) rather than TCCs (top-down approach). Some

departments have mandatory requirements for taught course training. For example, the Mathematics Department at Bath University requires all PhD students to undertake (and pass) six taught courses over the first three semesters of their PhD. In other departments, participation in taught course training is generally encouraged (and there may be guidance on this) but it is not mandatory.

As part of the survey, supervisors were asked whether there was a requirement in their university department for PhD students to undertake taught course training and if so, whether this was mandatory or voluntary. The findings from the supervisor survey show clearly that there is an expectation that PhD students will undertake taught course training in the majority of university departments. However, this only tends to be a mandatory requirement in university departments that are part of the SMSTC and MAGIC consortia (although the figure is also quite high for APTS).

Figure 2.2: Is There a Requirement at your University Department for PhD Students to Undertake Taught Course Training? (Supervisor Survey)



An issue for EPSRC / TCCs to consider is whether there should be a common TCC-wide requirement for taught course provision which is largely mandatory (as for SMSTC) or whether individual departments should set their own requirements for taught course provision which tends to be the position at the moment. If the bottom-up approach continues to prevail, EPSRC / TCCs may also wish to consider whether all departments should be expected to specify minimum taught course training requirements which are mandatory.

2.2.2 Organisation of the TCC Curriculum

It is clear that there is significant variation in the number and length of training courses across the TCCs, and in TCC attitudes to changing the curriculum from year-to-year. Table 2.1 summarises the position.

Table 2.1: Overview of the Curriculum at TCCs

	Number of Courses	Length of Courses[1]	Annual Curriculum Changes[2]
APTS	Low – core programme	Short	No
NATCOR	Low – core programme	Medium	No
SMSTC	Low – core programme	Long	No
MAGIC	High	Short	Yes
LTCC	High	Short	Yes
Oxford-Led	High	Medium	Yes

[1]Short is circa 10 hours or less per course, medium is circa 20 hours per course, long is 30+ hours per course

[2] This means significant changes to the course programme from year-to-year. It excludes minor course revision / updating which will happen as a matter of course at most TCCs.

Three TCCs operate a simple model where there is a relatively small number of core courses that are fixed from year-to-year (APTS, NATCOR and SMSTC). For example, the fixed programme of courses at SMSTC is shown in Table 2.2:

Table 2.2: SMSTC – Taught Course 'Streams'

Discipline	Stream
Pure	Algebra Geometry and Topology Pure Analysis
Applied	Applied Analysis & PDEs Applied Mathematical Methods Mathematical Models
Statistics	Probability Statistics

Three TCCs operate a potentially more complicated model where 25-30 different courses are provided each year. In addition, there are significant changes to the curriculum each year with many courses being dropped and new courses being introduced to take their place (MAGIC, LTCC and the Oxford-Led TCC). However, it must be stressed that some of these TCCs will be scaling back the introduction of new courses in the future and relying more on their 'back catalogue' of courses.

It is not possible to say definitively what is the best model. The evidence from the survey is that the breadth and range of taught course provision is rated highly for some TCCs that offer a relatively small number of core courses (for example APTS and NATCOR) and less highly at others that offer a greater number of courses (for example LTCC and MAGIC). This is an issue for TCCs to consider, but not one on which any specific recommendations can be made, except that a core fixed programme should have the advantage of being simpler and less resource intensive to operate.

Figure 2.3: Student Views on Breadth and Range of Training at TCCs

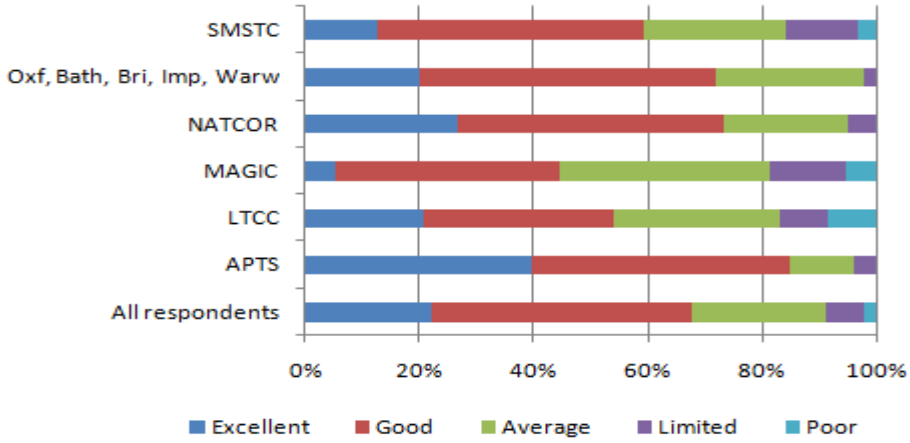
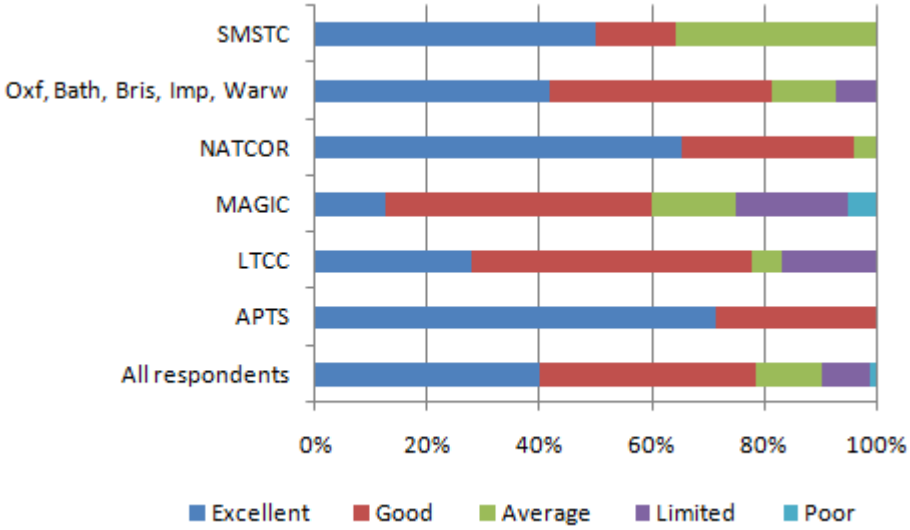


Figure 2.4: Supervisor Views on Breadth and Range of Training at TCCs



There is also variation in the length of courses provided across TCCs. The majority of courses are between 10-20 hours. SMSTC stands out as providing the longest courses at circa 40 hours each. However, there is no evidence from the survey that student and supervisor views on the value of TCC training is linked to the length of training courses.

2.2.3 The Method of Delivering Training at TCCs

As highlighted earlier, the TCCs use different approaches for delivering training. Students and supervisors were asked how they rated the effectiveness of different methods for delivering taught course training. If they had no experience of some delivery methods they were asked to specify that it was not applicable to them. Therefore, the survey findings represent the views of people who have actual experience of the different delivery methods and they show

clearly that 'traditional' forms of training such as face-to-face lectures and residential courses are preferred.

Figure 2.5: Student Views on Effectiveness of Methods for Delivering Training at TCCs

