Effects and Impacts of the Connecting STEM Teachers Project with regard to Teacher Coordinators and Teachers

An independent evaluation by:

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1. Executive Summary:

Background

This evaluation report acknowledges the need for an independent, quantitative approach to understand the workings and impacts of the Connecting STEM Teachers programme. The evaluation was based on prior qualitative evaluations over the first four years of CST, and expanded literature review and development of new, relevant, validated and focused questionnaires for Teacher Coordinators (TCs) and Teachers. The evaluation team has worked with/evaluated engineering and STEM education projects (especially with the RAEng) previously and provides a range of methodological skills in the areas of education and other social sciences.

Connecting STEM Teachers Programme

The CST Programme began in September 2011. The programme has been funded by a number of engineering (and STEM) industries and planned/administered by the Royal Academy of Engineering. CST originally aimed to *'create a national network of support for teachers across STEM subjects to build on teachers' knowledge of STEM and their confidence to engage students with STEM subject areas and careers'*, and this aim has become more refined through the dissemination of STEM knowledge and pedagogic practices, inclusion of engineering design elements, development of focused 'resources' for teachers and support for teachers (and their schools) via regional networks. At the time of this evaluation, 48 TCs (in 45 networks) are working on the programme in 28 regions across England, Scotland, Wales and Northern Ireland. These TCs have recruited 913 teachers for this cascaded training and support programme in the 2017/8 school year.

Intentions underlying this Quantitative Evaluation

As the CST Programme matured since 2011, it has become appropriate to conduct a programme wide evaluation investigating project effects with regard to approach, attitudes, experiences, efficacy and impact. The evaluation aimed to include all participating TCs and Teachers, and to generate unique, purposeful and valid questionnaires that could be used to ascertain changes over time. The quantitative findings both complement and extend the previous qualitative evaluations of the CST Programme. This evaluation has been undertaken independently.

Literature Review

To ensure that development of the evaluation/questionnaires were as comprehensive as possible, a focused literature review was undertaken regarding STEM education and professional development support to enhance STEM education. Key points drawn from the literature included the assurance that the Programme was based on real and authentic STEM experience, the orientation/use of (national) networks and what they promoted (including curriculum-oriented content, pedagogic approaches and support), attitudes to STEM education, levels of engagement on the programme and perceived impacts on students. In addition, the literature emphasised the need to move away from reliance on attitudes toward STEM to the inclusion of aspects of STEM and engineering efficacy that are likely to be associated with positive behaviour changes in support of STEM education. The literature also covered potential demographic characteristics of teachers and TCs that may affect their participation on the programme.

Phases of the Evaluation

The evaluation was undertaken in six phases: review of previous qualitative evaluations of CST; literature review of STEM education and teachers' professional development; semi-structured, thematic pilot interviews and analyses; development of questionnaire items for teachers and TCs; piloting and refinement of questionnaire items; questionnaire completion and descriptive/factorial analyses.

Preliminary Analysis of the Teacher Coordinator for Connecting STEM Questionnaire

44 of 48 possible TCs completed the questionnaire, coming from a variety of (mainly) science-based disciplines. Responses showed that TCs had generally high levels of involvement in the programme. They saw themselves as being 'good teachers' who spent much time/effort in showing and demonstrating aspects of the programme rather than developing support within their networks. TCs strongly agreed that STEM education should be inclusive. TCs had high levels of STEM and engineering efficacy and believed that the programme would have positive impacts on students. There was a low frequency of activity involvement that may be associated with the part-time nature of the TC role.

Factorial and Demographic Analyses of the Teacher Coordinator Questionnaire

Questionnaire item grouping broke down into factors that met criteria for factor analysis use. Comparatively few statistically significant differences were found in the factor by demographics analyses. Differences found related to school type (state schools were more likely to see the importance of STEM in schools); sex differences (men were less likely to see their role as supporting teachers); undergraduate/postgraduate qualifications (Design and Education less confident in science/ mathematics but D&T scored highest in STEM and engineering efficacy); and TCs with greater teaching experience/CST experience were more active and confident in STEM and engineering efficacy. School-based support for engaging in the CST Programme did not appear to affect any of the identified factors.

Preliminary Analysis of the Teacher Questionnaires Associated with the Connecting STEM Programme

Only just over 18% of the current CST teachers submitted questionnaires, making the following results indicative rather than representative. Most teachers had a science background, and many were in their early years of teaching/first year on the CST programme. Their interest in CST participation was to develop their STEM knowledge and pedagogic approaches. The appreciated the information provided by the programme but found only limited support (other than knowledge-based) from their networks. Teachers had a strong belief in STEM inclusivity (age, sex and attainment) although they felt inhibited by within school constraints, exams and limited time for activity involvement. Little time was found to reflect and develop pedagogic and social pedagogic approaches encouraged by the programme. Teachers had noticeably lower levels of STEM and engineering efficacy than their TCs but felt that the programme would have positive impacts on their students

Factorial and Demographic Analyses of the Teacher Questionnaire

Groupings of question met criteria for the use of factor analysis. There were comparatively few statistically significant differences in the factors by demographics analyses. School type showed few differences with primary teachers having the lowest STEM/engineering efficacy and most disagreement about the role of competition. No sex differences were found. Science/Mathematics teachers tended to be more conservative in views of STEM inclusion and school examination results. Teachers with Engineering experience were less certain that CST improves pedagogic confidence but showed highest levels of STEM efficacy. Experience of CST affected the positive perception of pedagogic elements of the CST programme. School-based support for engaging in the CST Programme did not appear to affect any of the identified factors.

Conclusions and Recommendations

Data collected and analysed from Teachers and TCs showed an overall positive response to the CST programme. Length of time associated with the programme brought about higher levels of STEM knowledge, an increased range of pedagogic approaches, increased STEM and engineering efficacy and understanding that STEM enhancement can/should take place within an inclusive (by age, sex and attainment) context. TCs and Teachers also perceived positive impacts on student knowledge of STEM and associated attainment. At the same time, discrepancies were identified with regard to disjunctions between STEM knowledge, pedagogies and social pedagogies (the contexts within which pedagogic activities take place). Areas that may receive further consideration as the programme continues to develop include a more substantial role for networks (and associated networking), allowing time for teachers to collaborative reflect on their STEM engagement and a greater understanding of how social pedagogic contexts may affect STEM (teaching) practices.

Recommendations identify areas for development within the programme, allowing for increased collaboration/networking, more support time for TCs, greater involvement of teachers within the 'Collaborative Projects', further attempts to develop inclusion within STEM, increased participation of primary school teachers and enhanced approaches to advise and STEM career counselling in schools.

2. Background:

Over the last decade, many post-industrial societies have been characterised as having a growing need for trained engineers and technicians while university and secondary school-based studies have shown a decline in student interest/take-up of STEM subjects and associated careers. A number of studies have identified that students' STEM-based subject and career interests are most malleable during the years of secondary schooling (Osborne & Archer, 2007; Kutnick et al., 2012; ASPIRES, 2013). Various programmes supported by the government, private industry and charities have been initiated to offer focused insights into STEM subjects and careers for secondary school students and their teachers. What is noticeable about these programmes is the requirement that school-based enhancement of STEM is largely the responsibility of teachers within schools with only limited opportunities to independently evaluate the effects and impacts of such programmes (Kutnick et al., 2012). Further, there has been little effort to integrate these programmes into the curriculum and ascertain the effects of a nation-wide roll-out in the United Kingdom. In the main, efforts to evaluate how various forms of professional development for STEM teachers have been based on the perceptions that teachers' knowledge and actions are the main route into enhancing their students' STEM aspirations (Goodall et al., 2005); and that the enhancement of STEM knowledge requires an interdisciplinary approach that does not currently characterise within-school teaching opportunities (Shernoff et al., 2017). Further, the main evaluations of STEM professional development programmes have focused on science (Scott et al., 2010) and report only a weak relationship between teachers' professional development and changes in student outcomes (Kudenko & Hoyle, 2014). Within STEM professional development programmes, though, there is an increasing desire to integrate engineering design opportunities (Avery & Reeve, 2013).

Connecting STEM Teachers (CST) is one such integrated project that was designed to enhance teachers' STEM understanding, integrate aspects of engineering design and enhance students' perceptions via a professional development programme for teachers. CST was originally based in nine regions (covering the UK), 28 sub-regions (via Teacher Coordinators) and affecting 400 secondary schools (with at least one teacher per school involved). Currently (at the time of this report, February 2018), there are 48 Teacher Coordinators, 913 Teachers potentially affecting STEM activity in 600+ schools. Early evaluations of the CST programme were undertaken in a qualitative manner (see below), which helped to set the foundations for a larger, independent quantitative evaluation of all current Teacher Coordinators and Teachers involved in the programme.

Results from this evaluation will set the basis for follow-up evaluations to ascertain effects of the programme over time and criteria for a (potential) further investigation into effects on student course choice and attainment in STEM subjects (via interrogation of the National Pupil Database). The baseline data which the current report provides can only offer indications and hypotheses as to the effects of the programme, but that data along with the instruments developed for the RAEng by the team will enable more focussed insights and comparisons in future.

3. Connecting STEM Teachers Programme

Initially, the CST Programme was funded by BG group, and subsequently supported by Petrofac, Shell, the Helsington Foundation, Petrofac, Boeing UK and BAE Systems. Responsibility for the project, its form and its delivery lay with the RAEng. The original aim of the Connecting STEM Teachers programme was:

> *'to create a national network of support for teachers across STEM subjects to build on teachers' knowledge of STEM and their confidence to engage students with STEM subject areas and careers'* (p.2, Gartland, 2012).

The Programme adopted a 'cascade' model of training 'so that expertise at the RAEng is shared with Teacher Coordinators (TCs) and subsequently with teachers across network schools' (p.2, Gartland, 2012). Since its inception, the aims of the Programme were slightly revised (RAEng, 2017), to provide additional local support for the teachers of STEM subjects so that they might develop the knowledge and confidence to:

- Illustrate the role of engineering in society to young people;
- Explain how engineers shape the world and improve our lives;
- Highlight how STEM learning at school is applied in the real world;
- Enrich the STEM curriculum;
- Engage a greater number and wider spectrum of students in STEM.

According to the RAEng, 'Central to the … success of this project is the work of the Academy's Teacher Coordinators (TC) who lead support networks for local STEM teachers across the UK. The TCs are experienced teachers of STEM subjects whose core responsibilities are to:

- Disseminate free training and learning resources to local STEM teachers
- Provide networking opportunities for teachers
- Lead enhanced learning opportunities for pupils
- Promote collaboration between STEM teachers
- Help to develop STEM learning resources'

The RAEng has recruited the TCs and supported their development and developed materials, such as resource boxes, for the TCs to use and to distribute to their network Teachers. The RAEng meets regularly with the TCs to provide training and receive feedback, and in turn the TCs meet with the Teachers in their network. TCs have the further responsibility of finding and integrating schools within their regions and appropriate STEM-based teachers within those schools. The Cascade model of training has been enhanced by reference to TC development of teacher 'networks' within specific regional locations. These networks allow TCs to meet with their teachers, introduce new resources and pedagogic approaches in fulfilment of the current CST aims. Network meetings have been scheduled so as not to conflict with teaching responsibilities of those involved (usually twilight or Saturday sessions), and take place once per term (although, in some networks the summer term meeting is replaced by a Collaborative Project Day). The meetings which TCs have with the RAEng coordinator also allow TCs to share experiences and approaches to STEM development; to be introduced to new resources and to consider/reflect upon the Programme. TCs meet for training and 'celebration' purposes three times per year at central locations.

The CST Programme began in September 2011. Before the start of this evaluation, a baseline report and three yearly qualitative evaluations (as presented in six reports) were undertaken by Dr Clare Gartland, working with Anna Pacuska. To gain data for these initial reports/qualitative evaluations, a limited number of Teacher Coordinators (from separate UK regions) and associated teachers within schools were interviewed and various sessions observed. Findings from the initial reports/evaluations are summarised in Appendix A.

4. Purpose of this evaluation

The qualitative evaluations conducted by Clare Gartland and Anna Pacuska provided valuable information for the development of the programme in its early days. As the Programme matured, it has become appropriate to conduct a programme wide evaluation with a focus on metrics that can provide a guide to its outcomes as a whole and through its different parts investigating project effects with regard to approach, attitudes, experiences, efficacy and impact. The evaluation aimed to include all participating Teacher Coordinators and Teachers, and draw upon not only the impact on both levels in the cascade, but also their reflections on school impacts and constraints and perceived impacts on students.

To reach this target audience in a timely and efficient manner, and to generate appropriate metrics, the development of unique, purposeful, valid and reliable questionnaires focused on Teacher Coordinators and Teachers was essential. Furthermore, it would clearly be of value to have as much overlap as possible between the two instruments so as to permit where appropriate a comparison of the effects on and views of the TCs and the teachers.

The initial intention was to use the novel instruments with two cohorts of Teacher Coordinators and Teachers to ascertain changes over time. Subsequently (explained in the Methods below) circulation of the questionnaires was delayed with the result that a single cohort of Teacher Coordinators and Teachers would be assessed at the beginning and end of a school year with a further (new) cohort being assessed allowing for experienced/inexperienced cohorts to be compared. The focus of this evaluation is on TCs and teachers with the recognition that change and development within schools in the support of STEM is led by teachers as they are the people most likely to affect change in their students' attitudes and engagement in educational activity (Goodall et al., 2005). An additional, associated evaluation to identify student subject choice as affected by their school's project involvement drawing upon the National Pupil Database is under consideration. That data will complete the picture of how effective the cascade has been in delivering change

The prior qualitative evaluations provided a valuable platform for beginning this work. The quantitative findings reported here both complement and extend the previous qualitative evaluations of the CST Programme. It scrutinises those findings via pre-piloting procedures and then ascertains to what extent these findings characterise the full cohort of TCs and teachers as well as sub-groupings of these participants. It was also recognised that an updated review and understanding of literatures concerning STEM teacher development, and teacher support via networks, would provide important additional guidance on how to structure the evaluation. This evaluation is also based upon a number of background issues regarding evaluations of continuing professional development programmes for STEM teachers – mainly in the UK but also noting international studies concerning the promotion of STEM education.

Finally it should be noted that this evaluation has been undertaken independently and should not be seen as an 'in-house' confirmation of an existing programme. The evaluators are based at three different universities, each providing academic insight into curricular and pedagogic aspects of professional education as well as a range of methodological and analytic skills to support this evaluation. The RAEng has provided important support and information to the evaluators and distributed the instrument. It has therefore taken responsibility for this study and it is conducted under its aegis, but the evaluators are wholly responsible for the analysis of the data collected and the inferences drawn to date.

5. Literature Review:

5.1 Landscape of STEM provision in the UK

There is currently a wide range of organisations working with schools to promote STEM within the UK. These organisations include STEM providers (such as STEM Learning, Young Engineers, Engineering Education Scheme Wales and the Smallpeice Trust), museums, subject-specific organisations (such as the Institute of Maths and its Applications, Rasberry Pi / Code Club, the Institute of Physics, the Royal Society of Chemistry and the Royal Society of Biology), the National Science Learning Centres, as well as a number of professional bodies representing engineering (including Engineering UK and the professional engineering institutes)[1]. The RAEng fits into this general group, especially with the CST Programme integrating engineering design within the more general STM (science, technology, mathematics) subjects as recommended by Avery and Reeve (2013) and Shernoff et al., (2017). These organisations all work broadly to promote engagement with and uptake of STEM subjects amongst school-aged students with the expectation of enhanced STEM achievement, more positive attitudes toward STEM concerns and increased course/career choice regarding STEM subject areas. In particular, STEM education is likely to: combine two or more of the STEM disciplines, draw upon real world problems and authentic contexts and to encourage engineering design (Shernoff et al., 2017) as well as encouraging critical thinking, collaboration and creativity among students (Burrows & Slater, 2014).

In promoting STEM education, most commentaries in this field identify that it is the activity planned and directed by teachers that is likely to have positive impacts (in attitudes, knowledge and career aspirations) on students from a variety of different age groups. Most activity promoted by these organisations identify practices, resources and procedures that work directly with secondary school pupils (Morgan et al., 2016) with much of this work focused on extra-curricular activity. The CST programme is unlike the majority of this activity in its focus on working with teachers; noting that teacher CPD (Continuing Professional Development, as defined by Goodall et al., 2005) provided by STEM education organisations is the most general route to enhance teacher (in anticipation of pupil-based) STEM learning. STEM-based CPD at the secondary school level is generally focused on improving teachers' knowledge and pedagogical skills, but most often is advanced via subject specific 'teaching' and resource exposure (e.g. teaching practical science: biology).

The ambition of the CST Programme is to promote a passion for STEM amongst teachers, to improve awareness of STEM in schools, to widen teachers' knowledge and experience of STEM, introduce aspects of engineering design, to enable teachers to gain STEM pedagogic and practice skills and to subsequently enhance student participation in STEM achievements, course and career choice. Following concern amongst those promoting engineering to cross disciplinary boundaries in schools (Hardre et al., 2016), an ambition of the CST programme is to promote collaboration between Science, Technology and Mathematics teachers while also introducing engineering topics of relevance to STEM education.

