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CENTRE FOR REAL-WORLD LEARNING

Learning to be an engineer: the role of school leadership

October 2018



Learning to be an engineer: the role of school leadership

A report for the Royal Academy of Engineering

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**About the Centre for Real-World Learning
at the University of Winchester (CRL)
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CRL is an applied research centre focusing on the teaching of learning dispositions. Its ground-breaking work in identifying creative habits of mind has been influential in the decision by the Organisation for Economic Development (OECD) to introduce the 2021 PISA Test of Creative Thinking.

Earlier research for the Royal Academy of Engineering proposed six engineering habits of mind in *Thinking like an engineer* and subsequently demonstrated how these could be implemented in schools in England and Scotland, *Learning to be an engineer*.

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Contents

Executive summary	1
1. Introduction	6
1.1 The role of school leadership	6
1.2 Engineering habits of mind and their signature pedagogies	7
1.3 Leadership challenges in schools	7
1.4 Summary	7
2. Approach to the research	10
2.1 <i>Thinking like an engineer and Learning to be an engineer</i>	10
2.2 Research design and methods	10
2.2.1 Literature review	11
2.2.2 Online survey	11
2.2.3 Structured interviews	11
2.2.4 Expert group	11
2.3 Summary	11
3. The role of leadership in schools	12
3.1 Context	12
3.2 The meaning of school leadership	13
3.3 School leadership in practice	13
3.4 The role of middle leaders in leading pedagogic change	14
3.5 How successful school leaders improve learning	15
3.6 Positioning engineering in schools	17
3.7 Leading integrated cross-curricular engineering projects	18
3.7.1 Primary	18
3.7.2 Secondary	19
3.7.3. Learning from the US experience of STEM integration	19
3.8 The importance of professional learning and enquiry in changing practices	20
3.9 Summary	20
4. Learning about leaders and leadership	22
4.1 Introduction	22
4.2 Findings from survey	22
4.2.1 Culture	23
4.2.2 Curriculum	23

4.2.3	Partnerships	23
4.2.4	Resourcing	23
4.2.5	Enablers	26
4.2.6	Challenges	26
4.2.7	Leadership attributes	26
4.2.8	Leadership journeys	26
4.2.9	Summary of survey responses	26
4.3	Findings from the interviews	29
4.3.1	Status of engineering in schools	29
4.3.2	The cross-curricular nature of engineering	30
4.3.3	Accountability pressures	32
4.3.4	Personal characteristics of effective leaders of engineering in schools	33
4.3.5	Leadership functions - setting direction	34
4.3.6	Leadership strategies - developing people	36
4.3.7	Leadership strategies - redesigning the organisation	39
4.3.8	Leadership strategies - managing teaching and learning	42
4.4.	Summary	44
5.	Putting it all together and moving forward	46
5.1	The challenge we face	46
5.2	Building on earlier thinking	46
5.3	Culture	47
5.4	Leadership attributes	47
5.5	Leadership functions and strategies	49
5.5.1	Setting direction	49
5.5.2	Developing people	50
5.5.3	Redesigning the organisation	50
5.5.4	Managing teaching and learning	50
5.6	The Leadership for Engineering in Schools model	50
5.7	Recommendations	52
	Glossary of abbreviations and terms	53
	References	54

Executive summary

This report, continuing the series of studies on embedding engineering in the education system through the introduction of *Engineering Habits of Mind (EHoM)*, explores the ways in which school leaders can create better and more engaging learning opportunities for would-be engineers. It includes findings and recommendations that will hopefully be helpful to all of those who are concerned to see engineering more widely taught and enjoyed in schools.

There is surprisingly little understanding about the leadership of education for engineering in schools

Despite the field of school leadership being well researched, it is hard to say what kinds of personal and professional attributes make for successful engineering education leaders in schools and what it is that successful leaders at all levels of schools do differently to facilitate it. This lack of evidence is, in part, because of the particular nature of engineering, as it is:

- multidisciplinary and not a national curriculum subject, therefore largely invisible on most school timetables
- mainly offered to pupils through informal opportunities, which are not assessed at Key Stage 4 and hence difficult to gain credit for under current accountability measures
- best taught through cross-curricular learning using 'real-world' design problems and problem-based pedagogy
- something that requires a deal of flexibility of school systems such as timetabling
- best understood with the help of practising engineers
- a subject for which many teachers need additional preparation to teach with skill and confidence as they work across subject boundaries on engineering themes.

Perhaps as a consequence of these features only a few hundred schools out of more than 24,000 in England are identifiable as places that actively promote engineering through the curriculum. Rather than scanning the totality of schools, this research looked instead at a small selection of schools that are successful outliers in introducing engineering and sought to learn from them.

Within the broader leadership literature there are three widely reported themes that feature in models of effective school leadership

From the broader literature, the authors identified three major themes that appear to be widely associated with effective school leadership: the personal and professional attributes of the leader; the leadership functions that they consider to be important; and the strategies they use to achieve their aims. More simply: who they are, what they do and how they put it into practice.

The authors sought to understand how these generic themes applied to education for engineering

It seems that school leaders who successfully create and sustain a vision for engineering do it by fostering a supportive culture across the school, maintaining and modelling a specific set of personal attributes, and enacting a coherent set of strategies, all of which are encompassed by the phrase *pedagogic leadership*.

School culture

Successful leaders of engineering in education create a school culture where education for engineering is a priority, and teachers experience high-trust, freedom to experiment and supported risk-taking. Failure is tolerated in these schools, with the learning from this widely shared. The school is outward-looking and focused on pedagogy.

Personal and professional attributes of school leaders

Of all the personal attributes school leaders seem to need the authors identify a number that are likely to be particularly important in this context. School leaders need to be: communicative, collaborative, courageous, creative thinking, flexible, improver, open-minded, persistent, resilient, risk-taker, vision-led. Professionally, two attributes came through very clearly and can best be summed up by the phrase 'pedagogic leadership' - these are the possession of a genuine interest in, and knowledge of, pedagogy and a parallel valuing of the professional learning processes that will develop staff to teach engineering effectively. These attributes are needed by headteachers and middle leaders alike.

Pedagogic leadership strategies and functions

Leadership strategies and functions go hand in glove; that the 'how' leaders lead is equally important as what they do. For example, a belief in the importance of pedagogy or of a certain kind of professional learning is only truly effective when it is also modelled by leaders themselves. This is brought together in an overview of effective school leadership for engineering shown in **figure 1** on page 4.

Recommendations

In order to strengthen support for leadership of education for engineering, the authors make recommendations that the Royal Academy of Engineering and the wider engineering community may like to consider in collaboration with the following bodies.

Headteacher organisations

The engineering community should engage with school leadership organisations, for example the Association of School and College Leaders (ASCL), to focus on pedagogic leadership with regard to education for engineering. This could involve holding a roundtable discussion to begin a national debate about leadership that promotes the value of incorporating engineering in the curriculum and recommends ways of supporting headteachers to develop and implement a strategic vision for engineering.

Engineering professional bodies and subject associations

School leadership issues involved in promoting engineering in collaboration with engineering professional bodies and subject associations should be highlighted. This might involve:

- producing case studies of the different approaches taken by school leaders to embed engineering in the curriculum, each emphasising one of the four leadership functions and including school leaders discussing their approach to the challenges of leadership
- collaborating with STEM Learning to develop CPD resources for all leadership levels that explore the challenges of leading and teaching cross-curricular learning
- discussing with providers of engineering challenges and awards how their success criteria might be aligned with EHoM.

Employers and employers' organisations

Engineering employers should encourage their engineers to support school leadership teams by joining schools' governing boards. Through EngineeringUK, the engineering community could also review guidance for employers on engaging with schools, and develop advice specifically aimed at working with headteachers and chairs of governors.

Government and awarding/assessment bodies

The engineering community should work with qualification awarding organisations and the Department for Education to explore examples of how cross-curricular links can be developed using engineering themes across the National Curriculum for computing, design and technology (D&T), mathematics and sciences.

The engineering community should also work with the Institute for Apprenticeships, in particular the employer panels drafting T level content in engineering and associated subjects, to explore ways of using the EHoM approach in the new qualifications.

The engineering community might like to encourage awarding organisations to develop GCSE qualifications in engineering based on an activity-led pedagogy and EHoM.

Ofsted

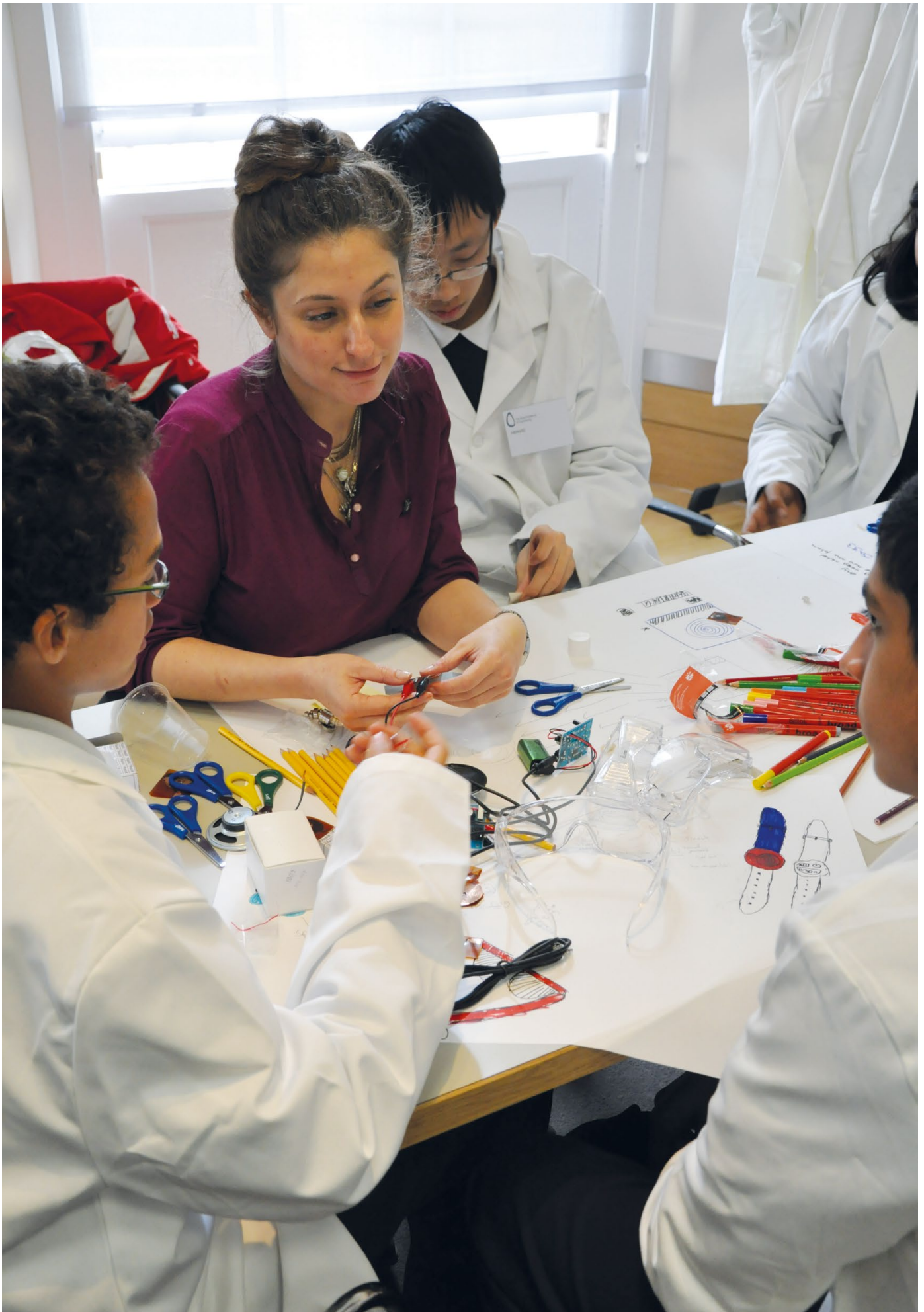
The Academy should encourage the Ofsted lead inspectors for STEM subjects to reflect on the ways in which inspection, specifically at upper secondary level, is 'bending the curriculum out of shape'. There is an opportunity for Ofsted to reinforce the messages learned from earlier research about the teaching of engineering using the EHoM approach. Equally it is a moment to take stock of the ways in which the English Baccalaureate (EBacc) accountability measure may, unintentionally, be making it more difficult for schools to teach important areas such as engineering and consider how breadth and balance may be maintained across the curriculum.

International organisations

The Academy might like to approach the OECD, building on the OECD's recent decision to introduce a new PISA test of Creative Thinking in 2021, to explore opportunities to develop thinking in 2024 or 2027 for a new kind of PISA test of engineering that would be of use, formatively, to schools.

External context: Skills demand; accountability regime; perception of engineering				
Culture (where): Engineering is a priority; high trust; freedom to experiment; supported risk taking; failure is tolerated; outward looking; pedagogy focused				
Personal attributes (who):	Leadership functions 1-4 (what) and leadership strategies (how)			
	1. Set Direction	2. Develop people	3. Redesign Organisation	4. Manage teaching & learning
Collaborative Flexible Resilient Open-minded Persistent Optimistic Courageous Vision-led Creative thinker Risk-taker Communicator Improver Knowledgeable	Whole-school focus on engineering; EDP & EHoM used for thinking across subjects; Education is for life; Create 'industry ethos'; Employers as critical partners; Pedagogy supports learning process as well as content; Long term vision; Varied communication strategies; Leadership by example.	Model desired pedagogy; Small steps of change to link new pedagogy to existing approach; Use internal staff expertise to share best practice; Offer teachers stimulating challenges; Trust teachers to take risks; Use problem solving approach with individuals to improve skills; Participate in teacher professional development; Find school governors with engineering expertise to support SLT.	Link rationale for engineering to school ethos; Align desired curriculum change to school ethos; Increase employer involvement in curriculum; Direct employer involvement to meet school needs; Expand engineering-focused ECA; Invite governors to experience the changes in the classroom; Research desired practice, start it off and then hand to others to embed; Build on teachers' existing skill sets; Engage parents using varied strategies; Create a curriculum for teachers to use and adapt to their subjects; Align curriculum change with existing learning habits; Use alumni as models.	Increase flexibility of timetable; Give staff flexibility to deliver the curriculum, but don't relax accountability; Use assessment to value engineering projects; Look for 'quick wins', but not at the expense of the long term vision; Align staff strengths and interests with curriculum needs; Provide supportive environment when staff tackle new challenges; Collaborate with other schools & local community to secure teaching resources.
Belief in value of engineering, in signature pedagogy and in power of professional learning				

Figure 1: Centre for Real-World Learning's Leadership for engineering in schools model



1. Introduction

In 2014, the Academy and Centre for Real-World Learning published the report *Thinking like an engineer - implications for the education system*¹ introducing a novel way of describing the way engineers think and act as six Engineering Habits of Mind (EHoM).

In the two years that followed this, a proof of concept trial was undertaken in 33 schools and one further education college in England and Scotland involving 84 teachers and more than 3,000 students. The trial established that, with appropriate support, teachers could focus on disciplinary knowledge (subjects such as mathematics and science) and reframe students' learning as a series of EHoM, shown in **figure 2**.

The results from the trial were published in *Learning to be an engineer - implications for the education system*². As well as establishing that

teachers found the use of EHoM to be a practically useful way of teaching many aspects of the curriculum, the research also identified four key principles underpinning the kinds of teaching likely to develop a passion for engineering in today's busy schools and colleges:

1. Clear understanding of EHoM by teachers and learners.
2. The creation of a culture in which these habits flourish.
3. Selection of the best teaching and learning methods, the 'signature pedagogy' of engineering.
4. An active engagement with learners as young engineers.

