

Evaluating a programme for the continuing professional development of STEM teachers working within inclusive secondary schools in the UK

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Abstract

Preparing teachers to enhance students' STEM education usually takes place via continuing professional (CPD) programmes. Many STEM-CPD programmes are criticised for short-term, information-dominated, and non-interdisciplinary approaches that lack critical consideration of learning communities, teaching contexts or STEM teaching is likely to take place in inclusive secondary schools/classrooms. We evaluate a UK-based, national, eight-year+ STEM-CPD programme targeting inclusive secondary schools, using a bootstrapped approach combining qualitative insights and quantitative comparisons. We found high levels of teachers' STEM competence, desire for student inclusion and perceptions of student impact. Yet, shortcomings in the operations of teacher networks, lack of pedagogic/social pedagogic support and school-based disciplinary boundaries inhibited effects of the programme. Theoretical considerations were built into methods development and evaluation outcomes.

Key words: STEM education, Continuing Professional Development, Inclusive secondary schools, Networks, Cascade model

Introduction

Industrialising and post-industrial societies have identified a growing need for STEM (Science, Technology, Engineering, Mathematics) trained engineers and technicians and the importance of STEM subjects within their curricula (for example, ASPIRES, 2013; HKCDC, 2015; Sohn & Ju, 2010). Yet, there has been a decline in secondary school student interest/take-up of STEM disciplines/careers especially among female students and those from lower socio-economic groups, black and minority groups (Smith and White, 2011; Morley, 2012, Baker et al., 2007). STEM-based discipline/career interests are most malleable during the years of secondary schooling (Osborne & Archer, 2007; Kutnick, Good &

Hossain, 2012; ASPIRES, 2013); hence secondary schools have been the particular focus of programmes to enhance STEM education via continuing professional development (CPD) training of teachers.

In the UK, there are many STEM organisations working with schools, teachers and students. Organisations include STEM providers (such as STEM Learning, Young Engineers, Smallpeice Trust), museums, discipline-specific organisations (Institute of Mathematics, Institute of Physics, Royal Academies of Engineering/Chemistry/Biology), National Science Learning Centres, and professional bodies (including EngineeringUK)¹. Enhancing STEM education is likely to: combine two or more of the STEM disciplines, draw upon real-world problems, and encourage engineering design (Shernoff et al., 2017) as well as critical thinking, collaboration and creativity (Burrows & Slater, 2015). Activities they promote often identify practices, resources and procedures for teachers to work directly with secondary school pupils (Morgan, Kirby & Stamenkovic, 2016) via continuing professional development (CPD) programmes. STEM-CPD at the secondary school level typically focuses on improving teachers' knowledge and pedagogical skills and is usually advanced via discipline-specific 'teaching' and resource exposure (Newton & Tonelli, 2020; Shernoff et al., 2017). What is noticeable about STEM education via these CPD programmes is that enhancement and impact falls mostly to teachers, and there are only limited opportunities for independent programme evaluation (Kutnick et al., 2012). In countries such as the United Kingdom, these programmes are often offered alongside the formal STEM curriculum disciplines (science, technology, mathematics²) with little integration into the formal curriculum.

Evaluations of STEM-CPD programmes that exist typically assume that: teachers' knowledge and classroom actions are the main route to enhance students' STEM aspirations (Goodall et al., 2005); enhancement of STEM knowledge requires an interdisciplinary approach that does not currently characterise within-school teaching (Shernoff et al., 2017); these evaluations tend to focus on science (Scott, Amettler & Edwards, 2010); and report only a weak relationship between teachers' professional development and changes in student outcomes (Avery & Reeve, 2013; Ralls, Bianchi & Choudry, 2020; Kudenko & Hoyle, 2014).

While many STEM-CPD programmes account for teachers' circumstances, it must be remembered that these studies take place within wider educational circumstances (Bronfenbrenner, 1979), comprising the school's own context, the type of institution, educational region and curriculum/examination guidelines that frame teaching/learning. The preponderance of enhanced STEM high schools and a focus on high-STEM ability students in these studies (Huang, Zhang & Huang, 2020; Lynch et al., 2013) do not readily inform STEM education for *all* secondary school students (especially those from ethnic minorities, educationally disadvantaged and females). Studies of high schools with an inclusive STEM focus (Eisenhart et al., 2015; LaFrance et al., 2019; Weis et al., 2015) find problems of drift, an over-reliance on remedial education, lack of interdisciplinarity and traditional pedagogic approaches (Lyons, 2006). The focus on STEM-intensive schools or within-school problems ignores the fact that most STEM education takes place in ordinary, inclusive classrooms within inclusive schools³; offer only a broad exposure to STEM disciplines taught by discipline-specific, non-specialist STEM teachers. Consequently, it is apparent that STEM-CPD should refocus onto STEM understanding/opportunities within an inclusive schools and classrooms (Lynch et al., 2018).

Issues Concerning Evaluations of STEM-CPD

STEM-CPD evaluations cover topics including: ‘effective’ CPD, pedagogies and their underlying theories, integrating CPD into classrooms, and theories/methods that underlie effective evaluation. Enhancement of STEM is strongly associated with within-school contexts (affected by school-system support, school-based support, appropriate resources and consistent/supportive expectations (Monk, 2008)) as well as teachers’ experiential/reflective learning and collegial support (Roeken-Winter, Hoyles & Blömeke, 2015). Monk concludes that ‘information is not enough (p.118)’. Shernoff et al. (2017) and Hoyle (2016) note that teachers must be encouraged to move beyond their discipline-specific training. Beyond school- and system-based contexts, effective STEM-CPD experience relies on groupings of teachers involved in co-construction of knowledge during their CPD (Khalil, Ardoin & Wojcik, 2016); suggesting that Lave and Wenger’s (1991) community of learners is organised around STEM learning tasks. Wenger (2000) further notes that members of any learning group will have a variety of experience and incumbency and, without consideration of how diverse members can become an inclusive group, it is likely that CPD learners will differentiate themselves into core and periphery subgroups. In planning for effective STEM-CPD, Khalil et al. (2016) identify the ‘centrality’ of the learner, thus ensuring that newcomers have the confidence and competence to experience and reflect with others in their CPD group. Within this context we also note that the lack of engineering courses in schools is likely to limit a full appreciation of STEM-CPD and career aspirations of students (Holman, 2007; Katehi et al, 2009).

CPD and Pedagogy: To facilitate teachers’ movement from knowledge to practice and reflection, several STEM-CPD studies acknowledge the role of pedagogy. Khalil et al. (2016) identified that these practices should be based on teachers’ co-construction of understanding

rather than a simple ‘cascading’ of knowledge from those with more experience or expertise. Newton and Tonelli (2020) advocate co-construction taking place within an ‘inquiry’ based pedagogy. Yet, both co-construction and inquiry-based learning are often at odds with STEM teachers’ discipline-based approach to knowledge (Shernoff et al., 2017) and traditional teaching approaches (Lyons, 2006). At the same time, STEM-CPD must consider how changes in classroom practice can be facilitated within inclusive classrooms (Vanteighen et al., 2020) – where student-student and student-teacher inquiry may be challenged by requirements to provide differentiated instruction and classrooms composed of disabled, non-disabled and marginalised students (OECD, 2015).

Evaluating effects and effectiveness of CPD and STEM-CPD: Evaluations of CPD tend to draw upon Guskey’s (2000) CPD model with five levels of focus (see also Kudenko & Hoyle, 2014) including: participants’ reaction, participants’ learning, organisational support and change, participants’ use of new knowledge and skills and learning outcomes for pupils. Desimone suggests that research indicates a core set of CPD programme features ‘associated with changes in knowledge, practice and, to a lesser extent, student achievement’ (Desimone, 2009:p.183). She identifies the need for content focus, active learning, coherence, duration and collective participation (Desimone, 2009). Whitworth and Chiu (2015) also note the central importance of school leadership teams in the development of successful CPD. Yoon and Klopfer (2006) highlight contextual features such as legislation and standardised testing, and the number of teachers in a school engaging with programmes. Thus, evaluations are likely to point to tensions between structure and agency (Monk 2008).

Consideration of ‘learning’ within evaluation tends to focus on both cognitive and socio-cultural perspectives (McCormick, 2010) and may be limited by teachers’ feelings of efficacy (Takahashi, 2011). CPD learning will thus be affected by their social pedagogic context

(Kutnick & Blatchford, 2014). Borko's (2004) mapping of professional development 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'(p.4). CPD learning activity and impact sees teachers as: a) active and involved while working within organisational constraints of networks and schools; and b) affected by personal feelings of efficacy (Bandura, 1997).

Studies focusing on STEM-CPD tend to be drawn from discipline-specific models. In science education, Loucks-Horsley et al. (1998) describe features such as: emphasising inquiry-based learning, investigations and problem-solving; building pedagogical skills, content knowledge and efficacy; modelling strategies that teachers will use with students; building learning communities; supporting teachers in leadership roles; and system changes to insure positive impact (Capps, Crawford & Constanas, 2012; Dogan, Pringle & Mesa, 2015). Capps et al.'s review of science CPD identified specific features including: time to process and address doubts and misconceptions; follow-up meetings; authentic experience; alignment of programmes to national standards; modelled inquiry lessons; and opportunities for reflection. On the other hand, few of these evaluations consider impacts at school, teacher and student levels (National STEM Learning Centre, 2018). Many of the above features are difficult for teachers to engage within their schools (Goodall et al., 2005). And, evaluations of CPD tend to focus on development and change in attitudes (Kutnick et al., 2012) while concerns expressed by Ajzen (2002) argues for actual changes in teacher/student behaviour to be based on a theory of efficacy.