Outreach practices (including CPD) to enhance teachers' STEM understanding and skills has been most strongly associated with science education, and have led to the perception that school-based STEM should really be referred to as STeM (noting that there is little formal teaching of engineering in schools: Holman, 2007; Katehi et al., 2009). Not to be left out of the STEM educational field, further CPD has been led by engineering organisations in the UK and developed on the basis that to meet the skills gap there is an urgent need to promote awareness amongst young people of engineering and of real world applications for STEM subjects and their relevance for society. Changing the Conversation (2009) highlighted the need to challenge public views about engineering in the US, and identified the lack of knowledge of what engineering involves and perceptions,

[1] According to the UK National STEM Directory there are 248 current STEM initiatives in schools and higher education as of February 2018 (STEM Directory, 2018).

particularly among girls, that helping people and making a difference were related to fields such as medicine not engineering. Key messages about engineering were advocated, including that engineers make a real difference in the world by using their knowledge to improve people's lives; engineers are creative problem solvers; engineers help shape the future and that engineering is essential to all aspects of our lives. These messages were also taken up in the UK for example in the London, Stoke and Barrow Engineering Projects. Practical engineering outreach also promotes approaches that link to the engineering design process championed by the National Academy of Engineering in the US and widely promoted in schools. Working with the RAEng in the UK, Lucas et al. (2017) have suggested that schools should promote 'Engineering Habits of Mind': systems-thinking, adapting, problem-finding, creative problem solving, visualising, and improving. Approaches in engineering outreach reflect a student orientation to learning and teaching, focusing on students being encouraged to actively construct knowledge, which have been widely advocated in teaching practice (OECD, 2009). Learning from previous RAEng projects, such as the London Engineering Project (Harrison, 2009) has highlighted the need to engage teachers and work collaboratively with schools to embed STEM (especially within existing curricula guidelines), as well as to support teachers who have little available time. With particular regard to the CST programme, resource boxes have been developed in response to a number of these approaches and designed to be undertaken within current UK-based curriculum guidelines.

With limited evaluations of STEM programme effects and impacts, what does not arise in this area of the literature are criticisms and concerns regarding the ineffectiveness of STEM CPD. Reviews of school-based STEM interventions (Kutnick et al., 2012) identify problems associated with using 'experts' to teach students, lack of relationship to current STEM curriculum guidelines, traditional teaching methods, lack of real-world orientation, focus on attitudes rather than impact, poor methodological planning, school policy and orientation to 'league tables' and more. Each of these problems is likely to inhibit students' understanding and desire to pursue engineering aspirations. A number of these problems have been identified in the more general teacher professional development literature.

5.2 Teacher Professional Development

A number of models for researching effective teacher professional development (PD) are cited in the literature. Professional development (and CPD) is a broad topic and studies of teachers' professional development include a range of diverse perspectives. Day (1999: 4) defined CPD as 'Professional development consists of all natural learning experiences and those conscious and planned activities which are intended to be of direct or indirect benefit to the individual, group or school, which constitute, through these, to the quality of education in the classroom'. Thus, many CPD practices tend to be school-based as this 'in-house' approach has to work within limited school budgets and classroom disruption. General evaluations of CPD tend to draw upon Guskey's (2000) widely cited call for an evaluation model with five levels of focus (Desimone, 2009; Main & Pendergast, 2015; Kudenko et al., 2011). These levels include: participants' reaction, participants' learning, organisational support and change, participants use of new knowledge and skills and learning outcomes for pupils (Kudenko et al. 2011: 26). However, whilst advocating a focus on pupil outcomes, Kudenko et al. point out, educators have questioned what change, particularly in pupils 'learning and engagement with science, can be expected from CPD episodes of varying length and intensity'(2011: 41).

Desimone (2009: 183) argues for the benefits of focusing on 'measuring … the features of professional developments that have been shown to be related to the outcomes we care about' and suggests that research indicates a core set of features of PD programmes that have been 'associated with changes in knowledge, practice and, to a lesser extent, student achievement'. She identifies the need for a 'core conceptual framework' to be used in studying the effectiveness of professional development. This framework includes 'content focus', 'active learning', 'coherence', 'duration' and ‘collective participation’ (Desimone, 2009: 184). Desimone’s conceptual framework proposes that these core features of PD will impact on teacher knowledge and skills and change attitudes and beliefs, which will in turn lead to changes in instruction and improved student learning. This framework is located in the context of teacher and student characteristics, curriculum, school leadership and the policy environment.

Findings from further studies reflect Desimone’s conceptual framework but have stressed particular features. Whitworth and Chiu (2015) highlight the central importance of school leadership teams in the development of successful PD. Yoon and Klopfer (2006) highlight contextual features as having a significant impact on the success of programs; important structural constraints are identified including macro level such as legislation and standardized testing as well as meso level structural constraints including the number of teachers in a school engaging with programmes. This links to Desimone’s observation of the critical importance of collective participation but points to tensions between structure and agency. This tension is reflected in Monk’s (2008) findings from STEM CPD in the UK, that it is valuable to engage departments rather than individual teachers but that change will not occur if ‘it does not fit the demands on teachers placed there by the examinations, the physical spaces and resources with which teachers work’(Monk, 2008: 117).

McCormick (2010: 401), in his review of continuing professional development (CPD) literature in England, points to the need for more developed theorising of the learning activity in research into CPD, and particularly theorising about how ‘learning is conceptualised’ (cognitivist or socio-cultural). While highlighting the importance of social cognitive ideas about teacher efficacy, Takahashi (2011) suggests that these ideas about how teachers’ beliefs are developed conceptualize individuals as separate from the context within which they are located, and present the view that learning is acquired (Sfard, 1998). She argues that meaning ‘is often unconsciously co-constructed among members of a group in their daily, shared practice’ (Takahashi, 2011: 734) and suggests that a socio-cultural perspective is important to understanding these processes. At the same time, these arguments open a perspective that CPD ‘learning’ must include a social pedagogic context (Blatchford & Kutnick, 2003) as well as an organised cognitive and curricular perspective on what is to be learned; this social pedagogic context may be described as a ‘learning community’ but is most likely to take place within a supported collegial ‘network’ of teachers. Borko (2004), in her mapping of the terrain of professional development, identifies the need for the theorisation of learning in PD and argues for a ‘situative’ perspective, conceptualising learning as ‘changes in participation in socially organised activities, and individuals’ use of knowledge as an aspect of their participation in social practices’. She argues that this perspective allows a focus on ‘individual teachers as learners and on their participation in learning communities’ (Borko, 2004: 4). Thus, the theorising on learning activity within CPD identifies that teachers are seen as: a) active and involved while working within social and organisational constraints of networks and schools; while b) involvement incorporates more than additions to their knowledge and that personal feelings of efficacy (from Bandura, 1997) are necessarily involved if programmes of professional development are able to impact on teachers (and through teacher onto students).

Studies focused on STEM CPD have identified subject specific models of effective PD. In science education, Loucks-Horsley et al. (1998) describe features of effective PD as emphasizing inquiry-based learning, investigations and problem solving; helping to build pedagogical skills and content knowledge; modelling the strategies teachers will use with their students; building learning communities where continued learning is valued; supporting teachers in leadership roles; linking to the educational system and changes to insure positive impact (Capps et al., 2012).The focus of CPD to both deepen teachers’ content knowledge and develop subjects specific pedagogies and efficacy should be emphasised in STEM CPD (Dogan et al., 2015). Capps et al. (2012) reviewed a number of studies pertaining to PD in science inquiry. They identified nine features of effective professional development in by drawing on existing models of effective PD and reviewing reform documents. These features included the ‘total time’ of a programme, suggesting that programmes should provide teachers with enough time to process and address the doubts and misconceptions they have regarding inquiry; 'extended support' including follow up face-to-face or remote meetings after workshop activities; 'authentic experience' where teachers were engaged in authentic inquiry themselves; 'coherency' and the alignment of programmes to national standards and to teachers' 'everyday work'; the development of inquiry based lessons; 'modelled inquiry' where programmes model inquiry based instruction ; 'teacher reflection'; opportunities for discussing how teachers 'might transfer materials or experiences into their classrooms' and science 'content knowledge'. Thus, aside from adequate 'time' for CPD, content knowledge needs to be presented in an active, collegial, authentic and reflective context; and these aspects are often difficult for teachers to draw upon and put into practice within their schools (Goodall et al., 2005). Monk (2008) similarly stresses the importance of 'active learning' (Desimone, 2009) in UK STEM CPD 'rehearsing novel learning schemes with colleagues as critical friends' (Monk, 2008: 116). Baker-Doyle and Yoon also stress the importance of 'teachers' constructing learning through collaborative inquiry and active learning' (2011: 76). Further, these aspects of STEM CPD are associated with a range of impacts and outcomes as identified by the National STEM Learning Centres' summary of STEM evaluations (NCETM accessed 2018):

For teachers, and school and college leaders:

- improve subject and pedagogical knowledge as well as awareness of STEM careers
- increase confidence, motivation and competence
- encourage leadership within STEM
- improve overall quality of teaching
- improve retention and career progression within STEM subjects

For pupils:

- improved student engagement, achievement and STEM literacy
- increased pursuit of STEM subjects and careers post-16

De Vries et al. (2014) identify a relationship between teachers' beliefs about learning and teaching and their participation in CPD, with teachers who were both student orientated and subject matter orientated more likely to participate. Specifically relevant to engineering, a further focus is on how CPD has impacted on perceptions of engineering (Nadelson et al., 2013) and the development of a STEM philosophy, in terms of an integrated approach to teaching STEM subjects (Avery & Reeve, 2013).). We further note that when evaluations of school-based interventions and CPD programmes have taken place the evaluations tend to focus on development and change in attitudes (Kutnick et al., 2012), yet a number of studies (see Ajzen, 2002 as described in Kutnick et al., 2018) identified that actual changes in behaviour (such as choosing STEM courses by students or confidence in the use of new pedagogic approaches by teachers) is based on a theory of efficacy.

5.3 Teacher confidence, beliefs and efficacy

Teacher efficacy has been identified as a major influence on teachers' professional development, and student motivation and success has been linked to a range of positive approaches including professional commitment, instructional experimentation, implementation of progressive methods as well as positive impacts on student attitudes and achievement (Tschannen-Moran et al., 1998). The concept of teacher efficacy has been widely used in measuring the impact of CPD programmes in STEM subjects (Nadelson et al., 2013; Lakshmanan et al., 2010; Powell-Moman & Brown-Schild, 2011; Bruce et al., 2010; Hardre et al., 2013) although a range of instruments have mainly been drawn upon from general teacher efficacy scales with few relying on domain-specific STEM teacher efficacy scales (although it has been argued that domain-specific efficacy scales have greater validity, Bandura, 1997).

Ideas about teacher efficacy grew out of two strands of thought. Teacher efficacy was first conceived by the RAND organization who found that teachers with high levels of efficacy 'believed they could control, or at least strongly influence, student achievement and motivation (Tschannen-Moran et al., 1998: 202). Another strand drew on, Bandura's (1977) ideas, with teacher efficacy seen a type of self-efficacy: as 'a cognitive process in which people construct beliefs about their capacity to perform at a given level of attainment' (Tschannen-Moran et al., 1998: 203) within a specific subject domain. These two stands of thought have been influential in the development of studies of teacher efficacy.

Teacher efficacy is viewed to be specific to context and subject matter, though the level of specificity at which this should be considered is contested (Tschannen-Moran et al., 1998). Contextual factors impacting negatively on teacher efficacy have been found to include professional isolation, alienation, excessive role demands and poor morale. (Webb & Ashton, 1987 in Tschannen-Moran et al., 1998). Chester and Beaudin (1996) found that the opportunity for collaboration increases self-efficacy (1996). Other school context effects on teacher efficacy include the level of attainment of students, the atmosphere of the school, and the leadership of the principal (Tschannen-Moran et al., 1998). The collective efficacy (Bandura, 1997) of teachers in schools has been found to be significant. Goddard, Hoy and Hoy (2000) found that teachers' beliefs about the capabilities of faculty were systematically related to student achievement. However, Takahashi (2011) found that the 'community of practice' (Lave & Wenger, 1991; Wenger, 1998) of teachers in her study were collectively co-constructing strong efficacy beliefs, despite their location in a school catering for diverse, low-income families with students who were not consistently reaching expected benchmarks.

Subject specific measures of teacher efficacy have been widely developed. Riggs and Enochs' (1990) Science Teaching Efficacy Belief Instrument (STEBI) based on Bandura's ideas of self-efficacy is a well-established model and teacher efficacy has been related to pedagogic approaches (e.g. hands on vs text based) and teacher effectiveness. More recently Nadelson et al. (2013) adapted the STEBI to encompass STEM in order to explore the impact of a CPD programme for elementary teachers. Yoon et al. (2014) have developed an instrument to measure teachers' self-efficacy in teaching engineering. The engineering self-efficacy scale includes scales exploring engineering pedagogical content knowledge, engineering engagement, engineering disciplinary self-efficacy and outcome expectancy. Within the STEM teacher efficacy literature there has often been a focus on pedagogic approaches. Marshall, Horton and Switzer (2009) developed a self-efficacy tool for inquiry based instruction. They found that teachers with more self-efficacy for inquiry based instruction spend more time devoted to inquiry during lessons. Powell-Moman and Brown-Schild (2011), using the same tool, found that a two year STEM CPD programme led to increased self-efficacy for inquiry based teaching.

Teachers with a high level of subject-based efficacy will be more confident and competent in undertaking their subject (pedagogic- and action-oriented) activities (Bandura, 1997). Nadelson et al. (2013) STEM scale, in part, measured teacher confidence in STEM, as confidence in teaching has been found to be important in the prediction of teachers' ability to effectively teach content related to STEM (Nadelson et al., 2013). Smith (2014) found that teachers' confidence in their science teaching skills were significantly raised following a sustained CPD programme for primary school teachers that provided opportunities for collaboration, sharing practices and knowledge and reflection. At the same time, while realising the importance of enhancing teachers' subject-domain efficacy, CPD programmes rarely (if ever) identify how these specific aspects of efficacy can be developed – assuming, perhaps naively, that efficacy enhancement will naturally be a product of CPD.

5.4 Teacher professional communities and networks

The significance of the communities within which teachers are located, in terms of CPD activity and in terms of their own schools, has been highlighted for aspects likely to enhance or inhibit this development (e.g. Desimone, 2009; Tschannen-Moran et al., 1998). Such groups of teachers are referred to in a range of ways including networks, collaborations, clusters and development groups (de Lima, 2010). While these terms are often not used consistently, they are generally used differently to refer to aspects of the organisation of these groups and the focus of specific CPD training. If the focus of CPD is simply to provide content knowledge or resources, then the role of 'community' holds limited importance. On the other hand, where active learning, collaboration and reflection are involved an effective community has a much greater role to play. An important distinction within the consideration of community is whether teachers are working collaboratively with others within their schools or with teachers in other schools (Jackson & Temperey, 2007). In the US the term Professional Learning Communities (PLCs) is widely used to refer to teachers working collaboratively to consider student achievement in order to improve learning and teaching, often within individual schools (Dogan et al., 2016). A range of benefits have been associated with teachers working collaboratively in such groups including increases in self-efficacy, confidence, leadership skills and collegiality (Dogan et al., 2016: 10). Similarly, Fulton and Britton (2011), following their 'knowledge synthesis' of literature relating specifically to STEM teachers in PLCs, claimed gains included increased discussion about mathematics and science amongst teachers, increases in understanding of science and mathematics, increases in preparedness to teach, attention to students' understanding as well as more diverse modes of engaging students in problem solving (Fulton & Britton, 2011). In their systematic review of the impact of networks that include at least three different schools, Bell et al. (2006: 4) found that networks between schools can be 'highly effective' in improving teaching, learning and can support students' attainment if associated teachers are committed to interacting with other members of the network and are able to share/reflect upon learning/pedagogic approaches and resources. Jackson and Temperey (2007) also suggest that teachers collaborating in a network with others from different schools can improve their teaching practice.

De Lima (2010) argues for more systematic and careful description and analysis of networks and identifies a series of 'key dimensions' (2010:4) that could be considered in research. The 'genesis' of networks is one such dimension and includes a focus on how the network was formed and whether it is emergent or externally sponsored. Another key dimension identified is the 'composition' of the network and whether it comprises of individual-actors or collective actors (or in the CST networks, individual teachers or groups of teachers from schools). The 'structure' of networks is another dimension, this includes: how dense the network is (i.e. how many possible network relations are activated); how centralised the network is and how connected network actors are. The 'substance' of networks is further key dimension, and includes whether the network is single or multi-purpose. Another key dimension is the network 'dynamics' and whether the network is goal-directed or serendipitous. A final key dimension according to de Lima is the 'effectiveness' of the network and whether it achieves its declared aims (de Lima, 2010: 11). De Lima also stresses the importance of the interactional aspects of networks and argues for an additional foci on 'internal processes', 'management and leadership', 'participation', 'learning', 'interpersonal relations and trust' and 'network ecology' as well as negative aspects of networks and factors that contribute to their 'disengagement and dissolution'. Underlying these dimensions is the original focus of a network, its pedagogic purpose being to inform practice /knowledge or to reflect/understand.