Learning to be an engineer described many positive outcomes for learners taught in this way, including: increased fluency in the key habits of mind;

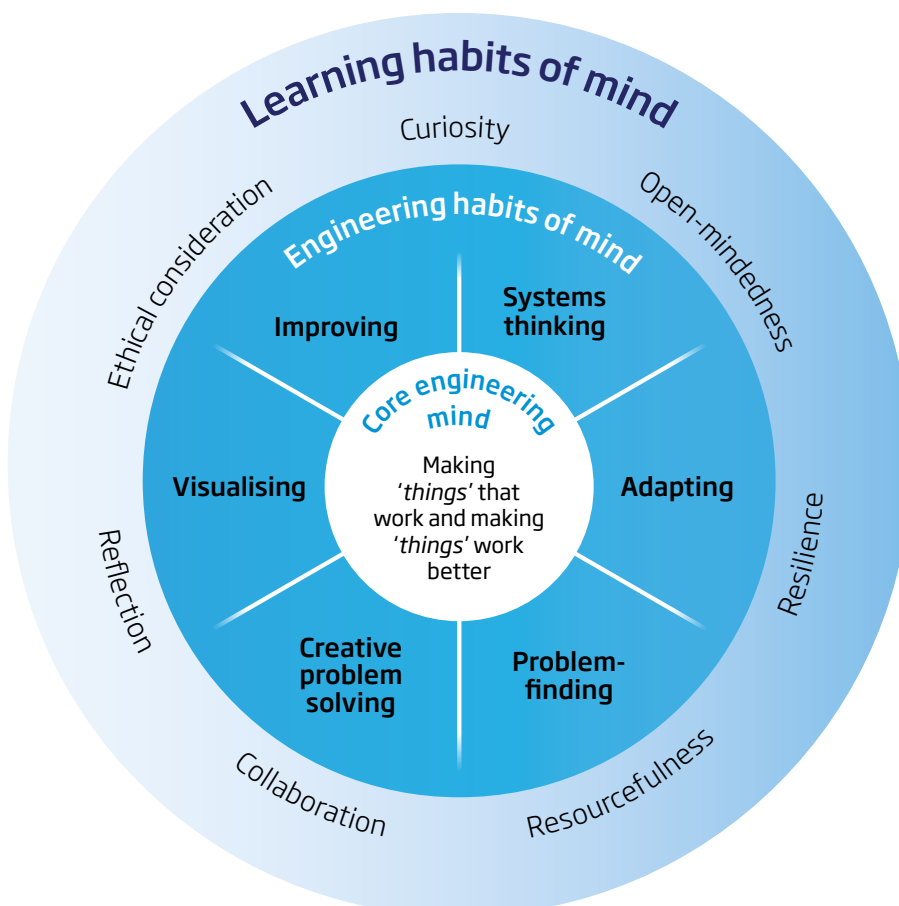


Figure 2: Engineering habits of mind (EHoM)

the development of 'growth mindsets'; improvements in literacy, numeracy and oracy; enhanced self-management skills; and better understanding of engineering. It described many benefits to the capability and confidence of teachers, in particular their engagement with practising engineers.

Learning to be an engineer also identified some key barriers to progress. These included the limitations of a subject-based curriculum in facilitating engineering with its necessary connection to many disciplines, a lack of confidence among many primary teachers to engage with engineering, and the particular pressures in the English system at secondary level resulting from new accountability measures such as Attainment 8 and Progress 8.

At the same time as this research was being completed, the Royal Academy of Engineering identified seven key areas that needed to be addressed if progress, in terms of uptake by students as potential engineers, was to be achieved³. The analysis reminds us of the complexity of creating the school conditions necessary for the successful teaching of engineering.

Based on the findings in *Learning to be an engineer*, the Academy made six broad recommendations. One of them was that a more strategic focus on school leadership in driving change in support of education for engineering should be developed. The research published in this report is an attempt to begin to respond to this suggestion.

1.1 The role of school leadership

It has sometimes been observed that the quality of teaching cannot exceed the quality of teachers⁴. By the same token, the quality of engineering and other important cross-disciplinary areas such as creativity is, the authors suggest, the outcome of the quality of school leaders in advocating and leading the changes necessary to bring this about.

There are very many traditions of leadership and as many definitions arising from these traditions. For the

purposes of this research the authors adopted a broad definition that might best be described as 'pedagogic leadership'⁵. In reaching this approach the authors reviewed the literature on educational leadership and were ultimately guided by the conclusions of a best evidence review conducted by Viviane Robinson and colleagues⁶ and this useful framing definition:

"... educational leadership is leadership that causes others to do things that can be expected to improve educational outcomes for students".

As the quotation implies through its phrase 'causes others', the Leadership for Engineering in Schools model is also, necessarily, a distributed one existing at senior, middle and classroom level.

1.2 Engineering habits of mind and their signature pedagogies

Research with schools over the last five years has further refined the habits of mind and their sub-habits (**Table 1**).

This more detailed description of the EHoM provides headteachers and their staff with a clear description of 'what' needs to be covered, just as a curriculum does for subject content.

Thinking like an engineer described a number of potentially useful teaching and learning methods that form a signature pedagogy⁷ for developing young engineers. *Learning to be an Engineer* identified three essential elements of such a signature pedagogy:

1. The engineering design process.
2. 'Tinkering' (an approach to playful experimentation).
3. Authentic, sustained engagement with engineers.

These three elements give a shorthand for the 'how' of what schools need to do.

1.3 Leadership challenges in schools

Leading a school, leading a team within a school and being a classroom

EHoM	Sub-habit 1	Sub-habit 2
CREATIVE PROBLEM-SOLVING is ... generating ideas and solutions by applying techniques from different traditions, critiquing, giving and receiving feedback, seeing engineering as a 'team sport'	Generating ideas: comes up with suggestions in a range of situations	Working in team: has good people skills to enable idea and activity sharing; good at giving and receiving critique/feedback
IMPROVING is ... making things better by experimenting, designing, sketching, guessing, conjecturing, thought-experimenting, prototyping	Experimenting: makes small tests or changes; sketching, drafting, guessing, prototyping	Evaluating: making honest and accurate judgments about 'how it's going'; comfortable with words and numbers as descriptors of progress
PROBLEM-FINDING is ... deciding what the actual question is, finding out if solutions already exist by clarifying needs, checking existing solutions, investigating contexts, verifying, thinking strategically	Checking and clarifying: questions apparent solutions methodically and reflectively	Investigating: has a questioning, curious and, where appropriate, sceptical attitude
ADAPTING is ... making something designed for one purpose suitable for another purpose, by converting, modifying, transforming, adjusting, changing, re-shaping, re-designing, testing, analysing, reflecting, rethinking	Critical thinking: analyses ideas, activities and products; able to defend their own thoughts and ideas in discussion and also to change their mind in light of evidence	Deliberate practising: disciplined; able to break tasks down into smaller parts and practise the hard bits
VISUALISING is ... seeing the end product, being able to move from abstract ideas to concrete, manipulating materials, mentally rehearsing practical design solutions	Thinking out loud: puts 3D ideas into words as they become pictures or rehearses possible lines of thought or action	Model-making: moves between abstract and concrete, making models to capture ideas
SYSTEMS-THINKING is ... seeing connections between things, seeking out patterns, seeing whole systems and their parts and how they connect, recognising interdependencies, synthesising	Connecting: looks for links, connections, relationships; working across boundaries	Pattern-making: uses metaphors, formulae, images etc. to find patterns to illustrate new meaning

Table 1: Six engineering habits of mind and 12 sub-habits

leader have always been challenging activities. However, the leadership of education for engineering is necessarily more complex as it requires teachers to adopt an approach that enables them to work across subjects that, as with the leadership of all cross-curricular and interdisciplinary concepts not necessarily appearing as options for examination.

This requires vision, advocacy, an explicit focus on pedagogy, a willingness to engage directly with engineers in the wider community, dealing with a number of assessment and accountability issues, and professional learning to ensure teachers are suitably skilled. Above all it requires a vision of the importance of engineering as well as practical strategies for change. The report

explores these issues in depth in section three.

1.4 Summary

Earlier research shows that a more strategic approach to school leadership needs to be developed if engineering is to be more widely incorporated into the curriculum. While some understanding of what needs to be done has been gained, engineering education professionals need to understand the nature of the leadership tasks more fundamentally and in more depth.



2. Approach to the research

2.1 *Thinking like an engineer and Learning to be an engineer*

To guide earlier research, the authors used an over-arching theory-based approach to frame their enquiry⁹ developing a kind of reverse-engineered hypothesis or ‘theory of change’ to describe the imagined sequence of events necessary to produce more and better opportunities for young people to develop as engineers in school. The theory of change is reproduced here as it continues to shape the approach in this third research project (**Table 2**).

This report focuses in more depth on the element of the theory of change that is about better understanding what school leaders and teachers need to do to change their practices to embed engineering more effectively in the curriculum. This will, in turn, enable the education profession to

share the understanding widely and more effectively support the process of successful implementation of engineering education in schools.

Four research questions have guided this report.

1. What are leaders’ roles at all levels of the system in creating opportunities for young people to develop an interest in engineering in schools?
2. What are the enabling factors?
3. What are the barriers?
4. What are the characteristics of effective leaders?

2.2 *Research design and methods*

The study had three elements, a literature review, an online survey and structured interviews. Given the large number of schools in England¹⁰, some



Positive deviance?
An awkward oxymoronic term. The concept is simple: look for outliers who succeed against the odds.⁸

Pascale et al, 2010

If we

- reframe engineering education to include desirable EHoM in addition to subject knowledge
- clearly articulate the principles and practices through which these EHoM can be cultivated in schools
- offer teachers targeted support for changing practices along with opportunities to co-design enquiries within the context of a reflective professional learning community

Then

- we can better understand what school leaders and teachers need to do to change their practices to embed more effective engineering education

So that we can

- share this understanding widely
- more effectively support the process of successful implementation of engineering education in schools

So that

- more schools embrace engineering
- more school students have high-quality experiences of engineering education
- more students choose to study engineering beyond school and, potentially, choose careers in engineering.

Table 2: *Learning to be an engineer - a four step theory of change*

24,280, and a wish to understand more about those schools that are *already* effective at embedding education for engineering, the authors adopted a positive deviance methodology¹¹. The premise of positive deviance is that solutions to common challenges exist most often in schools that are already performing outstandingly and that members of the school community will have tacit knowledge and wisdom from which it is possible to learn and generalise.

The three methods - literature review, survey and interviews - were buttressed by the input of an expert advisory group. Ethical approval to conduct the research was gained from the University of Winchester.

2.2.1 Literature review

The authors undertook an integrative review¹² of literature on school leadership with a specific focus on the leadership of complex issues such as interdisciplinary education and cross-curricular teaching that involved engineering themes and projects.

2.2.2 Online survey

In line with the positive deviance approach, around 210 schools with a declared interest in engineering were specifically targeted by the research team to receive an online survey¹³. From this population, a sample of 59 (28%) responded. The majority (45) were from secondary schools and the principal form of school governance was academy status (31), with 19 of those schools being a member of a multi-academy trust (MAT). A further 22 schools were under local authority control. The majority of schools (54) were mixed boys and girls. Only a third of schools (18) had a specialist designation associated with engineering, which was university technical college (UTC) status in most cases.

2.2.3 Structured interviews

Individual in-depth telephone interviews were carried out with a sample of school leaders. From the 28 individuals who expressed interest in being contacted at the end of the survey, 11 were

selected to include a mix of primary and secondary schools, academies and UTCs, a mix of leadership levels including heads and middle leaders, and those who indicated a positive deviance through factors such as achieving an engineering award. The authors used 'appreciative inquiry' to guide the development of the interview questions¹⁴, which explored participants' views on the value of engineering in schools, their successful experiences of leading education for engineering, and the skills and attributes they thought they brought to the role.

2.2.4 Expert group

An expert group was established, comprised of 14 individuals selected on the basis of their experience and understanding of leading engineering education in schools or doing so on behalf professional engineering bodies. The group met for an exploratory workshop when the research began. The discussion focused on leadership attributes, strategies and school cultures that foster young people's engagement with engineering. Key points that emerged included promoting a positive profile for engineering and EHoM, valuing creative innovation by teachers and displaying a growth mindset. A near final draft report was shared with the group and individual exchanges were organised to explore their advice and critique.

2.3 Summary

This was a mixed-methods study with a robust literature review underpinning it. As part of a positive deviance approach, both the online survey and in-depth interviews provided rich data about those schools currently seeking to value engineering and offer opportunities for their students to explore engineering. Inevitably, the positive deviance approach has its limitations. It is time-consuming and necessarily an imprecise science seeking to identify successful outliers at all levels of a large school system. By the same token, those who are succeeding against the odds are, de facto, unusual: their attributes and strategies may not always be easy to generalise from.

3. The role of leadership in schools

This section reviews existing literature on school leadership. Given that this is an enormous field, it focuses, in the spirit of the positive deviance framing, on leaders at all school levels who appear to be successfully promoting and embedding complex concepts such as engineering.

This section seeks to discover who these leaders are (their personal attributes), what they do (their leadership practices) and how they lead (the strategies they use along with the skills they bring to the job). It also looks at the particular challenges and enablers with regard to education for engineering in schools, especially its cross-curricular nature in an educational accountability system that values individual subjects more than the interdisciplinary approaches adopted by engineers in the real world.

The search is informed by the earlier definition of leadership implied by Viviane Robinson and colleagues (section 1.1.):

“... educational leadership is leadership that causes others to do things that can be expected to improve educational outcomes for students”¹⁶.

3.1 Context

In England, as in the majority of countries, engineering does not appear on the national curriculum of schools. Exceptions to this include aspects of the education systems in the USA, Australia, Denmark, Holland¹⁷ and South Korea¹⁸. It is something that school leaders can choose to do or not.

Consequently, embedding education for engineering into the school curriculum is a tough challenge. This is even true in England when the school is a specialist science

technology engineering and mathematics (STEM) school or an engineering UTC, as these schools are still governed by the same external accountability system – Ofsted. Nevertheless, unless this challenge is embraced by more school leaders in mainstream schools, both at primary and secondary levels, young people’s interest in engineering is unlikely to grow sufficiently to overcome the potential shortage of engineers in the future.

The main research question drove the focus of the search – what do leaders need to do to engage pupils in learning for and about engineering in schools? In reading and synthesising a large number of research papers, as well as significant amount of ‘grey literature’, the authors constantly looked for outliers of excellence and promising practices.

This section begins by exploring the meaning of leadership through some definitions and scopes the broader context in which school leadership is currently enacted. It then focuses specifically on pedagogic leadership and the importance of collaboration in achieving the changes necessary to lead educational innovation in engineering in schools. It looks at the promising ways in which headteachers and senior staff can build a culture within a school that empowers teachers to develop curricula that incorporate engineering challenges and foster engagement with engineering among young people. It investigates the extent to which these leadership challenges are similar or different in primary and secondary phases of education. Finally, because it is the most developed example, the authors look to learn from practice in integrating engineering into the school curriculum in the US, where it is becoming more mainstream.



Every school needs good teachers – but a school does not become a great place to learn until those teachers have the leadership and support to create a learning culture that is more powerful than even the best of them can sustain on their own.¹⁵

Fulton and Britton, 2011

3.2 The meaning of school leadership

The field of school leadership is vast and its growing significance is evident from increasing amounts and types of research exploring its nature and its impact on school improvement.

The definition that comes closest to encompassing school leadership in the context of innovation in education for engineering and within the effective approaches from best evidence already cited¹⁹ is derived from the work of Kenneth Leithwood and his colleagues:

“... the exercise of influence on organizational members and diverse stakeholders toward the identification and achievement of the organization’s vision and goals. This influence may have many sources (e.g. administrators, parents, teachers and trustees), is typically reciprocal rather than unidirectional, and is exercised through relationships between and among individuals, groups, and the settings in which they find themselves”.²⁰

This definition is put forward because it expands on Robinson’s by highlighting two particular aspects of interest in this study: the diverse stakeholders and the contextual nature of the school setting in leadership. These two elements appeared to reflect the importance of collaboration with a whole host of internal and external stakeholders and the different types of school settings in which engineering may be found, for example in primary and secondary phases, in academies and UTCs, and in selective and non-selective schools.

Furthermore, if we accept that leadership is primarily about influence, and can therefore be exercised by members of the school who mobilise others in the pursuit of a goal, particularly goals related to student learning outcomes²¹, it is evident that leadership is not just the sole province of the headteacher and others who hold positions of formal authority, which might be expressed as ‘power’. In leading pedagogic change, staff in middle leadership positions, such as curriculum leaders and heads of subject, can play a crucial role in persuading staff to engage in

curriculum change²². The *Learning to be an engineer* study found that middle leaders played a key role in successfully leading the curriculum changes necessary to embed EHoM into teaching, so this level of leadership is given as much attention in the research as that exercised by headteachers.

Much of the research into school leadership has been informed by theories such as transformational or distributed leadership but studies advocating the use of these approaches in schools rarely highlight any connection between the style and improved learner outcomes. This is mainly because the research’s focus has been on teacher change rather than on student outcomes²³. Because the study explores leadership that achieves successful outcomes for learners, it has focused mostly on the literature of pedagogic leadership at the expense of these broader themes and of other traditional theories such as contingent²⁴ or situational²⁵ leadership theories.