Focus on STEM-CPD evaluations: While there are literally hundreds of STEM-CPD programmes in operation across many countries (see STEM Directory (2018) for UK-based programmes) and a variety of requirements for effective STEM-CPD, a review of the

available literature regarding inclusive schools/classrooms identifies many problems and little consistency of approach. Problems range from: limited methodological consideration, inconsistent use of instruments and lack of STEM contexts (Katzenmeyer & Lawrenz, 2006; Monk, 2008); limited consensus between programmes (van den Hurk, Meelissen & van Langen, 2019); too strong an emphasis on out-of-school activities (van den Hurk et al., 2019); lack of underlying theory regarding CPD and evaluation (Lynch et al., 2013; Khalil et al., 2016; Saxton et al., 2014); and lack of impact and implementation in schools/classrooms (Carlton-Hug & Hug, 2010). A focus on theory should account for: CPD pedagogic structure – encouraging teachers to become reflective co-constructors of STEM knowledge (Khalil et al., 2016); the relationship of knowledge to teachers’ attitudes, behaviours, efficacy and competence (Ajzen, 2002; Dunn, Hattie & Bowles, 2018; Huang et al., 2020; Saxton et al., 2014; Vanteighen et al., 2020); and learning contexts in CPD programmes (Lave & Wenger, 1991) and schools/classrooms (OECD, 2009).

Within the limited evaluations of STEM-CPD programmes, there are a number of criticisms and concerns regarding effectiveness (van den Hurk et al., 2019). 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’. Each of these problems is likely to inhibit students’ understanding and desire to pursue STEM aspirations.

Teacher confidence, beliefs and efficacy: Efficacy is a major influence on teachers’ professional development, affecting student motivation, attitudes and achievement (Tschannen-Moran & Hoy, 2001). General teacher efficacy has been used in measuring the impact of STEM-CPD programmes (Brown-Schild, 2011; Bruce et al., 2010; Hardré et al.,

2013; Lakshmanan et al, 2010; Nadelson et al., 2013; Powell-Moman;) although few efficacy scales focus on domain-specific STEM teacher efficacy.

Teachers with high levels of efficacy believe that they can control or influence, student achievement and motivation (Tschannen-Moran & Hoy, 2001). Efficacy is viewed as specific to context/discipline, and may be affected by professional isolation, alienation, excessive role demands, atmosphere of the school/school leadership (Webb & Ashton, 1987). Chester and Beaudin (1996) found that the opportunity for collaboration increases efficacy. This ‘collective efficacy’ (Bandura, 1997) may help to overcome several hindrances to effective STEM-CPD; for example, Takahashi (2011) found that teachers were able to collectively co-construct strong efficacy beliefs despite working in a school characterised by diverse, low-income families with students who were not reaching expected benchmarks.

Discipline-specific rather than STEM-specific measures of teacher efficacy have been widely developed. Riggs and Enochs’ (1990) Science Teaching Efficacy Belief Instrument (STEBI) is a well-established model. Nadelson et al. (2013) adapted the STEBI to encompass STEM to explore the impact of a CPD programme for elementary teachers. Other studies focus on pedagogic approaches. Marshall, Horton and Switzer (2009) developed an efficacy tool for inquiry-based instruction, finding that teachers with more inquiry efficacy spent 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. Yoon et al. (2014) developed an instrument to measure teachers’ efficacy in engineering that included aspects of engineering pedagogical content knowledge, engineering engagement, engineering disciplinary self-efficacy and outcome expectancy. However, these STEM teacher efficacy studies neglect wider theoretical considerations such as Ajzen’s

(2002) *Theory of Planned Behaviour*, where the ‘doing’ of a discipline may be more important than the teaching of that discipline.

Teachers with high level of discipline-based efficacy are more confident and competent in undertaking pedagogic- and action-oriented activities (Bandura, 1997). Smith (2014) found that teachers’ confidence in their science skills was significantly raised following CPD that provided opportunities for collaboration, sharing practices, knowledge and reflection. While realising the importance of enhancing teachers’ discipline-based efficacy, CPD programmes rarely identify how it can be developed for use in inclusive classrooms, assuming (perhaps naively) that efficacy enhancement will be a natural product of CPD.

Teacher professional communities and networks in CPD: A teacher’s own community may enhance *or* inhibit their development (e.g., Desimone, 2009; Tschannen-Moran & Hoy, 2001; Wenger, 2000). These communities are referred to as networks, collaborations, clusters or development groups (de Lima, 2010). The terms are not used consistently but generally refer to social organisation for CPD training. If CPD is simply to provide content knowledge or resources, then the role of ‘community’ has limited importance. By contrast, where active learning, collaboration and reflection are involved, an effective community has a much greater role to play. An important distinction here is between teachers working collaboratively within their schools or with teachers in other schools (Jackson & Temperey, 2007). A range of benefits are associated with teachers working collaboratively – including increased self-efficacy, confidence, leadership skills and collegiality (Dogan et al., 2016), and in turn, reflection and efficacy. Fulton and Britton (2011) claimed that gains included increases in: discussion about mathematics and science amongst teachers; understanding of science and mathematics; preparedness to teach; attention to students’ understanding; and diverse modes of engaging students in problem-solving. In their systematic review of CPD

networks, Bell, Cordingley and Mitchell (2006) found that networks between schools/teachers 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. Jackson and Temperey (2007) and Dogan et al. (2016) also suggest that teachers collaborating in a network with others from different schools can improve their teaching practice. Yet, effective networking requires consideration of purpose, composition and connectedness of members that must coordinate with the CPD programme (De Lima, 2010).

Research into networks supporting STEM-CPD highlights the importance of these aspects in influencing effectiveness. Baker-Doyle and Yoon (2011) suggest that ‘closed’ networks constituted of ‘tight-knit’ groups can become ‘insular’ and less open to new ideas but, equally, ‘open’ networks can have a negative impact on the introduction of new ideas when social support is missing. They conclude (as does Wenger, 2000) that there is a need to make teachers more aware of others with relevant social expertise within their network, as teachers were prone to develop relationships with others whom they liked rather than teachers who could best support their learning (Baker-Doyle & Yoon, 2011). Hardré et al. (2013) similarly stress the importance of dissimilar people interacting in networks to generate ‘unique competence and identities’(p.411).

While sharing a focus on teachers’ co-communication and co-construction of understanding, Sillasen and Valero (2013) point to the contribution that central ‘hub’ figures make in supporting these networks. They highlight the significance to network development of several factors, which may include: contacts in the local STEM community; mobilization of resources to reach teachers; development of collaborative activities between teachers and

schools; and support for the development of new teaching activities within networks. 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 and whether a cascading pedagogic approach will allow for collective developments within the network (Sillasen & Valero, 2013; Brown & Flood, 2020).

A Focal Evaluation of a STEM-CPD Programme; the ABC⁴ programme in the UK and research questions

Given the need to enhance STEM education via CPD for inclusive schools and conduct informative evaluations, we report on a nation-wide programme for STEM teachers. Focus on this programme allows insight into participation and effects of STEM-CPD on teachers in inclusive secondary schools and the UK. ABC was designed to: promote a passion for STEM amongst teachers; improve awareness of STEM in schools; widen teachers' knowledge and experience of STEM; introduce engineering design; enable teachers to gain STEM pedagogic and practice skills; and, subsequently, enhance student achievements and participation in STEM courses and career choice. The programme initially aimed to: create supportive networks for teachers that would enhance their confidence/knowledge of STEM; facilitate teachers' enhancement of engineering (knowledge and confidence), real-world applications within the STEM curriculum; and promote STEM engagement for students. ABC drew upon a 'cascade' model of CPD, led by Teacher Coordinators (TCs) with regionally based teacher networks. ABC has been funded by several industrial groups and a STEM-focused educational charity. The project's design and delivery were the responsibility of the charity (referred to as the Host). ABC began in 2011 and has been in operation for ten years and is continuing.

TCs have been central to ABC's success. They were selected as experienced teachers of STEM disciplines who were able to: disseminate training, resources and collaboration for local teachers; provide teacher networking opportunities; and enhance learning opportunities for pupils. The Host supported TC development while developing STEM-oriented, curriculum-appropriate resource boxes. TCs meet regularly with the Host to: share experiences and approaches to STEM development; be introduced to new resources; and consider/reflect upon the Programme. TCs also consider feedback from our qualitative and quantitative evaluations. In turn, TCs: integrate appropriate STEM-based teachers from schools within their regions; and introduce ABC resources and pedagogic approaches to their networks. Network meetings take place termly and are scheduled not to conflict with teaching responsibilities.

In its early years, thought was given to the role of ABC evaluation. Three, yearly qualitative/exploratory evaluations were initially undertaken by independent evaluators to provide feedback on how ABC was undertaken at the network level. These evaluations drew on observations and interviews with the Host, TCs and network teachers. As ABC matured, a wider quantitative evaluation was undertaken (with a subsequent longitudinal survey), using TC and teacher metrics to describe and compare ABC experience, aspects of STEM education, STEM efficacy, and perceived impacts over time. Thus, this long-term evaluation allowed insight into research questions regarding: presentation of authentic/real-world STEM problems and how these were perceived/experienced by teachers; CPD presentation using a cascade model in network communities; pedagogic approaches/presentations and their relation to school inclusion; and effects on teacher efficacy.

Research Design

From the existing STEM, CPD and evaluation literatures, we identified a range of curricular, school, network and pedagogic considerations that should be accounted for within STEM-CPD programmes for inclusive secondary schools/classrooms. Such a programme should not be dominated by STEM ‘experts’, nor focus solely on STEM knowledge and attitudes. It should consider ‘real-world’ problems, teachers’ behaviour/development of efficacy, their ability to share information with colleagues and reflect upon their experiences in inclusive settings. As identified by Guskey (2000), this type of evaluation should draw upon teacher-participants/TCs as informants and assess levels of pedagogic/STEM efficacy and ascertain perceived impact on students. As recommended by Khalil et al. (2016), the evaluation should have theoretical underpinnings and a clear methodology. The evaluation also allowed focus upon: types of teachers and TCs who were likely to participate; their expectations of STEM education and the programme; types/amount of ABC participation; their competence/confidence in pedagogical planning and undertaking STEM activities; and their perceptions of impact of the programme on students. It was informed by considerations from the *Theory of Planned Behaviour* (Ajzen, 2002), and conceptions of efficacy (Bandura, 1997; Dogan et al., 2015), inclusion (Vanteighen et al., 2020) and collective networks (Wenger, 2000; Khalil et al., 2016). The evaluators throughout were independent academics with no connection to the funders and whose contractual guarantees included independence from the programme Host and funders.