Research into networks supporting CPD for STEM teachers highlights the importance of a number of different factors that influence their effectiveness. In their study, Baker-Doyle and Yoon (2011) stress the importance of the structure of networks and suggest that when networks are 'closed' and are constituted of 'tight- knit' group where teachers are well known to each other, they can become 'insular' and less open to new ideas. Such networks are, however, seen to be effective in sharing complex information and tacit knowledge. In contrast 'open networks' where there are few ties are seen to have a potentially negative impact on the introduction of new ideas because social support is missing. However, open networks are viewed to have better access to new information which can stimulate innovation (Baker-Doyle & Yoon, 2011). They suggest that this is important as, although teachers may effectively gain information from PD activity, it is through their social networks that this information is 'interpreted, shared, compiled, contextualised and sustained' (Baker-Doyle & Yoon, 2011: 90). They conclude that there is a need to make teachers more aware of others with relevant expertise within their network as they found teachers were prone to develop relationships with others they liked rather than teachers who could best support their learning (Baker-Doyle & Yoon, 2011: 89). Hardre et al. similarly stress the importance of dissimilar people interacting in networks in order to generate 'unique competence and identities' (2016: 411).

In their research into building networks to support science teachers, Sillasen and Valero (2013) point to the important contribution that central figures, teacher 'municipal consultants', make in supporting these networks. They highlight the significance to network development of consultants' contacts in the local science teacher community; their mobilization of resources to reach teachers; their development of collaborative activities between schools and their support for the development of new teaching activities within schools/networks of schools (Sillasen & Valero, 2013: 615-616). An important concern raised is that while individual teacher's learning in professional networks is important, it is also vital to consider the role of other participants, such as school leaders, in supporting systemic change in schools (Sillasen & Valero, 2013).

5.5 Setting the scene for the quantitative evaluation of the CST Programme

From the literature, the structure/aims of the CST Programme and previous qualitative evaluations, the quantitative evaluators were able to identify the following criteria as items for inclusion/contexts for inclusion in the evaluation reported below:

1. Whether the Programme was based on real and authentic STEM experience
2. How the cascade model of CPD worked in action, especially in relation to the national network being set-up by the RAEng
3. Was the Programme effective in providing appropriate curriculum-oriented content, pedagogic approaches
4. How might the Programme affect STEM and engineering efficacy
5. In particular:
    - Why did TCs and teachers engage in the Programme
    - What is their current experience of the Programme
    - What are their attitudes to STEM education
    - How actively have individuals been involved in the Programme
    - What levels of STEM, pedagogic and engineering efficacy characterise participants in the Programme
    - How do participants perceive various potential impacts of the Programme in students

This range of items would be asked of both TCs and teachers participating in the CST Programme. Further, as a range of education- and STEM-based research on teachers and CPD, the items will also be analysed for various demographic differences between participants: these differences may include: sex of participant, age and teaching experience of participants, subject training of participants, type of school within which participants work, whether participants were supported (by their schools) to attend the Programme, length of time engaged with CST, and whether participants had any engineering background.

6. Phases of the evaluation

The overall goal of this evaluation was to understand the impact of the programme on CST TCs and Teachers. Questionnaire items with appropriate ecological and content validity were to be the foundation of this understanding, and refined instruments for use in future evaluations were to be an important by-product. Phases in the development of the evaluation included the following:

First, a literature update regarding various secondary school-based programmes to enhance teachers' and students' understanding of and enhancing interest in STEM subjects and careers. In particular, this literature update identifies elements of teachers' Continuing Professional Development (CPD), Networking, Information Sharing and Confidence/Efficacy that have been effectively used in the promotion of STEM among secondary school students;

Second, as a result of the literature update and initial analyses of the qualitative evaluations by Gartland and Paczuska, a range of topic areas for semi-structured questioning were identified for groups of Teacher Coordinators and Teachers. A small, regionally-based sample of Teacher Coordinators and Teachers were invited to participate in semi-open ended interviews conducted by one of us (CG). The sample included TC representatives from 4 different regions (8 TCs in total) and two teachers from each of the 4 TC regions (8 teachers in total).

Third, results from the semi-structured interviews were thematically analysed – based on pre-identified themes arising from the previous qualitative evaluations, the literature update and allowing for the identification of new/unique theme not previously considered in the literature or qualitative interviews. From this a range of attitudinal, perceptual, efficacy and open-ended questions were constructed to address the full range of issues identified in the pre-pilot. Questions were then reviewed to ensure that reliability checks and coverage of issues are included.

Fourth, upon the completion of the draft questionnaires, a two-phase piloting was undertaken. In the first phase, a researcher revisited a number of pre-pilot Teachers and Teacher Coordinators to 'talk through' each of the questions – to ensure that none of their key issues and concerns had been left out and that the questionnaire items were intelligible. The second phase worked through each of the questions with the Teacher Coordinator organiser who also received advice from various Teacher Coordinators and Teachers on the CST programme. Drawing upon the second phase feedback, further revisions to the questionnaire were undertaken in preparation for the final distribution of the questionnaire.

Fifth, the value of the data to be collected in this exercise will be very sensitive to the timing of the yearly cycle of activities across the network. Network activity is timetabled by the coordinators and they do not all meet at identical points in the year. Furthermore, the other demands on a Teacher's time as a result of the different seasons in the school year have a significant impact on their opportunity and willingness to complete the questionnaire. This meant that distribution proved to be a far more challenging matter than originally envisaged and the change from a paper based distribution to an online version did not alleviate these difficulties.

Sixth, the questionnaires have been initially analysed on a question-by-question basis to provide a basic description of key features of the TC and Teacher experiences and beliefs as well as key demographic information. A second level of analysis has been undertaken using a factor analytic approach to ascertain whether teachers and teacher coordinators express a limited number of conceptual components in their project experience. If a range of reliable factors arise from this analysis, these factors will then be used to differentiate between subject, age, school and other contextual differences between teachers and teacher coordinators involved in the project. This will also allow the identification of the questions which are most revealing about these concepts and allow uninformative questions to be eliminated. These results will then be compared to the literature to ascertain innovative differences or consistencies with the project approach to the support of STEM teaching.

7. Teacher Coordinators; descriptive analyses

The findings reported in this section are based on the analysis of an original questionnaire circulated to all TCs involved in the CST Programme by the RAEng. Respondents completed the questionnaire between October 13th and November 5th 2017. This section provides a base level description of the responses to each element of the questionnaire. In considering these responses, it should be noted that:

1. 44 of the potential 48 TCs completed the questionnaire, a 92% response rate.
2. Not all respondents answered all questions
3. Within this analysis, there will be no comments about particular TCs. Those who participated in the survey were assured that all responses would be completely confidential and care has been taken to ensure that no information has been reported that might lead to the identification of individuals.
4. Readers should note that none of the TCs involved in this survey had a full-time position as a Teacher Coordinator – the time available for TCs to work/develop their networks was limited by their full-time teaching or other employment.

7.1 **Teacher Coordinator characteristics**

Approximately 2/3 of the TCs were male (65.1% male; 34.1% female). They ranged in age from 24 to 68 years of age – with quite an even distribution across the range. Any identification of an average or modal age would be uninformative.

34 of the TCs reported that they normally worked in an educational institution. Of these 34, most TCs worked in Academies (11 schools, 32.4%), followed by undifferentiated State schools (10, 29.4%), Comprehensive (6, 17.6%). There were few Independent (3, 8.8%) and Faith (1, 2.1%) schools represented. The great majority were currently employed as teachers (33, 73.3%), while 12 TCs were not currently employed as a teacher (26.7%). Currently, there is no information on the employment positions of the non-teaching TCs.

Qualification of TCs ranged from Bachelor's degrees to PhDs. 43 of the TCs provided information on their Bachelor's degrees: 32.6% had an Engineering degree; 30.2% Design; 9.3% for each of Biology and Education; and there were a few degrees in BioChemistry, Physics, Natural Science, Chemistry and Mathematics. 36 TCs had PGCE/Teacher Education degrees: 41.7% Design & Technology; 13.9% for each of Biology, Physics, and General; 8.2% Mathematics; 5.6% Computing; and one TC had an Arts degree. 19 TCs had a Master's degree: 63.2% General Education; 21.1% Engineering; and 5.3% for each of BioChemistry, Chemistry and Social Sciences. 5 TCs had doctorates. Thus, a high proportion of TCs had backgrounds in Engineering and Design, and when a comparison was made as to whether these were predominantly male or female TCs little difference was found.

TCs joined the programme between 2011 and 2017. Possibly as a result of the gradual increase in size of the programme, there was a fairly even distribution of TCs joining between these years – with a low point in 2014 (only 1 TCs joined) and a high point in 2016 (when 10 joined). There was little difference between joining the programme and when individuals became a TC (represented in a correlation of 0.932).

With a particular focus on engineering, analysis noted that 13 of the TCs had an initial (Bachelor's) degree in Engineering. The questionnaire also noted that at least 30 of the TCs had worked in areas outside of education at some point in their careers. Analysis of outside work showed that 14 TCs had engineering experience – and, interestingly, only 9 (of the 13) TCs with an Engineering degree had worked as an Engineer; this is still approximately 20% of all TCs.

7.2 Reasons for the involvement in the CST programme

TCs were asked to rate reasons for involvement in the programme on a 3-point scale (1 = Very significant, 2 = Significant, 3 = Not significant). Table 1 displays means and standard deviations for each of these questions, providing evidence of:

a) The most significant reasons included bringing 'real world' applications into the STEM curriculum alongside 'enhancing coordination among STEM teachers';
b) Connections with local (STEM) employers and experience of engineering were the least significant contributors to TC involvement;
c) Other reasons only showed moderate levels of significance in TCs joining the programme.

Table 1: Reasons for TC involvement on the CST programme

Reasons	N	Mean	s.d.
Personal connections with local employers	44	2.07	0.79
Enhancing coordination among STEM teachers	44	1.27	0.45
Experience working as an engineer	43	2.37	0.76
Extend opportunities to develop new STEM pedagogic approaches	43	1.40	0.54
Facilitate the inclusion of real world applications into STEM education	44	1.25	0.49
I have been a successful STEM teacher in school	44	1.55	0.73
Mentoring and support for CST teachers	41	1.59	0.67
Involvement with external STEM support organisations	42	1.43	0.55

7.3 Roles and responsibilities of the TC

TCs were asked to rate the range of roles and responsibilities that they incurred as a TC. Each of the 14 questions was rated on a 5-point scale (1 = Strongly Agree; 3 = Neither Agree or Disagree; 5 = Strongly Disagree). Means and standard deviations for each of these questions provided evidence of (see Table 2):

a) Overall, the means indicate general agreement with the range of role and responsibilities presented (identified roles and responsibilities were the result of pilot interviews and previous qualitative CST studies);
b) The strongest aspects of 'agreement' to the questions related to improving CST teachers' confidence in approaching STEM activities and attitudes via improved teacher confidence in approaching STEM problems, attitudes to STEM and establishing a 'community of learning') – although none of the question responses received an extremely high (near 1.00) mean;
c) There was a greater degree of equivocation as indicated by the mean scores and high associated standard deviations on questions related to helping teachers overcome management problems, prioritising help for newer CST teachers, providing collegial teacher mentoring within their networks and communication between network teachers when not in network meetings.

Table 2: Roles and responsibilities of the TC within the CST programme (N=43 for all questions)

Roles and responsibilities	Mean	s.d.
To be able to demonstrate all resources and activities provided by the CST programme.	1.74	0.88
To provide individual support for my CST teachers.	1.81	0.73
To support my CST teachers working together to solve STEM problems during network meetings.	1.79	0.71
To help overcome school management problems confronted by my CST teachers.	2.56	1.08
To identify ways in which my CST teachers can encourage communication among STEM teachers in their schools	1.67	0.72
To prioritise the needs of new CST teachers over more established members in my network.	2.74	0.85
To further develop/support improved STEM attitudes among my CST teachers.	1.53	0.67
To improve my CST teachers' confidence in approaching STEM problems in the classroom	1.35	0.61
To establish a long-term Community of Learning among my CST teachers	1.49	0.67
To find new schools to integrate into my CST network	1.67	0.68
To pass on my STEM knowledge to CST teachers.	1.72	0.79
To provide a forum for my CST Teachers to reflect on their STEM activities	1.51	0.70
To identify more experienced CST teachers to mentor new teachers coming into my network	2.28	0.91
To establish effective ways for my CST teachers to communicate outside of network meetings	1.98	0.80

While there were very few 'negative' points made with regard to the roles and responsibilities of the TCs, there are some indicative points that the CST programme may wish to follow-up. TCs suggest that they see their role as showing/demonstrating their STEM understanding to improve their teachers' perception of STEM. On the other hand, they appear to see themselves less involved in prioritising individual needs of newer network teachers, understanding the (management-based) contexts in which teachers must work within their schools and have not prioritised collegial aspects of mentoring and non-meeting communication within their networks. These issues might merit further discussion with TCs at a TC meeting.

7.4 Experiences and attitudes of TCs towards the CST Programme

TCs were asked to rate the TCs' range of experiences and attitudes towards the CST programme. Each of the 10 questions was rated on a 5-point scale (1 = Strongly Agree; 3 = Neither Agree or Disagree; 5 = Strongly Disagree). Unlike previous sets of questions, this set contains wording of questions that are both positive and negative, hence one cannot simply looks at means and standard deviations to understand how TCs have responded. A general overview of these means and standard deviations for each of these questions provided evidence of (see Table 3):

a) Highest levels of agreement related to enjoying their work with CST teachers and further developing their own STEM (and recommendations for) teaching;
b) TCs displayed fairly neutral (neither agree/disagree) sentiments regarding preparing for/arranging network meetings, promoting relationships between their network teachers and developing/exploiting relationships with local industries in support of CST; and
c) Only mildly encouraging feelings regarding changes/developments that CST has offered their (own) teaching and the need to be a good teacher to be effective in CST.

Table 3: Experiences and attitudes of TCs (N=44 for all questions)

Experiences and attitudes of TCs	Mean	s.d.
I need to be a good teacher in order to be an effective CST Coordinator	1.93	0.87
It is difficult to promote positive relationships among my network teachers	3.50	1.21
Preparing for CST meetings is too time consuming	3.27	0.85
The resource boxes from CST are essential for extra-curricular activities	2.18	1.11
CST has given me ideas which have changed my approach to recommendations for teaching STEM	1.82	0.89
Coordination of CST meetings is a natural expansion of my STEM responsibilities	2.23	1.08
I find it difficult to arrange CST meetings	2.89	1.17
I plan for CST network activities in addition to the regular meetings	2.39	1.04
I enjoy working with CST Teachers	1.39	0.62
It is difficult to persuade local industries to become involved in school based STEM activities	2.84	1.24

When TCs were asked to reflect on their CST experiences, they appeared keen on working with/teaching teachers within their networks. They saw themselves as competent teachers and work with CST was likely to enhance their recommendations for the teaching of STEM and their relationships with CST teachers. Organisational aspects of their CST networks appeared to have a lower priority than teaching/relational development – meetings were difficult to organise/time consuming in their planning, accessing local industries was not easy and little effort was devoted to the development of relationships among network teachers. Perhaps we may be making 'an interpretation too far', but in consideration of the role/responsibilities of TCs and this section, we might speculate that more time/effort could be spent on developing trusting and supportive relationships among network teachers and that these efforts may allow greater sharing of knowledge within the network regarding ongoing school problems, access to local industry and enhanced interdependence among teachers themselves – putting less pressure on TCs being 'good teachers' and efficient in meeting organisation.