However, distributed leadership practice does figure later in this report as an important factor in successful pedagogical leadership, as exemplified through ‘middle leadership’.

3.3 School leadership in practice

When examining leaders in the most challenging of English contexts, specifically those with the remit to turn around a ‘failing school’, Alex Hill and colleagues found that there were five recognisably different types of school leaders whom they called *surgeons*, *soldiers*, *accountants*, *philosophers* and *architects*²⁶. In brief, surgeons cut and redirect with a focus on test scores; soldiers trim budgets and tighten belts while focusing on the bottom line; accountants invest and grow while focusing on the top line; philosophers debate and discuss, driven by values; and architects redesign and transform, focusing on long-term impact as they quietly redesign the school and transform the community it serves. They also found that, while the type described as ‘architect’ was the most successful in turning schools around,

it was the type described as 'surgeon' who was most often appointed and rewarded. Surgeons focus on test scores and quickly redirect resources to areas perceived to be in need, but the higher scores achieved in the short term tend to decrease after the surgeon leaves the school. Architects focus on long-term impact by improving links with feeder primary schools and the community, and by taking measures to improve student behaviour and teaching and leadership, but their impact is less visible in the short term.

Surgeon and architect are, in a sense, archetypes of two prevailing approaches to leadership in schools, what this report calls transformer and pedagogue. The former offers quicker transformative leadership and the latter slower but more long-lasting pedagogic leadership.

The driver as to which style is adopted may well be linked to the tension observed within the English education system of freedom versus accountability²⁷. In academies and free schools leaders have high autonomy, which includes the freedom to deviate from the National Curriculum and they have also been encouraged to operate their schools as if an internal market applies. Yet like all schools, they are subject to a high stakes accountability culture, as evidenced by government-mandated tests, regulated exams and a national inspection service (Ofsted).

Furthermore, school leadership has become more complex with the growth of MATs, in which individual academy schools are formally grouped together through a charitable trust that oversees their corporate management with the support of a sponsor²⁸. Sponsors can be an individual, such as a business entrepreneur, or an organisation such as a company, a university or a faith-based organisation, and are accountable to central government rather than the local education authority. Within a MAT, one academy, usually the largest or best performing in the group, takes the lead responsibility, with the headteacher performing the role of chief executive officer. But whether leading an individual academy or a MAT, the extent to which the

headteacher can exercise autonomy, particularly in matters of the curriculum and teaching methods, is significantly affected by their relationship with the sponsor and their values and ethos^{29,30}.

It has been suggested that this combination of freedom and accountability actually makes it more likely that leaders will adopt a transactional style of leadership that is focused on securing immediate results, rather than working towards long-term goals and which, in turn, may lead to reduced opportunities for curriculum innovation and increased standardisation in pedagogic or curriculum innovation³¹. For these reasons, the personal attributes of leaders take on significance, because only school leaders with the courage, confidence and determination to rebel against the system or 'break the mould' will both manage the accountability requirements and achieve curriculum innovation³².

3.4 The role of middle leaders in leading pedagogic change

Middle-level school leaders are key to improving teaching and learning. They can have a significant impact on school improvement and in securing better learning outcomes for students³³. Middle leadership positions are often outside the senior leadership team and can be seen as a form of prescribed distributed leadership³⁴. They may have significant responsibilities for specific areas within the school, such as subject coordinator, director of teaching and learning, or head of department, and are 'usually at least one promotion step away from even considering being a principal'³⁵. However, their position can involve just as many tensions and challenges as that of a senior leader.

As with senior leaders, middle leaders need to be good at managing their team and at planning and resource management, but above all, they have to be professionally and pedagogically informed to be able to lead by example³⁶. They may encounter a number of challenges in operationalising their role effectively, often arising from school structures

and competing expectations about the role. Two tensions in particular have to be resolved. The first is the need to take a whole school focus or see the school as a system³⁷ yet remain committed to a department, and the second is having line management responsibility for fellow teachers yet continue to act in a collegial manner towards them^{38,39}.

When middle leaders manage a curriculum change process they may have to hold teachers accountable for their actions, so while they might filter news to their colleagues to avoid them being overwhelmed by change and may wish to respect teacher autonomy, they may well find that this responsibility for line management of their colleagues conflicts with their collegial values^{38,39} and hampers relationship building⁴⁰. It takes a middle leader with strong interpersonal skills to negotiate this complex web of structures and expectations, and because of the demands on them to represent their departments, they can actually become major barriers to change, if not given appropriate support by senior leaders.

These tensions are evident from numerous evaluations of STEM initiatives in schools, where nominating a STEM coordinator with a whole-school role was found to be helpful, both to ensure that a whole-school response to change was achieved, and also for successful liaison externally between the school and local industry. However, unless senior leaders actively supported the role, barriers to cross-curriculum working still emerged^{41,42,43}.

So, the relationship between middle leaders and headteachers is complex. Headteachers need to regard middle leaders such as heads of science as teaching innovation leaders rather than just resources managers⁴⁴. However, successful pedagogic leadership appears to require headteachers to take the lead in promoting and coordinating a teaching innovation in its early stages and then remain closely involved with it as it unfolds, advising and guiding teachers on it use^{45,46}. There is potential for further tension here if the work of the middle leader is impeded by this approach, so astute judgment is required on the

part of the headteacher as to when to maintain control and when to relinquish direct leadership of the initiative. But whatever their level, fostering a culture of learning must be a key aim for school leaders.

3.5 How successful school leaders improve learning

Schools that aim to foster academic achievement in all students place great emphasis on developing a culture of learning. A strong culture of learning includes frequent opportunities for collaboration and participatory leadership. However, although distributing power and authority to teachers may increase democracy and trust within the school⁴⁷ developing a learner-centred culture involves specific challenges for headteachers. So, whether leadership is exercised from the top or middle of the school hierarchy, we are beginning to build a picture of successful leadership that is contingent on the criteria used to judge success, the personal attributes that an individual brings to the role, the context in which the school operates and the timescales by which success is to be judged. For example, section 3.3 demonstrated how ‘surgeons’ may have a clear role in short-term turnaround but be less effective in embedding and sustaining change. School leadership is now recognised as having a powerful influence on student learning^{48,49} second only in influence to classroom teaching⁵⁰. Furthermore, a significant body of international research is now beginning to tell us that successful pedagogic leadership linked to student learning has some distinctive core features that are worth highlighting in relation to leading education for engineering.

A number of these international studies and meta-reviews of research on school leadership have confirmed that successful leaders engage in four core practices^{51,52} which are: building vision and setting direction, understanding and developing people, redesigning the organisation by building a collaborative culture, and managing teaching and learning. Other researchers have identified eight *values and strategies*⁵³ or nine *key dimensions of successful*

leadership⁵⁴ but the authors of this study believe that these can be accommodated within the four core practices.

Viviane Robinson *et al.*'s in-depth meta-analysis of the impact of pedagogic leadership on student learning outcomes⁵⁵ is of particular interest to this study. Her team identified five 'core dimensions', which can also be accommodated with Leithwood's four core practices, but the value to this research lay in Robinson's nuanced analysis of the strategies underpinning these practices that the authors used to explore their own findings. Robinson is clear on the importance of leaders establishing a culture of learning:

"Our primary conclusion is that pedagogically focused leadership has a substantial impact on student outcomes. The more leaders focus their influence, their learning, and their relationships with teachers on the core business of teaching and learning, the greater their influence on student outcomes⁵⁵."

Developing teacher capability is important for improving learning outcomes⁵⁶ but the more leaders did this through promoting and participating in teacher learning and development, the more successful they were overall. All of this report's research studies feature 'developing people' as a core practice, but Robinson suggested that the impact of the school leader also becoming the 'lead learner' was twice as great as any of the other dimensions she identified, re-iterating the advice given by John Hattie to school leaders to be 'the person who provides the goalposts for excellence'⁵⁷. Like Hattie⁵⁸, Robinson is clear about the relative importance of a pedagogic leadership approach as opposed to one that is driven by a wish to transform the institution. Lucas and Claxton⁵⁹ also emphasise the importance of creating a culture of collaborative inquiry as one of their four core elements for pedagogic leadership in the vocational education sector.

In line with earlier assertion that leaders' personal attributes are significant in the current climate, these

research studies also emphasise the important behaviours and personal characteristics of successful school leaders. In the *International Successful School Principalship Project*, which now spans 20 countries including England, three characteristics of principals' behaviour that stood out were their capacity to collaborate both within and outside the school, their personal courage and their adaptability⁶⁰, behaviours that also corresponded to earlier findings⁶¹. Another important ingredient in successful leadership is the ability of the leader to develop trust in followers; in fact this is a standout category according to Gurr⁶². So, although headteachers may be adept at capitalising on national and local policies to seize new opportunities and take calculated risks^{63,64}, they must keep the overall vision clearly in view to maintain their teachers' trust, even during times of uncertainty. They do this by adapting the school's 'institutional narrative', or the words used to describe the school, its attitude to learning and its place in the community⁶⁵.

To state the obvious, school leadership is complex and school leaders have difficult choices to make in terms of their chosen style and approach. Do they focus on transforming the whole school or embedding practices? Do they do both? Or is it something else? As has been shown above, this depends on a combination of factors including the school's context, the personality and vision of the headteacher, governors and staff, the school's Ofsted inspection rating and the local economy. Thinking in archetypes such as surgeons, soldiers, philosophers and architects is helpful in delineating broad approaches but loses much of the subtlety of the craft of leadership. There is a therefore a need for a deeper, more nuanced understanding, and through the research focused on in this section, we can begin to build a model of pedagogic leadership that clarifies how the various elements involved in this approach to leadership might be integrated, and begin to see some answers emerging to earlier questions about: who leaders are, what they do, and how they do it (**figure 3**),

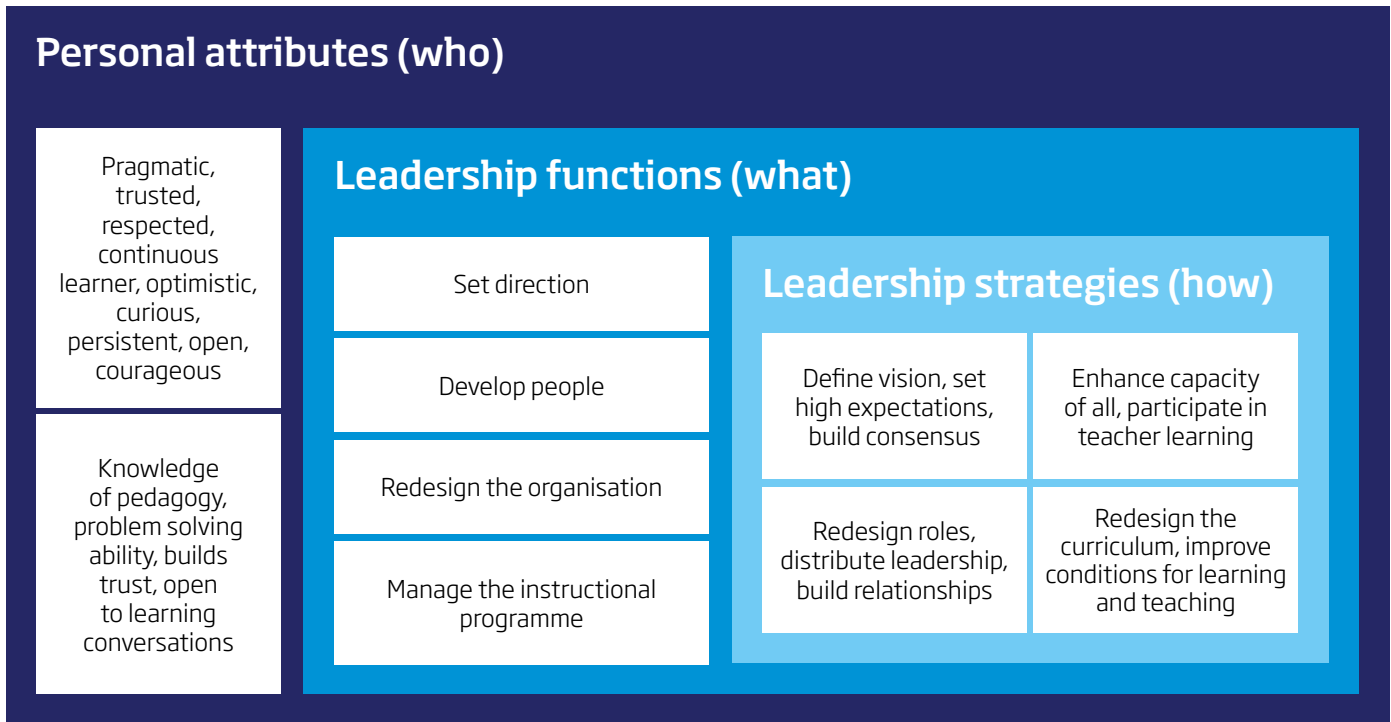


Figure 3: An overview of pedagogic leadership attributes, functions and strategies

and how these elements might be exercised when leading education for engineering in schools, which the report explores in the next section.

3.6 Positioning engineering in schools

Engineering in schools in England is not very visible to young people, either as a subject of study or a career option. A study by the Institution of Mechanical Engineers⁶⁶ found that at secondary level, despite a widespread positive attitude expressed towards the subject, students are unlikely to find engineering unless they already have a pre-existing inclination to seek it out. Apart from UTCs, few schools offer an engineering qualification at GCSE level; it is an expensive subject to offer and does not normally align well with Progress 8 metrics. An engineering experience could be introduced in D&T, where elements of the curriculum might be taught through engineering problems, but D&T itself is also struggling to maintain its position in schools beyond Key Stage 3. It remains to be seen if the new technical (T-level) qualification in engineering and manufacturing in England, designed to be equivalent to A levels, will dispel the common perception that

vocational qualifications are inferior to academic ones⁶⁷.

In UK primary schools, engineering is, in the main, virtually invisible. But, as seen in earlier research, where there is leadership and where teachers feel confident enough, *engineering thinking* can be successfully introduced to young children by using any one of three signature pedagogy elements: the engineering design process, tinkering, or engaging with engineers. Cross-curricular engineering problem-solving activities can be linked to many subjects at this level including literacy and numeracy. Schools in Scotland have a greater advantage over those in England, where engineering is included within the definition for the subject of Technologies in Curriculum for Excellence⁶⁸.

Despite this lack of visibility in the formal curriculum, examples of engineering activities as extracurricular enrichment are widespread and schools at all levels achieve significant levels of engagement, from after-school STEM clubs to national and international competitions such as *Bloodhound*, *Greenpower*, *Tomorrow's Engineers*, *EEP Robotics Challenge* and *FIRST Lego league*. Unfortunately for engineering,

engagement through enrichment and enhancement activities appears to have limited impact on the subsequent uptake of STEM subjects^{69,70}.

The Institution of Mechanical Engineers reminds us that positioning engineering in schools is essentially a cultural problem, as the title of its report *“We think it’s important but don’t quite know what it is”* suggests. The institution identified three broad approaches – engineering as D&T, the UTC model of education provision and engineering embedded into the culture. On the ground in schools, models are rarely neat, often combining aspects of various approaches and finding that cross-curricular teaching and learning through integrative projects are a key element of what is required.

3.7 Leading integrated cross-curricular engineering projects

Effective integration between subjects can extend and deepen children’s learning and help them make sense of the world⁷¹. When STEM subjects are integrated using engineering problems, children become more motivated learners and more easily understand the application of concepts from science, mathematics and technology^{72,73,74,75,76}. Furthermore, when introduced to the engineering design process, learners develop thinking skills such as problem solving and resourcefulness and personal skills such as teamwork and communication.

But teaching an integrated STEM curriculum is a complex process and leading teachers towards this goal offers particular leadership challenges. Leaders must ensure that teachers overcome perceptions about traditional subject boundaries to collaborate in teaching an integrated curriculum rather than teaching discrete subjects, and they must ensure that teachers have the confidence and knowledge to deliver and assess integrated learning^{77,78}.

These complications are multiplied when the arts are added to the integrative mix and STEM becomes STEAM. The aim of integrating the arts

into STEM is to interest a wider and more diverse group of learners in STEM subjects and emphasise the importance of creativity and aesthetics in the other four disciplines, in particular in engineering^{79,80} or promote new ways of thinking about science⁸¹. Collaborative professional development for teachers becomes even more essential in this context⁸².