The evaluation used qualitative/exploratory and quantitative methods to ascertain effects and perceived impacts on TCs, teachers and students. It was conducted between 2011 and 2019 following a ‘bootstrapping’ approach (Gorard & Taylor, 2004) that combined research

methods. Qualitative/exploratory evaluations provided an account of the workings of ABC from the viewpoints of teachers and TCs in its initial years. The quantitative evaluation (the core of this paper) focused on: the workings of the cascade model; perceptions of STEM and ABC experience and associated pedagogies; ABC demographics and participation rates; types of STEM competencies developed; and perceptions of ABC impacts on students. When initial results from the quantitative survey were reported, the Host asked evaluators to ‘shorten’ the questionnaire instrument and ‘re-present’ the amended survey to the following year’s cohort of TCs and teachers. This longitudinal extension was opportunistic and allowed a further evaluation of year-on-year changes in TCs and teachers. Ethical arrangements were approved by the Host, based on BERA guidelines (2011). All information was anonymised, and rights of withdrawal were agreed with all participants.

Initial qualitative/exploratory evaluation: methods and results

Undertaken during the initial three years of programme development, qualitative/exploratory studies provided accounts of activity from the perspective of participants. Evaluators explored regional networks, recorded successes and developmental issues, and considered the sustainability of the programme. Networks were purposively selected from three diverse, geographical regions; reflecting a national focus that included rural, urban and disadvantaged areas. Methods were inductive, drawing on ethnography (Atkinson et al., 2001) and constructivist grounded theory (Charmaz, 2014). Participant observations of network meetings were undertaken⁵, and interviews held with each TC and two participating network teachers from the three selected regions annually. Interview schedules were developed using a loosely structured narrative approach to provide opportunities for participants to explore their own understandings, knowledge, and experiences of the intent/actualisation of the ABC programme as freely as possible (Hollway & Jefferson, 2012). Interviews were recorded,

transcribed and coded/analysed using constant comparison (Charmaz, 2014). Baseline interviews and observations undertaken in the first year set a participant-oriented agenda for the following two years. Issues from these exploratory studies identified key foci (concerning: teacher and school backgrounds, perceptions of STEM education, the workings of ABC activities, pedagogies, and constraints of the TC role) to be followed-up more systematically in the quantitative evaluation.

Issues that arose in the qualitative/exploratory studies: Several matters raised by TCs and teachers informed the design of the subsequent quantitative evaluations. A constant theme identified was the disciplinary expertise of TCs. TCs felt that they had relevant STEM knowledge from their own teaching/advisory careers and were keen to enhance general awareness of STEM opportunities for teachers in their networks as part of delivering ABC resources. However, TCs were mostly ‘informed’ by their specific curricular area, with less expertise and fewer contacts in other STEM disciplines. Limitations of time commitment and financial support for ABC meant that TCs had to maintain their full-time (teaching/advising) positions alongside their work on ABC. This ‘split’ in responsibilities meant that TCs had limited time for programme support and network development. TCs suggested that, at times, they focused on committed/experienced (network) teachers in the hope of maximising impact of the programme despite their awareness of issues concerning the addition of new teachers to their networks.

For the teachers, involvement with ABC introduced them to a range of STEM supports and outside-of-school organisations which were seen to enhance STEM activities within-school. They valued ABC networks for STEM-based information and for the resources acquired, some of which they shared with school colleagues. Some teachers continued with ABC for the entire three years of the qualitative evaluations expressing feelings of increased competence and confidence in undertaking STEM lessons as well as in their own STEM

knowledge and ability to engage with STEM activities. However, they highlighted challenges relating to their personal development as STEM teachers, including: working within the constraints of their schools and curriculum; finding time for STEM activities; and time to attend ABC network meetings. All teachers taught individual STEM-based disciplines; none taught an integrated STEM-based curriculum. Most schools maintained a separation of STEM disciplines and there was little attempt to integrate these disciplines or provide time/encouragement for co-teaching of STEM disciplines. Only a few schools had a STEM coordinator and lack of involvement of senior leaders contributed to limiting the extent of perceived programme impact. More STEM support appeared to be provided in schools that met national (achievement) benchmarks. Schools struggling to meet benchmarks placed greater emphasis on 'core' disciplines, neglecting integrated STEM programmes. Few schools provided STEM-oriented careers and discipline support for students. Teachers expressed concern about the range and types of students attending STEM-based lessons and activities. Most STEM programmes were extracurricular, taking place in clubs and other out-of-school/after-school activities. Some teachers critiqued the effectiveness of their networks and questioned whether there would be sufficient resources for use with large groups in schools, and how the resources could be maintained.

The ABC programme responded to these findings, addressing the availability of resources for larger groups of students and promoting inclusion of teachers in networks from all school STEM subject areas. Following the qualitative evaluations, the ABC programme continued with the existing TC network and cascade model while focusing on network growth to extend its reach across the UK.

Quantitative Study: methods and results

Five quantitative phases were initially planned: a review of the qualitative evaluations to identify key topic areas for questionnaire design; semi-structured, thematic pilot interviews of TCs/teachers and related semantic analyses; development of questionnaire items for TCs/teachers; piloting and refinement of questionnaire items; questionnaire completion and descriptive/factorial analyses. Drawing from the literature and exploratory studies semi-structured, thematic pre-pilot interviews were undertaken in 4 distinct regions of the UK, 2 TCs per region (8 in total) and 2 teachers associated with each selected TC (16 in total). Resulting TC/teacher questionnaires identified main themes that included: understanding of STEM education and its role in schools; people who support STEM in schools; within-school constraints regarding STEM programmes; support for STEM outside of schools; support for STEM via CPD, networks, information sources; STEM confidence of TCs/teachers; types of student STEM engagement; school guidance and career advice for STEM; perceptions of ABC impact among teachers and students. From these themes a range of attitudinal, perceptual and efficacy questions were constructed and checked for validity and reliability. A two-phase questionnaire piloting was undertaken: 1) a researcher revisited pre-pilot TC/teachers to validate each of the questions; and 2) 20 randomly selected ABC teachers and 4 TCs were asked to read/answer all items and comment on any questions that may have caused difficulty in response. Upon completion of piloting, 99 questions were agreed for TCs and 85 questions for teachers (Tables 1 & 2). Distribution of the questionnaires was to include all TCs and as many teachers who had time/opportunity to complete the questionnaire. Question groupings are identified in Table 3, showing actual questions and bases for scoring.

Tables 1, 2 and 3 about here

Questionnaire distribution was via paper-based and electronic formats to increase the likelihood of teachers responding (Cohen et al., 2018). Initial analyses were descriptive, exploring each question and demographic variations. A second level factorial analysis (exploratory/principal component [EFA]; Worthington & Whittaker, 2006) ascertained whether factor(s) characterised each theme-based question group for TC/teacher responses. For each question group Kaiser-Meyer-Olkin (sampling adequacy) and Bartlett's Test for Sphericity (appropriacy for factor analysis) were undertaken. Within the EFA, Varimax factor rotation with a minimum eigenvalue of 1.0 were used for item discovery. Once factors per question grouping were identified 'alpha-if-deleted' tests ensured that only key contributing question items were included and that there was a sufficient level of reliability (0.70 or above). Identified factors were then assessed in relation to TC/teacher demographics. While there was a high level of initial TC response, relatively few teachers completed the questionnaire from the 1st Cohort. The Host, thus, suggested that the questionnaires be shortened to improve the teacher response rate for a 2nd Cohort in the following year. This second cohort allowed, longitudinally, further information to be collected about ABC as well as an identification of attitudinal and efficacy changes (among TCs and teachers) over time.

Summary of quantitative findings by question grouping from 2017 and 2018 cohorts of TCs and teachers

1. TCs, 2017 (1st cohort): Forty-four of the 46 TCs completed the questionnaire, a 95.6% response rate. 65% identified as male and 34% as female; ages ranged from 24 to 68 years. 74% worked as teachers in secondary schools, and 26% held education advisory positions. All TCs held Bachelor's degrees in STEM disciplines. Some had worked with ABC for as long as 6 years prior to the questionnaire, 22% had just joined ABC.

1.a. Involvement in ABC: The strongest reason for involvement was including real-world applications into STEM education (1.25 on the 3-pt. scale), while other aspects included coordinating STEM teachers, and developing STEM pedagogic approaches. Involving local employers and engineering experience were the least significant contributors to involvement. EFA identified one factor with low reliability: ‘STEM in school’ included four items (1.b., 1.f-h [see Tables 1 & 3 for analyses and questions]). TC demographics found: STEM in school was statistically less important for TCs trained after the onset of the National Curriculum ([NC] implemented in the UK in 1989).

1.b. TC roles/responsibilities: TCs typically ‘agreed’ with item questions. The strongest agreements related to improving teachers’ confidence in approaching STEM problems, attitudes to STEM and establishing a community of learners. TCs had neutral opinions regarding school-management problems, help for newer teachers, mentoring and communication between network teachers. One factor was identified: ‘Role commitment to teachers and network’ included nearly all the items (2.a-e, 2.g-f). There were no statistically significant TC demographic differences for this factor.