7.5 Experiences and views of STEM education

TCs were asked to rate their experiences and views of STEM education. Each of the 27 questions was rated on a 5-point scale (1 = Strongly Agree; 3 = Neither Agree or Disagree; 5 = Strongly Disagree). Like the previous set of questions, this set contains wording of questions that are both positive and negative, hence one cannot simply looks at means and standard deviations to understand how TCs have responded. Questions cover a range of topics from skills that students need to learn about STEM subjects to support for learning and social pedagogic contexts that may support or hinder learning. A general overview of these means and standard deviations for each of these questions provided evidence of (see Table 4):

a) Highest levels of agreement was associated with questions concerning students' need to develop interpersonal skills and the ability to work independent of the teacher (to enhance STEM learning), that STEM subjects should be taught in the context of real-world problems and that engineering should have a higher level of integration into the STEM curriculum;
b) TCs had neutral feelings (neither agree nor disagree) with regard to who and how support for STEM learning should take place. This neutrality was found with regard to parental support, extra-curricular activities within the school and competitions to promote STEM activities among students. TCs also felt neutral about persuading their teachers to collaborate with other STEM teachers in network schools, the role of small (student) groups to promote learning and the need to train students for (group) working. TCs were also neutral about level of trust underlying their relationships with network teachers.
c) The highest levels of TC disagreement were found associated with negatively worded questions and showed strong beliefs in an inclusive approach to STEM. TCs disagreed with the view that students had a 'fixed' level of ability, that they should be taught in single-sex groups and that STEM was only for high achievers. They also disagreed that (the activities involved in) STEM classes allowed student to 'mess about'. TCs also noted that effective teaching of STEM topics did not rely on students having fundamental knowledge of the scientific and mathematical bases of STEM, nor did a STEM career require a university career.

Table 4: Experiences and views of STEM education (N=43 for all questions)

Experience and views of STEM education	Mean	s.d.
Extra-curricular activities enable me to do valuable educational work with my students	1.72	0.85
Students will only develop a positive attitude to STEM subjects if they have full parental support	2.86	1.01
During hands on STEM activities, most students mess about	3.86	1.06
Extra-curricular STEM activities only attract students already interested in the subjects	3.14	1.10
Schools in my Network are very supportive of extra-curricular STEM activities	2.23	0.84
CST Teachers place a high level of trust in me to help solve their educational problems	2.65	0.89
In my network of schools, exam results will be the main measure of STEM success	2.30	1.04
Students only work well together if a teacher trains them in how to do so effectively	2.93	1.12
It is very difficult to persuade CST teachers to collaborate with other STEM subject teachers in their school	2.88	1.01
An understanding of underlying scientific principles is most easily achieved through practical exercises	1.98	0.83
A student's basic abilities are fixed	4.42	0.76
Problem and project based learning practices are encouraged in my CST network	1.81	0.63

Experience and views of STEM education	Mean	s.d.
Seeing real world applications is the best way of getting students interested in STEM subjects	1.37	0.54
Only high achieving students are able to study STEM subjects successfully	4.23	0.84
Competition in STEM clubs stimulates student learning	2.12	0.91
Students need exercises which enable them to reflect on what they have learnt in STEM lessons	2.14	0.71
Younger children are more receptive to STEM learning than older ones	2.98	1.07
Exercises which require a student to think on their own are an essential component of good STEM education	2.07	0.89
Female teachers are more successful in interesting female students in STEM subjects than male teachers	3.44	1.01
STEM activities should be conducted in single sex groups	4.28	0.91
STEM activities are best delivered to small groups (of two to six) students	3.12	1.12
Students should work independently of their STEM teacher from time to time during classroom lessons	1.74	0.90
STEM group activities develop a student's interpersonal skills	1.30	0.47
For a career in a STEM subject, a student needs a relevant University degree	3.98	0.99
Engineering should have a formal place in the school curriculum	1.74	0.76
It is more important to teach the fundamentals of science and mathematics than their STEM application	3.81	0.91
Student populations of some schools simply do not allow for effective STEM teaching	3.19	1.10

Table 4 (cont): Experiences and views of STEM education (N=43 for all questions)

TCs expressed an interesting and intriguing range of opinions with regard to this group of questions. They showed a strong belief that students of all levels of ability could benefit from STEM and that STEM teaching may be best presented in an inclusive manner – that did not require initial levels of understanding of the fundamentals of science and mathematics. They also identified that students could develop interpersonal and autonomy skills via STEM, although TCs were neutral with regard to training students for the interpersonal/autonomous skills, the extent of parental support required for students to develop positive attitudes to STEM, collaboration among STEM teachers and extra-curricular activities at school. More worrisome was a neutral level of belief that the network teachers 'trusted' their TCs.

7.6 Frequency of participation in CST activities

TCs were asked to identify how often you have done various actions/activities associated with the CST Programme in the past school year. Each of the 11 questions was rated on a 5-point frequency scale (1 = Never; 2 = 1-to-3 times; 3 = 4-to-6 times; 4 = 7-to-10 times; 5 = More than 10 times). Means and standard deviations for each of these questions provided evidence of (see table 5):

a) Overall, none of the actions/activities were undertaken with a high degree of frequency – the most frequently undertaken activities (undertaken less than 6 times over the previous year) involved contacting outside organisations (STEM or local industries);
b) There were moderate levels (approximately 3 or 4 times in the previous year) of activity that (in the main) related to organisational responsibilities of the TCs – contacting other TCs (probably at TC meetings organised by the RAEng), visiting and working with teachers in schools, developing STEM clubs. It should be noted that each TC would have had approximately 14 teachers per network, hence an activity level of 3 or 4 times per year is likely to indicate that less than a third of teachers may have been visited by the TC per year;
c) TCs very infrequently co-taught with their network teachers, discussed student confidence building actions or checked whether CST teachers were networking with one another. On the other hand, TCs reported very few problems in understanding the use of the resource boxes.

Table 5: Frequencies of actions/activities associated with the CST programmes in preceding year (N=43 for all questions)

Frequencies of various actions/activities associated with the CST programme in the last year	Mean	s.d.
Gathered feedback from your network concerning the resource boxes	2.53	1.03
Contacted other CST Coordinators to discuss aspects of your network meetings	2.37	1.19
Worked with your CST teachers in their schools on developing within class and extra-curricular STEM activities	2.30	1.17
Run into problems understanding the use of resource packs	1.47	0.59
Considered how to further develop a STEM club activity with your CST teacher/colleagues	2.67	0.99
Co-taught a STEM class with one of your CST teachers	1.60	0.96
Visited one of your CST schools to encourage support for STEM teaching and associated activities	2.28	1.08
Discussed with your CST teachers how to identify students becoming more confident in approaching a STEM activity	2.07	1.03
Contacted local and national STEM organisations to further support STEM education	2.95	1.07
Contacted local industry in support of your CST network	2.81	1.12
Checked with your CST teachers to see that they are 'networking' with one another	1.93	0.96

The CST programme has placed a range of responsibilities on TCs – especially in guiding and supporting teachers in their networks. Given that there are approximately 13 – 18 teachers in each network and that TCs were asked to reflect upon their previous year's activities, responses to none of the questions indicated a very high level of activity. Activities most often engaged in were functional for the network, especially contacts with STEM organisations and local industry; although it may be pointed out that 2 of the TCs did not engage with other STEM organisations and 6 did not engage with local industry. TCs, on the other hand, did periodically visit and worked with their network teachers (when their full-time positions allowed) and engaged with other TCs. Given the level of frequency of engagement with teachers (outside of actual network meetings), it appears that only a limited number of these teachers could have been visited/supported by the TC. Few functional problems were encountered with regard to RAEng developments such as the resource boxes.

7.6 Confidence and competence of TCs in promoting STEM and Engineering understanding:

The range of questions displayed in Table 6 focuses on various types of efficacy within the expected ranges of competence of TCs. These ranges include questions concerning: helping CST teachers (in their development and activities); TC teaching and advising competencies; and engineering efficacy (practical engineering skills). TCs were asked to respond to each question by assessing their confidence in have a particular skill or ability. These assessments were made on an 11-point scale (ranging from 1 = not at all confident to 11 = 100% confident). Table 7 displays means and standard deviations for each of these questions, providing evidence of:

a) From an overview of all questions/foci of question, these TCs perceive themselves as very competent and confident in their various responsibilities in the role of Coordinator;
b) TCs perceive themselves as particularly strong in the design of STEM activities for students (and average of 9.58);
c) Averages of each of the question foci showed perceptions of 70%+ levels of competence/confidence (Help teachers: 8.4; Practical activities: 8.51; Teaching & advising: 8.78; Engineering efficacy: 8.54; and Engineering efficacy for students: 9.58)

Table 6: Confidence and competence levels of TCs in promoting STEM understanding and engineering efficacy (N=43 for all questions)

Focus	Question	Mean	s.d.
Help teachers	Help a CST teacher to gauge a student's understanding of an engineering task	8.67	2.02
"	Provide guidelines to help CST teachers assess a student's engineering products	7.63	2.29
"	Help CST teachers promote a positive attitude to engineering among their students	9.60	1.37
"	Help CST teachers understand a difficult scientific concept	8.44	2.12
"	Help CST teachers to understand a difficult mathematics problem	8.07	2.15
"	Help CST teachers design a new technology lesson	8.00	2.88
Practical activities	Provide actual practices that will enable CST teachers promote student team work on engineer problems	8.81	1.35
"	Identify practical activities for CST teachers that will encourage students to think creatively about engineering problems	9.21	1.59
Teaching and advising	Teach CST teachers STEM subjects outside my core subject area	7.58	2.45
	Advise my CST teachers on how to organise extra-curricular STEM activities	9.74	1.31
	Advise students on the routes to a career in engineering	9.02	1.77

Focus	Question	Mean	s.d.
Engineering efficacy	Explain why a bridge collapsed	8.98	2.19
“	Explain why we recycle paper	9.81	1.56
“	Learn how to use a new programming language	6.40	3.57
“	Fix a broken machine	7.81	2.79
“	Use tools to build something	9.09	2.45
“	Develop design solutions	9.14	2.11
Efficacy for students	Design an effective new STEM activity for the weakest students in KS3	9.60	1.79
“	Design an effective STEM activity for the strongest students in KS3	9.91	1.59
“	Evaluate a novel technical design	9.23	1.82

Table 6 (cont): Confidence and competence levels of TCs in promoting STEM understanding and engineering efficacy (N=43 for all questions)

Overall, the TCs drawn upon for the CST programme see themselves as very highly competent in supporting and developing work with their network Teachers. They also have high self-perceived levels of engineering competence. Moreover, these TCs are very confident in their understanding of the design of STEM experiences for high and low performing students. However, on some of the questions it is clear that some TCs feel themselves to be far from confident. While that lack of confidence is not widespread, it may be important to provide opportunities for those lacking in confidence to acquire the relevant expertise and thereby bolster their confidence.

7.7 TC considerations concerning Impact of the Connecting STEM programme:

Two main questions concerned TCs perception of student engagement with aspects of the programme. With regard to ‘To what extent are students engaged in the Collaborative Project?, there was a strong positive response: responses ranged from 1(All students involved) to 6 (No students involved), the mean was 2.24 (Most students involved) with a standard deviation (s.d.) of 1.53. With regard to ‘How engaging do the students find the CST learning resource boxes?, an even stronger positive response was recorded: Responses ranged from 1 (Wholly engaging) to 5 (Not engaging at all), the mean was 2.03 (Mostly engaging), s.d. = 0.49. Thus, two main elements of the transfer of STEM training were seen to have very positive influences on students.

Nine further questions specifically sought information on TC perceptions of types of impact of the programme. Each of these questions was rated on a 7-point scale (from 1 = Strongly agree to 7 = Strongly Disagree). Table 7 displays means and standard deviations for each of these questions, providing evidence of:

a) A generally positive perspective of the impact of the CST programme on students (noting that means of 3 or lower showed agreement with the question/statement);
b) The strongest level of agreement indicated that relevance of the programme to the current school-based STEM curriculum;
c) There were only ‘slight’ levels of agreement that the programme affected boys and girls in an equivalent manner (seeing Science, Design, Engineering and Technology as good options);

d) Student involvement in the programme was perceived to have positive effects on their participation in STEM subjects and understanding of STEM careers.

Table 7: Aspects of impact on students related to participation on the CST programme (N=43 for all questions)

Question	Min	Max	Mean	s.d.
The learning experience is relevant to the students' STEM curriculum	1	5	1.91	0.95
Student attainment in STEM subjects will improve after participating	1	4	2.16	0.79
Students are motivated to choose Science subjects	1	5	2.4	0.88
Students see Science as a good option for both girls and boys	1	5	2.53	1.03
Students are motivated to choose Design, Engineering and Technology subject options	1	6	2.91	1.13
Students see Design, Engineering and Technology as good options for both girls and boys	2	6	3.00	1.16
Students gain an interest in Engineering careers	1	7	2.58	1.05
Students have a greater understanding of what STEM careers involve	1	4	2.07	0.86
Students know what to do next in order to become an Engineer	1	5	2.72	0.96

Further analyses revealed: 1) that there were no significant statistical differences between male and female TC responses to any of the above questions; 2) nor were there any statistically significant differences between responses to the above questions explainable by length of time involved in the CST programme.

7.8 Finale

Response rate for the TCs on this questionnaire was very high. 44 of a potential 48 Teacher Coordinators completed the questionnaire. Most of these TCs were teachers and worked in schools. The spread of backgrounds of the TCs showed: 1) a mainly STEM-based educational background, with a strong concentration on Engineering and Design/Technology; 2) those TCs with the combination of Design/Design & Technology (Batchelor/PGCE) degrees were the most likely to identify that the CST programme had a relatively low impact on students; 3) One TC had a Arts background, and it may be worthwhile exploring whether this individual has been able to introduce STEAM into the programme. Approximately 1/3 of the TCs were female, although there tended to be no significant differences between the sexes of TCs in responses to questions analysed here.

Responses to the sections of the questionnaire regarding roles/responsibilities, experience/attitudes of TCs, experiences/views of STEM education and frequency of CST activities showed that TCs had generally high levels of involvement in the programme although there were a number of variations and apparent contradictions in their responses. Particularly with regard to roles/responsibilities, many TCs saw themselves in the position of being 'good teachers' who spent much time/effort in showing and demonstrating aspects of the programme. It appeared that this showing and demonstrating aspect took priority within the TC role, thus providing less opportunity to focus on the needs of individual (especially newer) teachers in the network and little time to account for the various STEM contexts within their network schools. When findings are combined with experience/attitudes of the TCs, analyses showed that TCs liked to work with their teachers, but they felt the need to enhance the quality of their communication and support for teachers – possibly through enhanced mentoring. TCs did show positive expectation for the potential of STEM education, and took a very strong stance that STEM education should be inclusive – and not just for an elite. Yet, while TCs identified that students may develop social skills and the ability to reflect on STEM activities, they did not identify that their networks had been developed to incorporate these pedagogic skills. TCs also expressed a lack of certainty that their teachers placed a high level of trust in the TC to help/resolve STEM education problems. Finally, there was a relatively low frequency of associated CST activities engaged in over the previous school year by TCs. These activities included school visits, working with teachers in classrooms, giving/getting feedback on CST materials, etc.. Perhaps this low frequency level may be associated with the very part-time nature of the TC role – and it may be worthwhile exploring the constraints placed upon TCs when this role (vital to the success of the CST programme) may be seen as an 'add-on' to their full-time jobs.

There was strong positive agreement among the TCs in a range of impacts of the programme, although two qualifications may be noted: 1) there was a very limited perception of positive impact related to equal effects on male and female students; and 2) the strongest impacts appeared to be related to development and application of the STEM curriculum (also seen in TCs' confidence in providing curriculum-appropriate information for high and low performing students). Within the range of TCs involved in the programme, a very high proportion saw themselves as having a high degree of efficacy in supporting their network teachers and students as well as having high levels of competence in solving engineering-based problems.

Finally, within the limited analyses of sex differences among TCs and length of experience on the programme no significant differences were found. These results will need to be explored further, as they appear to differ from expectations established in the STEM literature and we have only analysed limited sections of the questionnaires.

8. Factorial and Demographic Analyses of the Teacher Coordinator Questionnaire

While a high percentage of the current TCs completed the questionnaire, the number of respondents is nevertheless quite small and so any further analysis must be treated with caution. An important next step in the development of the evaluation is the analysis of common response patterns across the different questions. Factor analysis can help identify such patterns in the sets of correlations between items, and where more than two items are highly correlated it can help specify the extent to which each item relates to a putative underlying common factor to which each item relates.

Identification of factors was undertaken on the basis of the individual question groupings structured into the questionnaire. For each question grouping, initial analyses were undertaken to ensure that factor analysis was an appropriate statistical approach (drawing upon the Kaiser-Meyer-Olkin test for 'sampling adequacy' and Bartlett's test for 'sphericity' to ensure that a factor analysis was appropriate for the data). Following well recognised procedures, an exploratory factor analysis was undertaken for each question grouping and the construction of each (identified) factor met minimal requirements of an 'Eigen value' greater the 1.0 and a component correlation greater than 0.50. Within this section of the report, we will refer to results from the factor analyses as 'factors' (with an explanation/name for each factor). Each of the identified factors was also checked for reliability (with a minimal alpha correlation of 0.7 or above).