So with collaboration being the hallmark of ‘good’ cross-curricular learning that occurs ‘when the skills, knowledge and attitudes from a number of different disciplines are applied to a single theme, problem, idea or experience’⁸³, leadership’s task is to take action to ensure that teachers are motivated to work together to change their teaching practice, that they have a sound knowledge base of effective instructional techniques, and that data is used to monitor impact. Without these factors in place, the quality of teaching and learner outcomes are unlikely to improve⁸⁴. The barriers and enablers to leading effective cross-curricular learning differ according to whether the context is primary or secondary education, which is explored next. We might also learn from experience in US where there is a growing movement for STEM integration, which concludes this section on cross-curricular leadership challenges.

3.7.1 Primary

Cross-curricular learning has been a feature of primary education for a long time. It is used to ‘develop children’s knowledge and understanding in two or more subjects at the same time, with the aim of showing children how to transfer skills from one subject to another, and give greater purpose in their learning’⁸⁵.

Even so, there appears to be a somewhat ambivalent view expressed by primary teachers in England about the value of STEM integration, particularly integration between science and mathematics. Many teachers recognise that integration through the use of real-world problems can instil greater understanding of the relevance and applicability

of mathematics and science to everyday life^{86,87}. Furthermore, while 'working scientifically' and 'working mathematically' are both important to their respective subjects of science and mathematics, they can benefit from integration and the two subjects can complement each other in powerful ways. Science offers opportunities to apply mathematics and engage children purposively in solving real-life problems. With mathematics, science offers the context to apply numerical and reasoning skills and support children to move from qualitative observation to quantitative expression⁸⁸. Some teachers fear that too much integration might cause blurring of subject boundaries and confuse learners or erode understanding about the uniqueness of science⁸⁹. While others view integration as a means of protecting time for science, which they feel is being eroded through primacy given to English and mathematics^{90,91}.

Teachers, therefore, need practical support from leaders to develop effective integrated curricula, such as sufficient planning time, encouragement to work in teams to trial innovations, input from subject specialists and engineers such as STEM Ambassadors, and models for developing authentic learning experiences^{92,93}.

But they also need to experience a shift in mindset to recognise and value the thinking habits of each other's disciplines^{94,95,96}. It therefore falls to the leader to establish the vision for engineering within the curriculum to help teachers unpack the similarities and differences between the disciplinary ways of thinking.

3.7.2 Secondary

At secondary level, teaching through engineering themes offers the same benefits as at primary level, so when engineering problems provide the context for science learning, young people experience enhanced motivation and expanded career aspirations⁹⁷. STEM integration can also reverse negative attitudes towards science and mathematics and overcome stereotypes about engineering careers often held by pupils and their parents⁹⁸.

However, the challenges around perceived disciplinary differences between STEM subjects are magnified at secondary level. Although the new GCSE and A level science and mathematics curricula have encouraged greater collaboration between the two departments and teachers are being supported to identify commonalities and address inconsistencies in their teaching, as Needham notes, there is a 'distinctive flavour to the nature of mathematics used in different science disciplines due to the types of data they handle'⁹⁹.

Developing further integration between STEM subjects to provide an interdisciplinary experience that uses engineering as an enabling connective agent requires significant coordination, not only between STEM departments within the school, but also between the school, parents and local employers. Yet traditional departmental structures at secondary level present a significant barrier, not just to developing integrated teaching but in leading any change to teaching practice. Secondary heads and their senior leadership team (SLT) must negotiate the micro-politics of subject departments if they are going to influence pedagogy and learning culture successfully¹⁰⁰. Banks and Barlex briefly outline some of the structural challenges in English schools that influence decisions on which of the curriculum subjects - science, technology or mathematics, engineering might be embedded within and who might teach it. They suggest that it would be worth exploring the situation in the USA to see how collaboration between STEM teachers is shaping up under the new science curriculum¹⁰¹.

3.7.3. Learning from the US experience of STEM integration

In the US the leadership and teaching of integrated STEM programmes is taking hold in primary and secondary education¹⁰² since the inclusion of engineering in the *Next Generation Science Standards* (NGSS)¹⁰³. It aims to raise the status of engineering design to the same level as scientific inquiry in classroom teaching¹⁰⁴. Much can

be learned from this experience by exploring how school leaders support teachers to meet challenges brought about through perceived disciplinary differences, as well as lack of subject knowledge and confidence to teach engineering projects.

The leader's challenge in this situation is to persuade teachers to move outside their own discipline context and see the connections between their own subject and others. The help of professional engineers to achieve this has proved to be invaluable, as Cavlazoglu and Stuessy (2017)¹⁰⁵ demonstrated when they developed teachers' knowledge base by engaging them in discussion with earthquake engineers, who showed the teachers how they used science and mathematical concepts to design and build earthquake-proof structures.

In other practical aspects, school leaders not only provided teachers with more planning time, but also actively organised time for collaboration between departments to develop a shared sense of purpose, and to enable teachers to become a source of support for each other^{106,107,108}.

While the leadership challenge to embed integrated STEM programmes and projects using engineering themes is similar in some respects across primary and secondary levels, there are also differences. Some of these can be better understood by reviewing practice in countries such as the US where the experience of integrating engineering into science and technology is more advanced. One of the key leadership functions is to prepare teachers to change their practice, which includes updating their knowledge of content and pedagogy and helping them develop the confidence to make changes to their teaching.

3.8 The importance of professional learning and enquiry in changing practices

One of the functions of school leadership is to develop people, specifically teachers, who play

as significant a role in achieving educational change as school leaders do:

"Educational change depends on what teachers do and think - it's as simple as that"¹⁰⁹

One of the most powerful mechanisms for supporting teachers to make changes to their pedagogic practice, and through which pedagogic leadership is enacted, is by creating opportunities for teachers to undertake their own small tests of change in the classroom and share their learning in groups. Such activity is variously described as action research, professional enquiry, disciplined enquiry or collaborative enquiry^{110,111}.

The whole process is increasingly referred to as participation in a professional learning community. In many different settings it is possible to see how such approaches improve outcomes for students and, importantly, enable teachers to adopt new teaching and learning methods, changing and reflecting on their practice as they go¹¹².

In our earlier research¹¹³ one of the main findings was that professional learning that encourages teachers to undertake their own enquiries was a significant reason for schools' success in embedding engineering, allied to the role of school leaders in committing to significant culture change and resourcing the learning necessary to enable this. There is extensive literature about the leadership necessary for effective professional learning and the implications are well described by Dylan William's nine-stage model¹¹⁴ and by Cunningham and Carlsen in their principles for designing effective CPD in engineering education¹¹⁵. These two strands of thought have been merged to create a brief set of guidelines in **Table 3**.

3.9 Summary

The leadership challenges associated with implementing engineering in schools are many. In England, engineering does not often appear on the curriculum and provides very

Table 3: Guidelines for leading professional learning for education for engineering

Guidelines for leading professional learning for engineering education (adapted from <i>William (2016)</i> and <i>Cunningham and Carlsen (2014)</i>)
Start with volunteers
Structure professional learning meetings tightly
Set a motivating goal
Find a moral argument
Help them [teachers] understand engineering as a social practice
Identify small steps of change that teachers can make
Develop teachers' understanding of the connections between science [and technology] and engineering
Engage teachers in engineering practices
Model a growth mindset
Model pedagogies that support engineering practices
Create time for professional learning
Give teachers experience as teachers and learners
Build routines and habits for teachers
Use the early volunteers as advocates for other teachers.

few examination opportunities. Few teachers feel qualified to teach STEM subjects. Best practice from the US and elsewhere suggests that the UK should be aiming to address gaps in teachers' knowledge and encourage them to explore and make visible disciplinary differences. They need to see connections between disciplines but also appreciate the distinctive ways of thinking in the STEM disciplines. We also need to develop their confidence to teach in student-centred ways. Middle level leaders, such as science or technology subject leaders, are important intermediaries in securing this understanding and confidence, but they too need support from senior leaders.

The next section explores the findings from an online survey and in-depth discussions with a number of outliers who are succeeding against the odds in the contexts that have been described, in order to build a greater understanding of how leaders at all levels of schools are rising to the particular challenges of incorporating education for engineering.

4. Learning about leaders and leadership

This section builds on findings from earlier research and draws on the survey and interviews undertaken for this research. No one headteacher is the same as another and, as seen throughout this report, many different people in a school can adopt leadership roles. Nevertheless, from discussions with those whose practices are in some way promising, some common strands are evident.

4.1 Introduction

From earlier research, *Thinking like an engineer* and *Learning to be an engineer*, based mainly on the views of teachers rather than of school leaders, it was possible to make some generalisations about the nature of leadership strategies that support teachers' ability to engage in pedagogic innovation. These strategies focused on pedagogic leadership, change management, alignment, middle leadership and professional learning.

Pedagogic leadership enabled successful schools to look beyond subjects to dispositions or habits of mind as a means of being more specific about what they were looking for in terms of student outcomes. In order to facilitate change, school leaders ensured that engineering was embedded in the visible life of the school and not solely dependent on extracurricular activities. They also allowed a reasonable period – at least a year – for changes to be secured. Alignment between innovation and existing school processes and structures was achieved through securing resources that supported pedagogical purposes, such as materials and toolkits, appropriate time-tabling and physical spaces.

Middle leaders emerged as key members of staff who encouraged their teams to get involved. They modelled the EHoM learning dispositions,

interpreted the change and helped teachers link new approaches to their current practices.

Professional learning was organised to enhance teachers' confidence and skill levels and empowered them to take risks with their teaching. Teachers' participation in professional learning communities was encouraged. Schools made a point of supporting the professional learning of middle leaders given the critically important role they have in supporting other teachers.

Having heard from teachers how important school leadership was in their attempts to incorporate engineering into their teaching, the authors wanted to know more about the specifics of pedagogic leadership and the leading of cross-curricular subjects such as engineering, in this case by hearing directly from school leaders who are already successfully integrating engineering into their schools: how they actually make this happen, who they are, what they do, and how do they do it.

4.2 Findings from survey

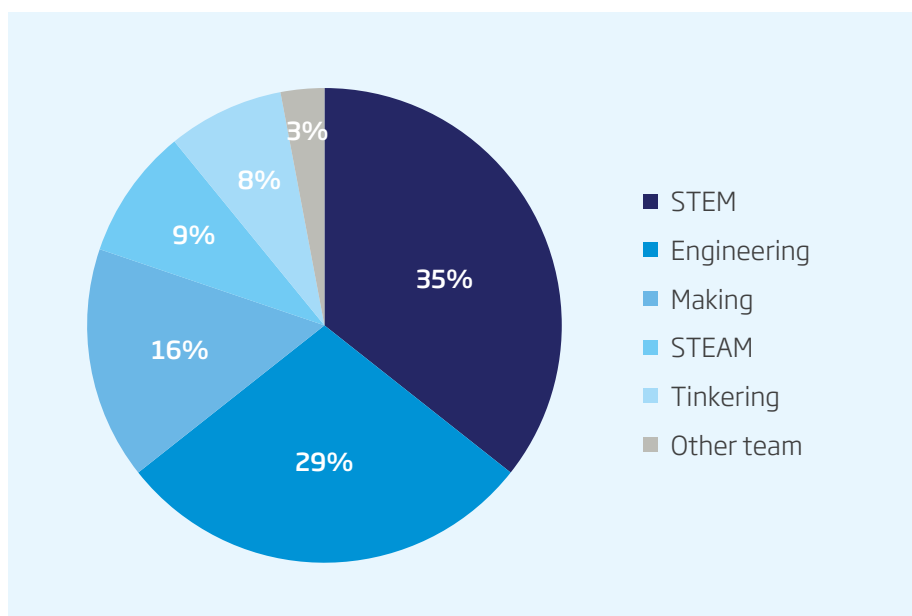
Turning first to the results of the survey, respondents consisted of leaders of all kinds: governors, headteachers, deputy and assistant heads, heads of department, curriculum leaders and heads of year, classroom teachers, and a few other staff roles. Approximately two-thirds were senior and middle leaders with about a third being classroom teachers. In slightly under half the schools (47.5%), an individual was specifically designated to take responsibility for engineering, half of whom actually had engineering in their job title; others referred to STEM, science or technology, and one instance of STEAM. Engineering was the second most popular term after STEM used by schools for the subject area in the research (**figure 4**).



You need to lead by example. I see my role as headteacher as being that, so I still teach, I still get into classes. If I'm going in to coaching, if I'm going in to challenge aspects of teaching that I've seen, that I think could be improved, I have to do that with knowledge.

Headteacher, primary school

Figure 4: Terms used in schools



The survey aimed to further understanding about the balance between offering opportunities to learn about engineering through the formal curriculum and through extra or co-curricular activities. Within the formal curriculum 57 schools replied, giving a total of 326 choices, which are shown in **Table 4**. It is encouraging to see that engineering appears across all the contributing STEM subjects, although less frequently in mathematics and art and design. However, the high number of references to cross-curricular projects and employer engagement are also positive, as is the occurrence of STEM careers guidance. The place of engineering qualifications in the curriculum was a topic that came up later in the interviews.

The range of extra/co-curricular engineering-related activities is also interesting (**Table 5**). 54 schools responded to this question, giving a total of 273 choices.

4.2.1 Culture

Earlier research and the literature review identified four potentially important cultural factors that enable engineering education to flourish: allowing teachers freedom to experiment, the existence of a high trust culture, supported risk-taking in developing new pedagogies, and the presence of engineering in the school's improvement plan (SIP). Taking the

total of those who indicated an item was very important or important, the figures that follow show respondent opinions in more detail. With regard to school culture, respondents believed that all four of these factors are equally important in enabling effective teaching and learning about engineering in schools (**figure 5**).

4.2.2 Curriculum

All five potential factors received support from respondents, with 'having a creative approach to curriculum design' the approach that was most singled out (**figure 6**).

4.2.3 Partnerships

Establishing partnerships with external organisations and engineers is confirmed as an important leadership capability in enabling effective teaching and learning about engineering. An active partnership relationship with pupils is significant at both secondary and primary levels (**figure 7**).

4.2.4 Resourcing

The availability and deployment of resources are critical concerns for any school leader. Respondents thought that developing the capability of staff through professional development and the availability of appropriate teaching spaces were the most important resource issues, together with a

Subject/curriculum activity	Response count	Percent response*
Within design and technology	39	12%
Cross-curricular projects	36	11%
Visits to employers linked to the curriculum	36	11%
STEM careers advice and guidance	35	11%
Within science	30	9%
Projects in collaboration with engineers	29	9%
Within computing	25	8%
Within mathematics	21	6%
Integrated subject teaching	18	6%
Specific engineering qualifications	17	5%
Suspended timetable	15	5%
Embedded across whole school	13	4%
Within art and design	12	4%
Total number of responses	326	101**%

*Participants could select multiple options. Percentages calculated out of total number of individual choices
 ** Due to rounding

Table 4:
Engineering
within the formal
curriculum

Activity	Response count	Percent response*
After-school clubs	38	14%
STEM Challenge Days	37	14%
Participation in external competitions	35	13%
Visits to exhibitions	31	11%
STEM Ambassador visits	30	11%
Visits to employers	30	11%
Support from parents who are engineers	23	8%
Engineering focus in school assemblies	20	7%
Mentoring of pupils by engineers	17	6%
STEM companies' roadshows	12	4%
Totals	273	99.00**%

*Participants could select multiple options. Percentages calculated out of total number of individual choices
 ** Due to rounding