1.c. Experience of ABC: TCs enjoyed their work with teachers and developing their STEM teaching. Attitudes were neutral regarding preparing for/arranging network meetings, enhancing relationships among network teachers and involving local STEM industries. TCs saw themselves as competent teachers, able to pass-on information to network teachers. Two factors were identified: ‘Organisational problems’ included four items (3.b.,c.,g.,j.); ‘Role comfort’ included four items (3.a.,f.,h.,i.). There were no statistically significant demographic differences in relation to either factor.

1.d. Experience of STEM education: Questions covered topics including skills that students need to learn about STEM disciplines, support for learning and social pedagogic contexts that support/hinder learning. High agreement levels concerned students’ need to develop

interpersonal skills and ability to work independent of the teacher, and STEM disciplines taught as real-world/engineering problems should have better integration into the STEM curriculum. TCs showed a strong inclusive approach to STEM, that students did not have a ‘fixed’ level of ability, should not be taught in single-sex groups, nor was STEM only for high achievers. Effective STEM teaching did not rely on students having fundamental knowledge of science/mathematics, nor did a STEM career require a university education. TCs were neutral regarding how support for STEM learning should take place. This neutrality was found regarding parental support, extracurricular activities and competition to promote STEM. TCs were also neutral about promoting within-school STEM interdisciplinarity and developing social pedagogic skills among students. One factor was identified: ‘Student STEM success’ included 12 items (4.c.,d.,g.,h.,k.,n.,p.,q.,t.,x.,z.,aa.). These were generally negatively-worded questions and by disagreeing TCs demonstrated an inclusive STEM approach. There were no statistically significant demographic differences for this factor.

I.e. Participation in ABC activities: The most frequent activity (up to 6 times over the previous year) involved contacting outside organisations. Moderate activity levels (approximately 3-4 times in the previous year) related to ABC organisational responsibilities. Each TC network had approximately 14 teachers per network, hence an activity level of 3-4 times per year indicates that less than one-third of teachers were visited. TCs rarely co-taught with network teachers, discussed student confidence building actions or checked whether teachers were networking with one-another. Two factors were identified: ‘ABC activity level’ included nearly all items (5.a.,b.,c.,f.,g.,h.,i.,k.,l.); ‘External support for STEM’ included two items (5.k.,l.). There were statistically significant differences for the first factor with male TCs, experienced TCs, and Pre-NC TCs more frequently engaged in activities. There were no statistically significant demographic differences for the second factor.

1.f. Confidence/competence in promoting STEM and Engineering: TCs perceived themselves as being competent/confident in these responsibilities. They were particularly confident in: designing STEM activities for students; helping teachers; engineering efficacy; and promoting students' engineering efficacy. They were also confident in designing STEM experiences for high/low performing students. Three factors were identified: 'Confidence in engineering/STEM support' (6.a.,b.,d.,e.,h.,i.,k.,l.,p.,q.,t.); 'Help in Science/Mathematics' (6.f.,g.); and 'Help high/low attainers' (6.n.,o.). Statistically significant demographic differences were found for 'Confidence in engineering' (D&T TCs scored highest), teaching experience (new TCs were least confident) and engineering experience (TCs with engineering experience were most confident). For 'Help in Science/Mathematics', statistically significant differences were found for Bachelor's qualification (D&T and Education majors were least confident), postgraduate qualification (science/mathematics TCs were most confident), teaching experience (least experienced TCs were least confident) and engineering experience (experienced engineers were most confident).

1.g. Impact of ABC: Items specifically addressed TC perceptions of ABC impacts on students. Overall, perceptions were positive, especially regarding current school-based STEM curricula for boys and girls. Student involvement was perceived to have positive effects on participation in STEM disciplines and careers. One factor was identified: 'Impact of ABC' included all impact items (7.a.-i.). The only statistically significant demographic difference related to the NC: TCs who had trained before the NC were less likely to see positive impacts of ABC.

1.h. Overview of TC responses: TCs had generally high levels of involvement in the programme, although there were variations and contradictions in their responses. TCs saw themselves as being 'good' teachers who spent time/effort in showing/demonstrating aspects of the programme. They focused less on the needs of individual (especially newer) teachers

in their networks and schools. They liked working with teachers and saw a need to enhance the quality of their support for teachers. They held strong views that STEM education should be inclusive and identified that students should develop social and reflective skills but did not provide practical network support to develop these skills. TCs saw themselves as having a high degree of efficacy in supporting their network teachers and solving engineering-based problems but rarely engaged in school visits where they could provide classroom-based support. There was strong positive agreement on a range of ABC impacts. Further, TCs with more ABC experience engaged in more ABC activities and were more confident in STEM/engineering capabilities. Having an engineering background was associated with higher levels of STEM and engineering competencies, helping students in science/mathematics and designing STEM programmes for various students. School-based support for engaging in the ABC Programme did not appear to affect any of the identified factors.

2. Teachers 2017 (1st cohort): Approximately one-third (32.5%, n= 172) of the ABC teachers completed the questionnaire. This response rate was lower than expected from an ostensibly committed population. The questionnaire paralleled the TC questionnaire except for questions concerning TC role/responsibilities. Respondents worked with over 90% of the TCs, although half worked with just 5 TCs. There were equal numbers of teachers by sex (48.0% male; 51.5% female) with an average age of 40. Most teachers worked in inclusive, state-funded schools (96.9%). All respondents had teaching degrees; 71.3% were STEM-based, although 97% of teachers taught STEM-based disciplines. Most respondents were new to ABC (52%), while others had been involved with the programme for up to 6 years. Only 31.6% stated that their ABC commitment was part of their school duties.

2.a. Joining ABC: The most significant reasons for joining ABC were development of STEM pedagogy and support for STEM (real-world applications, pedagogic approaches,

coordination among STEM teachers, and involvement of STEM organisations). Of less significance was their previous success as a STEM teacher, experience with STEM organisations and mentoring/support they might receive. Two factors were identified: 'Commitment to STEM' comprised nearly all items (1.a.,b.,d.,e.,f.,g.,h.); and 'Engineering and industry' (1.a.,c.). No statistically significant demographic differences were found for 'Commitment to STEM'. Regarding 'Engineering and industry', only teachers with engineering experience identified this as an important factor.

2.b. Experience of ABC: No respondents offered 'strong agreement' for any item. Moderate agreement related pedagogically to use of resource packs and associated materials for in-class/extracurricular use. Low agreement characterised reflection on their teaching approach, raising morale via network meetings, and feeling involved in ABC. Neutral feelings characterised ease of attendance at network meetings and making/maintaining contact with fellow 'teachers' outside of the meetings. One factor was identified: 'Pedagogic confidence' drew upon most items (3.1.a.,b.,c.,d.,e.,f.,h.,i.). 'Pedagogic confidence' had a high mean, although this was less so for those with an engineering background.

2.c. Experience of STEM education: Items covered the skills that students need for STEM disciplines, support for learning and social pedagogic contexts that may support/hinder learning. There were no consistent 'strong agreements' for any item. Moderate agreement concerned students' development via presentation of real-world problems, developing interpersonal skills and reasoning ability within practical and extracurricular activities. Lower levels of agreement concerned facilitation of learning via student reflection and ability to work independently of teachers. Teachers were critical of their schools, perceiving that examination results were a strong indicator of STEM success, and schools did not encourage problem-based learning. Teachers had neutral feelings regarding parental support and providing training for student engagement and group work. High levels of disagreement were

found on negatively worded questions and showed strong belief in an inclusive approach to STEM; students did not have a 'fixed' level of ability, should not be taught in single-sex groups, nor was STEM for high achievers only. Two factors were identified: 'Inclusivity' (4.b.,c.,k.,n.,s.,u.); and 'Student STEM autonomy' (4.m.,o.,p.,v.,w.). Responses indicated a shared socially inclusive orientation towards STEM education. There were no statistically significant demographic differences regarding 'Student STEM autonomy'.

2.d. Participation in ABC activities: None of these activities was undertaken with a high frequency. Moderate frequency levels (3-5 times per year) were found for contacting STEM organisations and local industries. Teachers infrequently (1-4 times per year) co-taught with other STEM teachers, contacted network teachers, or provided feedback regarding resource boxes. One factor was identified: 'ABC activity level' covered all items (5.a.-g.,i.,j.,k.). Demographically, more experienced teachers engaged in more activities.

2.e. Confidence/competence in promoting STEM/engineering: Teachers perceived themselves as competent/confident regarding pedagogic aspects of STEM teaching and supporting engineering. They were least competent/confident in solving/explaining engineering problems. Highest levels of competence/confidence (70-80%) were found in pedagogic promotion of positive engineering attitudes, lesson design, teamwork among students and cooperative learning. Relatively lower levels of competence characterised engineering efficacy, assessing engineering products, teaching STEM disciplines without preparation/outside their discipline and explaining mathematics in engineering. Two factors were identified: 'Universal STEM efficacy' (6.a.-i.,k.,l.,p.-u.,w.,x.); and 'Develop students' scientific understanding' (6.f.,v.). 'Universal STEM efficacy' was statistically significantly lower for teachers who studied social sciences and those with the least experience of ABC. 'Develop students' scientific understanding' was lowest for D&T teachers.

2.f. Impact of ABC: There was a positive perception of impacts on students for all question items. Strongest impacts indicated relevance of the programme to the school-based STEM curriculum, followed by pupil attainment, improvement in STEM disciplines and science as a ‘good’ option for boys and girls. Weaker impacts were identified regarding course choice options and careers. One factor was identified: ‘Impact of ABC’ included all items (7.a.-i). No statistically significant demographic differences were found.

2.g. Overview of teacher responses: There were comparatively few demographic differences. We note that while teachers came from a range of backgrounds, their ABC and STEM experiences were relatively homogeneous. School type showed few differences and most teachers strongly agreed that resource boxes engaged their students. Science and mathematics teachers showed a slight tendency towards more conservative views regarding STEM inclusion and school examination results. Teachers with engineering experience showed highest STEM efficacy levels although they were less certain that ABC improved pedagogic confidence. No differences were found for length of teaching experience nor whether they received school support for ABC participation.