Demographic analyses provide an identification of key variables that can be assessed against each of the factors. The demographic variables were identified in discussion with members of the RAEng CST Programme team and drawing upon previous studies in the literature and current practice within the Programme. Demographic variables are identified and described as:

a. School type: Drawing upon the main school types in the questionnaire, the variable separated State (including comprehensive) from Academy and Other schools.
b. Sex: A simple breakdown into Male and Female TCs, with a small proportion not identifying their sex.
c. Bachelor's Qualification: Grouping TCs undergraduate qualification into Sciences, Mathematics, Design, Engineering, General education (undifferentiated degree) and Social sciences.
d. Postgraduate Teaching Qualification: Grouping TCs postgraduate teaching qualifications into Sciences, Mathematics, Design & technology, Computing, Social sciences and Arts.
e. Teaching Experience: Dividing number of years teaching experience into 1-5 years, 6-10 years, and 11+ years, representing newer, somewhat experienced and very experienced teachers.
f. Training Pre- and Post-National Curriculum: A variable to ascertain whether changes in teacher training associated with the legislated onset of the National Curriculum (NC) might be associated with attitudes and experiences of the TCs.
g. Experience working as an Engineer: Separating engineering experience into No experience, Limited experience (1-3 years) and Experienced (4+ years) working as an engineer.
h. Experience as a TC: Dividing the years of TC experience on the CST Programme into 1 year (New), 2-3 years (Slightly experienced) and 4+ years (Experienced)
i. School Recognition for participation in the CST Programme: A simple division into whether or not the TC's current school (if the TC is employed in a school) recognises the individual's participation in the Programme.

8.1 Reasons for the involvement of Teacher Coordinators on the CST programme:

In response to the question 'Within your commitment to improving STEM education, what were your reasons for becoming a CST Coordinator?', two reliable factors were identified. 'STEM in school' was composed of four items (Enhancing coordination among STEM teacher; I have been a successful

STEM teacher in School; Mentoring and support for CST teachers; and Involvement with external STEM support organisations); thus, supporting their network teachers as well as being a competent STEM teacher. 'STEM in the World' was composed of three items (Personal connections with local employers; Experience working as an Engineer; and Facilitate the inclusion of real world applications into STEM education); thus being able to draw upon STEM experiences from outside of the school. Regarding STEM in school, significant demographic differences were only found for School type (TCs in Academies) and those that had trained after the on-set of the NC saw this factor as less significant than other TCs. Regarding STEM in the World, pre-NC and those without Engineering experience saw this as less significant than other TCs.

8.2 Roles and responsibilities of the TC

In response to the questions about your roles and responsibilities as a Coordinator of the CST Programme, one factor and one item of interest were identified. To be able to demonstrate all resources and activities provided by the CST programme. 'Role commitment to teachers and network' included nearly all of the questionnaire items (To be able to demonstrate all resources and activities provided by the CST programme; To provide individual support for my CST teachers; To support my CST teachers working together to solve STEM problems during network meetings; To help overcome school management problems confronted by my CST teachers; To identify ways in which my CST teachers can encourage communication among STEM teachers in their schools; To further develop/support improved STEM attitudes among my CST teachers; To improve my CST teachers' confidence in approaching STEM problems in the classroom; To establish a long-term Community of Learning among my CST teachers; To find new schools to integrate into my CST network; To pass on my STEM knowledge to CST teachers; To provide a forum for my CST Teachers to reflect on their STEM activities; To identify more experienced CST teachers to mentor new teachers coming into my network; To establish effective ways for my CST teachers to communicate outside of network meetings); thus, a strong commitment to improve their network teachers' STEM teaching responsibilities especially within the context of their schools). The additional item of interest was labelled 'Integrating new teachers' and was composed of one questionnaire item only - To prioritise the needs of new CST teachers over more established members in my network. There were no significant demographic differences found for either the factor or item; with Role commitment to teachers and network showing 'agreement' with this factor and 'neutrality' with regard to Integrating new teachers.

8.3 Experiences and attitudes of TCs towards the CST Programme

In response to questions about experiences and attitudes as a Coordinator of the CST Programme, two factors and one item of interest were identified. 'Organisational problems' included four questionnaire items (Preparing for CST meetings is too time consuming; I find it difficult to arrange CST meetings; It is difficult to persuade local industries to become involved in school based STEM activities; and It is difficult to promote positive relationships among my network teachers); thus denoting problems associated with organising and supporting networks. 'Role comfort' included four items (I need to be a good teacher in order to be an effective CST Coordinator; Coordination of CST meetings is a natural expansion of my STEM responsibilities; I plan for CST network activities in addition to the regular meetings; and I enjoy working with CST Teachers); thus identifying positive aspects of coordination, planning and working with teachers. The additional item of interest referred solely to the use of the resource boxes, based on one question item (The resource boxes from CST are essential for extra-curricular activities). There were no significant demographic differences in relation to Organisational problems (with TCs agreeing on the existence of these problems). Regarding Role comfort, there was a nearly significant difference with females TCs more strongly agreeing than their male counterparts. Regarding the Resource boxes, TCs in state schools, male TCs and those with less experience of the CST programme showed significantly less agreement than their counterparts.

8.4 Experiences and views of STEM education

In response to questions about experience and views of STEM education as a whole, one factor and two further items of interest were found. 'Student STEM success' included 12 question items (During hands on STEM activities, most students mess about; Extra-curricular STEM activities only attract students already interested in the subjects; In my network of schools, exam results will be the main measure of STEM success; Students only work well together if a teacher trains them in how to do so effectively; A student's basic abilities are fixed; Only high achieving students are able to study STEM subjects successfully; Students need exercises which enable them to reflect on what they have learnt in STEM lessons; Younger children are more receptive to STEM learning than older ones; STEM activities should be conducted in single sex groups; For a career in a STEM subject, a student needs a relevant University degree; It is more important to teach the fundamentals of science and mathematics than their STEM application; Student populations of some schools simply do not allow for effective STEM teaching); thus, these appear as negatively worded questions and by disagreeing (having higher average scores) TCs would demonstrate an inclusive approach to STEM – coverall students of all ages, both sexes, and a range of abilities without having to be taught theory-based traditional science/mathematics subjects. Additional items asked for TCs views on student competition in support of learning (Competition in STEM clubs stimulates student learning) and the role of reflection to support student learning (Students need exercises which enable them to reflect on what they have learnt in STEM lessons). There were no significant differences for the demographic variables in relation to the Student STEM success factor or the individual items. All TCs appeared to be neutral or in disagreement to the (negative) aspects that may promote/inhibit their students' STEM learning. On the other hand, all TCs agreed (not strongly) that competition and reflection enhanced student learning.

8.5 Frequency of participation in CST activities

In response to questions about how often TCs have done various activities associated with the CST Programme in the past school year, two factors and one additional item were identified. 'General CST activity level' covered nearly all of the question items (Gathered feedback from your network concerning the resource boxes; Contacted other CST Coordinators to discuss aspects of your network meetings; Worked with your CST teachers in their schools on developing within class and extra-curricular STEM activities; Considered how to further develop a STEM club activity with your CST teacher/colleagues; Co-taught a STEM class with one of your CST teachers; Visited one of your CST schools to encourage support for STEM teaching and associated activities; Discussed with your CST teachers how to identify students becoming more confident in approaching a STEM activity; Contacted local industry in support of your CST network; Checked with your CST teachers to see that they are 'networking' with one another) except for contacts with STEM organisations and problems with resource boxes. 'External support for STEM' included two question items (Contacted local and national STEM organisations to further support STEM education; Contacted local industry in support of your CST network) and is pretty much self-explanatory. The additional item asked whether TCs had 'Run into problems understanding the use of resource packs'. Significant demographic differences were found with regard to General CST activity level for Sex (males more frequently engaging in activities), Teaching experience (TCs with more experience more frequently engaging in activities) and National Curriculum (Pre-NC TCs more frequently engaging in activities). There were no significant demographic differences with regard to External support for STEM (with most TCs engaging in activities between 4 and 6 times in the previous year). And, Pre-NC TCs were the most likely group to run into resource box problems.

8.6 Confidence and competence of TCs in promoting STEM and Engineering understanding

In response to questions concerning beliefs about TC capabilities regarding STEM education with a particular focus on Engineering and Engineering practice, three factors were identified. 'Confidence in engineering and STEM support' covered most of the questionnaire items (Help a CST teacher gauge a students' understanding of an engineering task; Provide guidelines to help CST teachers assess a students' engineering products; Provide actual practices that will enable CST teachers promote student team work on engineering problems; Identify practical activities for CST teachers that will encourage their students to think creatively about engineering problems; Help CST teachers design a new technology lesson; Teach CST teachers STEM subjects outside my core subject area; Explain why a bridge collapsed; Explain why we recycle paper; Fix a broken machine; Use tools to build something; Develop design solutions; Evaluate a novel technical design; Advising students on the routes to a career in Engineering); thus covering two main areas, helping CST teachers in their pedagogic activities and engineering efficacy. 'Help in Sci/Maths' included two question items (Help CST teachers understand a difficult scientific concept; Help CST teachers understand a difficult mathematics problem) and is self-explanatory. 'Help high and low attainers' included two question items (Design an effective new STEM activity for the weakest students in KS3; Design an effective new STEM activity for the strongest students in KS3), thus showing TC confidence in designing activities for a wide range of student attainment. Significant demographic differences were found for Confidence in engineering and STEM support for Postgraduate qualification (Design & Technology TCs scored highest), Teaching experience (TCs with the least amount of teaching experience were least confident) and Engineering experience (TCs with the least amount of engineering experience were the least confident). With regard to demographic analyses of Help in Sci/Maths, significant differences were found with regard to Bachelor's qualification (Design and Education majors were least confident), Postgraduate qualification (science and mathematics TCs were most confident) Teaching experience (least experienced TCs were least confident) and Engineering experience (the most experienced engineers were most confident).

8.7 TC considerations concerning Impact of the Connecting STEM programme

In response to questions concerning potential aspects of impact of the CST programme on students, one factor was found. 'Positive impact of CST' included all impact question items (The learning experience is relevant to the student's STEM curriculum; Student attainment in STEM subjects will improve after participating; Students are motivated to choose Science subjects; Students see Science as a good option for both girls and boys; Students are motivated to choose Design, Engineering and Technology subject options; Students see Design, Engineering and Technology as good options for both girls and boys; Students gain an interest in Engineering careers; Students have a greater understanding of what STEM careers involve; Students know what to do next in order to become an Engineer); thus perceiving a wide range of impacts on students. On average, there was a general level of agreement concerning the positive impact(s) of the CST programme on students. The only significant difference found among the demographic variables related to the National Curriculum, where those TCs who had trained before the onset of the NC showed a higher level of disagreement (than other TCs) regarding the positive impact of the Programme.

8.8 Some general implications of the factorial and demographic analyses

Groupings of question items in the TC questionnaire broke down into reasonably sensible factors that met criteria for the use of factor analysis in terms of the significance of separate factors and their level of reliability. Given that there are only a limited number (although nearly the full population) of TCs that responded to the questionnaire, we reiterate that these analyses are more indicative than definitive. Further, given the number of analyses that were undertaken, it would be surprising not to find a number of significant differences with regard to the various demographic variables that we pursued. Never-the-less there were comparatively few statistically significant differences in the overview of questionnaire factors as they related to the demographic variables. Given the few significant differences, we can identify that while TCs come from a range of backgrounds, their CST and STEM experiences are relatively homogeneous. School type showed few differences although TCs from state schools were more likely to see the importance of STEM in schools. Among the Sex differences, men were less likely to see their role as supporting teachers (Role comfort) and were more engaged in CST activities. Qualifications at undergraduate and postgraduate levels saw those with Design and Education backgrounds less confident in science and mathematics but D&T saw themselves as the highest scoring group in their general STEM and engineering confidence. TCs with greater levels of teaching experience engaged in higher levels of CST activities, were more confident in STEM and engineering capabilities as well as helping students with mathematics and science problems. Also indicative of teaching experience was the differentiation between Pre- and Post-NC training. Having an Engineering background/experience was associated with higher levels of STEM and engineering competencies, including helping students in science and mathematics and designing STEM programmes for various student attainment levels. Experience as a TC was only found to affect confidence in using the resource boxes. And, perhaps surprisingly, school-based support for engaging in the CST Programme did not appear to affect any of the identified factors.

9. Teachers; descriptive analyses

The findings reported in this section are based on the analysis of an original questionnaire circulated to all Teachers involved in the CST Programme by the RAEng. Respondents completed the questionnaire between November 1st 2017 and January 5th 2018. This section provides a base level description of the responses to each element of the questionnaire. In considering these responses, it should be noted that:

1. 172 of a potential 913 Teachers completed the questionnaire, an approximate response rate of 18.5%. We note that some form of response was received from over 200 teachers, but 32 questionnaires were submitted with no answers to the questions. Furthermore for many questions the number of respondents fell to 130-140, effectively a response rate of not much more than 15%.
2. This response rate is rather lower than might have been expected from a well-identified and committed population, and currently we have no basis for determining how representative this sample is. The sample did include teachers who worked with 40 of the 48 TCs, but just over half of these responses were from teachers who worked with just five of the TCs.
3. Within this analysis, there will be no comments about particular Teachers or their Teacher Coordinators (TCs). This is a quantitative overview of Teacher responses. The respondents were guaranteed that their responses would be anonymised in the expectation that this would encourage candour in their responses
4. This analysis will focus on all questionnaire themes and questionnaire items, including: Teacher backgrounds, their experiences of the CST Programme and network and their perceptions of Impact of the Connecting STEM Programme.
5. Teachers and support staff involved in this survey were primarily in within-school employment (mainly as teachers); hence their involvement in the CST Programme was limited by their full-time teaching or other employment.
6. This questionnaire parallels a questionnaire given to all TCs and shares a number of items

9.1 Background information on the Teachers

There was an approximately equal distribution of teachers by sex (48.0% male; 51.5% female; 0.5% prefer not to say). They ranged in age from 23 to 70 years of age. There was an average age of approximately 40, although we note that there was quite a range of distribution between the ages.

Of the 172 respondents, 90.1% were currently employed as teachers and 9.9% held other positions in their schools. Of the 164 reports of type of school 'working in' the most respondents was employed in state funded secondary schools (76.5%); see Table 8.

Table 8: Percentage of Respondents in each school type

Type of school	%
State	18.5
Comprehensive	29.6
Academy	28.4
Grammar Independent	3.1
Free	3.7
Faith	2.5
Primary	10.5
Other	3.7

Most respondents worked in comprehensive schools or academies, and few worked in independent, free or faith schools. And, while the CST Programme was not set-up to include primary schools, nearly 11% of respondents worked in these schools. A curious anomaly that we may wish to look at arises in the question: If you are currently working in a school, is attending CST meetings recognised as part of your duties? In response, 13 respondents (approximately 8%) stated that they were not currently employed in a school.

Qualification of respondents ranged from Bachelor's degrees (see Table 9) to PhDs, and there was a large range of other certificates held. The largest proportion of respondents held an undifferentiated 'Education' degree and, as would be expected, the majority of other respondents held a science-oriented degree – including nearly 14% having an Engineering degree. Only 126 respondents identified that they held a post-graduate certificate in education (PGCE), and the profile of these respondents is somewhat different from first degrees (see Table 10). We note that amongst the 'Other' response a) there were 24 respondents with an Engineering PGCE; b) approximately 6% did not hold a science-oriented PGCE; c) 'Computing' becomes a formal subject of study; and d) there is an increase in number of Physics PGCEs verses Physics at Bachelor's level. 41 of the respondents have a Master's degree of which 17 were in General Education/Social Science and the rest were in science-oriented subjects (including Engineering). 8 respondents held PhDs, and all of these were in science-oriented subjects.

Table 9: BA, BSc, BEd or equivalent degree held

Subject	Frequency	%
Education	34	22.2
Design	23	15.0
Engineering	21	13.7
Biology	20	13.1
Chemistry	14	9.2
Physics	11	7.2
Social Sciences	10	6.5
Other Natural Science	9	5.9
Mathematics	7	4.6
Biochemistry	4	2.6

Table 10: PGCE degree held

Subject	Frequency	%
Design & Technology	24	18.6
Other/Engineering	24	18.6
Physics	21	16.3
Biology	19	14.7
Chemistry	14	10.9
Mathematics	14	10.9
Computing	5	3.9

Subject	Frequency	%
Humanities	4	3.1
Arts	3	2.3
Social Sciences	1	.8

Table 10 (cont): PGCE degree held

Those respondents currently in teaching positions have a wide range of school experience. The oldest teacher has been teaching for 47 years while the youngest have only been teaching for one year. Approximately 24% of the teachers have been teaching for fewer than 6 years and nearly half of the teachers have been teaching for 10 or fewer years. Whether this represents a generational divide in orientation towards the importance of outreach programmes for encouraging STEM interest; factors reflecting a stage of career development or some other factor might merit further investigation.

The majority of teachers were found to 'teach' at Key Stage 3 (KS3) and the first half of KS4. As displayed in Table 11, the number of year groups taught (876) indicates that CST teachers each taught a number of different age groups – up to 5 or 6 separate age groups within a school year. Subjects taught, again, indicated that the vast majority of teachers taught STEM-oriented subjects and many teachers taught a number of different subjects (see Table 12).