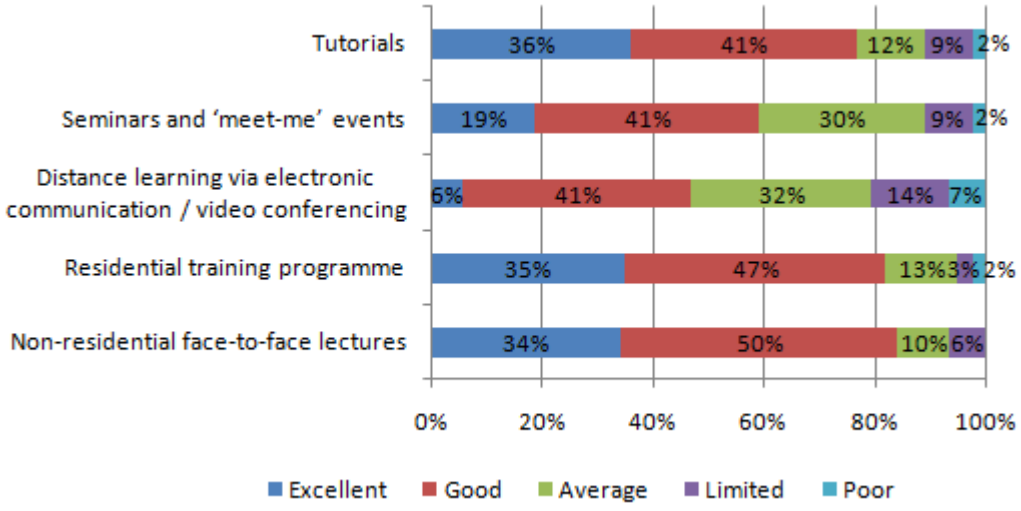
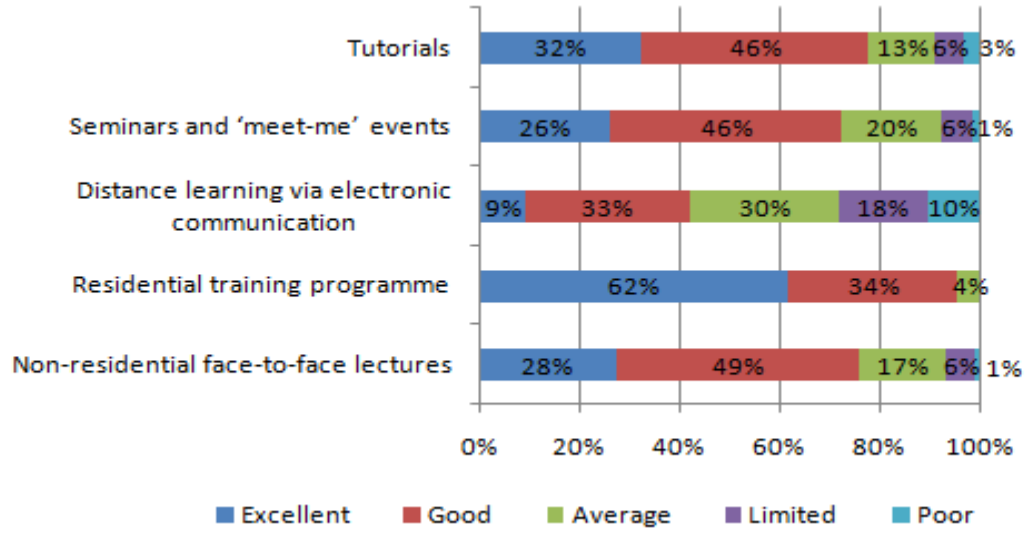
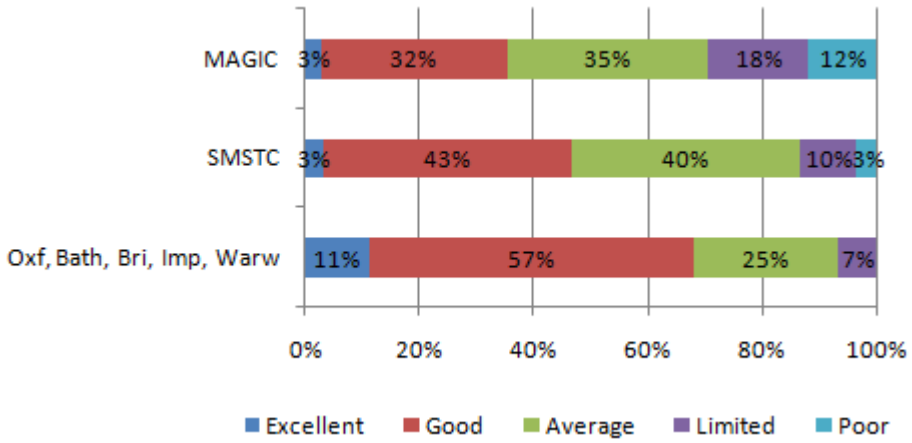


Figure 2.6: Supervisor Views on Effectiveness of Methods for Delivering Training at TCCs



The proportion of students and supervisors providing 'excellent' and 'good' ratings for distance learning via electronic communication is considerably lower than for other delivery methods. However, when the student data on this is analysed by the individual TCCs that use this delivery method, it shows that students rate the distance learning technology used by the Oxford-Led TCC quite highly (nearly achieving the levels for traditional training delivery). Conversely, the proportion of students rating the distance learning technology used by MAGIC as 'excellent' or 'good' is low with SMSTC in-between.

Figure 2.7: Student Views on Effectiveness of Distance Learning Via Electronic Communication



We do not have any hard data to help explain this variation in the effectiveness of video-conference (VC) delivery. Possible factors that should be investigated further include:

- The more institutions in the TCC network, the more difficult it is to maintain the quality of taught course delivery. Oxford-Led has 5 participating universities, SMSTC 8 and MAGIC 19
- The robustness of the technology and VC centres. Anecdotally, the impression is that MAGIC has suffered more that other TCCs using this technology, particularly in terms of audio quality. Also, the Oxford-Led TCC has invested carefully in the quality of its sound-proofing and the quality of its teaching environments
- Delivery methods could vary between TCCs – for example SMSTC operates 2 hour courses, whereas others operate 1 hour courses, which may be more suitable for VC delivery.

Over and above these possible explanatory factors, there may be statistical error given the relatively small sample sizes at the individual TCC level. .

2.2.4 The Availability and Effectiveness of Course Materials

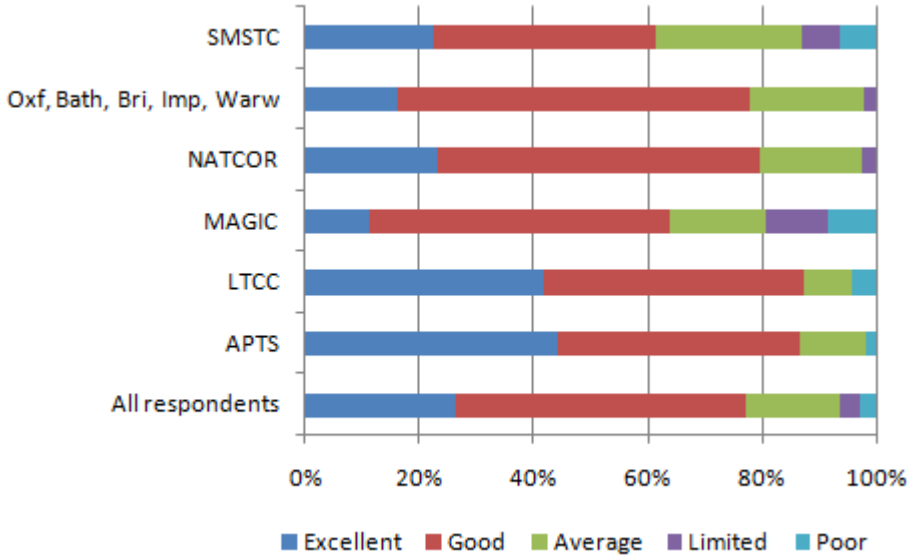
Taught course material should be considered a 'public good' for the benefit of students not only in the UK but overseas. Some TCCs operate a restrictive policy with regard to access to, and the dissemination of, their taught course material. Given the public sector funding from EPSRC to support the development of course material, it should be a requirement of TCCs to make their material available publicly for the wider benefit of society.

At other TCCs, lecture notes and presentation material are available through TCC websites. However, the position can be a bit patchy with course materials available for some, but not all, courses. There is also no promotion of this information resource. Clearly, TCCs need to move to a position where course materials for all current and past courses (where appropriate) are available on their website and promoted more widely by universities and EPSRC.

Students were asked about their views on the effectiveness of course materials. Overall, 78% of respondents said they were either 'excellent' or 'good' and only a tiny proportion said they

were 'limited' or 'poor'. Thus, the only issue here is ensuring good availability of course materials.

Figure 2.8: Student Views on the Effectiveness of Course Materials Used by TCCs



2.2.5 Formal Course Assessment in TCCs

Course assessment encourages student engagement and provides tangible evidence of knowledge acquisition through the taught course programme. There is considerable variation across the TCCs in their approach to course assessment.

The **SMSTC** stands out as the only TCC where formal assessment is mandatory.

SMSTC – Profile of Course Assessment

The formal responsibility for assignments and marking lies with each stream leader, but in practice this is usually delegated to the person/people teaching that part of the stream. Each stream sets 2, 3 or 4 assignments, and the lecturer(s) of the relevant bit of the course will select exercise questions for that assignment. In some cases all the questions are compulsory, and in others the students are given a larger number of problems and told to attempt a specific number of them and submit these. The lecturer(s) then grade the students' attempts, record the marks and give the stream leader a list of marks for that assignment. At the end of the session the stream leader will combine all the assignment marks for an individual student and use that to produce a grade for the stream. Grades of A, B, C and U for unclassified are given. The expectation is that students achieve A or B grades.

In many cases it will be a straight sum of the marks, and the overall average will then determine the grade, but this is not always the case. It is up to the stream leader to come up with a sensible strategy for their stream, and to ensure that the students know what is expected of them and how they can achieve a high grade. SMSTC does not impose an overall way to do it on all the streams, because different types of assessment are appropriate

for the different subject areas. For example, some of the assignment questions for the "methods" stream (and possibly also for statistics) involve computer programming, whereas for other topics all the questions could be calculations / proofs, or even a survey essay. However, the parameters are set by the stream, and not by the student or supervisor.

The grades which students are awarded for their streams are taken into account in the review of student performance at the end of year 1.