3. TCs 2018 (2nd cohort): Again, a high proportion of the TCs (44 of 46 TCs or 95.6%) responded to this shortened questionnaire. TC age, type of institution, and undergraduate/post-graduate degrees (aside from teaching qualification) were excluded as these provided little information of value for the first cohort. Demographically, 2nd cohort TCs were similar to the 1st cohort. Most TCs had been recruited directly into the TC role.

3.a. Involvement in ABC: Principal reasons for involvement were similar to the 1st cohort. The same factor (‘STEM in school’) was used for demographic comparisons and no differences were identified between the cohorts.

3.b. TC Roles/responsibilities: Items for the 2nd cohort were reduced from 14 to 10. TCs showed the strongest levels of agreement regarding reflection (2.1.), confidence (2.h.),

resources (2.a.), and community (2.i.). They did not see their role as facilitating network communication (2.n.) nor mentoring (2.m.). Hence, TCs idealised a ‘learning community’ but did not appear to engage in the groundwork that may establish/support this learning community. A new EFA identified one factor: ‘STEM pedagogic coordination’ included all items (2.a.,c.,f.,h.-n.). There were no statistically significant demographic differences; both TC cohorts aligned themselves with the values of ABC while lacking time/capacity to support teachers in developing pedagogies within their networks.

3.c. Experience of ABC: 2nd cohort items were reduced from 10 to 7. Strongest TC agreements identified enjoying work with teachers (3.i.) and being a good teacher (3.a.). TCs were neutral regarding positive network relationships (3.b.), meetings (3.g.) and local industries (3.j.). One factor was identified: ‘Organisational problems’, similar to the 1st cohort. One statistically significant demographic difference found females more likely to disagree than males. The relative lack of demographic differences further reinforced concerns about organising of network meetings, promoting relationships among network members, and links to local employers.

3.d. Experience of STEM education: Items were reduced from 27 to 18. TCs strongly agreed that students should work independently (4.v.), developing student’s interpersonal skills (4.w.), value of extracurricular (4.a.), real-world applications (4.m.) and problem/project-based learning (4.l.). They also showed strong pedagogic disagreement with fixed student abilities (4.k.), STEM disciplines for high-achievers (4.n.), single-sex groups (4.t.), students messing about (4.c.) and the importance of science/mathematics fundamentals (4.z.). Two factors were identified: the mainly negatively-worded, inclusion-oriented ‘Student STEM success’ (4.c.,d.,g.,k.,n.,p.,t.,z.,aa.); and ‘Pedagogy within STEM’ (4.l.,m.,p.,r.,v.,w.). There were no statistically significant demographic differences found for either factor, and results were very similar to the 1st cohort.

3.e. Participation in ABC activities: Items were reduced from 11 to 7, and results showed a wide variation in engagement. Some TCs reported themselves as undertaking activities more than 10 times in the year. One-third of TCs never contacted other TCs to discuss networks; 21% undertook no work in school to help their network teachers; 19% had not contacted local STEM industry/employers; and 24% did not check with their teachers to ascertain/help/support networking within their group. One factor was identified that contained all items, ‘General ABC activity level’ (5.a.,b.,c.,f.,j.,k.,l.). One statistically significant demographic difference found experienced TCs more likely to engage in the more activities; this was like the 1st cohort.

3.f. Confidence/competence in promoting STEM and Engineering: Items were reduced from 20 to 11, and the competence scale was reduced from 11- to 5-points. TCs showed very high confidence levels for all questions, in the range of 70% to >90% confidence, and no TC reported a confidence level lower than 50%. Two factors were identified: ‘Enhance ABC practices’ (6.a.,c.,d.,e.,n.,t.); and ‘Engineering confidence’ (6.j.,k.,l.,p.,r.). Statistically significant demographic differences found: non-teaching TCs scored higher for ‘Enhance ABC practice’; and male TCs scored significantly higher for ‘Engineering confidence’ than females. No direct comparisons could be made between the two cohorts. We may speculate that the intervening year allowed for greater homogeneity among TCs and more confidence-building throughout the year.

3.g. Impact of ABC: The original 9 items were reduced to 7. Responses to all questions showed high levels of agreement regarding positive impacts of ABC (7.a.,b.,c.,e.,f.,g.,h.). One factor was identified: ‘Impact’ included all question items. Statistically significant demographic differences were found for: teaching qualification – with chemists having the highest level of agreement on impact. As with the 1st cohort, there was strong agreement that ABC had a range of positive impacts on students’ development.

3.h. Overview of TC responses: Overall, TCs responses were positive. There were many similarities between the two cohorts, given the continuity of TC membership and stability in their views. Variation amongst TCs related to engagement in ABC activities and planning/support for networks as learning communities. Experienced TCs were more STEM confident and engaged with their networks. Less experienced TCs lacked confidence/competence and engaged less with their networks.

4. Teachers 2018, 2nd cohort: For the 2nd teacher cohort the number of question items were reduced but the same groupings were retained. A limited number of teachers completed the questionnaire (25% response rate, n= 142) . The sample included teachers who worked with most of the TCs, although over half of these responses were from teachers who worked with just six of the TCs. When compared to the 1st cohort, there was a higher proportion of teachers with a general education qualification and a lower proportion with qualifications in Biology, Chemistry, Physics and Engineering. 39.7% of these teachers were new to ABC.

4.a. Joining ABC: The original 8 items were reduced to 6. Most questions were responded to positively except for engineering work experience. The strongest reasons for joining included: improve STEM in school (1.i.); real-world applications (1.e.); and involving STEM organisations (1.h.). Extending opportunities to develop new STEM pedagogic approaches (1.d.) was rated at a lower level. Two factors were identified: ‘General STEM experience’ (1.a.,e.,f.,i.); and ‘STEM pedagogy’ (1.d.,e.). One statistically significant and curious difference emerged. Teachers in high questionnaire submission networks saw ‘General STEM experience’ as more significant than those in low submission networks – similar to the 1st cohort. ‘STEM pedagogy’ appeared important to all 2nd cohort teachers.

4.b. Experience of ABC: Items were reduced from 9 to 6. The most positive programme experiences identified support gained from other network members (3.1.a.) and the acquisition of new materials for class/extracurricular activities (3.1.c). Teachers were less

positive in reflecting on their teaching (3.1.e.). They expressed neutral opinions regarding contacting members of their networks (3.1.h.) and difficulties in attending network meetings (3.1.g.). One factor was identified: ‘Teaching support’ (3.1.a.-e.). Teachers with a general education qualification and those with greater experience of ABC identified ‘Teaching support’ as more important than other teachers. Both cohorts appeared to recognise the importance of ABC in providing STEM-based information and some (limited) form of collegial support.

4.c. Experience of STEM education: Items were reduced from 25 to 15. There was strong agreement regarding ‘social pedagogy’ issues: developing student’s interpersonal skills (4.w.); value of extracurricular activities (4.a.); and real-world applications (4.m.). Social pedagogy agreements were also found regarding: competition in STEM clubs (4.o.); students working independently of their STEM teacher (4.v.); and students reflecting on STEM lessons (4.p.). Strong disagreement was found regarding ‘social inclusion’ aspects of STEM: single-sex groups (4.t.); fixed abilities (4.k.); only high achieving students can study STEM (4.n.); students mess about (4.c.); teaching science/mathematics fundamentals (4.z.); and school populations do not allow effective STEM teaching (4.aa.). Two factors were identified: ‘Social inclusion’ and ‘Social pedagogy’ (described above). No statistically significant demographic differences were found. Similar to the 1st cohort, most teachers had a strong social inclusion orientation and agreed that social pedagogic factors were important in the promotion of STEM education.

4.d. Participation in ABC: Items were reduced from 10 to 7. A striking feature in these responses is that some teachers responded ‘Never’, and some used never multiple times. Most frequent activities concerned ABC resources and within-school work with other teachers (5.c.,e.). 64% percent of mathematics teachers and 47% of physics teachers never used resource materials in class (5.e.). Non-participation was especially high for co-teaching a

STEM class (63.1%; 5.g.). 60% of teachers had contacted local industry for STEM support (5.k.). 44% of teachers had not provided feedback to ABC concerning resource boxes, while 70% of new ABC members did not provide any feedback (5.a.). One factor and one sub-factor were identified: 'Total' (all questions 5.a.-1.); and 'Use of Resource Box' (5.a.,e.). Statistically significant differences identified length of ABC involvement; teachers with more experience of ABC undertook more activities. Like the 1st cohort, teachers participated in ABC activities 1-3 times in the year, and activity involvement correlated with number of years on the ABC programme.

4.e. Confidence/competence in promoting STEM/engineering: Items were reduced from 24 to 13, and the original 11-point scale was reduced to 5-points. Teachers showed high confidence for all questions; the average confidence was 3.8, a 70+% confidence level. A few teachers (10%) were not confident at all – and this was especially demonstrated in designing an effective activity for weak students (6.n.) and help students understand a difficult scientific concept (6.g.). Non-confident teachers tended to be the newest/least experienced in ABC and in TC groups that submitted the least number of questionnaire replies. Highest levels of confidence characterised a range of teaching, social pedagogic and engineering skills (promote a positive attitude to engineering [4.31(mean), 6.c.(question)], why we recycle paper [4.25, 6.l.], promote teamwork on engineering problems [4.10, 6.d.], think creatively about engineering problems [4.08, 6.e.], extracurricular STEM activities [4.00, 6.j.]). Analyses identified one factor 'Total confidence' (included all items, 6.a.-x.) and three sub-factors: ('Social pedagogic confidence' (6.a.,c.,d.,e.,f.,v.); 'Engineering confidence' (6.a.,k.,l.,p.,r.,t.); and 'STEM teaching confidence' (6.j.,n.)). There were many statistically significant differences. Teachers with an engineering qualification showed the highest levels of confidence for 'Total Confidence' and each of the sub-factors. Mathematics teachers and teachers new to ABC showed the lowest confidence in each of these. Work as an engineer

was higher for ‘Total confidence’ but did not affect ‘Social pedagogic’ confidence nor ‘STEM teaching’ confidence. As with the 1st cohort, scoring on the ‘Total confidence’ factor was related to length of experience on ABC.