Table 11: Year groups taught by CST teachers

Year Group Taught	Number	%
pre Year 7	50	5.71
Year 7	130	14.84
Year 8	135	15.41
Year 9	136	15.53
Year 10	137	15.64
Year 11	133	15.18
Year 12	75	8.56
Year 13	70	7.99
Post year 13	10	1.14

Table 12: Subjects taught by CST teachers

Subject Taught	Number	%
Physics	71	14.55
Combined Science	66	13.52
Design and Technology	66	13.52
Chemistry	65	13.32
Biology	59	12.09
Mathematics	58	11.89
Computing	41	8.40

Subject Taught	Number	%
Engineering	31	6.35
Social Sciences/Humanities	16	3.28
Other	15	3.07

Table 12 (cont): Subjects taught by CST teachers

More than half of the 124 respondents have worked outside of education for more than 4 years (53.23%) although 20+% have not worked outside education/teaching. Again, this may provide a useful further category (experience outside of education) with which to analyse the main question groupings below. And, with particular regard to work as an engineer, Table 13 displays that approximately 17% of respondents have engineering work experience. As would be expected, the vast majority of respondents with engineering work experience took Engineering as their undergraduate degree.

Table 13: Have you ever worked as an Engineer?

Work as engineer	Number	%
Yes for a year	7	4.12
Yes, for two years	1	0.59
Yes for three years	1	0.59
Yes for four years	1	0.59
Yes for more than four years	19	11.18
No, I have never worked as an Engineer	141	82.94
Total	170	100.00

Respondents joined the programme between 2011 and 2017, with a majority of respondents having only recently joined CST (see Table 14). The table identifies a gradual increase in number of respondents over time (to be associated with the increase in size of the programme since 2011), and note in particular the very large increase in respondent numbers in 2017 and consider whether this is an anomaly of the small percentage of overall (possible) respondents or whether newer members of the programme are more likely to respond to the call for questionnaire completion than older members. When asked 'If you are currently working in a school, is attending CST meetings recognised as part of your duties?', of the 155 responses, only 31.6% stated that their CST commitment was part of their school duties. Thus, more than two-thirds of respondents appear to have involved themselves in the CST Programme voluntarily.

Table 14: When did you join the CST Programme?

Year of joining CST	Number	%
2011	9	5.33
2012	11	6.51
2013	4	2.37
2014	15	8.88
2015	22	13.02
2016	20	11.83

2017	88	52.07

Table 14 (cont): When did you join the CST Programme?

As a final point of information for this section, respondents were asked 'Which year groups in your School have access to STEM careers advice?'. From the reports collected, it appears that all year groups in secondary schools have access to STEM career advice (see Table 15) with slightly more emphasis in Years 10 and 11. Given the number total of 550, we note that each school was likely to provide this advice to multiple year groups, although it may be worthwhile checking (in future) whether this type of distribution is characteristic of all types of secondary school or whether it is related to the performance of particular secondary schools. Clearly having access does not entail that the advice is accessed by all, nor indeed available to all.

Table 15: Which year groups in your School have access to STEM careers advice?

Year group	Number	%
Year 7	69	12.55
Year 8	67	12.18
Year 9	84	15.27
Year 10	105	19.09
Year 11	102	18.55
Year 12	64	11.64
Year 13	59	10.73
Total	550	100.00

Reasons for joining the CST Programme

Respondents were asked to rate their reasons for the CST Programme. 8 possible reasons were specified (see Table 16), and each was rated on a 3-point scale (1 = very significant; 3 = not significant). Means and standard deviations for each reason are provided.

As can be seen, the most significant reasons for joining the programme had to do with development of STEM pedagogy and types of support among STEM teachers (Facilitate the inclusion of real world applications, extend opportunities to develop new STEM approaches, enhance coordination among STEM teachers, and involve STEM organisations). Of less significance was their previous success as a STEM teacher, experience with STEM organisations and mentoring/support that they may receive. Actual experience as an engineer was not seen as significant (with regard to this 'reason'; 15% of respondents thought this very significant but 60% thought it not significant).

Table 16: Reasons for joining the CST Programme (N = 146)

Reason for joining	Mean	s.d.
Personal connections with local employers	2.02	0.73
Enhancing coordination among STEM Teachers	1.61	0.57
Experience working as an Engineer	2.44	0.74
Extend opportunities to develop new STEM pedagogic approaches	1.53	0.62
Facilitate the inclusion of real world applications into STEM education	1.34	0.51

Reason for joining	Mean	s.d.
I have been a successful STEM Teacher in School	1.99	0.75
Mentoring and support for CST Teachers	2.16	0.71
Involvement with external STEM support organisations	1.66	0.69

Table 16 (cont): Reasons for joining the CST Programme (N = 146)

Thus, it appears that respondents were concerned about the knowledge and practice of STEM teaching, but points of (possible) concern include:

a) The role and contribution of engineering was not seen as particularly important by a large proportion of respondents;
b) Mentoring and support was not seen to be significant. Although this was not one of the principal motivations for building the networks it would be surprising if it did not emerge as a feature of the networks. This may be explored in greater detail when comparisons are made between those rating this reason as 'very significant (18%)' versus 'not significant (36%)', and may represent an opportunity for future development of the networks
c) Personal connections to local employers was given a relatively low rating, and may indicate a disconnection between STEM teaching and linkage to careers in the locality of schools.

9.2 Experiences and views of the CST Programme

Respondents were asked about their range of experiences and views towards the CST Programme. Each of the 9 questions was rated on a 5-point scale (1 = Strongly Agree; 3 = Neither Agree or Disagree; 5 = Strongly Disagree). Unlike previous sets of questions this set contains wording of questions that are both positive and negative, hence one cannot simply look at means and standard deviations to understand how the nature of responses. A general overview of these means and standard deviations for each of these questions provided evidence of (see Table 17):

a) None of these questions was responded to at a high level of 'strong agreement', where analyses would expect a mean below 1.5;
b) Highest levels of agreement related, pedagogically, to use of the resource pack and associated materials for use in-class and in extra-curricular activities and to support from other CST network members;
c) Respondents were in general agreement as to personal effects of the CST Programme – allowing them to reflect on teaching approach, raising morale via CST meetings and feeling involved in the programme; but
d) Only neutral feelings were identified with regard to ease of attendance at CST meetings and making/maintaining contact with fellow CST 'teachers' outside of the meetings.

Table 17: Experiences and views of Respondents (N = 150/160 for questions)

Experiences and views of Respondents	Mean	S.D.
I value the support from other members of the CST Programme	1.76	0.74
The resource packs are very useful for extra-curricular activities I run	1.74	0.78
Being part of CST has given me new materials for use in classes	1.77	0.74
CST has given me new ideas for how to teach my subject	1.89	0.80
Being part of CST has lead me to reflect on my approach to teaching	2.10	0.85
I feel I am centrally involved in what goes on at CST meetings	2.38	0.94
It is difficult for me to attend CST meetings	3.04	1.00

I often make contact with other members of CST outside of the meetings	3.03	1.08
Attending CST meetings raises my morale	2.23	0.84

Table 17: Experiences and views of Respondents (N = 150/160 for questions)

When respondents were asked to reflect on their CST experiences, they appeared most keen on developing/using teaching resources with some support from CST colleagues. There was only weak evidence of personal development and reflection, although this may be further explored in relation to type of 'teaching' background and length of teaching experience and participation on the CST Programme. Networking amongst members of the programme was given the lowest rating, and the programme may wish to look into dynamics by which network involvement and commitment to colleagues may be further developed.

9.3 Experiences and views of STEM education

Respondents were asked about their experiences and views of STEM education generally. Each of the 25 questions was rated on a 5-point scale (1 = Strongly Agree; 3 = Neither Agree or Disagree; 5 = Strongly Disagree). Like the previous set of questions, this set contains wording of questions that are both positive and negative, hence one cannot simply looks at means and standard deviations to understand responses. Questions cover a range of topics from skills that students need to learn about STEM subjects to support for learning and social pedagogic contexts that may support or hinder learning. A general overview of these means and standard deviations for each of these questions provided evidence of (see Table 18):

a) Throughout the 25 questions, there was no consistent 'strong agreement' on any of the points raised;
b) Highest levels of agreement were associated with questions concerning students' development via presentation of 'real world' problems, developing interpersonal skills and reasoning ability. These developments may be encouraged in practical and extra-curricular activities. Tied to these agreements is an acknowledgement (perhaps a perverse one) that competition among students can stimulate learning;
c) Respondents showed lower levels of agreement with regard to facilitation of learning via student reflection and ability to work independently of teachers. Perceptions showed that schools still (classically) saw examination results as a strong indicator of STEM success and were not particularly encouraging of problem-based learning; although results indicate that respondents perceived their network schools as encouraging STEM education and that engineering should have a place within the curriculum;
d) Respondents had neutral feelings (neither agree nor disagree) with regard to the role and effects of their practices. This neutrality was found with regard to parental support, the need to provide training to enhance student engagement, knowledge of fundamental theoretical background for STEM and the role of group work. This neutrality may be seen as a positive factor with regard to perceptions that students can learn/be involved in STEM at all ages, they do not require prior interest for their involvement and that both male and females teachers can be successful in STEM teaching;
e) The highest levels of Respondent disagreement were found associated with negatively worded questions and showed strong beliefs in an inclusive approach to STEM. Respondents disagreed with the view that students had a 'fixed' level of ability, they should be taught in single-sex groups, STEM was only for high achievers and the need for a university degree to pursue a STEM career. They also disagreed with regard to (the activities involved in) STEM classes allowed student to 'mess about'.

Table 18: Experiences and views of STEM education (N = 151/156)

Experience and views of STEM education	Mean	s.d.
Extra-curricular activities enable me to do valuable educational work with my students	1.71	0.69
Students will only develop a positive attitude to STEM subjects if they have full parental support	2.63	0.99
During hands on STEM activities, most students mess about	3.73	0.93
Extra-curricular STEM activities only attract students already interested in the subjects	2.69	1.07
Schools in the Network are very supportive of extra-curricular STEM activities	2.15	0.73
In my school, exam results are the main measure of STEM success	2.70	1.15
Students only work well together if a teacher trains them in how to do so effectively	2.66	0.93
An understanding of underlying scientific principles is most easily achieved through practical exercises	1.95	0.70
A student's basic abilities are fixed	3.94	1.07
Problem and project based learning practices are encouraged in my school	2.21	0.91
Seeing real world applications is the best way of getting students interested in STEM subjects	1.69	0.66
Only high achieving students are able to study STEM subjects successfully	3.74	1.01
Competition in STEM clubs stimulates student learning	1.89	0.65
Students need exercises which enable them to reflect on what they have learnt in STEM lessons	2.05	0.61
Younger children are more receptive to STEM learning than older ones	2.97	1.03
Exercises which require a student to think on their own are an essential component of good STEM education	1.91	0.68
Female teachers are more successful in interesting female students in STEM subjects than male teachers	3.12	1.04
STEM activities should be conducted in single sex groups	4.00	1.01
STEM activities are best delivered to small groups (of two to six) students	2.67	0.94
Students should work independently of their STEM teacher from time to time during classroom lessons	2.01	0.76
STEM group activities develop a student's interpersonal skills	1.72	0.64
For a career in a STEM subject, a student needs a relevant University degree	3.41	1.02
Engineering should have a formal place in the school curriculum	2.08	0.83

Experience and views of STEM education	Mean	s.d.
It is more important to teach the fundamentals of science and mathematics than their STEM application	3.22	1.12
Student populations of some schools simply do not allow for effective STEM teaching	2.99	1.10

Table 18 (cont): Experiences and views of STEM education (N = 151/156)

Respondents expressed a range of opinions with regard to this group of questions. They agreed that for students to benefit from STEM experiences, students need practical pedagogic approaches and a range of interpersonal and thinking/reflection skills that may be offered in-class and in extra-curricular clubs (concepts supported in parallel science education studies). How respondents perceived that they are able to develop these pedagogic approaches may be more problematic as they were neutral about the role of training students (in interpersonal skills and group work) and had a positive belief in the role of competition to promote learning. Respondents may be inhibited from developing these practices due to the examination orientation and lack of support for problem-based learning in their schools. On the other hand, neutrality showed a positive perception about the inclusion of all students in STEM learning (age, ability, etc.).

9.4 Frequency of participation in CST activities

Respondents were asked to identify how often they have undertaken various actions/activities associated with the CST Programme in the past school year. Each of the 11 questions was rated on a 5-point frequency scale (1 = Never; 2 = 1-to-3 times; 3 = 4-to-6 times; 4 = 7-to-10 times; 5 = More than 10 times). Means and standard deviations for each of these questions provided evidence of (see table 19):

a) Overall, none of the actions/activities were undertaken with a high degree of frequency – the most frequently undertaken activities (undertaken up to 9 or 10 times over the previous year) involved working with other (STEM) staff within their respective schools and using the CST resource materials in school;
b) There were moderate levels (approximately 3 to 5 times in the previous year) of activity that (in the main) related to organisational responsibilities such as contacting STEM organisations and local industries or consider how to (further) develop STEM activities with CST colleagues;
c) Respondents infrequently (about 1 to 4 times per year) co-taught with another STEM (especially D&T) teachers or contacted network teachers outside of CST meetings. On the other hand, respondents rarely had problems or provided feedback with regard to their (RAEng) resource boxes.

Table 19: Frequencies of CST Programmes actions/activities over the preceding year (N = 148/149 for all questions)

Frequencies of various actions/activities associated with the CST Programme in the last year	Mean	s.d.
Provided feedback to the CST Programme concerning the resource boxes	1.80	1.03
Contacted network teachers from other schools outside CST meetings	1.84	1.08
Worked with other staff members in your school on developing within class and extra-curricular STEM activities	2.41	1.19
Used materials from the resource packs in your classroom activities	2.26	1.20

Frequencies of various actions/activities associated with the CST Programme in the last year	Mean	s.d.
Run into problems using resource packs	1.52	0.76
Considered how to further develop a STEM club activity with your CST colleagues	2.10	1.01
Co-taught a STEM class with a teacher from a different STEM subject	1.67	0.99
Worked with a D&T teacher to support my classroom STEM teaching	1.74	0.96
Found the students to be more confident than yourself in approaching a STEM activity	1.81	1.05
Contacted local and national STEM organisations to further support STEM education in your school	2.08	1.17
Contacted local industry for support of your school's STEM activities	1.92	1.11

Table 19 (cont): Frequencies of CST Programmes actions/activities over the preceding year (N = 148/149 for all questions)

Effects of working on/with the CST were continuous throughout the year and were identified in the various frequencies of participation. Underlying the programme has been the training for and use of resource boxes – which were used in an unproblematic manner by the respondents. Perhaps this point identifies how well the boxes were (pedagogically) constructed but, at the same time, this did not spur collegial discussions amongst the respondents beyond network meetings. Given that respondents involved were most likely to be carrying a full-time teaching load, good efforts were made to contact STEM organisations and local industries. At the same time, it appears that respondents were more likely to interact/develop work with STEM colleagues in their schools than their CST colleagues, and this may pick-up on a theme that networks can be further developed in a collegial and supportive manner as evidenced in the TC analysis and elsewhere in this report.

9.5 Confidence and competence of Respondents in promoting STEM understanding:

The range of questions displayed in Table 20 focuses on various types of efficacy within the expected ranges of competence for classroom teachers. These ranges include efficacy questions concerning: understanding/development of learning for engineering, understanding/development of learning more generally for STEM and efficacy in solving/explaining engineering problems. These assessments were made on an 11-point scale (ranging from 1 = not at all confident to 11 = 100% confident). Table 20 displays means and standard deviations for each of these questions, providing evidence of:

a) From an overview of all questions, these Respondents perceive themselves as generally competent and confident with regard to pedagogic aspects of STEM teaching and some aspect of teaching to support engineering. They are less competent/confident in solving/explaining engineering problems;
b) Highest levels of competence/confidence (in the range of 70-80% confident) were found in pedagogic promotion of positive attitudes (to engineering), lesson design, teamwork among students and cooperative learning. These pedagogic aspects may appear contradictory to responses to previous (associated) questions in which Respondents do not appear to offer training for development of interpersonal skills, group work, etc.;
c) Aside from relatively lower levels of competence in Engineering Efficacy, other aspects of low confidence (in the 50-60% range) were found in assessing engineering products, teaching STEM subjects without preparation, teaching STEM subjects outside their particular subject and explaining mathematics that may underlie an engineering construction.