Assessment is also undertaken by most students attending **NATCOR** since it is built in to the end of each residential course. However, it is more informal than at SMSTC with students given a task to run through as a group in conjunction with the lecturer, as a means of reinforcing their understanding of what they have learnt on the course.

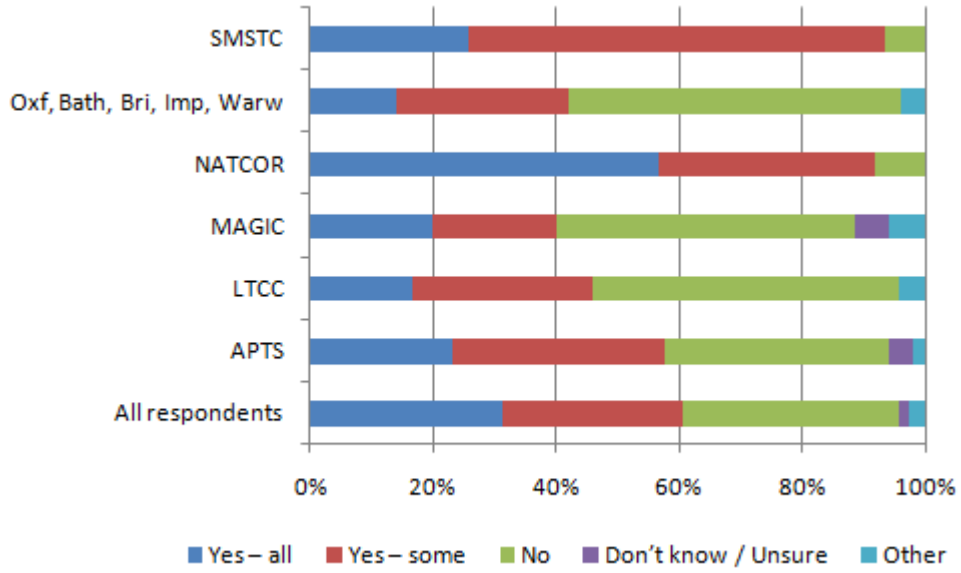
All the other TCCs have measures in place for course assessment but it is up to university departments or PhD students themselves to undertake the assessment:

- **APTS**: The Lecturer provides assessment material at the end of residential courses but it is up to students and their departments to decide whether, and how to use them.
- **MAGIC:** This is similar to APTS where the lecturer provides assessment material but responsibility for undertaking any assessment is devolved to the individual university departments.
- **LTCC:** The approach is slightly different in that the lecturer provides assessment material and is also responsible for undertaking the assessment However, assessment is not mandatory so it only tends to be undertaken by students where this is a requirement specified by their university department. Approximately a third of assessments were completed in 2009/10. The process is that the lecturer (on basic courses only) provides a take-home paper which students download and return to the lecturer electronically. Then the paper is assessed and graded by the lecturer.
- **Oxford-Led TCC:** This is similar to LTCC. The lecturer provides assessment material which typically takes the form of problem sheets, mini projects or oral examination, and is responsible for undertaking the assessment. However as for LTCC, assessment is not mandatory so students tend to participate in the assessment process to meet requirements specified by their department. Where students do not have specific requirements to meet or are doing extra courses on top of these requirements, they may not engage in the assessment process.

Students were asked about the extent to which there was assessment of courses they had undertaken at TCCs. The findings mirror the position described above. The vast majority of students who have attended courses at SMSTC and NATCOR said that all, or some, of the courses they had undertaken had been assessed[1]. The level of course assessment is much lower at the other TCCs.

[1] The reason why most students at SMSTC report that some, not all, courses are assessed is not known. However, it may be due to the fact that the 'stream' is so extensive – covering 40 hours – and therefore the assessment exercises only cover a proportion of the stream syllabus.

Figure 2.9: Whether Students Have Been Assessed on Courses Undertaken at TCCs



An issue for EPSRC and TCCs is whether there should be a mandatory requirement for students to engage in some form of assessment for every course they attend, or at least for a minimum number of courses. It may not be appropriate for PhD students to sit formal exams on taught courses, but some form of assessment is considered to represent good practice in that it provides tangible evidence of knowledge acquisition through the taught course programme (in which both EPSRC and universities are investing considerable resources).

The other key benefit is that a process of formal assessment encourages students to take the courses seriously, which improves attendance, course completion and study/revision which supports the learning process.

2.3 Quality of TCC Management

In reviewing the quality of TCC management, the brief requires three key questions to be addressed:

- Are the management and administrative arrangements appropriate?
- Are the TCCs operating efficiently and effectively?
- Do the TCCs collaborate and share good practice?

Each of these questions is considered below drawing upon the evidence from the field visits, documentary evidence and the supervisor survey.

2.3.1 Management & Administration Arrangements

Table 2.3 summarises the key management and administrative arrangements across the six TCCs.

Structure – most of the TCCs have recognised the importance of having both a governance function drawing upon external academics in addition to the executive function to oversee the effective management of taught course development and delivery. However, the management structure adopted by the TCCs varies:

- *Single 'Committee'* – SMSTC and Oxford-Led have gone for a single tier of management, which combines both roles in a single body. They support this model on the basis of simplicity, minimisation of bureaucracy and speed of decision-making.
- *Two Tier 'Committee'* – APTS, NATCOR and LTCC have adopted an overarching Advisory Board and a separate Management/Executive committee. They are also very supportive of this system – it works well for their model and there is no desire to change the structure.
- *Three Tier 'Committee'* – MAGIC has operated for four years with the two tier model, but in early 2010 it was agreed that a new approach to the review and approval of courses on an annual basis would have to be initiated. They have therefore formed a separate Programme Committee which reports into their Academic Steering Committee.

We believe the management structures are appropriate – be they single or two tier and are fit for purpose. The evolution of MAGIC's three tier model reflects the difficulty of managing a 19 university network and combining this with an annual course review process.

Management – the number of Directors per TCC varies from one to two. The role of the 'Director' has been critical in leading the development, operation and process of continuous improvement for each of the TCCs. Our review has identified the following:

Table 2.3 – Summary of TCC Management and Administrative Arrangements

Issue	MAGIC	SMSTC	NATCOR	APTS	Oxford-Led	LTCC
Structure	• Scientific Advisory Committee (SAC) • Academic Steering Committee • Programme Committee	• Academic Steering & Management Committee	• Advisory Board • Executive Committee	• Advisory Committee • Executive Committee	• Mangement Committee	• External Advisory Board • Management Committee
No. of 'Committees'	3	1	2	2	1	2
Management	2 x Principal Investigators (Manchester & Sheffield)	1 Director (Edinburgh) 1 Deputy Director (Strathclyde)	1 Director (Lancaster)	2 x Co-Directors (Warwick)	1 Director (Oxford)	1 Director (UCL)
Administrative support	No admin support (except minute taking for SAC)	Administrator (0.3 FTE) Support from ICMS	P/T Administrator	Programme Manager Administrator	Administrator (0.2 FTE)	Administrator (0.6 FTE)
Technical support	• Web site – Principal Investigator Sheffield • VC – Access Grid Support Centre (Manchester)	• Web site – ICMS • VC – Heriot-Watt	• Web site – technical support from Lancaster	• Web site – technical support from Warwick	• Technical Support Officer (0.4 FTE) plus staff at other nodes.	• Web site – responsibility of Administrator

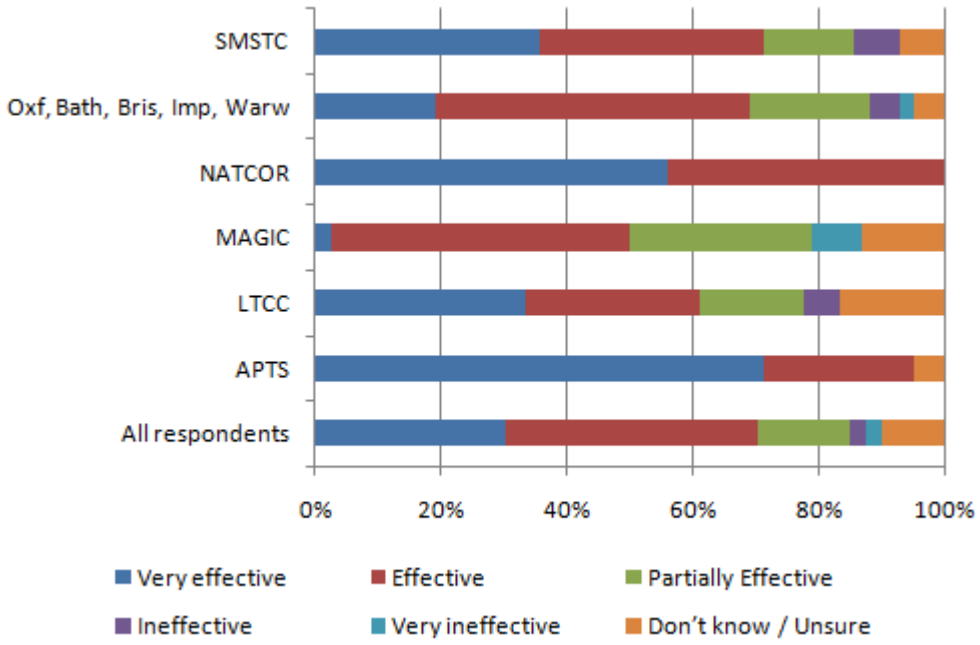
- *Commitment* – the substantial time commitment provided by the Directors and key supporting staff in each of the TCCs. Supporting staff include Deputy Director role, other academic staff taking the lead in web site development, supporting VC roll-out and operation, leadership of course development, etc. All TCCs demonstrated a real engagement by management with the TCC concept and have supported its development and implementation

- *Process* – all of the TCCs had very clear and documented guidance for how their TCC should be structured, the remit of committees, representation, chairing, frequency of meetings, minute taking, etc.