Table 5:
Extracurricular
engineering-
related activities

Figure 5: School cultural factors influencing education for engineering

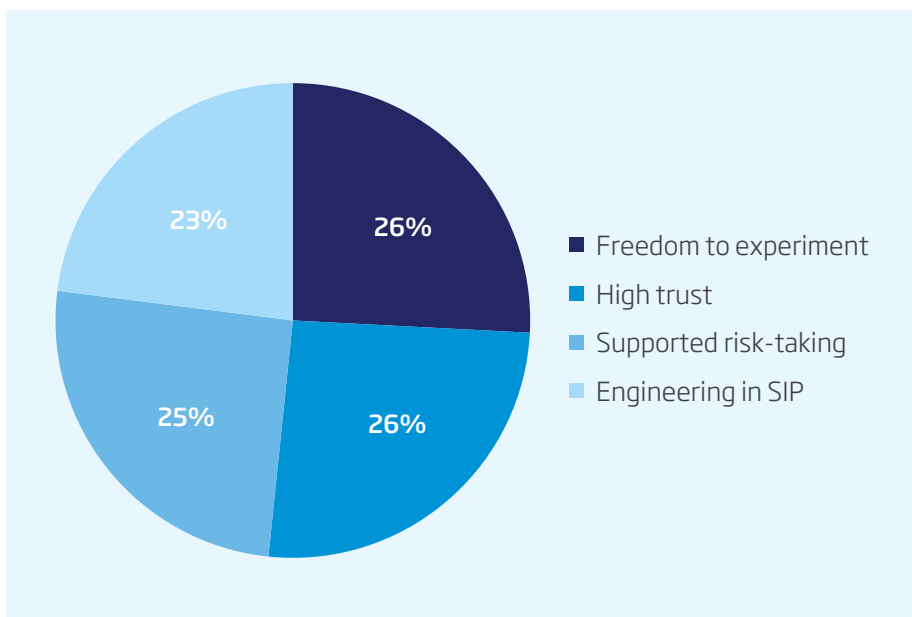


Figure 6: Curriculum factors influencing education for engineering

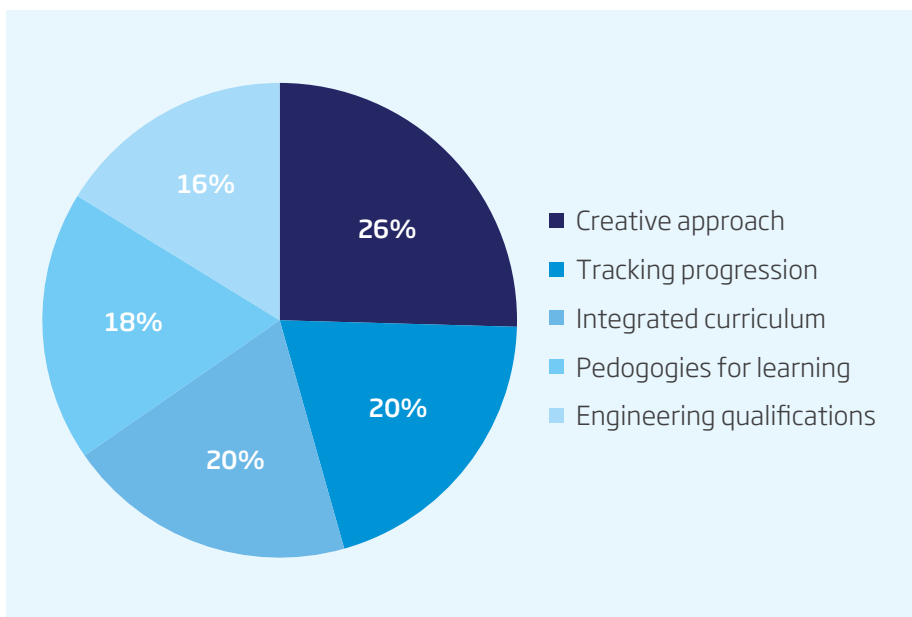
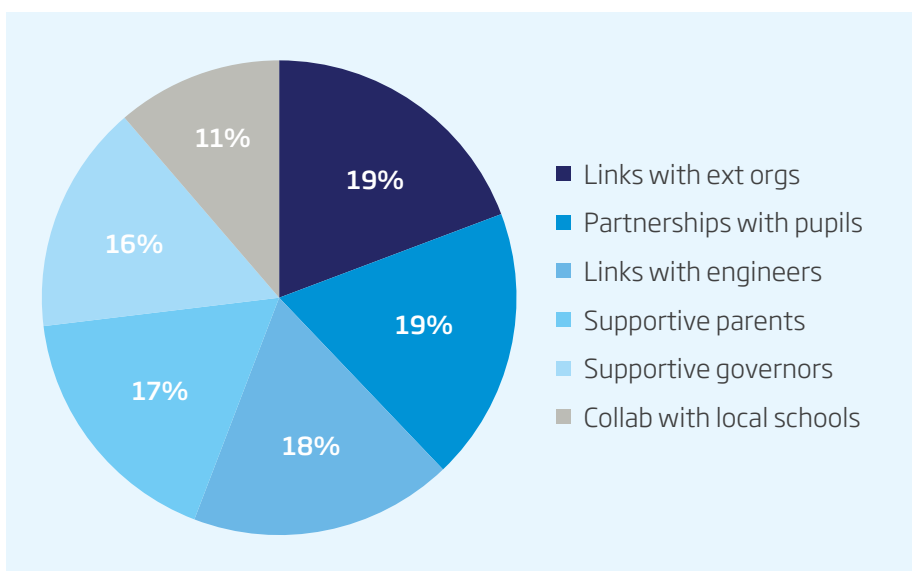


Figure 7: Partnership factors influencing education for engineering



number of other factors. However, enabling teachers to spend time in engineering workplaces, which has been reported by teachers in previous research as giving them confidence to engage with engineers, is not given such high priority (**figure 8**).

4.2.5 Enablers

When invited to suggest any further factors that they believed were important in facilitating engineering education in schools, respondents suggested additional items that often expanded on the areas previously probed on school culture, the curriculum, partnerships and resources. Some examples are given in **Table 6**.

4.2.6 Challenges

When invited to suggest challenges that they believed were important to overcome before engineering education in schools could be more widely adopted, respondents identified issues associated with the status of engineering, both as a school subject and as a career option, the pressure of current accountability measures, staffing, learning resources and partnerships. Some examples are given in **Table 7**.

4.2.7 Leadership attributes

Respondents were invited to identify which personal attributes they felt

successful leaders of education for engineering needed to display. The top four personal strengths included being collaborative, flexible, resilient and open-minded (**figure 9**).

4.2.8 Leadership journeys

Finally, respondents were asked to reflect on their leadership journey and their key learning points. A sample of their thoughts is in **Table 8**.

4.2.9 Summary of survey responses

The responses from the survey confirmed the indicative findings from earlier research about the role and significance of school leadership for engineering. The extent to which engineering was used as a term by the schools responding to the survey suggested that the study was reaching its target 'positive deviance' population. Within the formal curriculum, engineering is still found mainly through D&T and schools offer a wide range of extracurricular opportunities to help students and parents find out more about engineering. Building on the responses, the authors decided to find out more about how leaders created an appropriate culture of trust and freedom to experiment, how they facilitated curriculum change and how they used their experience to develop partnerships with engineers. They also

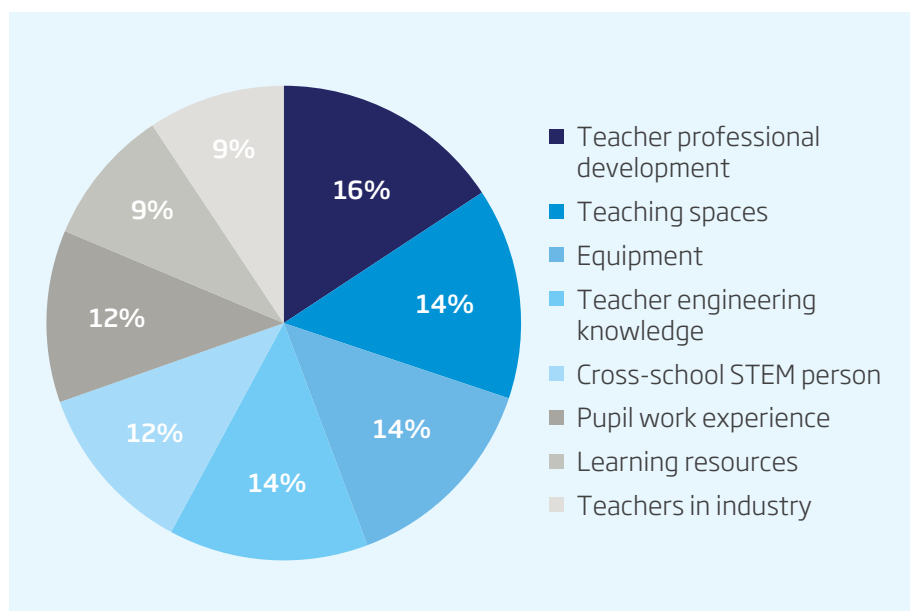


Figure 8: Resources influencing education for engineering

Table 6:
Additional
enablers for
education for
engineering

Enablers	Illustrative quotes
School culture	<p>"Supportive headteacher"</p> <p>"Creating role models within the school community"</p> <p>"Staff awareness and confidence"</p> <p>"Creative, problem-solving environment"</p> <p>"The pedagogy is critical; developing and embedding engineering habits of mind to ensure relevance and coherence"</p>
Curriculum	<p>"Having visits to the school from engineering specialists to support projects"</p> <p>"Engineering education needs to be recognised as a complex academic subject and given the same weighting as other GCSEs"</p> <p>"Non-selective options process"</p>
Partnerships	<p>"Engineering companies willing to work with a school in the long term and in a way that fits the needs of the school"</p> <p>"Constructive partnerships between schools, further education colleges and employers"</p> <p>"Support from those at either college or university level providing regular support"</p>
Resources	<p>"Time to co-plan with others involved in STEM"</p> <p>"A route to move technology teachers into engineering"</p>

Table 7:
Challenges still to
overcome

Challenges	Illustrative quotes
Status of engineering	<p>"STEM tends to become SM – with a whole school focus on science and maths as these are key measures in EBacc. Getting engineering and technology back into the forefront of thinking is very hard"</p> <p>"There seems [to be] little support from government to support the importance of engineering at Key Stages 3/4/5"</p> <p>"Parental conception of the world of engineering, especially for female students"</p>
Accountability measures	<p>"Assessment of the engineering habits of mind. Raising the profile of STEM as it isn't an examined subject"</p> <p>"Engineering qualifications that carry GCSE equivalence all fall within the 'open' option buckets of the new Progress 8 measure. This means performance in these subjects is compared to other qualifications that are less academically demanding. This reduces the incentive for schools to teach engineering-based education because of the impact this can have on results tables"</p>
Staffing	<p>"It is more of a challenge when teachers have weaker subject knowledge or a desire to learn"</p> <p>"Lack of enthusiasm or understanding of the importance of STEM from other colleagues"</p>
Learning resources	<p>"Planning and implementing STEM and engineering experiences within the nursery [Early Years] environment can be challenging"</p> <p>"Good accessible projects for students that are intellectually challenging enough, but that can be made"</p>
Partnerships	<p>"Failure by schools to fully engage local organisations in their aims and aspirations"</p> <p>"Involving parents and regular opportunities for engineers to work in school alongside staff"</p>

Figure 9: Personal attributes of leaders of education for engineering

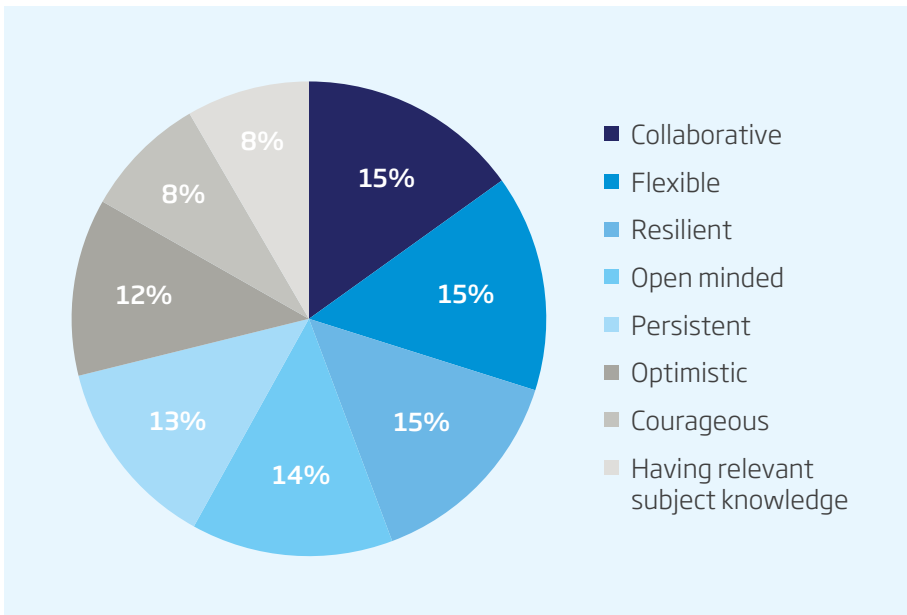


Table 8: Key learning points on the leadership journey

Key leadership learning points - Illustrative quotes
"It's important to find the right projects and people that will inspire your cohort"
"Takes time and involves failures en-route - 'failures' in that a project may not reach its intended goal but success if measuring pupil progress and uptake of engineering as a mindset"
"Leading engineering has been really important in my own professional development - it has enabled me to gain skills and understanding and given me the opportunity to lead a team on a project that I am passionate about"
"If you have the drive to take the first step, then others will get behind you and things will start to fall in to place. You have to continually find ways to maintain the status of the brand and look after the misconceptions by other staff, pupils and stakeholders"
"That the habits of minds of engineers can be used across the wider curriculum"
"Tremendous enthusiasm and motivation from pupils to be involved in real-life contexts provided by engineering education"
"Teachers need to learn to be unafraid on engineering and not see it as a highly technical pursuit that they do not have the skills to teach"
"Having engineering experts coming into the school enhances my teaching practice and the enthusiasm of the pupils. Links to the real world of work have been essential"

wanted to learn more about them as individuals, and how their personal attributes had contributed to their successful leadership.

4.3 Findings from the interviews

The leaders who were interviewed were all very proud of the significant gains they were making in enhancing engineering in their schools, in spite of some major challenges. This section begins with reporting on the context in which they were enacting leadership and discuss their perceptions of the status of engineering in schools, the cross-curricular nature of engineering and accountability pressures. Those findings are followed by an analysis of the personal characteristics demonstrated by the leaders, and finally examples of the strategies they used to enact leadership practices.

4.3.1 Status of engineering in schools

At both a philosophical and a practical level, leaders said that, despite campaigns about STEM by government and professional bodies, the place of engineering in schools remains unclear. For the leaders interviewed it was clear that STEM literacy is important and that engaging in engineering projects can enhance pupils' wider skills, such as leadership, team-working and time management:

"It's not just STEM skills that they were learning, they were also learning about leadership and management, allocation and use of resources, time management, the wider design process, and being critical of their own and others work, in a positive way."
(Chair of governors, secondary school)

However, engineering's place in the curriculum is unclear even in secondary schools established specifically to offer it. There are many reasons for this. There are very few GCSE-equivalent engineering qualifications that 14 year olds can opt for. Performance measures refer to discrete subjects, which engineering with its multidisciplinary nature does not fit. Engineering at

secondary level tends to be located in science departments or technology departments, so if not specifically located within the curriculum, engineering seems to be 'done by stealth', via science or technology. While some leaders were comfortable with a stealth approach they recognised its lack of scalability.

School curricula are crowded. Schools have limited space in Key Stage 4. Many schools are doing a three-year Key Stage 4 now, to prepare students for GCSE. UTCs are beginning to recruit at age 13 rather than 14 to accommodate this. Engineering can seem a bit too far in the distance for most students in 11 to 16 schools, and with no A level in engineering offered at their school they may or may not select an engineering degree. Engineering is often only found as part of a STEM club, 'tagged on at the edge of the curriculum'.

However, adapting existing qualifications and their assignments in partnership with awarding bodies, for example OCR, and employers to develop engineering-focused projects, while highly time-consuming, can be done, resulting in far more challenging and interesting projects and assignments for students to undertake, as one leader described:

"We take the assignment brief that has been developed as a standard mock assignment brief from the awarding organisation and we take the employer context and we build a project that's linked directly to what the employers do industrially. It meets all the requirements of the assessment and builds that into the curriculum."
(Principal, UTC one)

Nevertheless, for those schools incorporating engineering through other means such as a cross-school STEM programme or extracurricular projects, it is difficult to find ways of giving the same value to pupils' outcomes as that provided by a formal assessment process, particularly when it comes to demonstrating progression in skills and dispositions such as EHoM. Some primary schools are developing their own progression instruments, but secondary schools are finding it

more difficult. While the number of organisations offering extracurricular engineering projects for schools is impressive, it can be frustrating for teachers if they cannot be linked to curriculum outcomes:

“If I wanted I could fill the whole week with projects, there’s always people wanting to do something but it’s a case of trying to balance that request from industry with getting enough progress for learners.” **(Engineering project lead teacher, primary school)**

Recognition of effort is also important to pupils, and credentialing of learning undertaken outside the classroom and standard qualifications matters to them. One leader told us about the CREST Awards that he aligned with the curriculum, so pupils can do a STEM project, having learnt some of the necessary skills:

“So students ... at the end of at year 9 ... [are asked] ‘do you want to do a STEM project? If you do, you’re going to be working towards the Silver Crest award and you’re going to be doing it in either a biology area, a maths area or electronics’ and in year 10 we teach them some skills ... and in year 11 we allow them free rein, where they can choose what they want to do, how they want to apply those skills that they’ve learnt.” **(Director of STEM, secondary school)**

The D&T curriculum offers great potential for formally introducing students to engineering, but respondents raised concerns about the level of challenge in D&T projects and the perceived devaluing of D&T as a subject in some schools. Although some also recognised that their schools benefited from being able to recruit well-qualified D&T teachers and re-enthuse them by offering the opportunity to teach engineering:

“It’s the specialisms, it’s quite amazing but that is what actually attracts them to come and work here in many ways. I think it’s to do with the devaluing of design and technology and engineering subjects in traditional schools.” **(Principal, UTC one)**

For non-STEM specialist schools, it appears that the providers of engineering challenges could help schools by aligning their challenge success criteria with STEM curriculum outcomes and by considering how the development of progression in EHoM might be recognised through their challenges.