Table 20: Confidence and competence in promoting STEM understanding and engineering efficacy (N = 136-139)

Focus	Question	Mean	s.d.
Efficacy re Engineering education	Gauge my students' understanding of an engineering task	7.19	2.68
	Assess my students' engineering products	6.71	2.80
	Promote a positive attitude to engineering among my students	8.28	2.61
	Promote student team work on engineering problems	8.24	2.50
	Encourage my students to think creatively about engineering problems	8.13	2.49
	Explain the maths underlying an engineering construction to my students	6.74	2.94
	Advising students on the routes to a career in Engineering	7.37	2.84
Efficacy re STEM education	Organise extra-curricular STEM activities	8.03	2.71
	Help an average student understand a difficult mathematics concept	7.52	2.46
	Help an average student understand a difficult scientific concept	8.22	2.28
	Help a colleague design a new science or technology lesson	8.41	2.48
	Enable cooperative learning between students	8.73	2.12
	Exploit a student's naive intuition in understanding a scientific concept	7.71	2.28
	Use STEM resources in the classroom without any preparation	6.59	2.77
	Teach STEM subjects outside of my core subject area	6.91	2.57
	Evaluate a novel technical design	7.24	2.79
	Design an effective new STEM activity for the weakest students in KS3	7.34	2.97
	Design an effective new STEM activity for the strongest students in KS3	7.56	3.00
Engineering efficacy	Explain why a bridge collapsed	7.42	2.59
"	Explain why we recycle paper	8.59	2.27
"	Learn how to use a new programming language	6.40	3.31
"	Fix a broken machine	6.69	2.95

Focus	Question	Mean	s.d.
"	Use tools to build something	7.95	2.69
"	Develop design solutions	7.53	2.81

Table 20 (cont): Confidence and competence in promoting STEM understanding and engineering efficacy (N = 136-139)

Respondents did not reach the higher levels of confidence/competence that were found among the TC responses to similar questions. While a number of Respondents had a background in Engineering, generally they felt less competent in planning for and supporting engineering-based learning (in classrooms) than the more general STEM subjects (aside from mathematics). Similarly, there were only moderate levels of competence identified with regard to Engineering Efficacy (or the explanation/solving of engineering-based problems). We also note the aforementioned contradiction that Respondents identified higher levels of competence in promoting cooperative learning, group work and similar interpersonal skills while previously they noted that they did not need to introduce/teach these topics in their classrooms. Generally, as the efficacy literature identifies that higher levels of competence/confidence are more likely to be associated with promotion of/career development, our results identify that this may be an area which requires further development within the CST Programme.

9.6 Perceptions as to the impact of the Connecting STEM Programme:

Two sets of questions sought to identify perceptions of the impact of the CST Programme on students within network schools. Initially two questions concerned perception of student engagement with aspects of the programme. And, a further nine questions sought information on the types of impact that may be associated with the programme.

With regard to the first set, two particular questions were asked. The first question asked 'To what extent are students engaged in the Collaborative Project?'. 135 responded to the 6-point scale (which ranged from 1 = All students involved to 6 = No students involved). The mean was a positive 3.27 (Most students involved) with a standard deviation (s.d.) of 1.48. Nearly 40% of respondents stated that the project engaged all or most of their students, but another 40% of students were much less engaged (moderate to non-engagement). With regard to 'How engaging do the students find the CST learning resource boxes?', a stronger/positive response was recorded. 132 Respondents answered this question and used a 5-point rating scale (1 = Wholly engaging to 5 = Not engaging at all). The mean was 2.35 (Mostly engaging), s.d. = 0.89. Thus, the resource boxes were seen to be of high value and more information needs to be sought as to the more limited effect of the collaborative projects.

The nine further questions specifically sought information on types of impact of the programme. Each of these questions was rated on a 7-point scale (from 1 = Strongly agree to 7 = Strongly Disagree). Table 21 displays means and standard deviations for each of these questions, providing evidence of:

a) A generally positive perspective of the impact of the CST Programme on students (noting that means of 3 or lower showed agreement with the question/statement) with an average mean of 2.52;
b) The strongest level of impact indicated that relevance of the programme to the current school-based STEM curriculum followed by the perception that pupil attainment will improve in STEM subjects and science is a good option for boys and girls;
c) The weakest level of impact (but still an agreed positive impact) was found with regard to course choice options and careers – with the highest means for knowing what to do next to

become an engineer, students seeing DET as good for both boys and girls and their motivation to undertake/study DET course options.

Table 21: Perceived impact on students of the CST programme (N = 137/133)

Question	Mean	s.d.
The learning experience is relevant to the students' STEM curriculum	2.15	0.98
Student attainment in STEM subjects will improve after participating	2.30	1.03
Students are motivated to choose Science subjects	2.39	1.04
Students see Science as a good option for both girls and boys	2.36	1.06
Students are motivated to choose Design, Engineering and Technology subject options	2.72	1.16
Students see Design, Engineering and Technology as good options for both girls and boys	2.87	1.26
Students gain an interest in Engineering careers	2.56	1.16
Students have a greater understanding of what STEM careers involve	2.41	1.12
Students know what to do next in order to become an Engineer	2.88	1.21

Respondents generally identified a range of positive impacts of the CST programme. They were particularly positive about the engagement effects of the resource boxes but much less positive with regard to student involvement on the collaborative project. The full CST programme was seen to be relevant to students' STEM learning and future attainment in these subjects. At the same time, there is a potential 'disconnect' between what has gone on in the CST Programme and students' course option/choices and routes to STEM (especially engineering) careers, and it may be worthwhile exploring the relationship between STEM careers advice and the CST Programme.

Finale

Response rate for these Respondents was not very high at 18.5%, and it will be difficult to identify how representative the above or subsequent analyses are. We will have distributional data relating to the gender of the respondents, school type etc. and, if the RAEng holds information about the participants, a comparison of the sample with the entire set may indicate how representative the sample is. At the same time, we note that questionnaire completions were received from virtually all of the TC networks, although most network-based responses arrived from 1-3 teachers per network, a few networks provided 15+ responses. This is unfortunate as it will make the identification of important network differences virtually impossible.

At this stage of analysis, the above report is mainly descriptive of the distribution of answers from respondents. Had there been a more representative submission of questionnaires, it would have been worthwhile engaging in a deeper level of analysis – where comparisons can be made between sex, subject area, age and teaching experience of respondents. By way of conclusion, the following summary observations are worth noting:

Teacher profiles

a) There were 172 responses to the survey with the overwhelming majority from teachers.
b) Most of the teachers work in secondary schools, predominantly comprehensive schools and academies and a small minority (10%) in primary schools.

c) Most hold Bachelor's Degrees in a Science-orientated subject or in Education and a high number are in the first ten years of their teaching careers.
d) The majority of these teachers teach STEM subjects at KS3 and initial years of KS4.
e) Over 53% of the teachers had worked outside education, with 17% having worked in engineering. Most of these teachers joined the CST Programme recently (52% in 2017).
f) More than two thirds have involved themselves with the CST Programme voluntarily, and not as part of their school duties.

Reasons for Joining the CST Programme:

g) The most significant reasons for joining the CST Programme were connected to the development of STEM pedagogy and support among STEM teachers.
h) Less significant was involvement with STEM organisations, mentoring and support and experience of engineering.

Experience and views of the CST Programme:

i) Teachers were most positive about the resource packs and associated materials for use in class and extra-curricular activities and the support from other CST network members.
j) There was weaker evidence of personal development and reflection.
k) Networking amongst members was given the lowest rating.
l) There are certain contradictions between what teachers identify that they encourage as opposed to actually support within their teaching.
m) Overall, respondents identified a positive impact of the CST Programme on their students.

Experience and views of STEM education:

n) There was a strong belief in inclusivity in teaching across age, sex and attainment ranges.
o) To benefit from STEM experiences, students need practical pedagogic approaches and a range of interpersonal and thinking/reflection skills.
p) But, teachers were neutral about the role of training students (in interpersonal skills and group work).
q) Teachers believed that competition promoted learning in STEM subjects.
r) STEM development by teachers may be inhibited by within school constraints and exams

Frequency of CST activities:

s) Resource boxes were (pedagogically) constructed and used, but did not spur teachers to engage in collegial discussions.
t) Good efforts were made to contact STEM organisations and local industries.
u) Teaches were more likely to interact with school colleagues rather than their network

Confidence and competence related to STEM and engineering efficacy:

v) Respondents did not reach the higher levels of confidence/competence that were found among the TCs; they felt less competent in planning for and supporting engineering-based learning.
w) Only moderate levels of Engineering Efficacy were found.

Perceived impact on students:

x) Teachers were positive about the engagement effects of the resource boxes but much less positive with regard to student involvement on the collaborative project.
y) The CST programme was relevant to students' STEM learning and future attainment.
z) More efforts could focus on the relationship of the programme students' course option/choices.

10. Factorial and Demographic Analyses of the Teacher Questionnaire

As with the TC questionnaire, the next step in the evaluation was the identification of patterns within the responses provided by the Teachers using factor analysis to identify underlying factors.

Demographic analyses, again, provide an identification of key variables that can be assessed against each of the factors. The demographic variables were identified in discussion with members of the RAEng CST Programme team and drawing upon previous studies in the literature and current practice within the Programme. Demographic variables are identified and described as:

a. School type: Drawing upon the main school types in the questionnaire, the variable separated State (including comprehensive) from Academy and Other schools. In addition, there were a number of primary school teachers involved in the CST Programme, and we identified this within the School type variable.
b. Sex: A simple breakdown into Male and Female teachers, with a small proportion not identifying their sex.
c. Bachelor's Qualification: Grouping teachers undergraduate qualification into Sciences, Mathematics, Design, Engineering, General education (undifferentiated degree) and Social sciences.
d. Postgraduate Teaching Qualification: Grouping teachers postgraduate teaching qualifications into Sciences, Mathematics, Design & technology, Computing, Social sciences and Arts.
e. Teaching Experience: Dividing number of years teaching experience into 1-5 years, 6-10 years, and 11+ years, representing newer, somewhat experienced and very experienced teachers.
f. Training Pre- and Post-National Curriculum: A variable to ascertain whether changes in teacher training associated with the legislated onset of the National Curriculum (NC) might be associated with attitudes and experiences of the teachers.
g. Experience working as an Engineer: Separating engineering experience into No experience, Limited experience (1-3 years) and Experienced (4+ years) working as an engineer.
h. Experience as a teacher: Dividing the years of experience on the CST Programme into 1 year (New), 2-3 years (Slightly experienced) and 4+ years (Experienced)
i. School Recognition for participation in the CST Programme: A simple division into whether or not the teachers' current school recognises the individual's participation in the Programme.

10.1 Reasons for the involvement of Teacher Coordinators on the CST programme:

In response to the question 'Within your commitment to improving STEM education, what were your reasons for joining the CST programme?', two reliable factors were identified. 'General commitment to STEM' was composed of nearly all question items (Personal connections with local employers; Enhancing coordination among STEM Teachers; Extend opportunities to develop new STEM pedagogic approaches; Facilitate the inclusion of real world applications into STEM education; I have been a successful STEM Teacher in School; Mentoring and support for CST Teachers; Involvement with external STEM support organisations), thus a combination of previous involvement in STEM and associated organisations/employers, pedagogic and real world applications. 'Engineering and industry' included two questionnaire items (Personal connections with local employers; Experience working as an Engineer). Regarding General commitment to STEM, there were no significant demographic differences found for any of the variables while noting that the factor mean indicated that these aspects for their involvement were only 'significant' as opposed to 'very significant'. Regarding Engineering and industry, it was only those teachers with engineering experience that identified this factor as significant, all other demographic variables were non-significant.

10.2 Experiences and attitudes of teachers towards the CST Programme

In response to questions about experiences and attitudes as a teacher-member of the CST Programme, two factors and one item of interest were identified. 'Programme involvement improves pedagogic confidence' drew upon most question items (I value the support from other members of the CST programme; The resource packs are very useful for extra-curricular activities I run; Being part of CST has given me new materials for use in classes; CST has given me new ideas for how to teach my subject; Being part of CST has lead me to reflect on my approach to teaching; I feel I am centrally involved in what goes on at CST meetings; I often make contact with other members of CST outside of the meetings; Attending CST meetings raises my morale); thus focusing on pedagogic enhancement and materials with some limited support from other CST network members. 'Remedial support' drew upon two question items (It is difficult for me to attend CST meetings; I often make contact with other members of CST outside of the meetings); noting that while difficult to attend CST meetings, teachers think it helpful to maintain contact with CST network colleagues. Programme involvement improves pedagogic confidence was seen as significant generally (amongst teachers) although those with an engineering background were less likely to see this as significant. Regarding Remedial support, teachers did not see this as significant and there were no significant differences found on the demographic variables.

10.3 Experiences and views of STEM education

In response to questions about experience and views of STEM education as a whole, one factor and two further items of interest were found. 'Teacher-centricity' included six question items (Students will only develop a positive attitude to STEM subjects if they have full parental support; During hands on STEM activities, most students mess about; A student's basic abilities are fixed; Only high achieving students are able to study STEM subjects successfully; Female teachers are more successful in interesting female students in STEM subjects than male teachers; STEM activities are best delivered to small groups (of two to six) students); this factor consists mainly of negative aspects of STEM (must have parental support, messing about, high achievers only, female teachers for female students) and by this negation appear to assert the role of the teacher. 'Promoting student autonomy in STEM' included five question items (Seeing real world applications is the best way of getting students interested in STEM subjects; Competition in STEM clubs stimulates student learning; Students need exercises which enable them to reflect on what they have learnt in STEM lessons; Students should work independently of their STEM teacher from time to time during classroom lessons; STEM group activities develop a student's interpersonal skills); these are mainly pedagogic/social pedagogic aspects (real world, exercises for reflection, ability to work independently from teacher, interpersonal skills) although we are not sure why competition is included. Thus, 'Competition' to promote learning was included as a separate item. An additional item was the role of 'School exam results'. Overall, teachers slightly disagreed with the Teacher-centricity factor with teachers from a mathematics background and those slightly experienced in the CST Programme expressing higher levels of disagreement than their colleagues. There were no significant demographic differences with regard to Promote student autonomy although, on average, most teachers agreed with this factor. Science and Computer teachers were most likely to agree that school-based approaches to STEM were dominated by School exam results. And, only primary school teachers disagreed that Competition promoted STEM learning.

10.4 Frequency of participation in CST activities

In response to questions about how often teachers have undertaken various activities associated with the CST Programme in the past school year, two factors and one additional item were identified. 'CST activity level' covered all of the question items (Provided feedback to the CST Programme concerning the resource boxes; Contacted network teachers from other schools outside CST meetings; Worked with other staff members in your school on developing within class and extra-curricular STEM activities; Used materials from the resource packs in your classroom activities; Run into problems using resource packs; Considered how to further develop a STEM club activity with your CST colleagues; Co-taught a STEM class with a teacher from a different STEM subject; Worked with a D&T teacher to support my classroom STEM teaching; Found the students to be more confident than yourself in approaching a STEM activity; Contacted local and national STEM organisations to further support STEM education in your school; Contacted local industry for support of your school's STEM activities). With regard to the demographic variables, CST activity level showed a relatively low average level of activity (of 1-3 times per year), and only those teachers more experienced in the CST Programme engaged in higher levels of activity than their teacher colleagues.

10.5 Confidence and competence of teachers in promoting STEM and Engineering understanding

In response to questions concerning beliefs about teachers' capabilities regarding STEM education with a particular focus on Engineering and Engineering practice, two factors were identified. 'Universal STEM efficacy' covered all of the question items except Learn how to use a new programming language (Gauge my students' understanding of an engineering task; Assess my students' engineering products; Promote a positive attitude to engineering among my students; Promote student team work on engineering problems; Encourage my students to think creatively about engineering problems; Organise extra-curricular STEM activities; Help an average student understand a difficult mathematics concept; Help an average student understand a difficult scientific concept; Help a colleague design a new science or technology lesson; Enable cooperative learning between students; Exploit a student's naive intuition in understanding a scientific concept; Use STEM resources in the classroom without any preparation; Teach STEM subjects outside of my core subject area; Explain why a bridge collapsed; Explain why we recycle paper; Design an effective new STEM activity for the weakest students in KS3; Design an effective new STEM activity for the strongest students in KS3; Explain the maths underlying an engineering construction to my students; Fix a broken machine; Use tools to build something; Develop design solutions; Evaluate a novel technical design; Advising students on the routes to a career in Engineering); thus covering main areas in STEM pedagogy and engineering efficacy. 'Developing students' scientific understanding' included question items (Help an average student understand a difficult scientific concept; Exploit a student's naive intuition in understanding a scientific concept); showing an ability to work with students to draw out/develop their (non-engineering) STEM understanding. Universal STEM efficacy was found to be significantly lower in primary school teachers than other CST colleagues, teachers who studied Social sciences as an undergraduate degree, and teachers with the least experience of the CST Programme. Developing students' scientific understanding was significantly lower for those teachers who studied Design as an undergraduate degree and, as one may expect, was significantly higher for those who studied Science subjects.