- *Transparency* – the minutes of advisory and executive committees have been comprehensively recorded.

Overall, we were impressed with management commitment and performance. This view is supported by the strong survey finding from supervisors: see Figure 2.10. Seventy per cent of respondents rated the effectiveness of management arrangements across the TCCs as either 'very effective' or 'effective'. Only 5% rated this to be 'ineffective' or 'very ineffective'.

Figure 2.10: Supervisor Views on Effectiveness of Management Arrangements at TCCs



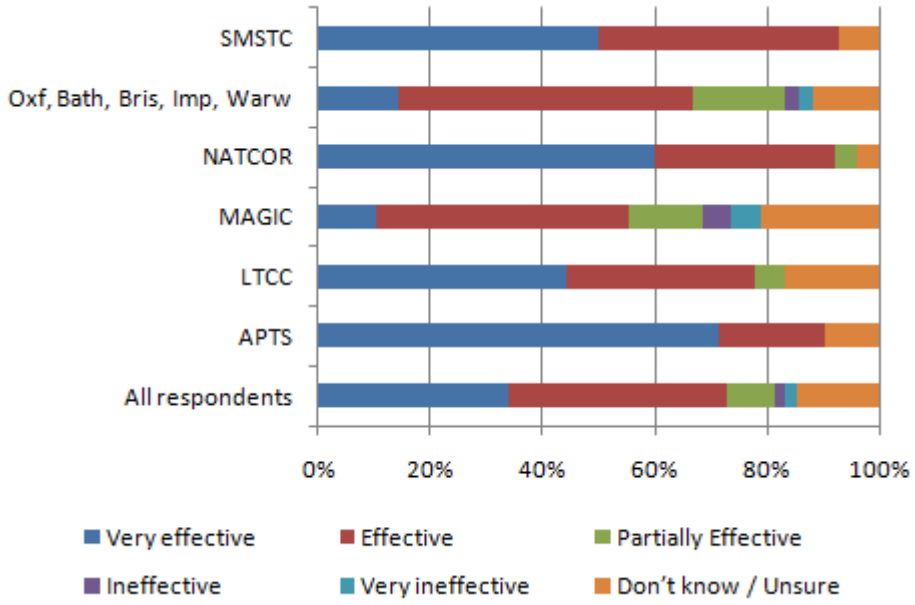
However, at the individual TCC level there was a spread in perceived performance, with NATCOR at 100% very effective/effective and MAGIC at 50%. It is interesting to note that the two residential TCCs come out with the strongest management rating and we believe this relates to the greater difficulty in managing delivery spread across multiple sites using virtual VC technology as opposed to the simpler blocks of residential provision on a single site.

Administrative Support – with the exception of MAGIC, all TCCs have engaged part-time administrative support, varying from 0.2 – 0.6 FTE. For some this has also been supplemented with additional support:

- *SMSTC* – they have benefited from the support infrastructure provided by the International Centre for Mathematical Sciences (ICMS) based at the University of Edinburgh. The administrative and technical skills of their six person team have benefited SMSTC, especially during the earlier set-up period;
- *APTS* – they employ a Programme Manager in addition to an Administrator.

The impression we have is that the administration system runs effectively across all TCCs, with > 70% of supervisors rating the standard of administration as either 'very effective' or 'effective': see Figure 2.11.

Figure 2.11: Supervisor Views on Standard of Administration at TCCs



MAGIC has the lowest rating of the TCCs at < 60%. We believe this to be the consequence of:

- Not having a dedicated administrative resource with the result that the two Principal Investigators have had to take on a large amount of basic administrative work which would more cost-effectively be delivered by an administrative resource.
- The difficulty of having to administer a service across 19 institutions.
- A split management and administrative function spanning Manchester and Sheffield Universities.

Technical Support – all of the TCCs have committed staff time and resources to providing technical support, which covers web site development and management; and for the three TCCs operating a distance learning model, the development and operation of VC technology. The way in which this support has been provided varies widely:

- The Access Grid Technology Centre which supports the MAGIC AG network
- The commitment of the Principal Investigator at Sheffield who has led the development of the MAGIC web site
- The Technical Support Officer (0.4 FTE) who is engaged by Oxford University for the Oxford-Led TCC along with technical staff at the other nodes.

The evidence from our review of TCC web sites and consultee feedback on the operation of the VC technology suggests that this support has been effective in the delivery of the taught courses. However, there is some evidence of problems with the robustness of VC technology, particularly across the MAGIC network, but this is not to do with technical support per se, but rather the AG system and technology being used across a 19 site network. See further discussion of this point relating to Figure 2.7 and the views of students on the effectiveness of VC technology.

Conclusion – our assessment is that, in general, management and administrative arrangements are effective.

2.3.2 TCC Collaboration

There has been limited collaboration between the TCCs during both the development and operational phases. In particular, one would have expected extensive collaborative working between the pure and applied mathematics focused TCCs: SMSTC, MAGIC, LTCC and Oxford-Led (APTS and NATCOR are more stand alone models). We find this surprising in that one would expect the needs of mathematical PhD students would be comparable irrespective of their geography or institution. We are aware of TCCs inviting representatives from other TCCs to sit on their Advisory Board/Committee – but that is about the extent of it. The only formal meeting between TCC Directors was initiated by EPSRC in Nov 2009.

To conclude, we believe there is scope to share good practice which is not happening at present. This could facilitate knowledge exchange in a number of areas such as:

- Sharing course material
- Developing a set of published material on behalf of the TCC UK network
- Learning about the technical pitfalls from the VC technology and potential solutions
- Improving governance and management
- Exploiting the benefits of PhD student conferences more widely across the UK
- How to exploit the VC infrastructure more effectively across the UK for the benefit of mathematical sciences more widely
- Creation of a TCC portal which links the six TCC web sites and allows students more effective navigation across the different taught course offers.

To help stimulate TCC collaboration and the sharing of good practice, the following suggestions are put forward for consideration:

- Creation of a forum for the Directors of TCCs to meet either six monthly or annually
- The establishment of task groups to focus on sharing good practice in specific areas where economies of scale and learning benefits could be derived (see ideas listed above).

Such mechanisms would also allow TCCs to network on priorities for the future and to challenge the status quo. For example, what should the fundamental outcomes of taught course provision be? In particular, what should it be about broadening mathematical education per se, or have more applied goals in terms of improved linkages with industry, improved career outcomes inside and outside academia, etc.

2.4 Comparative Costs Across TCCs

It is interesting to compare the unit cost per student user and per training hour received across the TCCs. This is based on the total costs of TCCs using estimates that have been provided by universities of their contributions to TCCs. These are only estimates and the data below should be used only as an approximate guide of unit costs since it could be influenced by the way in which universities have estimated their costs. For example, the leverage rate for APTS and NATCOR is much lower (1:0.2 and 1:0.3 respectively) than it is for the other TCCs where it is between 1:1 to 1:3).

Table 2.2: Unit Costs of Training Across TCCs

	Leverage Ratio of EPSRC to University Funding for TCC	Unit Cost Per User (£)	Unit Cost Per Training Hour Received (£)
APTS	1:0.2	1162	19
NATCOR	1:0.3	737	12
LTCC	1:1	1660	58
Oxford-Led TCC	1:1	2562	68
SMSTC	1:3	4100	68
MAGIC	1:2	4107	68

- There is significant variation in unit cost per user. Possible reasons for this are Unit cost per user will be influenced by the length of training courses provided. We would expect unit costs per user to be higher at SMSTC than at NATCOR because a greater quantity of training per user is generally being provided (approximately 120 hours versus 80 hours per student).

A better measure of the relative cost effectiveness of TCCs is the unit cost per training hour received. This shows a remarkable similarity in unit cost across the four non-residential TCCs. LTCC has a slightly lower cost than the other, presumably because it has not had to invest in distance learning technology which has been a significant cost for the other TCCs. The low unit costs at APTS and NATCOR could relate to the relative simplicity of the delivery model compared to other TCCs and / or the lower level of university funding compared to other TCCs.