4.3.2 The cross-curricular nature of engineering

As shown in earlier research¹¹⁶, engineering includes six habits of mind that transcend subject boundaries. Engineers in the real world draw on a range of disciplinary knowledge including design, biology, chemistry, mathematics, history, geography and technology, but most schools are organised by subjects.

In primary education, teaching through topics is more common so engineering projects have a better fit. Interviewees argued that engineering must not be seen as an add-on, but an integral part of the curriculum from Key Stage 1 onwards. Those who were already describing engineering in terms of EHoM found this a useful way of embedding engineering into every area of the curriculum and was easily understood by the children:

“... there’s a reason behind the processes that the children are undertaking, so that we can have a crossover to different subjects and different things, but we can use the language of engineering habits of mind and also learning powers and growth mindset.” **(Curriculum leader, primary school)**

Flexibility within the school day is important, in particular at primary level when a project approach is adopted, so that teachers and their pupils have time to finish projects. However, at secondary level timetabling is, inevitably, the main challenge. Flexibility, either through blocked-timetabling to enable teachers from different subjects to work together at the same time or via some kind of modular or elective approach, typically in Key Stage 3, were means of offering engineering. At GCSE level, engineering



is almost impossible to offer in most Key Stage 4 curricula. Once beyond GCSE, engineering qualifications at A level can involve collaborative interdepartmental working more frequently, as science and mathematics teachers crossover to teach their specialisms.

4.3.3 Accountability pressures

A number of issues associated with accountability indicators were raised, primarily centring on the role of Ofsted in England and its reporting on recent requirements for progress within GCSE. Respondents said that a combination of EBacc and Progress 8 does not enable schools with an interest in engineering to thrive, even those with a specific engineering specialism or designation such as UTC.

Recent policy changes have led to GCSE subjects being grouped together into what are referred to as 'buckets' with students required to make their choices from different 'buckets' or option choices between certain specific subjects. One UTC leader described the GCSE choices which need to be made:

"The Progress 8 measure does not work in our favour at any point. The whole middle three buckets are all EBacc based and outside of the sciences, the students can do humanities here, we don't force them to do the EBacc, so it's our sciences that sit in those qualifications that get us our grades. Then it's got the open bucket qualification." (Principal, UTC one)

This leader went on to explain how the 'open bucket' had to include all their engineering qualifications, which are much more challenging subjects than some of the other subjects that normally count in this group, to the detriment of his students who would have to get higher grades in these subjects than students taking other subjects in this group, in order for progress to be demonstrated.

UTCs were established to promote take-up of technical subjects such as engineering. However, leaders from this sector said that newly opened UTCs have to establish their

reputation quickly, meaning that first Ofsted results are critical and tensions can arise between, for example, making decisions about curricular and subject choices:

"... based on what's right by our employers, what's right by the young people and what's right to allow students to progress into future apprenticeships, employment, or university ... which isn't always compatible with traditional accountability methodologies." (Principal, UTC one)

UTC leaders suggested that UTCs should be judged using different criteria reflecting their context and student intake, rather than by their adoption of the EBacc, which they felt discouraged them from offering practical subjects at GCSE.

Looking ahead to the new T levels, the new technical courses being developed in England to sit alongside A levels, there was uncertainty among leaders as to whether they would be likely to improve the situation, despite their espoused aim of achieving an equal status with A levels. Those leaders who were familiar with how T levels were developing thought that the academic-vocational divide was likely to remain. They suggested that accountability pressures were likely to push students down the A level route, whereas a combination of A and T levels might be the best preparation for continuing to study engineering. T levels might limit students' ability to progress in different directions.

Notwithstanding this, there are opportunities for Ofsted (and Education Scotland) to comment favourably at both primary and secondary levels if they observe active learning in lessons or if they see engaging and challenging lessons. If school inspectors hear school leaders, teachers, students and governors all talking the same language about learning, for example using EHoM, this too can have a positive effect.

In the primary sector, school leaders face dealing with an enhanced emphasis on performance and progress in English and mathematics, which can

overwhelm a leader's aim to maintain a balanced, broadly based curriculum. The pressure to perform well in English and mathematics may well lead to a culture of 'jumping through hoops' to achieve good grades, rather than focusing on 'building engineers and young citizens of the future', depending on how capable the school leader is, and how confident they feel about sticking to their vision and 'moral purpose' when faced with criticism from governors or trust directors.

Other factors came into play when considering the learner-led pedagogies necessary for project-based learning. A pedagogy in which students are collaboratively engaged in project work in the classroom can be noisy and appear chaotic and messy to an outside observer. So middle leaders and those still closely involved in classroom teaching were aware of an internalised accountability pressure on them, which was difficult to shake off. In the past, a noisy classroom used to be associated with poor teaching, lack of control and poor teacher performance, so they often approached project-based learning or student-led learning with some hesitation and fearing censure from senior management.

On an encouraging note, leaders were convinced they could show positive impact for learners in areas other than engineering when they engaged in engineering and employer projects, for example: younger learners' increased ability to talk fluently about their learning; 100% student employment on leaving secondary school; high praise by employers for the calibre of their students; employers sending their own children to the school; higher than the national average for continuation from school on to engineering degrees; girls choosing to attend schools because of their reputation for engineering. Students who have studied engineering, they suggested, stand out from others with their creativity and resilience. Respondents told us that students like engineering and understand its importance but, if it is the only one of the STEM subjects not examined, they question its importance and immediate usefulness.

4.3.4 Personal characteristics of effective leaders of engineering in schools

Given this challenging context, the personal attributes of school leaders are critical to their success. A strong consensus emerged from the interviews as to the kinds of personal characteristics adopted by engineering leaders. In many cases these are similar to the generic attributes described earlier in **figure 3** on page 17. But there are some specific characteristics that seemed particularly important, possibly as a consequence of the particular challenges attendant on the nature of engineering, its societal value, its many subject disciplines and its uncertain status.

Successful leaders have a passionate belief in the moral purpose of school and see the incorporation of engineering and EHoM as a means of giving young people the tools not only for living a productive economic life, but also for looking at how it can be improved:

"It comes down to values, it comes down to vision ... we're saying it because we genuinely believe it, because it's the heart of what we do. If all we do is get our students great exam results then we have failed, that's not what education is about." **(Deputy headteacher, secondary school)**

They are creative thinkers, good at generating ideas and not worried if sometimes things do not go as planned:

"It's being able to be a creative thinker and also not worrying about making mistakes. It's all part of the journey." **(Curriculum leader, primary school)**

They are risk-takers, necessarily in the current context, having to go beyond what it is safe for schools to do. But they have the courage to take the risk, and the perseverance to see it through:

"We had to take a leap of faith, there was a risk element, I understood that, but I gave them [governors] a guarantee that the data would improve, actually not knowing the

data would improve, but I knew that the pedagogy of the school would improve, and the children would love it.” **(Headteacher, primary school)**

Interviewees said that they seek to mitigate any risks through careful research and planning before implementing their projects. They understand the importance of timing and they understand the ‘politics’ of the context, so they are usually successful when approaching people for support:

“I am happy, having looked at something and researched something, to make up my mind that I don’t like the status quo and I think it should change and I’m happy to have that confidence and then I know the next step needs to broaden that out, working with others, and it’s the working with others that really generates the ideas that you can take forward, then you can champion it.” **(Deputy headteacher, secondary school)**

Their success increases their confidence to look for new challenges, or to seek to improve on their original work:

“I had a department that was really succeeding very well academically, so for me to look to see how I could make progress and improve things was pretty challenging, if it was just going to be on raw results level.” **(Director of STEM, secondary school)**

Perhaps because of the desirability of engaging with engineers and employers outside of school, the leaders that were interviewed were both determinedly outward-facing and ready to network with intent:

“Being out and about, being available for people to just say ‘do you know what, yes we love to try that’. That’s huge, that’s about networking, keeping your eyes and ears open, that’s a big thing, and actually just going out there and saying ‘would you like to come in and share what you’ve done with us?’” **(Vice principal, primary school)**

If necessary, they were deliberately pushy:

“What I find is most academics or companies are really receptive

to the idea of promoting STEM in schools so it’s really easy, I’ll go online, do a bit of searching, find someone who’s reasonably close and email. If I don’t hear, I phone them, so I might be a bit pushy actually, I don’t know, it has invariably worked.” **(Director of STEM, secondary school)**

The school leaders were characteristically interested in and knowledgeable about teaching and learning:

“Having a knowledge and understanding of what engineering habits of mind are and a true belief that how it’s going to support those children, then you can sell it a lot better to other companies.” **(Curriculum leader, primary school)**

All those who were interviewed were excellent communicators. These skills were considered essential by most leaders, and in particular, the ability to persuade others, including teachers, students, governors and employers, to buy into their vision. This ability was complemented by empathy for others in developing relationships and a willingness to take on responsibility:

“I think I can take people with me because they see me work hard and they want to join in.” **(Engineering project lead teacher, primary school)**

In common with many effective leaders, they place a high value on trust:

“I trusted them [teachers] that they would obviously drive towards the high standards that we were trying to achieve. It was about staff being fascinated about what they were doing as much as the children.” **(Headteacher, primary school)**

4.3.5 Leadership functions - setting direction

Examination of how leaders set direction and established their vision for the school found that they believe that education is not just a means of improving young people’s learning but

also for providing them with the means to excel in their future life:

“We have a vision of our students as game changers and what we mean by that is young people with qualifications and skills to do whatever jobs they are doing well.” **(Deputy headteacher, secondary school)**

Their vision encompasses learning as process rather than product, using pedagogy to support the learning process, as well as core curriculum subjects:

“Talking to colleagues, we’ve been talking more about process-driven outcomes to learning rather than being ‘I’m good at maths, I’m good at language, I’m good at science’, it was more about ‘how do we get to that point?’ ...being a bit more of a problem solver.” **(Engineering project lead teacher, primary school)**

For these leaders it was important that they emphasised a whole-school focus for engineering skills and habits of mind that could be embedded in every aspect of the curriculum:

“A key thing for us, it’s not just about the skills, it’s about applying the skills to different situations and those habits are things that are going through every area of the curriculum not just engineering.” **(Chair of Governors, secondary school)**

For some schools, in particular UTCs, where an engineering focus already existed, interviewees talked of a culture more akin to the workplace, or ‘industry ethos’ than to a typical school.

But if engineering was not already within the curriculum or part of the school ethos, they promoted their vision through an intervention that offered a whole-school focus for enhancing its status within STEM subjects, for example by incorporating the engineering design process and EHoM into all subjects, ‘bucking the trend’ in which leaders’ actions reduced focus on other subjects to ensure the primacy of English and mathematics.

With the constant churn of change in education at the national level, teachers can experience initiative

fatigue, but these leaders recognised the need to establish the long-term vision and accept that habit change takes time to embed. It is important to give teachers time to improve if their performance is not yet where you want it to be. A key factor in achieving this was ensuring that their teachers realised that success was not going to be measured solely by external accountability measures, but by goals set collaboratively within the school, for example teachers undertaking action research projects to generate their own evidence on what worked in their context:

“It wasn’t that teachers were suddenly freed up and became really creative, I had to go through another cycle of that and then once people realised that their pay was based on the research they were doing, as opposed to GCSE grades that pupils got, that enabled me in the second year to do it again.” **(Headteacher, secondary school)**

They set high performance expectations for staff, often leading by example by being seen teaching in the classroom, which gave them credibility if they wanted to challenge teachers about their practice:

“You need to lead by example. I see my role as headteacher as being that, so I still teach, I still get into classes. If I’m going in coaching, if I’m going in to challenge aspects of teaching that I’ve seen, that I think could be improved, I have to do that with knowledge.” **(Headteacher, primary school)**

An important skill needed for setting direction is effective communication and it was evident that these leaders used a wide range of communication strategies to articulate their vision, depending on the audience. They talked regularly with staff and led discussions about different practices to introduce students to engineering:

“I just made sure that I regularly spoke with the staff, gave them some support and encouragement, and suggested some ideas initially about the sort of things we could do; from activities in school to taking the pupils out to the workplace.” **(Chair of governors, secondary school)**

They persuaded staff to move in the direction of the desired change by appealing to teachers' commitment to enhancing the learning and achievement of their pupils, thereby demonstrating that the change was not just the latest 'fad', it was a genuine way in which the school curriculum was going to be improved:

"That's how I sold it to the staff; it wasn't an add-on, it was something that could make our curriculum very exciting. It was something that would make learning stick." **(Headteacher, primary school)**

But they involved everyone in the discussion about what the vision looked like, they frequently use 'we' instead of 'I' as they worked with their teachers to foster a common understanding of the vision:

"We identified what compelling learning looked like for our vision and we got teachers to work on that, so what does it look like for a pupil, what does it look like for a teacher? And we came up with basically a piece of writing, it's not very long, it's a short couple of paragraphs. But that identifies what we are as a school, what we're about and what we're wanting to achieve." **(Headteacher, secondary school)**

They persuaded employers to engage with the school by pointing out the gains for the employer, as well as for the school:

"Sometimes you've really got to sell your product if you want to get any kind of support financially, because people are not going to put money into something that they don't think they're going to gain anything out of." **(Curriculum leader, primary school)**

This became easier once the school had developed a track record for succeeding in introducing innovative projects or used language that represented a vision they could sell to employers or others in the community who could provide help:

"You just need to keep talking to other people that really get where the

subject is and where you're wanting it to go to; there's a lot of new language in our school and some of that's really helpful." **(Engineering curriculum leader, secondary school)**

They kept on communicating the vision to parents:

"I kept talking about it all the time in the letters to parents, 'this is a compelling learning experience, this is what we're trying to do'. Eventually, they get it." **(Headteacher, secondary school)**

Middle leaders with a vision for promoting engineering had to be adept not only at communicating with employers and securing their involvement in projects, but also in communicating up the hierarchy and in persuading the headteacher to agree to their involvement in the first case. This Director of STEM used the school's existing pride in its extra-curricular offerings to persuade the headteacher to let him set up a STEM Club and found exciting engineering projects for students to get involved with and which looked good for marketing the school:

"The management is almost like a collegiate system. They are, and always have been, enormous supporters of any extracurricular provision. So the school prides itself on all sorts of offerings outside of the classroom." **(Director of STEM, secondary school)**

4.3.6 Leadership strategies - developing people

The second core practice of successful leaders is developing people and these leaders demonstrated a variety of strategies to do this in ways that kept the focus on the pedagogies and values they wanted to instil in teachers.