10.6 Teacher considerations concerning Impact of the Connecting STEM programme

In response to questions concerning potential aspects of impact of the CST programme on students, one factor was found. In addition, as the questionnaire included separate item questions concern student engagement on the Collaborative project and use of Resource boxes, these were also analysed as individual items. 'Universal impact of CST' included all impact question items (The learning experience is relevant to the student's STEM curriculum; Student attainment in STEM subjects will improve after participating; Students are motivated to choose Science subjects; Students see Science as a good option for both girls and boys; Students are motivated to choose Design, Engineering and Technology subject options; Students see Design, Engineering and Technology as good options for both girls and boys; Students gain an interest in Engineering careers; Students have a greater understanding of what STEM careers involve; Students know what to do next in order to become an Engineer); thus perceiving a wide range of impacts on students. On average, teachers identified a general level of agreement (but not strong agreement) concerning the positive impact(s) of the CST programme on students. With regard to Universal impact of CST, there were no significant differences found for any of the demographic variables. With regard to the Collaborative Project, teachers only noted a moderate level of student engagement – and there were no significant differences for any of the demographic variables. With regard to use of the Resource boxes, teachers had noted that most students were engaged in the associated activities – with primary school teachers identifying the highest level of student engagement.

10.7 Some general implications of the factorial and demographic analyses

Groupings of question items in the teacher questionnaire broke down into characteristic factors that met criteria for the use of factor analysis in terms of their significance and reliability. Given the limited number of teachers who responded to the questionnaire, we reiterate again that these analyses are more indicative than definitive. As with the TC factorial analyses, given the number of analyses that were undertaken it would be surprising not to find a number of significant differences with regard to the various demographic variables that we pursued. Never-the-less there were comparatively few statistically significant differences in the overview of questionnaire factors as they related to the demographic variables. Given the few significant demographic variable differences, we again note that while teachers come from a range of backgrounds, their CST and STEM experiences are relatively homogeneous. School type showed few differences with primary teachers showing the lowest levels of STEM/engineering confidence, disagreement about the role of competition to promote learning but most strongly agreeing that resource boxes engage their students. There were no Sex differences found amongst the teachers on these variables. Science and Mathematics teachers showed a slight tendency towards more conservative views of STEM inclusion and the role of school examination results. Teachers with Engineering experience drew upon their engineering and organisational background in becoming a CST teacher, were less certain that CST improves pedagogic confidence but showed higher levels of STEM efficacy. No significant demographic differences were found for length of teaching experience (including whether they training Pre- or Post-NC) or whether they received school support for CST participation.

11 Conclusions and recommendations

11.1 Conclusions

- Teachers (and TCs) were positive in their responses about the CST programme, particularly about the resource packs and support from other teachers.
- The data indicate that the programme is having a positive impact on teachers' confidence and efficacy and the programme is seen by teachers to improve their pedagogic confidence.
- Findings indicate that teachers had joined the CST programme to support the development of STEM pedagogy and for support from other STEM teachers. That teachers value the programme as is demonstrated by their voluntary attendance and agreement that a CST meetings raise morale.
- Teachers' responses also indicate that they view the programme to be having a positive impact on students, particularly in relation to the current school-based STEM curriculum and on attainment in STEM subjects.
- There are indications from the data that longer term involvement (2+ years) has positive impacts.
    - The factor analysis indicates that teachers become more confident in their use and value resources pack more, and use them more in their classrooms if they have been members of networks for longer.
    - There was also a significant difference between teachers' views about the CST programme providing them with new teaching ideas, with teachers involved longer viewing the programme as having had a greater impact. These teachers were also more likely to view the Programme as having led to them reflecting more on their teaching approach.
    - Analyses also point to lower levels of STEM efficacy amongst teachers who are new to the CST programme than their counterparts who have been involved longer term.
    - Higher levels of CST activity (e.g. working with other staff in schools, use of resource packs) were found amongst teachers who have been involved with the programme for longer.
    - Teachers more experienced in the CST programme also appear to be less teacher-centric in their views of pedagogical practices.
- Findings point to an emphasis in the role of the TCs on showing/demonstrating, providing less opportunity to focus on the needs of individual and network development. Findings indicate that teachers are interacting/developing work with STEM colleagues in their schools which is an ambition of the programme. However, teachers were not so effectively networking amongst members of the programme.
- Whilst the resource packs are viewed by teachers to promote high levels of student engagement, the collaborative project was not viewed to be as engaging. This finding suggests that the collaborative project activities do not maintain the high pedagogic quality of the resource boxes although this conclusion is probably mediated by the relatively low numbers of teachers who have been involved/participated in the collaborative projects arranged thus far in the CST programme.
- A relatively weak level of programme impact was found with regard to course choice options and careers. This finding may relate to the general lack of focus on careers in schools and the lack of priority this is therefore given by teachers. Personal connections to local employers was

also given a relatively low rating as motivation for joining the programme, and may indicate a disconnection between STEM teaching and linkage to careers in the locality of schools.

- There was some ambivalence about whether the programme was having an equal effect on girls and boys.
- Worth noting is that the highest levels of student engagement with the resource packs were identified by primary teachers. Also highlighted is that teachers in primary have the lowest levels of confidence. These findings indicate the potential value of the CST programme for primary school teachers and pupils.

11.2 Recommendations

- Opportunities for collaboration and networking between members could be enhanced to encourage network members to share and reflect on pedagogic practices, and to encourage stronger ties between network members and increase their commitment to each other. Training for TCs could focus on their role in developing this collaboration and support for networking.
- TCs (as well as teachers) only had limited time to engage in CST activities. It may be worthwhile seeking alternate/extended funding for more 'buy-out' time for TCs – allowing then to engage more frequently in school and organisational visits.
- The collaborative project, and ensuring this is as engaging for students as the resource boxes, is another area of consideration and extension to a greater number of teachers. (This may be supported by an increased focus on sharing pedagogic practices, developing ties and support within networks).
- Both teachers and TCs see that STEM developments in schools have a strong focus on inclusion (across age, sex and attainment); this important focus may be drawn upon in future network meetings to facilitate further encouragement of these practices and to share practical approaches that teachers may have developed within their classrooms.
- A consistent focus on gender and ensuring activities are equally engaging for girls and boys is important and TCs should be encouraged to be persistent in ensuring this is a focus during meetings.
- A sharper focus on subject choice and careers in discussion of use of resource packs and other pedagogic practices could be developed to encourage teachers to prioritise this more in schools.
- Networks were perceived mainly as information-giving opportunities, thus posing differences (and possible areas for development) at the interfaces of subject knowledge, pedagogic knowledge and social pedagogy.
- Teacher and TC responses identified the importance of teamwork, collaboration and group work, but networks (and actual teaching experience) did not identify or develop practices within which these interpersonal skills may be identified. The development and practice of these types of skills may also help to promote greater trust and concern among members of the individual networks.
- Teachers showed lower levels of competence/efficacy than their TCs, especially with regard to engineering. Perhaps efficacy in this area can be enhanced via further inputs in the networks.
- Differences arose between teachers and their backgrounds. Of note were the more conservative views of science, computing and mathematics teachers towards STEM and inclusivity. Also, design teachers felt less confident in supporting their student with regard to science and mathematics problems. These points may indicate another reason for networks to consider how to incorporate the role of reflection into their sessions, helping teachers to develop more competencies and overcome problems related to a single-subject STEM focus.

- Indications from the data that the CST programme could be particularly valuable in primary schools are worth further consideration. Primary schools' timetables provide more flexibility for activities to be undertaken with whole class groups during the school day than is found in secondary schools. The important of working with students from an early age to support the development of STEM identities has been highlighted (e.g. Archer et al, 2010).
- To encourage a substantially higher response rate from teachers for the June/July cohort, a number of initiatives need to be planned and implemented. TCs will need to understand and disseminate the importance of the continuing evaluation process (with their network teachers) and evaluators will initiate a review of current questionnaires to ascertain whether identified factors can be drawn upon to reduce the number of questions without compromising the integrity or comparability between autumn and summer cohorts.

12 References

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Appendix A brief summary of key findings from the original CST report and three qualitative evaluations

A range of key findings identified in the report and evaluations undertaken between 2012-2014 include:

1. Teacher Coordinator findings:
    a. TCs have different subject backgrounds and these are likely to be aligned with subjects of STEM teachers that have become associated with the project in the TC's region;
    b. TCs have within-school and out-of-school professional positions that have evolved over the period of the project;
    c. TC involvement with the project is only on a part-time basis, and there are associated problems of time available for project support and development;
    d. TCs have taken-on responsibilities for CPD, enhancing awareness of STEM opportunities, development/maintenance of Networks and individual teacher support;
    e. Given constraints on the TC time available, there is a tendency to focus on the most committed STEM teachers; and
    f. Over the time of the project, TCs gave been confronted with dilemmas concerning the addition of new teachers (while maintaining existing teachers) and school management support (or lack of) in schools.
2. Teacher findings:
    a. Teacher involvement was initially based on selection by TCs (see 1.a. above);
    b. Teachers were often biased by their subject background and had little experience of STEM-based cross curriculum teaching;
    c. Teachers expressed a range of competence and confidence in undertaking STEM lessons - over time, self-perceived levels of confidence have increased;
    d. Teachers received support via their networks and received/gave information to colleagues – developing a 'bottom-up' loyalty to the project;
    e. After introduction to a range of STEM supports, a number of teachers were able and confident in approaching outside organisations for specialised or focused support within their schools; and
    f. Teachers were concerned about types of students to involve in STEM activities - concerns for diversity within STEM take-up by students.
3. School Curriculum findings:
    a. Main school STEM orientation separated rather than integrated subjects; and
    b. Over time, some teachers/schools began to appreciate an integrated approach to STEM subjects.
4. School organisation findings:
    a. Variable support from Senior Leadership Teams - STEM rhetoric versus senior management background in STEM;
    b. Amount of time allocated to/importance of STEM teaching related to how well schools meet national benchmarks – relationship of school to SES;
    c. Some schools have a dedicated STEM coordinator;
    d. Differences in orientation to STEM in single-sex (male v female) and co-educational schools;
    e. STEM-based subject choice and careers advice lacking in many schools;

f. Teachers and TCs involvement was affected by teacher promotion, change of schools and government dictated 'educational' priorities;
g. Some schools (especially if in a 'chain') identified their own CPD which may/may not include aspects of STEM; and
h. Budget concerns by schools – can they support STEM?

5. Extracurricular findings:

   a. Main form of school STEM programme found in STEM clubs and associated extracurricular activities;
   b. STEMNET provided information, coordination with TCs and teachers; and
   c. Through the project, teachers were able to realise the importance and availability of business involvement and other sources of STEM information and careers although a potential conflict with school-based 'academic' orientation was also noted.

6. Other concerns:

   a. Network construction, adaptability and sustainability - constraints associated with geography of region and lack of knowledge concerning effective networks;
   b. Little information was provided on effective CPD approaches;
   c. Little information was provided on impact of project at student level;
   d. Resources concern the these be maintained and further developed; and
   e. Students appear to appreciate 'real world' orientation to Resources provided.

Appendix 12b: Teacher Coordinator Factorial by Demographic Results Table

Variables/Factors	Sch Type	Sex	BQual	PostQual	TeachExp	NatCur	Engineer	Exp as TC	School Rec
BECOME TC:1.1: STEM in School	F(2,31)= 6.19, >.006 Ac>St	N.S.	N.S.	N.S.	N.S.	F(1,38)= 4.11, >.05 Post higher	N.S.	N.S.	N.S.
BECOME TC:1.2: STEM in World	N.S.	N.S.	N.S.	N.S.	N.S.	F(1,43)= 4.55, >.039 Pre higher	F(2,41)= 6.98, >.003 Eng lowest	N.S.	N.S.
ROLES AND RESPONSIBILITIES: 2:1: Commitment to teachers and network	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
ROLES AND RESPONSIBILITIES: 2:2: Integrate new teachers	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
EXPERIENCE AND ATTITUDES TOWARDS CST: 3:1: Organisational problems	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
EXPERIENCE AND ATTITUDES TOWARDS CST: 3:2: Role comfort	N.S.	F(1,43)= 3.73,>.06 M>F	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
EXPERIENCE AND ATTITUDES TOWARDS CST: 3:Q1: Resource box	F(21,33)= 3.49,>.043 St>others	F(1,43)= 9.44, >.004 M>F	N.S.	N.S.	N.S.	N.S.	N.S.	F(2,44)= 3.23, >.05 Less>otrs	N.S.
EXPERIENCE AND VIEWS OF STEM EDUCATION: 4:1: (NEG) Student STEM success	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
EXPERIENCE AND VIEWS OF STEM EDUCATION: 4:Q1: Competition	N.S.	N.S.	N.S. but Sci high	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
EXPERIENCE AND VIEWS OF STEM EDUCATION: 4:Q2: Reflection	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

FREQUENCY OF CST ACTIVITY: 5:1: General CST activity level	N.S.	F(1,43)= 5.92, >.019 M>F	N.S.	N.S.	F(2,43)= 5.82, >.006 Exp high	F(1,43)= 8.25, >.006 Pre higher	N.S.	N.S.	N.S.
FREQUENCY OF CST ACTIVITY: 5:2: External support for STEM	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
FREQUENCY OF CST ACTIVITY: 5:Q1: Resource pack problems	N.S.	N.S.	N.S.	N.S.	N.S.	F(1,43)= 7.24, >.01 Pre higher	N.S.	N.S.	N.S.
CAPABILITIES RE STEM & ENGINEERING: 6:1: Confidence in STEM & ENG	N.S.	N.S.	N.S.	F(5,35)= 3.08, >.023 D&T high	F(2,43)= 5.98, >.005 Lo exp/con	N.S.	F(2,42)= 5.03, >.011 LoEng=low	N.S.	N.S.
CAPABILITIES RE STEM & ENGINEERING: 6:2: Help in SCI/MATHS	N.S.	N.S.	F(4,42)= 4.28, >.006 Des/Ed low	F(5,35)= 3.55, >.012 Sci/Math highest	F(2,43)= 4.68, >.016 Lo exp/con	N.S.	F(2,42)= 4.32, >.02 Eng most help	N.S.	N.S.
CAPABILITIES RE STEM & ENGINEERING: 6:3: Hi and Low attainers	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	F(2,42)= 12.65, >.001 limited eng = lo	N.S.	N.S.
IMPACT: 7:1: General	N.S.	N.S.	N.S.	N.S.	N.S.	F(1,43)= 4.29, >.044 Pre higher	N.S.	N.S.	N.S.

Appendix 12 c: Teacher Factorial by Demographic Results Table

Variables/Factors	Sch Type	Sex	BQual	PGCEQual	TeachExp	NatCur	Engineer	Exp on CST	School Support
REASON FOR JOINING CST: 1.1: General Commitment to STEM	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S., Sup more agree
REASON FOR JOINING STEM: 1.2: Engineering and Industry	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	F(2,137)= 3.82, >.024 Eng lowest	N.S.	N.S.
EXPERIENCE AND ATTITUDES TOWARDS CST: 2:1: Improves Pedagogic Confidence	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	F(2,145)= 4.03, >.02 Eng high	Nearly sig., exp'd hi	N.S.
EXPERIENCE AND ATTITUDES TOWARDS CST: 2.2: Remedial Support	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
EXPERIENCE AND VIEWS OF STEM EDUCATION: 3.1: Teacher-Centricity	N.S.	N.S.	N.S.	F(4,91)= 2.98, >.023 Neutral w maths disagree	N.S.	N.S.	N.S.	F(2,139)= 3.91, >.022 2-3 yr slightly higher	N.S.
EXPERIENCE AND VIEWS OF STEM EDUCATION: 3.2: Promote Student Autonomy in STEM	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
EXPERIENCE AND VIEWS OF STEM EDUCATION: 3Q1: School Exam Results	N.S.	N.S.	N.S.	F(5,93)= 4.70, >.001 Sci/Com agree	N.S.	N.S.	N.S.	N.S.	N.S.
EXPERIENCE AND VIEWS OF STEM EDUCATION: 3Q2: Competition	F(2,124)= 3.33, >.039 Primary hi	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
FREQUENCY OF CST ACTIVITY: 4:1: General CST Activity Level	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	F(2,136)= 20.27,	N.S.

								>.001 Exp'd hi	
CAPABILITIES RE STEM & ENGINEERING: 5:1: Universal STEM Efficacy	F(2,109)= 12.24, >.000 Pri lowest	N.S.	F(5,118)= 2.49, >.035 Eng hi, SocSc low	N.S. but SocSc hi	N.S.	N.S.	N.S. but Eng higher	F(2,123)= 4.42, >.014, Exp'd highest	N.S.
CAPABILITIES RE STEM & ENGINEERING: 5:2: Develop Student Scientific Understanding	N.S.	N.S.	F(5,121)= 3.43, >.006 Des low, Sci high	N.S. but SocSc hi	N.S.	N.S.	N.S.	N.S.	N.S.
IMPACT: 6:1: Universal CST Impact	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
IMPACT: 7.1: Collaborative Project	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S. but 2-3y high	N.S.
IMPACT: 8.1: Resource Box	F(2,208)= 3.89, >.024 Primary lowest	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.