3. Is the TCC Initiative Achieving its Objectives?

Key questions addressed in this section are:

- Has the TCC Initiative helped PhD students move towards broader mathematical knowledge?
- Will the TCC Initiative help PhD students to be more competitive in the international academic jobs market?
- Is the TCC Initiative of value to PhD students in helping with career decisions and direction?
- What are the views of students and supervisors on the overall value of undertaking taught courses as part of PhD training?
- Is there a case for developing some form of national standard for broadening training?
- Is there scope to extend the TCC Initiative either in mathematics or more generic skills?

3.1 Has the TCC Initiative Helped PhD Students Move Towards Broader Mathematical Knowledge?

There is no agreed definition of what is meant by 'broadening mathematical knowledge' for the TCC Initiative. PhD students could be undertaking taught courses for three reasons:

- Broadening knowledge outside their discipline. For example, a pure mathematician learning about operational research.
- Broadening knowledge within their discipline but outside the sub-area of their PhD research. For example, a pure mathematician learning about other aspects of the discipline not related directly to their PhD research.
- Acquiring knowledge directly relevant to their PhD research.

As part of the survey, students who had undertaken courses at TCCs were asked to describe the taught courses they had undertaken as part of their PhD (using the framework above). It is clear from Figure 3.1 that the vast majority of students consider their course to have been about broadening knowledge within their discipline but outside the sub-area of their PhD research. This is also the view of supervisors and of TCC staff consulted for the study.

Students were also asked whether they expected to have a broader mathematical knowledge base outside their PhD research through attending courses at TCCs. As the majority of students said their courses had been mainly about broadening knowledge outside the area of their PhD research, it is not surprising that nearly all students said they expected to have a broader mathematical knowledge base beyond the area of their PhD research as a result of attending courses at TCCs (see Figure 3.2).

Figure 3.1: Best Description of the Type of Courses Attended at TCCs (Student Survey)

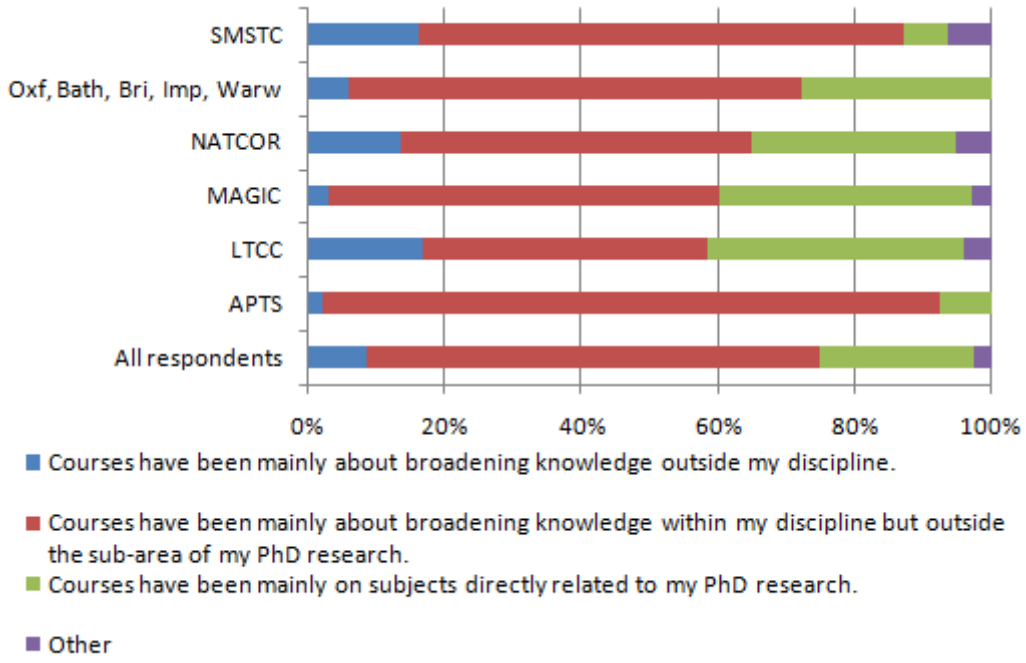
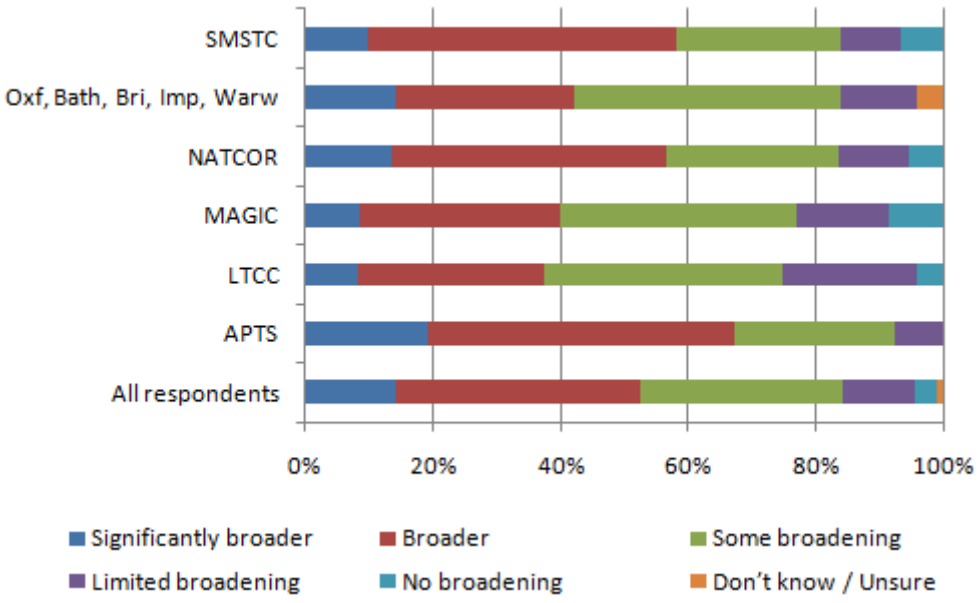


Figure 3.2: Whether Students Expect to have a Broader Mathematical Knowledge Base Outside Their PhD Research Area Through Attending Courses at TCCs



Thus, if 'broadening mathematical knowledge' is defined as increasing knowledge of a discipline outside a student's PhD area, the TCC initiative is clearly achieving its objective.

If EPSRC believes the objectives of the initiative should be broader than this in terms of increasing knowledge of other discipline areas within mathematical sciences or increasing more generic skills, then these need to be communicated and discussed with TCCs.

3.2 Will the TCC Initiative Help PhD Students to be More Competitive in the International Academic Jobs Market?

One of reasons for establishing the TCC Initiative was to help UK PhD students to compete on a more level playing field with overseas PhD students for academic jobs. This was in recognition that overseas students generally spend more time working on a PhD than students in the UK.

It is too early to fully assess the impact of TCCs in achieving this goal. The first students to participate in TCCs are now generally at the end of the third year of their PhD and have not yet entered the jobs market. However, students who have undertaken courses at TCCs should have a good appreciation of how this training is likely to help with securing employment and achieving other career goals in the future. Thus as part of the survey, students were asked how they thought taught course provision would impact on different aspects of their career development in the future. Supervisors were also asked the same question and the findings are shown in Figures 3.3 and 3.4.

Figure 3.3: Impact of TCC Initiative on PhD Students (Student Survey)