Leaders use coaching and modelling extensively to support staff to develop new teaching skills, but not overtly in front of the children, as if coming into a classroom on an inspection visit:

"I would introduce it, this is what resilience looks like, etc. so this week when I come into the classroom on

Friday, we have a coaching session on the Friday but the children see it as me dropping in to look at their work and what they've achieved that week." **(Headteacher, primary school)**

They modelled the desired pedagogy to other teachers and linked the new pedagogy to the existing approach, so it did not appear to be too much of a leap:

"So, I would model something and then I would verbalise how that was something that she was already doing. So, she didn't have to have that specialist knowledge. We did get engineers to come in with the specialist knowledge, as well, but I was able to verbalise and model for her, saying 'you're already doing that, I've only changed the language a bit.'" **(Engineering project lead teacher, primary school)**

Leaders researched the desired practice themselves, at the same time as drawing in others, so they became sufficiently familiar with it to understand where staff resistance might occur. They would start it off, but judge the right time to hand over the initiative to another staff member who would carry it forward:

"I research it collaboratively to generate something that is really motivational, launch it, implement and then hand across to practitioners who are very good at the completer/finisher parts of it." **(Deputy headteacher, secondary school)**

But when they became aware of the potential for a pedagogic initiative to go off track because of the actions or attitudes of particular staff, they were not averse to taking back control or taking direct responsibility for changing the views of staff who found it challenging to adopt new ways of teaching that developed EHoM:

"My head of science ... it took quite some time for her to change her view. So I line managed her in the second year ... because I knew that I could get that across more in her terms if I was to line manage her" **(Headteacher, secondary school)**

Interestingly, when introducing their new pedagogic practice, the leaders we interviewed chose to make use of internal expertise rather than bringing in an 'expert' from outside. This may reflect the outlier nature of the sample and their higher levels of confidence:

"I'm a big believer that, from a CPD perspective, from a teaching and learning perspective, you find that the skill-set is usually in the building somewhere. So, we are big believers in the fact that we have great expertise in-house." **(Principal, UTC one)**

They offer staff stimulating challenges:

"Most of these things are led not by the senior management team but by class teachers, who then report back to the senior management team." **(Engineering project lead teacher, primary school)**

However, they recognise that in doing this, they have to encourage teachers to take risks and they accept the consequence that failure might happen occasionally, but these are opportunities for learning, not censure:

"This might sound a bit twee but I always say, 'has anyone died, and is the school at risk?' and if the answer is no to both of those questions, then well, let's just look at what we've done and let's learn from it and let's refine it." **(Headteacher, secondary school)**

As noted earlier, they take a problem-solving approach with individual teachers to improve their skills:

"We've got a headteacher ... who wouldn't come in and say 'this is really noisy, keep it down', they would come into the classroom and spend time working alongside you. Things would go wrong, but they would say 'what could we do now?'" **(Engineering project lead teacher, primary school)**

They participate in teacher learning and development, taking an active role in preparing staff for the change, involving lots of people to promote collective responsibility, getting staff to buy into the 'bigger picture', securing trust from staff:



“Taking the right people to see the right things, so we went to the [external school name] to start to get the foot soldiers of this thinking in the right way and on board and helping to develop the vision.” **(Deputy headteacher, secondary school)**

School governors can also play an important role in promoting the vision by using their expertise to support the SLT and encourage trust rather than suspicion about their role, as this school governor, with expertise as an engineer, did when working with the headteacher and the heads of departments to create an after-school STEM Club, and used contacts to gain external funding for the club:

“I have heard tales of staff being wary or concerned, or even scared, when the chair of governors comes into their department; but I don’t think we’ve got that relationship. I think we’ve got that relationship where, generally, they welcome the governors coming in and seeing what they can offer to support them in school.” **(Chair of governors, secondary school)**

In terms of building staff capability, leaders were very visible during the training and preparation of staff:

“I was very conscious of making sure that I attended every training event, every aspect of development with the teaching team.” **(Headteacher, primary school)**

They were clearly participants, showing their engagement and welcoming different opinions:

“What’s really good is we can actually challenge each other about the processes and why things have been included, and why suggestions have been made.” **(Curriculum lead, primary school)**

They fostered the growth of learning communities by promoting and participating in activities such as action research projects or peer reviews that helped teachers appreciate the pedagogy behind the changed approach rather than seeing the initiative as a lot of new ‘stuff’:

“We also have a TLC [teaching and learning community] in school where we swap colleagues and they observe us, and we go to their classes, with a different stage, so I might go into an Upper Stage class and the Upper Stage might come to the Infants to observe.” **(Engineering project lead teacher, primary school)**

Newly qualified teachers were also supported to ensure that they quickly acquired the school's ethos and mindset:

"So, with newly qualified teachers, we give them the support within the STEM lessons, and training within the school day as well, in different areas where the STEM curriculum or the ethos around engineering habits of mind can be incorporated into the other subjects." **(Curriculum leader, primary school)**

Leaders told us they took every opportunity to celebrate school successes and raise the profile of engineering. They also engaged in the activities for national prizes, which recognised and rewarded the individuals involved, but also had the aim of retaining their talent for the school:

"I said 'I think you should go for a [name] award'. He applied for it, went for an interview in London and he won [£XX,000] for the school. They were so impressed with what he was doing. Well, that was him staying at [school name], and then it just snowballed." **(Headteacher, primary school)**

4.3.7 Leadership strategies - redesigning the organisation

The third practice of successful school leaders is their focus on redesigning the organisation. This involves finding ways to strengthen school cultures by modifying existing structures and building collaborative processes that support teachers and students. It involves creating powerful educational links within the school and drawing on the community resources outside the school to expand the school's curriculum.

Having created their engineering vision for the school, the leaders then ensured that curriculum changes were aligned to supporting this new ethos:

"You build a school improvement plan that fits around EHoM and that kind of learning and then it's about building the relationship to make

that effective." **(Headteacher, primary school)**

One way of encouraging staff to move in the desired direction is to adapt the existing organisational structures, for example the performance management system, to accommodate the leader's vision:

"When we set those targets, the first one, the performance management target for everyone, was to create a compelling learning experience. We set no data targets, so there was no data in terms of 'your pupils have got to make this amount of progress', we took all that away so that teachers' pay was not linked to pupils' outcomes." **(Headteacher, secondary school)**

It is interesting that the headteacher above discusses change using the plural 'we' suggesting the involvement of the leadership team in these decisions. Traditional organisational structures such as lesson observations were also replaced with more collaborative processes such as lesson study:

"I didn't do formal lesson observations, stopped all that, I didn't grade lessons as soon as I went there." **(Headteacher, secondary school)**

Middle leaders also were supported to develop curricula structures that were new, but at the same time, aligned to existing school structures to create continuity and coherence:

"I'm part of the middle leadership team...and I also work quite closely with [colleague name] who's our STEM leader. Together we have created a STEM curriculum for this year that shows progression in skills but also is enhancing the foundations of learning as well as the engineering habits of mind." **(Curriculum leader, primary school)**

As a secondary curriculum leader, this respondent clearly adopts responsibility for setting the standards for the subject team:

"There are another seven faculty leads in the school and there's a big focus on being collaborative ... I think my role is to put my whole team in a

position to teach at a very high level. It's very technical and we try put us in a position to fulfil our status, it has a bit more status than those subjects do in other schools. We want to maintain that and grow." **(Engineering curriculum leader, secondary school)**

A sense of having special status was reinforced through the reorganisation of the classroom spaces, for example as studios or STEM workshops, being sufficiently large enough to accommodate large groups of students all doing the same project at the same time, all of which served to strengthen the sense of collaboration among students.

As part of the vision-defining and consensus-building, interviewees talked of the importance of collaborating with a school's non-executive leaders, their governors, and stressing the importance of ensuring that they were familiar with the leaders' vision for the school. One primary school leader made a point of inviting governors into classrooms to gain experience of the primary curriculum, something that had not been done before, but paid off in this case because during the next inspection visit they were able to confirm to Ofsted the appropriateness of the headteacher's vision:

"I knew obviously that Ofsted were coming in, I had to have governors speaking that language as well and when they were interviewed, literally all pieces of the jigsaw fitted together and it did work, it worked." **(Headteacher, primary school)**

Fostering collaboration between the school and the local community was a key strategy used by these leaders to increase employer involvement in the curriculum, but the support sought from employers was highly targeted and aligned to achieve the overall vision, rather than the previous ad-hoc arrangements:

"We were starting to bring companies into our way of thinking and get them thinking about how they could support that, whereas what we had before was very much companies

providing a workshop or an away-day or whatever." **(Deputy headteacher, secondary school)**

But once this collaboration with employers began to grow, it is important to ensure that it was organised effectively, which may mean creating a role for a member of staff to do this, in order to sustain the practice. However, it is still necessary to ensure that the subject teacher is involved in this collaboration because it is only they who fully understand the needs of the curriculum:

"If you have got an employer working on every single unit ... across all years, you can't manage that unless you have a dedicated individual whose sole remit is employer engagement but even they don't understand the content of the qualification or the structure ... as well as the actual subject teacher who's actually delivering that unit of work." **(Principal, UTC one)**

Building engagement in engineering led most of those we interviewed to examine the ways in which they engage parents. This had mixed results, with some finding that there were no engineers among their parents, or having to adopt a range of cunning strategies to entice them into the school:

"There is a real reluctance to engage, we actually pay them to come in. We have a virtual bank and if parents engage in workshops, for instance, when we've run science afternoons or reading workshops, we offer a virtual amount of money that goes into their virtual accounts and they can redeem that against uniform and trips and visits." **(Vice principal, primary school)**

As part of fostering stronger links between the school and the local community, members of the local community, including past pupils who have gone into engineering, were seen as powerful resources:

"We've had a few pupils coming back, really good female role models, which was fantastic. We had an ex-student of mine who came back in who was working on the [project name] and she



came back in and she just brought all this stuff in and did a presentation to year 5 and Year 6.” **(Headteacher, primary school)**

4.3.8 Leadership strategies - managing teaching and learning

The final core practice undertaken by successful leaders is managing teaching and learning which involves improving the conditions and environment in which both can flourish. To do this it is necessary to ensure existing staff have the resources they need to improve teaching and learning and that, where necessary, appropriate staff are recruited, retained and deployed effectively. One UTC principal tried to ensure that teachers with a specialism were able to teach it, which could be challenging but worth the effort of recognising staff expertise:

“What I try and do, which is a bit of a challenge from a timetabling perspective, is to take the specialisms of the individuals and allow them to teach in subjects that they are specialist in, so in engineering we have staff who have responsibilities for units of work based on their specialism.” **(Principal, UTC one)**

This alignment between staff strengths and interests and curriculum needs, building on teachers’ existing skillsets, was used effectively by leaders to re-ignite staff motivation and re-energise those who might be looking around for other posts:

“I thought ‘this is a way in, I can tap into people’s skill sets and we can start afresh in a sense.’” **(Headteacher, primary school)**

Another strategy is to align employer-led coursework projects with assessment tasks, which takes time and effort to work with awarding bodies to adapt their schemes of work, but is far more meaningful in terms of student outcomes because the activity and its assessment are aligned:

“So, they [students] don’t do an employer project and then get a coursework assessment that’s

completely abstract, or a generic product that’s just written for the purposes of meeting the assessment criteria, those two are interlinked and therefore we see students developing an immense amount of skill.”

(Principal, UTC one)

Leaders afforded teachers flexibility to deliver the curriculum to encourage innovation, but they managed to retain the teachers’ focus on accountability:

“Our approach is quite creative in terms of the flexibility that teachers have to enable them to do these things, rather than just straight jacket them by saying ‘right ok, the be all and end all is maths and English’. Obviously, we hold them to account over that, they need to do it, but it’s about how they go about doing that we pride ourselves on.” **(Vice principal, primary school)**

They look for ‘quick wins’, but not at the expense of the long-term vision:

“What we had was an awful lot of energy, an awful lot of people that were pulling together with a singular focus and we were getting some excellent ideas that we were able to implement within the curriculum easily and swiftly.” **(Deputy headteacher, secondary school)**

They provided a supportive environment when staff tackled new challenges, and tended to delegate responsibility, for example for engaging with employers down to the member of staff who was directly involved, rather than this being a senior leader role:

“We try and give individual staff members responsibility for key units and although the curriculum director will oversee that link and that engagement, the actual staff member delivering that qualification becomes the key link with that particular employer.” **(Principal, UTC one)**

However, leaders recognised that while it was possible for staff to get caught up with the excitement of developing real-world projects in collaboration with employers, it was important to make sure they kept the requirements of the curriculum in mind, to ensure that

effort was not wasted, they allowed calculated risks to be taken:

“There’s always this danger that you can do lots of exciting things that seem great, let’s take a risk here or a risk there, do this and do that, but if that takes your attention too far away from the curriculum then you end up chasing your tail when it comes to crunch time in the summer.” **(Principal, UTC one)**

One secondary leader pointed out to us that there is no engineering teacher supply chain, which often results in recruiting D&T teachers to teach engineering. Then, it is necessary to be clear about what engineering really is within the school, to ensure that the new recruits have both the right skillset and the belief in what the head is trying to do. One response to this challenge is to redesign teachers’ job titles and specifications to ensure that teachers are recruited who are attuned to the requirements of teaching a cross-curricular subject such as engineering, and rather than seeing themselves as D&T teachers, they are STEM teachers:

“The staff you employ, when they come in, they are not a D&T teacher, they are a STEM teacher, and they are a head of STEM... so they have been very powerful for us.” **(Deputy headteacher, secondary school)**

Several leaders suggested that it was the high status given to engineering in their schools that enabled them to attract high-quality staff:

“Part of it is the context of the school itself, working within a structure where it’s valued and it’s got support and it’s a fairly flat hierarchy, when it needs to be, and you can share ideas.” **(Engineering curriculum leader, secondary school)**

UTC leaders pointed out the benefits for teachers working in a UTC environment, with its strong emphasis on engagement with employers and parity of esteem of vocational subjects with academic:

“Our staff can come here and have all the excitement of working with

employers, being the showcase, not being the small department down the back of the school that’s had its budget cut time and time again and you only get the kids who are deemed to be ones that can’t cope with the traditional academic curriculum.” **(Principal, UTC one)**

Collaborating with other schools to secure teaching resources was also accepted as necessary by leaders:

“We also collaborate with another multi-academy trust in the region, so we’re supported by [name] learning trust as well and we work collaboratively with those where we might have sole workers in particular departments, to collaborate on one thing and another.” **(Principal, UTC one)**

This was true of both people and physical resources:

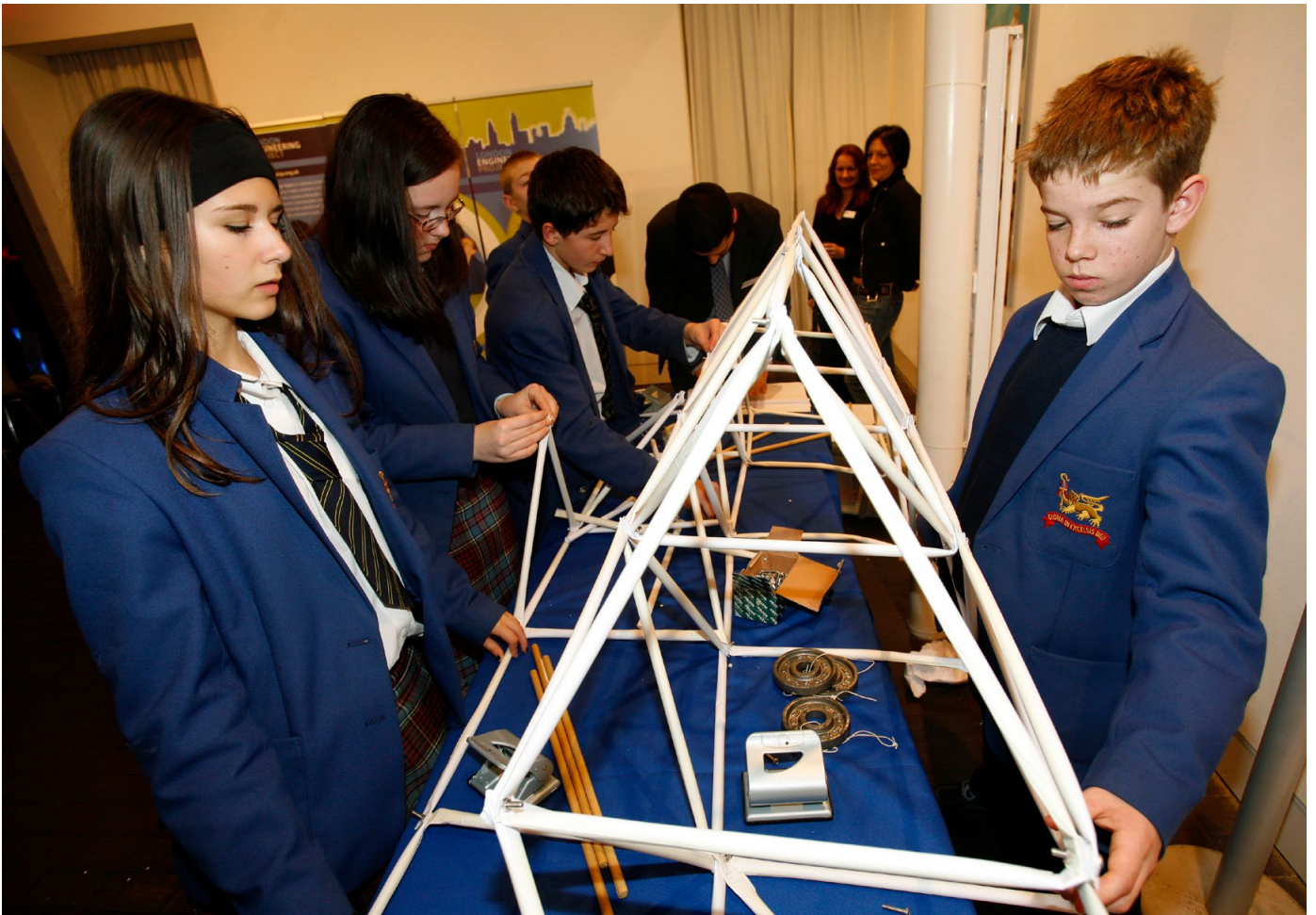
“Looking at going out of the school building, looking at what you’ve got in your own environment that would enrich what you’re offering in school.” **(Headteacher, primary school)**