4.f. Impact of ABC: Items were reduced from 9 to 7, and the original 7-point scale was reduced to 5-points. All respondents agreed that ABC had a range of positive impacts on students, with an average score of 1.94. There was no ‘Strong Disagreement’ with any item. Strongest agreements were found with: relevance to the STEM curriculum [1.80, 7.a.]; understanding STEM careers [1.82, 7.h.]; student attainment [1.89, 7.b.]; and interest in engineering careers [1.90, 7.g.]. Weakest agreement was found regarding: choosing DT&E discipline options [2.11, 7.e.). Teachers that provided ‘No Opinion’ or ‘Disagree’ responses included those with physics qualifications, had just joined ABC, and taught at upper secondary level. One factor was identified: ‘Total perceived impact’, with a high mean (1.94) and included all items (7.a.-i.). The only statistically significant difference was found regarding experience on ABC, where recently joined teachers were most likely to have ‘No Opinion’ or ‘Disagree’ with impact statements – similar to the 1st cohort.

Discussion

In undertaking the ABC evaluation, we opened a lengthy and complex topic for consideration, in which attention to detail carries great importance in identifying the range of factors and items that contribute to a full understanding of this project. We were ambitious in responding to a range of evaluation and STEM concerns, as well as reporting 8 years of evaluation. Indeed, one of the main findings here is that it is unwise, even misjudged, to look for singular, straightforward or simple answers and solutions to matters concerning the efficacy and practice of STEM-CPD. Rather, the complexity of contextual and pragmatic factors played a significant role in the efficacy and impact of the STEM-CPD reported here.

While it is possible to identify some key contributors to effective STEM-CPD (e.g., importance of networking, quality of communication/reflection, social inclusion) and contributors to less effective STEM-CPD (e.g., disciplinary divides, time, practical pedagogic support), the overall message is that of the significance of local and institutional factors and players, and that these vary from institution-to-institution, and from network-to-network. In other words, whilst it may be possible to tease out some key elements – the ‘signal’ – in fact a major message is that the ‘noise’ is actually the signal. Contexts and their dynamics matter.

We note that relatively few STEM-CPD studies focus on inclusive schooling, develop focused evaluation methods and analyses covering both programme and its perceived impacts. In following Guskey’s (2000) and Desimone’s (2009) evaluation recommendations, we drew information from teachers and TCs, concerning their participation in learning, organisational support, pedagogic and social pedagogic aspects of CPD and collective/network participation. Our bootstrapped methodological approach enabled the evaluation to reveal insights as ABC developed, various effects of the programme and consideration of demographic differences among teachers and TCs.

Qualitative findings identified key questions and concerns that were followed-up in the quantitative findings. Teachers/TCs involved in the early ABC implementation were drawn from a range of STEM discipline backgrounds, yet few had experience of integrated STEM teaching (Avery & Reeve, 2013; Carlton-Hug & Hug, 2010). As TCs/teachers could only devote a limited amount of their time to the programme, potential shortcomings of a CPD programme were identified: for TCs, there was limited time or expectation to visit/observe network teachers, promote development of networks, integrate new teachers into networks (Khalil et al., 2016; Wenger, 2000), and/or to consider alternative pedagogic and social

pedagogic approaches regarding socially inclusive classes (Kutnick & Blatchford, 2014). Teachers had high levels of STEM efficacy. But that efficacy was not necessarily related to pedagogic and social pedagogic practices. Participants received little help to: overcome their single (STEM) discipline background (Shernoff et al., 2017); experience and reflect on integrated curriculum teaching; or plan for/overcome the diversity of students in their classes (Kudenko & Hoyle, 2014). School-based reports (from teachers) also found few efforts to integrate STEM disciplines (Newton & Tonelli, 2020), provide within-school STEM leadership/careers support for students or help teachers to overcome conflicts between current STEM responsibilities and traditional promotion processes. Integrated STEM experience was most frequently promoted within extracurricular activities (Vanteighen et al., 2020) which was unlikely to offer inclusive opportunities for all students. The qualitative findings identified a range of involvements and concerns that might have affected the realisation/fulfilment of ABC's intentions.

The quantitative data also provided comparative information on complex issues of: TC/teacher involvements, differences between types of participants and more focused information concerning reasons for: joining the programme, experience of STEM and ABC, depth of programme participation, types of STEM and teaching efficacy and perceptions of programme impact on students⁶.

Given the high proportion of TC questionnaire responses in both cohorts, we are reasonably certain of the trustworthiness of their responses. Throughout the two cycles of questionnaires, TCs showed endurance in their general involvement. Within their reasons for ABC involvement, TCs expressed positive intentions to bring STEM education into the 'real-world' and to provide pedagogic support for network teachers. Here we see a distinction

between positive intention and actual experiences that TCs were able to provide. TCs saw their role as ‘supporting’ (Kudenko & Hoyle, 2014) teachers (providing a forum to reflect on STEM, establishing a community of learners, increasing STEM classroom confidence) but were not positioned to facilitate this support – especially regarding integrating/mentoring inexperienced teachers within their networks. While networks were the predominant tool used to enhance teachers’ understanding/application of STEM, the variation between networks identifies a need for further exploration into network effectiveness.

This distinction between a ‘supporting’ role and the opportunity and position to facilitate this support is further identified in TCs’ low/non-frequency of school/classroom visits and teachers’ expressed lack of time for reflection and within-class support. TCs liked working with teachers and sharing positive STEM experiences, although TCs were more ambivalent concerning the need to effectively plan for network meetings and to promote positive relationships among their teachers (Khalil et al., 2016). Regarding STEM education, TCs were strongly supportive of the ideals behind ABC, and showed strong inclusion, pedagogic and social pedagogic beliefs. Their attitudes to STEM education showed that it should be open to all types of students and that students should be actively involved in their learning. A number of these STEM education attitudes would place both TCs and their teachers in conflict with the current organisation of schools, wherein STEM was likely to be taught in separate disciplines, students were differentiated by prior attainment, schools were ‘exam-oriented’, and STEM had an over-reliance on extracurricular activities. And, while schools did not appear to support STEM education and inclusion ideals, many TCs were not positioned to help in overcoming these problems. Over 20% of TCs did not contact other TCs to work through common problems, did not visit or enter their network classrooms or contact teachers to enhance network support.

TC support via engagement in ABC activities was strongly related to years of experience on the programme and indicated that many TCs were committed to sharing knowledge rather than facilitating a learning community (Monk, 2008). On the other hand, engaged TCs had consistently high levels of confidence/efficacy (from Bandura, 1997) in pursuit of ABC goals; and confidence levels increased between the 1st and 2nd cohorts. Finally, in considering perceived impact on students (NCTM, 2018) all TCs were very positive about perceived programme impact, although we note that this perception was likely to be based on knowledge/information sharing aspects of ABC rather than dedicated/reflective discussions with network teachers or school visits.

The response rate for the two teacher questionnaires limited their representativeness. Nevertheless, teachers from all TC networks responded, showing a range of STEM disciplinary backgrounds and a mix of sex and age. Perhaps the firmest of conclusions that we can draw is that teachers within experienced TC networks provided the most positive responses to ABC. This is an important finding. Most teachers in both cohorts taught their disciplines in the upper years of secondary schools, i.e., where one would expect to find stronger disciplinary pressures (Shernoff et al., 2017). Teachers in both cohorts joined ABC to improve STEM education and to provide ‘real-world’ STEM applications/pedagogic approaches in their classrooms. Teachers showed the highest levels of agreement to programme aspects that provided information/knowledge/resources and extracurricular activities rather than developing the inclusive classroom (Vanteighen et al., 2020). Teachers did not show a propensity to network with other members, although teachers with more experience of ABC were likely to make greater use of their networks.

Teachers in both cohorts were concerned about social inclusion (Vanteighen et al., 2020) and active, collegial and real-world learning (Monk, 2008), but were not positioned to consider how various social pedagogic approaches may be implemented in their classrooms. Teacher engagement in ABC activities was most frequently found among teachers with more experience of ABC; yet teachers showed little collegial engagement in schools or networks and provided very limited reflective feedback regarding ABC information/resources. Teachers were most likely to use resource boxes in schools (one-to-three times in the year), although mathematics and physics teachers were least likely to use these resources.

Confidence/efficacy questions identified that teachers were confident in their social pedagogic, teaching and engineering skills although this confidence was only at 50% levels for designing activities for weaker students and converting students' intuitive understanding into scientific understanding. The relatively high level of confidence is important as Ajzen (2002) identifies that this behavioural control aspect is strongly related to bringing positive intentions to actual fruition. Behavioural control is also different from the expectation that simply undertaking STEM classroom activities (behaviours) in teams and groups is likely to be effective, as opposed to training for socially inclusive learning (Kutnick & Blatchford, 2014). Finally, the longer teachers had been part of ABC, the more they were committed, confident, and perceived positive student impacts.

What emerges from the findings is that the agency and control over decision-making in promoting STEM subjects very frequently resided in matters that were outside the control of the participants. Structural matters, school priorities and organisation that, again, were outside the control of the participants, exerted a highly constraining effect on the development and operations of effective STEM and STEM-CPD in the ABC project. Given

the nature of the issues identified here, the sizeable scope of the project, and the spread of the sample, the suggestion here is this has implications that can be generalised to schools and education much more widely. The very considerable promise of networked solutions is undermined by obstacles outside their control.