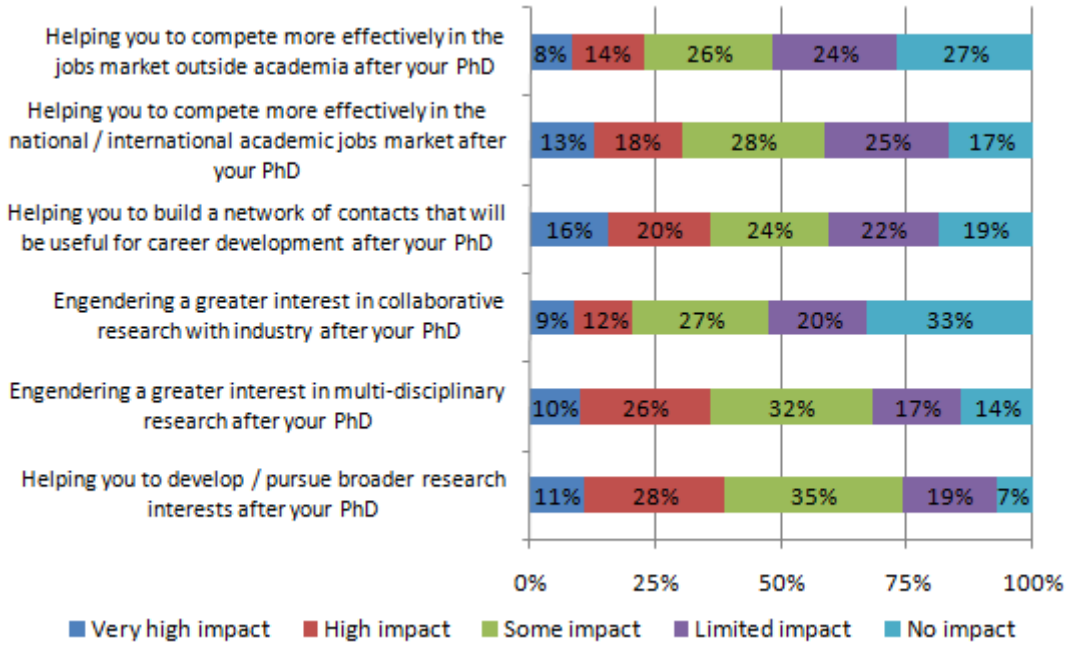
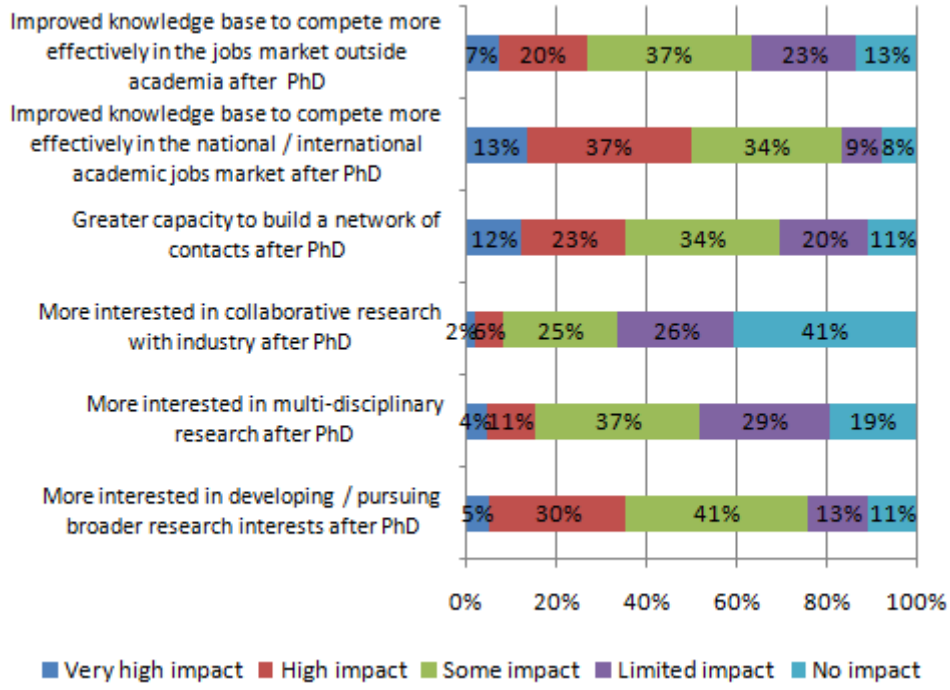


Figure 3.4: Impact of TCC Initiative on PhD Students (Supervisor Survey)



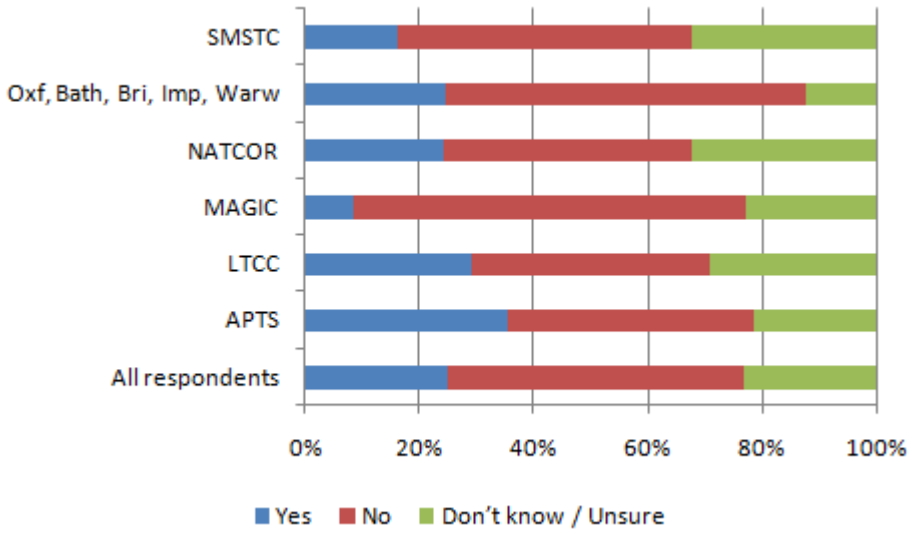
55% of students said taught course provision would have a positive impact in helping them to compete more effectively in the international academic jobs market in the future (28% said the impact was high or very high). Supervisors were even more positive about this. 84% of supervisors said taught course provision would have a positive impact in helping PhD students to compete more effectively in the international academic jobs market in the future (50% said the impact was high or very high). This is an indication of the strong support for TCCs among the mathematical sciences academic community which is picked up again later in the report.

Although it is not possible to definitively assess the impact of the TCC Initiative on helping PhD students to be more competitive in the international academic jobs market, there is evidence that that the TCC Initiative should have a positive impact on achieving this goal.

3.3 Is the TCC Initiative of Value to PhD students in Helping with Career Decisions and Direction?

Figure 3.5 shows that only a small proportion of students believe that participation in the TCC Initiative has broadened their career options. This is not surprising since the courses undertaken by students focus on broadening mathematical knowledge within their discipline, rather than broadening knowledge of other mathematical disciplines. They also focus on broadening *mathematical knowledge* rather than more generic knowledge such as using a mathematical sciences PhD outside academia.

Figure 3.5: Whether Taught Courses Have Broadened the Range of Career Options Students will Consider in the Future



It is, however, clear from Figures 3.3 and 3.4 that taught courses are expected to have a positive impact on the career development of PhD students in other ways:

- About 75% of students said taught course provision would have a positive impact on making them more interested in **multi-disciplinary research** and in pursuing **broader research interests** at the end of their PhD. This is a positive outcome since it is acknowledged that scientific challenges in the future will require more multi-disciplinary working. Supervisors are not quite as positive about this but again around 75% said taught course provision would have at least some impact on encouraging PhD students to pursue broader research interests at the end of their PhD.

- About 70% of students said taught course provision would have a positive impact in helping them to build a good network of contacts after their PhD, which is important for career development.

However, there is limited evidence that taught course provision encourages PhD students to make or develop links with industry. This is not surprising given that this is not the focus of the type of training that is provided at TCCs currently.

In summary, there is evidence that the TCC initiative will encourage PhD students to pursue broader research interests at the end of their PhD. However, there is limited evidence that the TCC initiative will have an impact on broadening career options and links with employers outside academia. This is not seen as being a core part of the remit of TCCs currently. If EPSRC sees this as an important part of the TCC Initiative, then this needs to be communicated and discussed with TCCs.

3.4 What are the Views of Students and Supervisors on the Overall Value of Undertaking Taught Courses as Part of PhD Training?

The findings reported to date would suggest that the majority of students and supervisors value taught courses as part of PhD training. The survey provides evidence of this as shown in Figures 3.6 and 3.7. Overall, 92% of students said there was value in undertaking taught courses and 60% said there was high or very high value from this (students attending courses as APTS and NATCOR were most positive). A similar proportion of supervisors said there was value in undertaking taught courses and 67% said there was high or very high value from this (the survey findings are similar across all TCCs on this except MAGIC where they are a bit lower).

Figure 3.6: Student Views on Value of Attending Taught Courses at TCCs

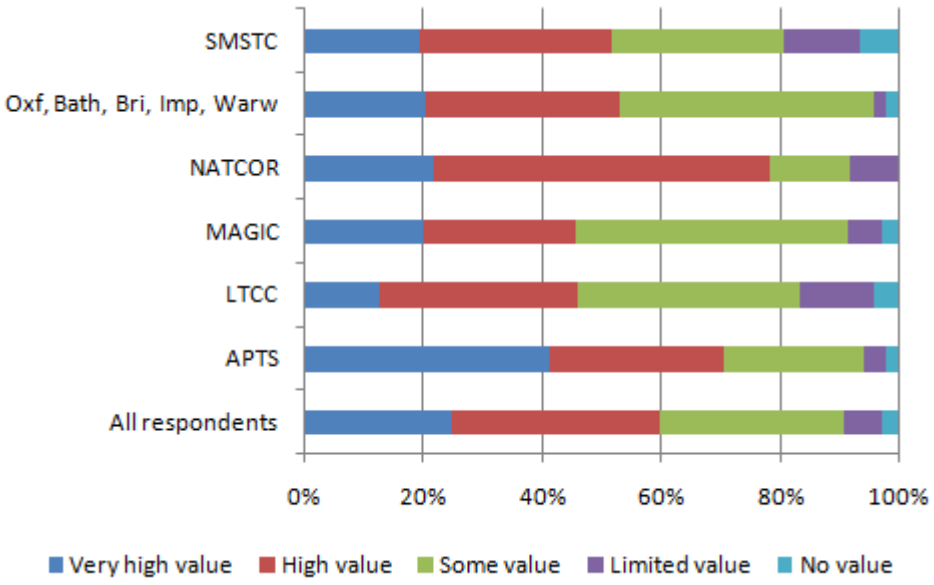
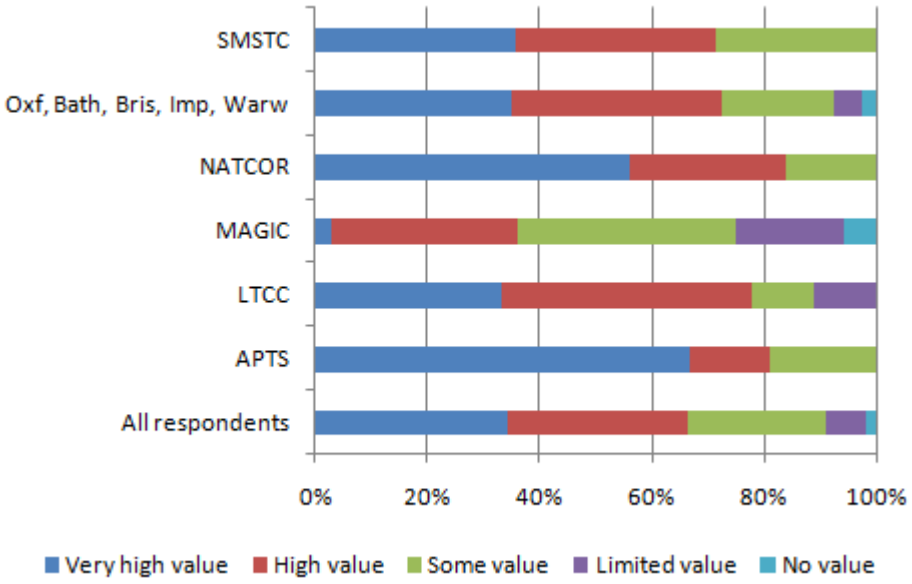


Figure 3.7: Supervisor Views on Value of Students Attending Taught courses at TCCs



3.5 Is there a Case for Developing Some Form of National Standard for 'Broadening Training' in TCCs?

There are two issues here:

- All involved with TCCs presently interpret 'broadening training' as broadening mathematical knowledge within a student's discipline but outside their PhD subject area. . If EPSRC believes the objectives of the Initiative should be broader than this, for example in terms of increasing knowledge of other discipline areas within mathematical sciences or broadening knowledge on career options and links to industry, then this needs to be communicated and discussed with TCCs. Funding would also need to be provided to support TCCs in making it happen.

- There is essentially a national standard for broadening mathematical knowledge in statistics and operational research because there are national TCCs for these disciplines. If TCCs that presently provide statistics courses outside the national centre (LTCC, MAGIC and SMSTC) sent their statistics students to APTS, there would be a common approach across all statistics students and arguably students would benefit from the wider networking opportunities. There is nothing approaching a national standard for broadening knowledge in pure and applied maths. The four TCCs that operate in this area have very different approaches. There is not necessarily a need to have a common curriculum across the TCCs given that all have evolved their own programmes over the last four years. However, it would certainly be beneficial for there to be greater communication between the TCCs to share good practice, to build on their strengths and to achieve as much consistency as possible. We believe there is significant scope to work a lot smarter at the national level including sharing course material, improving open access and facilitating networking across TCCs.

3.6 Is there Scope to Extend the TCC Initiative either in Mathematics or More Generic Skills?

All involved with TCCs presently interpret 'broadening training' as broadening mathematical knowledge within a student's discipline but outside their PhD subject area. The evidence from the review is that students and supervisors are generally happy with the range and breadth of courses provided by TCCs to meet this goal (see Figures 2.3 and 2.4).

If EPSRC believes the objectives of the Initiative should be broader than this, for example in terms of increasing knowledge of other discipline areas within mathematical sciences or broadening knowledge on career options and links to industry, then this need to be communicated and discussed with TCCs. Funding would also need to be provided to support TCCs in making it happen. TCCs are unlikely to provide generic training on their own as PhD students already receive generic skills training at their universities through 'Roberts funding'.

4. The Sustainability of the TCC Initiative

The TCCs are intended to be self-sustaining after EPSRC funding ends. This section considers the following key questions raised in the brief:

- Are the TCC consortia committed to maintaining centres after pump-priming funding ends?

- What support, if any, do the TCCs need to establish long-term sustainability?

DTZ is convinced that TCC consortia are committed to maintaining centres after EPSRC funding ends and they will continue whether or not further EPSRC funding is available. This is because there is strong support for TCCs across the mathematical sciences academic community.

However, in the absence of on-going EPSRC funding, TCCs may need to scale back some current provision or increase charges. This may be counterproductive in terms of achieving EPSRC goals for broadening PhD training. EPSRC may, therefore, wish to consider some on-going financial support for TCCs. This would be at a considerably lower level than now, but would mean EPSRC continued to have some influence over TCCs and their future evolution.

DTZ's assessment is that TCCs could continue to provide the same range and quality of service as now with on-going support from EPSRC in the region of £20,000 per annum. This would also mean EPSRC continued to have some influence over TCCs in the future.

5. Comparative Experience

As part of the review, DTZ sought to identify similar taught course initiatives for PhD training that have been set up in the UK. The purpose of this was to see whether any lessons could be learnt for taking forward Mathematical Sciences TCCs in the future. Similar initiatives were identified through a web search and information from EPSRC programme managers. Given the limited budget for this exercise we did not have resources to undertake further research than this.

From our review it seems that TCCs are still quite unusual. Apart from EPSRC Doctoral Training Centres where taught courses are an integral part of PhD training, initiatives that resemble TCCs seem to have been initiated by Physics Departments.

5.1 Scottish Universities Physics Alliance (SUPA)

The Scottish Universities Physics Alliance (SUPA) is a research alliance in Physics between eight universities. Its main aim is to make Scotland a leading nation in physics research though "an agreed national strategy, an inter-institutional management structure, and co-ordinated promotion and pursuit of excellence".

The organisation runs an intensive postgraduate training programme though their SUPA Graduate School. This programme consists of 60 courses across seven technical physics

themes. The programme also includes generic skills development and inter-theme courses, delivered by departments, universities and research councils.

Most courses are delivered by video-conferencing technology, some are delivered online through web-based facilities and a few are delivered through residential face-to-face sessions. SUPA designated video conferencing training suites are available to facilitate the training and a purpose built Virtual Learning Environment is available where all information about SUPA is made available.

Around 100 students a year are recruited and there are in total about 450 students enrolled in the SUPA Graduate School. Out of these 350 are PhD students. All PhD students are required to undertake a minimum of 40 hours of technical physics studies and 20 hours of generic skills training in their first two years of their studies. Some specific research themes have a higher requirement of courses. The technical courses are assessed and must be passed.

5.2 Midlands Physics Alliance (MPA)

The Midlands Physics Alliance comprises Birmingham, Nottingham and Warwick Universities. The aim of this strategic alliance is to coordinate research and to build a Graduate School to compete with top international universities. The funding is provided by HEFCE.

The Midlands Physics Alliance Graduate School (MPAGS) delivers taught modules to physics PhD students of the three universities. The Graduate School has around 250 PhD students in total, with an annual intake of around 100 students. The courses are delivered in year 1 and 2 of the degree, with the majority delivered in year one. Around three to four modules are taken in the first year and around two in the second.

The level of compulsion varies across the universities, but the courses are strongly encouraged at all the universities.

Teaching is provided in person at one university and provided through video conferencing using Access Grid technology to the other two Alliance universities. This enables course material to be shared across the Alliance. Each semester, one to two joint workshops are organised where all the Graduate School students have the chance to get together. It is in combination with these thematic workshops that formal assessments are carried out. Other resources include summer schools, as well as generic training.

5.3 Comparative Findings

From these two case studies of physics taught course provision the following findings tend to mirror the approach which has evolved within the mathematical sciences TCCs:

- The pooling of resources and expertise across a network of university departments
- The use of video-conferencing technology, supplemented with face-to-face delivery and residential
- The importance of seminar and workshop events to get students together as a group

- The variance between Scotland where SUPA has adopted a more centralist and defined programme including formal assessment and the more consensual and flexible approach adopted by MPA in the Midlands. This has strong parallels with the way in which SMSTC operates as opposed to MAGIC and LTCC.

One can therefore conclude from this brief investigation that the physics 'TCC' case studies tend to endorse the approach adopted by the mathematical sciences TCCs rather than challenging them with a radically different model or methods of delivery.