Concluding remarks

Referring to our research questions, the authors make three types of comment related to: the design of ABC, the evaluation and concerns about the effects of this inclusive STEM-CPD programme. Initially, ABC was designed to enhance teacher and student understanding and future engagement with STEM topics in a ‘real-world’ orientation. Inclusion/pedagogy was not specifically ‘planned’ into the programme although most teachers (over 95%) engaged in the programme were from inclusive secondary schools. Knowledge dissemination was planned to take place via a TC-led cascade system, promoting teachers’ knowledge and attitudes towards STEM education and providing real-world problems upon which teachers could develop practical STEM understanding, reflective practices and efficacy. Support for teachers was planned within collective networks that would last over several years. This was not a short-term or one-off/stand-alone dissemination of knowledge programme that had been previously criticised (Monk, 2008). The programme expected to impact upon students’ STEM awareness, attitudes, attainment and course/career choice.

Considering criticisms in the literature, this evaluation was planned on the bases of theory (Ajzen, 2002), domain specific and pedagogic efficacy (Bandura, 1997), and learning community (Wenger, 2000)). Methods were bootstrapped to assess insights from programme participants that identify concerns underlying the implementation of ABC and demographic aspects of participants.

Regarding evaluation points in the research questions, we summarise the following:

- a. *Programme based on real, authentic STEM experience*: Teachers/TCs agreed on the need to base STEM education on real-world problems and identified that ABC resources provided were based upon these problems. Teachers, though, were not consistent in applying these real-world resources in their inclusive classrooms – resources were most often used in extracurricular STEM clubs, were least likely to be used in traditionally taught disciplines (mathematics/physics) and schools that did not encourage/support STEM interdisciplinary teaching or hands-on pedagogies.
- b. *Did the cascade model work effectively for ABC and support a community of learners*:
The evaluation identified tensions between the cascade model and grouping teachers into networks to enhance their STEM-CPD. The most obvious tension was found in the pedagogic model of cascade – where ABC provided high quality resources and knowledge/practice in using the resources but did not follow-up on teachers’ reflections/feedback concerning resource use or social pedagogic models of application within classrooms, nor was it supportive of a community of learners.
While teachers identified that STEM students should be able to work independently from the teacher, in small/supportive groups, integrate boys and girls from across the attainment range in an active and engaging manner, they were not provided with opportunities nor TC classroom support to implement these social pedagogic strategies. The cascade model appeared constrained by the limited time available for network meetings and TC visits, leaving ABC dependent on knowledge/practice rather than promoting deeper understanding and implementation (Monk, 2008). This constraint on the cascade model was particularly evident for teachers that were new to the network, where actualisation of the model did not appear to consider how ‘new’

teachers could be better integrated into the existing ‘community’ of their network nor how teachers may have adapted their resources/approaches to their own/existing practice (Khalil et al., 2016; Wenger, 2000).

- c. *Did ABC provide curriculum-appropriate content and pedagogic approaches to network teachers:* Resources provided added to real-world STEM learning for classroom curriculum and extracurricular activities. At the same time, ABC’s interdisciplinary orientation appeared to be at odds with the continuing discipline-based teaching of most teachers/schools (Shernoff et al., 2017). Teachers had a strong desire for a socially-inclusive STEM pedagogy but there appeared to be little network time/support to allow for reflections, feedback and sharing of pedagogic practices among the teachers. Hence, a strong outcome of this evaluation is the suggestion to move beyond CPD criticisms of an over-reliance on knowledge/practice and include a deepening of pedagogic and social pedagogic considerations and enabling networks to make a real difference, i.e., ensuring a commitment by the institutions themselves to support the intervention as well as developing more effective network/support practices.
- d. *Did ABC affect STEM and engineering efficacy of network teachers:* While a simple answer to this problem is ‘yes’, there is a more complicated explanation. Both TCs and teachers held consistently high levels of STEM and engineering efficacy. At the same time, teachers with more years of engagement in ABC had the highest levels of efficacy/competence and we note that this aspect of ‘behavioural control’ (Ajzen, 2002) is most highly associated with the intention to change and develop. Certain insecurities were also identified by some teachers; these had to do with the inclusive practice of planning for/integrating low attaining students in their STEM classrooms and understanding certain ‘building/taking apart’ engineering skills. Integrating low

attaining students into inclusive classrooms is a continuing problem exacerbated by government recommendations for ‘differentiated’ classes and teaching. And, again, these pedagogic insecurities may have been exacerbated by limited developments within networks (such as better integration of new teachers, more time for reflection and greater consideration of pedagogic/social pedagogic practices). The engineering design insecurity may be explained by the limited amount of engineering study found within the secondary school curriculum (Holman, 2007; Kathei et al., 2009), and is unlikely to be overcome until engineering is allocated the same curriculum status of science, technology and mathematics.

In a final, reflective comment, we note that ABC has moved beyond ‘stand-alone’, ‘external provider’ due to its longevity and ability to produce innovative resources. The programme’s initial objectives and expectation of outcomes will need to be expanded within its inclusive school/classroom application. Hence, more consideration of beneficial aspects of pedagogic and social pedagogic approaches to STEM education can usefully be integrated into ABC’s further development. Most teachers and TCs have shown their commitment to the programme through their multiple years of programme experience, although their networks need to consider how inexperienced teachers may be better integrated. A final concern, not previously considered here, is why the quantitative evaluations had such a low response rate from teachers. This response rate represented teachers from all networks – and we have found that response rate increased in networks with more experienced TCs and teachers. Perhaps, this concern relates to the need to establish a more coherent ‘learning community’ ethos among network members – especially enhanced integration of new teachers.

There is clear advice from this evaluation for the designers of this intervention. The desire to engage with an evaluation is to be applauded. The limitations which resulted will be obvious,

but rather than dwell on those we wish to offer three recommendations which may be of value for future interventions and their evaluation.

1. In developing the evaluation, we drew upon various theoretical bases to help focus the evaluation. As we noted above, approaches to evaluation of STEM-CPD programmes lack consistency and fail to build on existing findings and theories. Much is to be gained from building into the design of an intervention a suitably grounded evaluation framework. This would guide the design and deliver greater understanding of its value allowing the relevant communities to build a body of useful knowledge.
2. A cascade model which operates via intermediaries to teachers and then ultimately to students is the only feasible approach if any agency wishes to target a large population of school students in an inclusive fashion. However, the creation and longevity of the social networks and social capital upon which they are based cannot be left to chance.
3. Interventions which operate independently of organisational, curricular, social and resource contexts in which teachers and their students operate will always face the difficulties which follow from this seclusion and miss the opportunities which appropriate contextualisation can provide.

End notes

1. According to the UK National STEM Directory there were 248 current STEM initiatives in schools and higher education as of February 2018 (STEM Directory, 2018); most of these were single disciplinary.

2. We note that STEM is composed of four disciplines, although there is little formal teaching of engineering in schools (Holman, 2007; Katehi, Pearson & Feder, 2009) and low take-up of engineering courses is especially evident among girls and various minorities (National Academy of Engineering, 2009). The few aspects of engineering found in STEM tend to be associated with ‘engineering design’ and are identified as an aspect of ‘design and technology (D&T)’ courses (Shernoff et al., 2017; Guzey et al., 2016). It appears contradictory that engineering design and inquiry approaches to real-world learning have been championed in the UK (Lucas et al., 2017) while actual ‘engineering’ is not identified (OECD, 2009).

3. 'Inclusive' education calls for 'all children in the same classrooms in the same schools' (<http://www.unicef.org/education/inclusive-education>, accessed 2 February 2022). Learners of a similar age are unlikely to be differentiated by gender, attainment or disability.
4. In the preparation of this manuscript, the evaluators and those running, funding and organising the programme (the Host) agreed to anonymise name of programme, funders and the Host.
5. A typical network meeting would start with informal networking over refreshments followed by a welcome to attendees and any new members. This was followed by a brief discussion about the resource box introduced in the previous meeting and a new resource box introduced with suggestions for curricular use. Attendees, working in groups, undertake the resources activity. A brief feedback session follows and then attendees are informed about various national and regional STEM events. Attendees frequently remain after the end of the meeting to continue conversations over tea and coffee.
6. As evaluators we note that the Host has received our comments over the years and has moved to further develop the ABC programme as it expanded in number of teachers and TCs. ABC now trains TCs in leading CPD, inclusive pedagogies and STEM pedagogies.

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Table 1: TC: Question groupings and items, items per grouping, response type and factors for Cohorts 1 and 2

Question groupings	Cohort 1				Cohort 2			
	Items per grouping; Response type	Factors identified per grouping (reliability**)	Factor (mean)	Demographic differences	Items per grouping; Response type	Factors identified per grouping (reliability**)	Factor (mean)	Demographic differences
Involvement in ABC	8 questions; 3-pt Likert*	STEM in school (.557)	1.44 (.402)	PreNC>NC	6 questions; 3-pt Likert*	STEM in school (.310)	1.35 (.279)	Biol>others
Roles/responsibilities of TC	14 questions; 5-pt Likert*	Role Commitment (.892)	1.76 (.512)	-	10 questions; 5-pt Likert*	STEM pedagogic coordination (.702)	1.33 (.373)	-
Experience of ABC	10 questions; 5-pt Likert*	Organisational problems (.769) Role comfort (.528)	3.08 (.890) 1.96 (.593)	- -	7 questions; 5-pt Likert*	Organisational problems (.621)	3.33 (.671)	Female>male
Experience of STEM education	27 questions; 5-pt Likert*	Student STEM success (.807)	3.38 (.620)	-	18 questions; 5-pt Likert*	Student STEM success (.438) Pedagogy within STEM (.655)	3.55 (.395) 1.78 (.447)	- -
Participation in ABC activities	11 questions; 5-pt Frequency^	General ABC activity level (.837) External support for STEM (.862)	2.28 (.722) 2.95 (1.195)	Males>female; ExpTC> NonexpTC; Eng>NonEng -	7 questions; 5-pt Frequency^	General ABC activity level (.723)	2.31 (.735)	ExpTC> NonexpTC
Confidence in promoting STEM and Engineering	20 questions; 11-pt Confidence!	Confidence in Engineering/STEM (.908) Help in Sci/Maths (.861) Help Hi/Low attainers (.956)	8.09 (2.275) 8.50 (1.794) 9.56 (2.083)	D&T>other subjects; ExpTC> NonexpTC; Eng>NonEng ExpTC> NonexpTC; Sci/Maths>other subjects; Eng>NonEng -	11 questions; 5-pt Confidence!	Enhance ABC practice (.803) Engineering confidence (.645)	4.32 (.504) 4.20 (.572)	Non-teachTC> TeachingTC; Eng>NonEng Male>female
Impact of ABC	9 questions; 7-pt Likert*	Impact of ABC (.863)	2.44 (.689)	PreNC>NC	7 questions; 5-pt Likert*	Impact (.707)	1.99 (.514)	Chem>Others

*All Likert scaled as: 1 = strongest agreement; high score = strongest disagreement

**Some of the alpha reliabilities reported are lower than normally included, these factors are included as they may be of interest to readers

^Frequency of activity scaled as: 1 = never participated in this activity; 5 = participated more than 10 times

!Confidence scaled as: 1 = not confident at all; 11 = extremely confident

Abbreviations: PreNC (PreNational Curriculum), NC (National Curriculum), Exp (Experienced), Nonexp (Nonexperienced), Eng (Engineer), NonEng (Non-Engineer), Biol (Biology), Chem (Chemistry), Others (other curriculum subjects)

Table 2: Teachers: Question groupings and items, items per grouping, response type and factors for Cohorts 1 and 2

Question groupings	Cohort 1				Cohort 2			
	Items per grouping; Response type	Factors identified per grouping (reliability**)	Factor (mean)	Demographic differences	Items per grouping; Response type	Factors identified per grouping (reliability**)	Factor (mean)	Demographic differences
Joining ABC	8 questions; 3-pt Likert*	Commitment to STEM (.733) Engineering & Industry (.496)	1.76 (.413) 2.23 (.598)	- Eng>NonEng	7 questions; 3-pt Likert*	General STEM experience (.681) STEM pedagogy (.660)	1.59 (.420) 1.52 (.494)	HiNet> LowNet -
Experience of ABC	9 questions; 5-pt Likert*	Pedagogic confidence (.872)	2.11 (.619)	NonEng>Eng	6 questions; 5-pt Likert*	Teaching support (.845)	1.69 (.577)	ExpTeachers> NonexpTeachers
Experience of STEM education	25 questions; 5-pt Likert*	Inclusivity (.798) Student STEM autonomy (.463)	3.30 (.677) 1.87 (.455)	- -	15 questions; 5-pt Likert*	Social inclusion (.579) Social pedagogy (.608)	3.95 (.519) 1.79 (.399)	- -
Participation in ABC activities	10 questions; 5-pt Frequency^	ABC activity level (.893)	1.92 (.737)	ExpTeachers> NonexpTeachers	7 questions; 5-pt Frequency^	Total activity (.801) Use of resource boxes (.831)	2.09 (.743) 2.11 (.921)	ExpTeachers> NonexpTeachers; HiNet> LowNet -
Confidence/Competence in promoting STEM and Engineering	24 questions; 11-pt Confidence!	Universal STEM efficacy (.958) Develop students' scientific understanding (.849)	7.62 (1.932) 7.97 (2.122)	ExpTeachers> NonexpTeachers D&T<others	13 questions; 5-pt Confidence!	Total confidence (.909) Social pedagogic confidence (.826) Engineering confidence (.860) STEM teaching confidence (.713)	3.81 (.729) 3.94 (.734) 3.71 (.823) 3.66 (1.074)	ExpTeachers> NonexpTeachers; Eng> NonEng; Maths< others Eng> NonEng; Maths< others Eng> NonEng; Maths< others Eng>NonEng; Maths<others
Impact of ABC	9 questions; 7-pt Likert*	Impact of ABC (.937)	2.52 (.909)	-	7 questions; 5-pt Likert*	Total perceived impact (.881)	1.94 (.543)	ExpTeachers> NonexpTeachers

*All Likert scaled as: 1 = strongest agreement; high score = strongest disagreement

**Some of the alpha reliabilities reported are lower than normally included, these factors are included as they may be of interest to readers

^Frequency of activity scaled as: 1 = never participated in this activity; 5 = participated more than 10 times

!Confidence scaled as: 1 = not confident at all; 11 = extremely confident

Abbreviations: PreNC (PreNational Curriculum), NC (National Curriculum), Exp (Experienced), Nonexp (Nonexperienced), Eng (Engineer), NonEng (Non-Engineer), Biol (Biology), Chem (Chemistry), D&T (Design and Technology), Maths (Mathematics), Others (other curriculum subjects), HiNet (High network participation), LowNet (Low network participation)

Table 3: ABC items per question grouping for Teacher Coordinators and Teachers by Cohort 1 and 2

Question groupings and items	TC Cohort 1	TC Cohort 2	Teacher Cohort 1	Teacher Cohort 2
Involvement in ABC				
1.a. Personal connections with local employers	√	√	√	√
1.b. Enhance coordination among STEM teachers	√			
1.c. Experience as an engineer	√	√	√	√
1.d. Extend opportunities to develop new STEM pedagogic approaches	√	√	√	√
1.e. Facilitate inclusion of real-world applications into STEM education	√	√	√	√
1.f. Been a successful STEM teacher in school	√	√	√	√
1.g. Mentoring and support for ABC teachers			√	√
1.h. Involvement with external STEM support organisations				
1.i. Improve STEM education in my school				
Roles/responsibilities of TC				
2.a. Demonstrate resources/activities provided by ABC	√	√		
2.b. Provide individual support for my ABC teachers	√			
2.c. Support my ABC teachers to solve STEM problems during network meetings	√	√		
2.d. Help overcome school-management problems confronted by my ABC teachers	√	√		
2.e. Identify ways my ABC teachers can encourage STEM communication in their schools	√	√		
2.f. Prioritise needs of new ABC teachers over established members in my network	√	√		
2.g. Develop/support improved STEM attitudes among my ABC teachers	√	√		
2.h. Improve my ABC teachers' confidence in approaching classroom STEM problems	√	√		
2.i. Establish long-term Community of Learning among my ABC teachers				
2.j. Find new schools to integrate into my ABC network				
2.k. Pass my STEM knowledge to my ABC teachers				
2.l. Provide a forum for my ABC teachers to reflect on their STEM activities				
2.m. Identify more experienced ABC teachers to mentor new network members				
2.n. Establish effective ways for my ABC teachers to communicate outside network meetings				
Experience of ABC				
3.a. I need to be a good teacher to be an effective TC	√	√		
3.b. It is difficult to promote positive relations among my network teachers	√	√		
3.c. Preparing for ABC meetings is too time consuming	√	√		
3.d. ABC resource boxes are essential for extracurricular activities	√			
3.e. ABC ideas have changed my approach to recommendations for STEM teaching	√	√		
3.f. Coordination of ABC meetings is a natural expansion of my STEM responsibilities	√	√		
3.g. I find it difficult to arrange ABC meetings	√	√		
3.h. I plan for ABC network activities in addition to regular meetings			√	√
3.i. I enjoy working with ABC teachers			√	√
3.j. It is difficult to involve local industries in school-based STEM activities			√	√
3.1.a. I value the support of other members of the ABC programme			√	√

4.v. For a STEM subject career, a student needs a relevant university degree				
4.y. Engineering should have a formal place in the school curriculum				
4.z. It is more important to teach science/maths fundamentals than their STEM application				
4.aa. Student populations in some schools do not allow for effective SYEM teaching				
Participation in ABC activities				
5.a. Engaged in network feedback concerning resource boxes	√	√	√	√
5.b. Contacted other ABC TCs/teachers to discuss aspects of your network meetings	√	√	√	√
5.c. Worked with other ABC TCs/teachers to develop within-class/extracurricular activities	√		√	√
5.d. Run into problems understanding the use of resource boxes	√	√	√	√
5.e. Used resource box materials in your classroom activities	√		√	√
5.f. Considered how to further develop a STEM club activity with ABC TCs/teachers	√	√	√	√
5.g. Co-taught a STEM class with one of your network teachers/teacher colleagues	√	√	√	√
5.h. Visited one of your ABC schools to encourage support for STEM teaching/activities				
5.i. Discussed identifying students becoming STEM confident with ABC teachers/colleagues				
5.j. Contacted local/national STEM organisations to further support STEM education				
5.k. Contacted local industry to support your ABC network/school				
5.l. Checked to whether your ABC teachers are networking with one-another				
Confidence in promoting STEM/engineering				
6.a. Gauge a student's understanding of an engineering task	√	√	√	√
6.b. Provide guidelines/assess a student's engineering products	√	√	√	√
6.c. Help/promote a positive attitude to engineering among students	√	√	√	√
6.d. Provide actual practices/promote student team work on engineering problems	√		√	√
6.e. Provide materials to ABC teachers help students think creatively about engineering	√		√	
6.f. Help ABC teachers/students understand a difficult scientific concept	√	√	√	√
6.g. Help ABC teachers/students understand a difficult mathematics problem	√	√	√	√
6.h. Help ABC teachers/colleagues design a new technology lesson	√	√	√	√
6.i. Help teach a STEM subject outside my core subject discipline	√	√	√	√
6.j. Advise ABC teachers/teachers how to organise extracurricular STEM activities	√	√	√	√
6.k. Explain why a bridge collapsed	√	√	√	√
6.l. Explain why we recycle paper			√	
6.m. Learn how to use a new programming language			√	√
6.n. Design an effective new STEM activity for the weakest students in KS3			√	
6.o. Design an effective new STEM activity for the strongest students in KS3			√	
6.p. Fix a broken machine				
6.q. Use tools to build something				