6. Conclusions and Recommendations

The purpose of the review was to:

- Evaluate how well the initiative has met its objectives
- Analyse the efficiency and effectiveness of the TCCs
- Consider the future of the TCCs.

6.1 Achievement of Objectives

An international review of UK Mathematical Sciences observed that UK PhD students usually have less breadth and experience than their peers from other countries. In order to keep UK PhD students competitive in the jobs market (particularly for academic jobs where the jobs market is highly international), the review recommended that PhD students needed to be given the opportunity to develop a greater breadth of knowledge as part of their PhD. The TCC initiative was EPSRC's response to this recommendation.

If 'broadening mathematical knowledge' is defined as increasing knowledge of a mathematical sciences discipline outside the sub-area of a PhD student's research, there is strong evidence that the TCC initiative is achieving its objective.

It is too early to fully assess the impact of TCCs in helping UK PhD students to compete on a more level playing field with overseas PhD students in the jobs market, particularly for academic jobs. The first students to participate in TCCs are now generally at the end of the third year of their PhD and have not yet entered the jobs market. However, students who have undertaken courses at TCCs (and their supervisors) have a good appreciation of how this training is likely to help with securing employment and achieving other career goals in the future. 55% of PhD students and 84% of supervisors surveyed as part of the study said taught course provision will have a positive impact on helping students to compete more effectively in the academic jobs market after their PhD.

The survey evidence also indicates that the TCC initiative is encouraging PhD students to pursue broader research interests and more multi-disciplinary research after the end of their PhD. This is a positive outcome since it is acknowledged that scientific challenges in the future will require more multi-disciplinary working.

There is limited evidence that the TCC initiative is encouraging PhD students to consider a broader range of career options and links with employers outside academia. This is not surprising since the courses undertaken by students focus on broadening *mathematical knowledge* rather than more generic knowledge such as careers in mathematical sciences across different sectors of the economy. If EPSRC believes the objectives of the TCC initiative should be broader than they are currently, this needs to communicated and discussed with TCCs (see later).

6.2 The Efficiency and Effectiveness of TCCs

DTZ believes that the TCCs are in general managed and administered efficiently and effectively. However, there are a number of areas which we have identified that TCCs may wish to reflect on in terms of the process of continuous development and improvement. These include a number of issues which have already been raised in this report:

- **Formal Assessment** – a uniform commitment from member universities to the formal assessment of students we believe would improve course completion, learning effects and support more fully the core objective of broadening mathematical knowledge amongst the PhD student cohort. This is the approach adopted in Scotland by both SMSTC and SUPA.
- **Course Development** – agreeing a fixed schedule of courses would be more cost-effective than the process of annual review and replacement which is adopted by some TCCs. In the interests of refreshing course material and making it directly relevant this could be undertaken at fixed points – say every five years.
- **Sharing Knowledge** – we were surprised that no attempts appear to have been made to share course development efforts across the TCCs where this would be relevant. For example LTCC, the Oxford-Led TCC, MAGIC and SMSTC have all independently developed course material across pure and applied mathematics. The scope to work in a more joined-up and integrated basis to achieve economies of scale is worth investigating for the future.
- To help stimulate TCC collaboration and sharing of good practice more generally, the following suggestions are put forward for consideration:
    - Creation of a forum for the Directors of TCCs to meet six monthly or annually.
    - The establishment of task groups to focus on sharing good practice in specific areas where economies of scale and learning benefits could be derived. For example, how to exploit teleconferencing infrastructure more effectively across the UK with representatives from SUPA and MPA also perhaps invited to share their knowledge and expertise in this area (further ideas are listed in Section 2).
- **Mandatory Course Uptake** – it would be helpful if the TCCs stipulated a minimum level of taught course provision which was implemented consistently across their networks. This would ensure that all PhD mathematical students were guaranteed to have completed x hours of taught course provision. This is the approach at SUPA. At present there is significant variance between universities and the consequence is that the impact on student education will also be highly variable.
- **Depth vs Breadth** – although our remit was not to comment on the content of course provision, we believe there to be significant variation in the level of taught course provision. In some of the TCCs, some courses are very specialised and of a level which means they are not relevant to broadening mathematical education for the vast majority of students. There is scope to be more focused on courses which meet the 'broadening' agenda rather than the 'depth' agenda.
- **Course Selection** – there is evidence that sometimes students are selecting course options close to their PhD subject. This tends to negate the objective of broadening

education and consideration should be given to making course selection more structured so students have to move out of their 'comfort zone'.

- **Public Good** – the taught course material should be considered a 'public good' for the benefit of students not only in the UK but overseas. Some TCCs operate a restrictive policy with regard to access to, and the dissemination of, their taught course material. Given the public sector funding from EPSRC to support the development of course material, it should be a requirement of TCCs to make their material available publicly for the wider benefit of society.
- **Student Representation** – we believe there are merits in including a PhD student representative on the Executive Committees of the TCCs. This would stimulate a more customer focused approach in areas relating to course provision and assessment.
- **Networking** – a valuable feature of the residential-based training is the opportunity it provides for networking. TCCs that rely on teleconferencing technology for course delivery should consider bringing students together occasionally for workshops where they can network and get to know each other better.

These suggestions should improve the cost-effectiveness of taught course provision and help better meet the core objective of broadening the mathematical knowledge of PhD students.

6.3 The Future of TCCs

6.3.1 Are the consortia committed to maintaining centres after EPSRC funding ends? What support, if any, do they need?

DTZ is convinced that TCC consortia are committed to maintaining centres after EPSRC funding ends and they will continue whether or not further EPSRC funding is available. This is because there is strong support for TCCs across the mathematical sciences academic community.

TCCs may, however, need to scale back some current provision or increase charges to cover their costs when EPSRC funding ends. This could be counterproductive in terms of achieving EPSRC goals for broadening the mathematical knowledge of PhD students. DTZ's assessment is that TCCs could continue to provide the same range and quality of service as now with on-going support from EPSRC in the region of £20,000 per annum. This would also mean EPSRC continued to have some influence over TCCs in the future.

EPSRC should implement the recommended actions highlighted by DTZ for each TCC and ensure each TCC has a formal sustainability plan in place by the end of the year.

6.3.2 Is there a case for developing some form of national standard for broadening training?

An issue is whether it is appropriate to have six separate centres going forward and / or whether there should be some form of national standard for broadening training.

There is essentially a national standard for broadening mathematical knowledge in statistics and operational research because there are national TCCs for these disciplines. If TCCs that

presently provide statistics courses outside the national centre (LTCC, MAGIC and SMSTC) sent their statistics students to APTS, there would be a common approach across all statistics students and arguably students would benefit from the wider networking opportunities. This is a suggestion for EPSRC and TCCs to consider.

There is nothing approaching a national standard for broadening knowledge in pure and applied maths. The four TCCs that operate in this area have quite different approaches.

However, there is not necessarily a need to have a national mathematics TCC. It makes sense to have different TCCs that exploit particular strengths and existing partnerships, as long as they are operating efficiently and effectively and make a conscious effort to collaborate and share good practice. As highlighted above, DTZ believes the TCCs are operating efficiently and effectively but there is a need for greater collaboration.

There is also not necessarily a need to have a common curriculum across the TCCs focussing on pure and applied maths, given that all have evolved their own programmes over the last four years and these are generally supported by students and supervisors. However, it would certainly be beneficial for there to be greater communication between the TCCs to share good practice, to build on their strengths and to achieve as much consistency as possible. As discussed above, we believe there is significant scope to work a lot smarter at the national level including sharing course material, improving open access and facilitating networking across TCCs.

6.3.3 Is there scope to extend course provision at TCCs?

At present, those involved with TCCs generally interpret 'broadening training' as increasing mathematical knowledge within a student's discipline but outside the sub-area of their PhD research.

However, as only 20% of mathematical sciences PhD students remain in academia with 60% employed in private companies and 20% in other parts of the public sector,[2] an issue is whether TCCs should be encouraged to invest more resources in broadening the generic knowledge of PhD students as a better preparation for work in industry. For example, how a mathematical sciences PhD can be used across different sectors of the economy.

If EPSRC believes the objectives of the TCC initiative should be broader than they are currently, this needs to communicated and discussed with TCCs. Funding may also need to be provided to make it happen, as university departments perceive that generic skills training is already being provided for PhD students through 'Roberts funding'. However, they acknowledge the limitations of provision through Roberts funding in that this is aimed at PhD students as a whole and does not allow for tailored provision for mathematical sciences PhD students. It is noticeable that both SUPA and MPA include some generic training as part of their curriculum.

One way of moving forward on this issue would be to use the new TCC collaboration mechanisms suggested by DTZ as a forum for challenging the status quo and debating priorities for the future. For example, what should be the fundamental outcomes of taught course provision? Should it be about broadening mathematical knowledge per se or should it

[2] According to data on EPSRC PhD students

have more applied goals in terms of broadening knowledge of careers outside academia and promoting links with industry?