Finally, having already referred to the accountability demands that schools and teachers are subject to, one key aspect of managing teaching and learning is for school leaders to act as a buffer for teachers, to prevent them from being overwhelmed by unproductive external demands:

“I still give staff the information that I think they need and also protect them from some of the information that I don’t think they may need at that particular point, because it’s not going to be worthwhile.” **(Headteacher, primary school)**

Although UTCs might be expected to offer interesting accounts of effective engineering education, as many of our observations show, UTC principals were convinced that ‘normal’ school leaders could also develop the vision for a broader education for engineering:

“UTCs were put here to deliver an employer-led curriculum but nothing is stopping normal schools doing that in subjects that they deliver already and



that's a very tangible way of getting engineering-based philosophies and ambition into students and institutions." **(Principal, UTC one)**

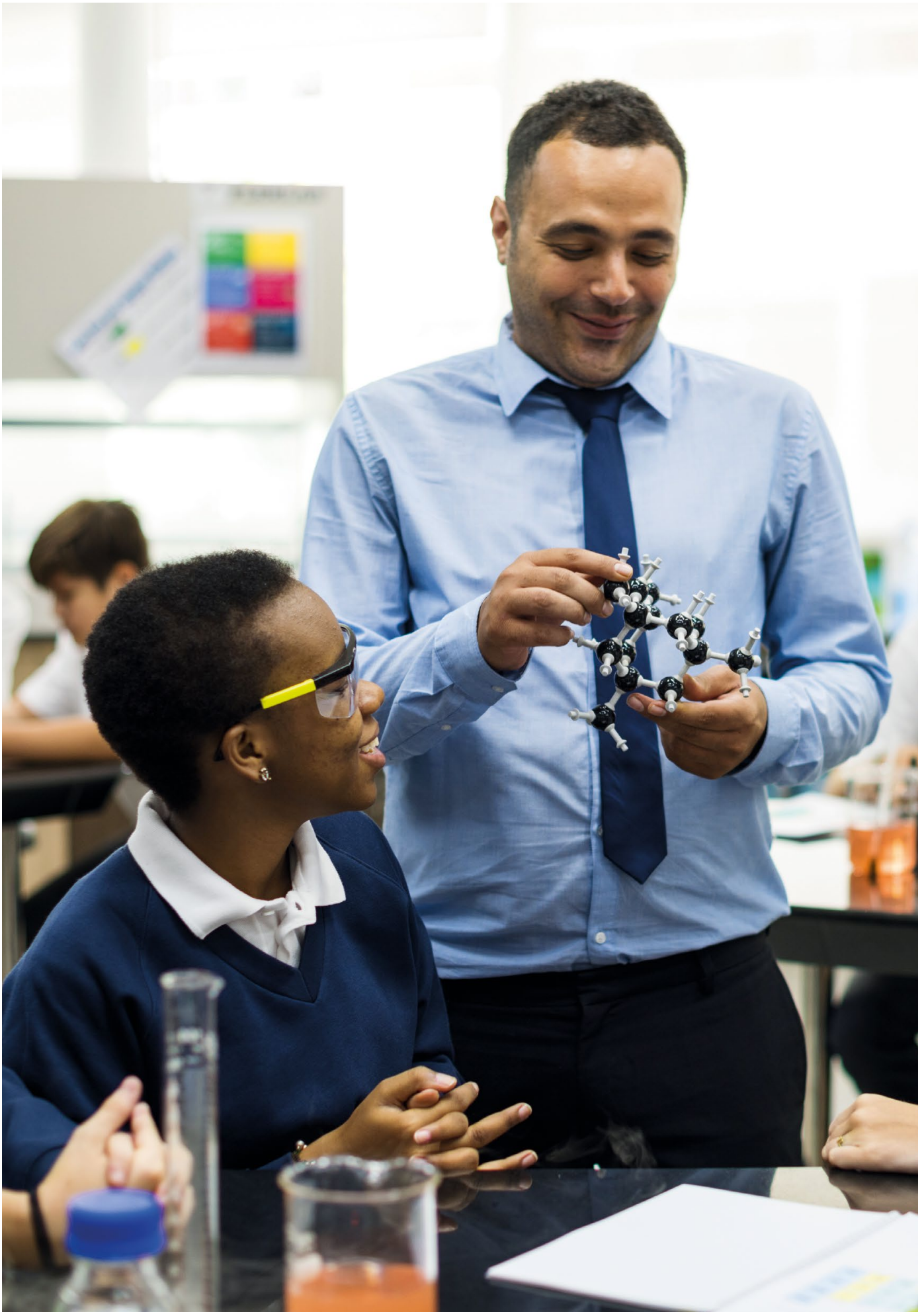
4.4. Summary

Although there is a large literature exploring successful school leadership there is remarkably little which explores the specific challenges relating to engineering, specifically:

- its lack of clear status (despite national governmental campaigns)
- the lack of exam options at GCSE
- the necessity of collaborating with engineers and engineering organisations

- its interdisciplinary nature
- the pedagogies that work best to teach it
- the professional development needed in most schools
- the practical implications for timetables and teaching spaces
- the external scrutiny by Ofsted, itself reflecting other government priorities such as EBacc and Progress 8.

It is nevertheless possible to learn from the talented outliers that have been studied and begin to make some cautious generalisations from these.



5. Putting it all together and moving forward

This study has sought to understand more about what school leaders and teachers need to do to change their practices to embed more effective education for engineering, one step of our Theory of Change (see page 10). Specifically, it has explored the characteristics of successful school leaders of engineering – who they are, what they believe is important and what they actually do.

This study is an acknowledgment that all is not well in schools with regard to opportunities for children and young people to experience learning that will both engage their interest in engineering and develop the EHoM, along with the knowledge and skills that they will need to develop as engineers.

As this study has explored the strategies of those who are successfully making progress, key questions have been considered. What are the roles of leaders at all levels of the system in creating opportunities for young people to develop an interest in engineering in schools? What are the enabling factors? What are the barriers? What are the characteristics of effective leaders?

5.1 The challenge we face

We have a problem in England, in the UK and, indeed, in many countries across the world. Schools are simply not producing sufficient quantity, variety and quality of young people who have the STEM literacy skills, or EHoM, to function effectively in the modern workplace and contribute to society, let alone progress on to further engineering qualifications.

There are many challenges for schools trying to address this problem and these are most acute at secondary level. They include the fact: that engineering is

interdisciplinary and cross-curricular by nature and does not easily fit into a subject-dominated school timetable; that, while engineering may be valued by government and employers, it has no obvious place on the curriculum and very few assessed courses are available; that many teachers are unconfident and believe they lack expertise, and resources to teach it; and that a school's performance as judged by Ofsted may suffer.

5.2 Building on earlier thinking

Thinking like an engineer established a different way of describing engineering in schools, not as a set of disciplines but as six habits of mind. Schools have said that this has three advantages. First, it enables teachers of many different subjects to see beyond their particular discipline and see engineering in a way that is free from whether it is, for example mathematics, science or D&T. Secondly, it resonates well with engineers and provides a useful talking and connecting piece between teachers and engineers, both of whom may be wary of the other. Thirdly, and probably most importantly, it opens up a discussion about teaching and learning – pedagogy – that is free of any one subject and can focus on how teachers can best develop EHoM through whichever subject or subjects work best for them.

Learning to be an engineer, a small-scale proof of concept study with more than 30 schools, showed that teachers in both secondary and primary schools, with support and appropriate professional development, can adjust the way they teach to offer a much richer set of curricular opportunities for their pupils. As the authors worked with this group of largely self-selecting schools it became evident that their



We therefore need to show that it isn't such a big step between having fun in your bedroom, garage, or garden shed, and solving the 'grand challenges' that exist in the world today. And we need the next generation to solve these challenges through engineering ... As educators we must provide this encouragement to young people, curriculum permitting or not.¹¹⁷

George, 2017

leaders, whether operating at senior, middle or classroom level, seemed to be slightly different from other leaders encountered.

Given the large number of schools in the UK and the enormous scale of the problem, this study adopted a positive deviance approach. Through networks, especially those emanating from the Royal Academy of Engineering, it identified a sample of schools who are, in some way, doing extraordinary things to promote and embed engineering. Adopting a largely qualitative approach allows the authors to begin to understand more about the leadership issues facing schools.

To be sure that the study was not overly influenced by a small sample of some 60 enthusiastic schools doing interesting things with engineering, it was grounded in a broader literature survey to establish secure models of effective leadership against which it could locate its findings. In addition to establishing general principles, the study aimed to understand wider thinking about the leadership challenges of embedding something such as engineering, for which the school system is poorly set up given its nature and status. The authors also used their knowledge of approximately 30 other schools with which they have worked closely over the last three years, to help to sense-check the emerging findings.

As a consequence, the study was able to understand more about the context and its challenges and describe the features of school culture, which seem most conducive along with the attributes of effective leaders, the strategies they value and the activities they consider to be most useful.

5.3 Culture

Schools are busy places and their leaders face demands from many quarters. Whether or not to focus on engineering is something that has to be a conscious decision if it is to stand a chance. A conducive culture has to be created for education for engineering to thrive.

The evidence suggests that there are six core elements of such cultures.

Engineering is **valued**, either as an experience, as a way of thinking, as a vehicle through which other subjects are made relevant to pupils. In some form, it is explicitly part of the school's development plan and drives curriculum, pedagogy and professional learning within the institution.

Teachers operate within an atmosphere of **high trust**. If staff are going to be encouraged to experiment and undertake small tests of change, they need to be given a level of trust over time to see things through.

Related to this, there needs to be a **freedom to experiment**, to try out new teaching methods, to adapt spaces, to investigate new resources, to engage people from outside the school and to give pupils new roles.

These endeavours need to be undertaken within an environment of **supported risk-taking**, where time is made available, professional learning is provided and teachers are able to co-design lessons together. **Failure** is tolerated as part of the process of gathering evidence on what works.

Given the necessity of engaging with individual engineers and engineering businesses, it is axiomatic that schools need to be actively **outward-looking**.

Perhaps most importantly, as the conditions in which engineering and EHoM can flourish depend ultimately on decisions about teaching and learning, the culture and the efforts of all those with a leadership role within it need to be **pedagogy-focused**.

5.4 Leadership attributes

As seen in sections 3 and 4, the kinds of attributes needed for successful leadership vary according to the phase of school and its context. Nevertheless, the following set of 12 attributes seems to be important in this context: communicative, collaborative, courageous, creative thinker, flexible, improver, open-minded, persistent, resilient, risk-taker, vision-led and knowledgeable.



Such attributes would, of course, stand most leaders in good stead. They are, to an extent, useful in most contexts.

In terms of leadership for engineering they come with certain nuances. Communication is important both within and beyond school as a key element of advocacy because, in the absence of engineering's place on the curriculum, leaders have to argue persuasively for it. Collaborative is required both within disciplines and with external bodies. Courageous is there as any discretionary act by schools in a period of high external accountability requires courage.

Creative thinking exists at many levels – in terms of management structures, the organisation of space, the development of novel partnerships, and the trialling of new methods of teaching and learning. Flexibility, especially at secondary level, is critically important if something that is essentially beyond any one subject discipline is to find its way onto the timetable. Improving is what engineers do all the time, never being satisfied with the current approach or model; unsurprisingly it seems an important habit of mind for leaders.

Open-mindedness is essential where there is often no one right way in an area of emerging practice. Persistence is essential as the kinds of shifts in teaching and learning required to cultivate EHoM take time, often more than one school year.

Resilience, the companion of persistence, matters because it is inevitable that, when trying out new things, some will not 'fly' and leaders will need to hold the nerve and bounce back. Nothing new happens without risk-taking.

The last attribute, knowledgeable, is used here to describe an informed understanding of signature pedagogy for engineering along with the importance of engineering to the local and national economy.

At the heart of all of these attributes is a vision of the importance of engineering, of how the school's pedagogical approaches need to

change if young people are to be given the full range of opportunities and the kinds of professional learning most likely to achieve this.

A powerful school leader of engineering would seem to have both a set of widely noted leadership attributes and some specific habits of mind encompassing their valuing of engineering, their interest in pedagogy, and a passion for a kind of professional learning that sees teachers as active agents in changing their practices as part of a professional learning community.

5.5 Leadership functions and strategies

Figure 3 on page 17 offered a relatively widely accepted view of leadership, derived from the literature, that separates out attributes, strategies and functions. But when analysing the survey and interview data it became increasingly clear that the distinction between strategy and function, how and what, was potentially an artificial one.

Instead the authors saw and heard several things under each of the four headings – set direction, develop people, redesign organisation, and manage teaching and learning – which are summarised here.

5.5.1 Setting direction

Effective leaders:

- have whole school focus on engineering
- use the engineering design process and EHoM or similar to help them think across the boundaries of individual subjects
- have a view of education being for life not just in school
- seek to create an 'industry ethos'
- see employers seen as critical partners
- show that pedagogy supports learning process as well as subjects
- have a long-term vision

- use varied communication strategies depending on audience
- lead by example.

5.5.2 Developing people

Effective leaders:

- model desired pedagogy to others
- encourage staff to make small steps of change to link new pedagogy to existing approaches
- use internal staff expertise to share best practice
- offer teachers stimulating challenges
- trust teachers to take risks
- use problem-solving approaches with individual staff to improve their skills
- personally participate in teacher professional development
- engage school governors with engineering expertise to support SLT.

5.5.3 Redesigning the organisation

Effective leaders:

- link a rationale for engineering to their school ethos
- align any desired curriculum change to school ethos
- increase employer involvement in the curriculum
- encourage and direct employer involvement to meet school needs
- expand the range of engineering-focused extracurricular activities
- invite governors in to experience the changes in the classroom
- research desired practice, start it off and then hand to others to embed
- build on teachers' existing skillsets
- engage parents using varied strategies

- create a curriculum for teachers to use and adapt to their subjects
- align curriculum change with existing learning habits
- use alumni as models.

5.5.4 Managing teaching and learning

Effective leaders:

- increase flexibility within the timetable
- use assessment and progression to demonstrate value of engineering
- give staff flexibility to deliver the curriculum, without relaxing accountability
- look for 'quick wins', but not at the expense of the long-term vision
- align staff strengths and interests with curriculum needs
- provide a supportive environment when staff tackle new challenges
- collaborate with other schools and the local community to secure teaching resources.

5.6 The Leadership for Engineering in Schools model

Leadership for engineering in schools is not radically different from good school leadership more generally. Nevertheless, there are certain key features of school culture, personal attributes, strategies and functions that are, when taken together, noteworthy.

Drawing on earlier synthesis of thinking about leadership and the more detailed analysis of some school leaders, this study has begun to paint a picture of the kind of leadership model that seems to enable engineering to flourish, which has been brought together in **figure 10**.

It would seem that successful school leaders of engineering know the kind of culture they need to create and maintain. They have a set of relatively commonly noted leadership

External context: Skills demand; accountability regime; perception of engineering				
Culture (where): Engineering is a priority; high trust; freedom to experiment; supported risk taking; failure is tolerated; outward looking; pedagogy focused				
Personal attributes (who):	Leadership functions 1-4 (what) and leadership strategies (how)			
Collaborative Flexible Resilient Open-minded Persistent Optimistic Courageous Vision-led Creative thinker Risk-taker Communicator Improver Knowledgeable	1. Set Direction	2. Develop people	3. Redesign Organisation	4. Manage teaching & learning
Belief in value of engineering, in signature pedagogy and in power of professional learning	<p>Whole-school focus on engineering;</p> <p>EDP & EHoM used for thinking across subjects;</p> <p>Education is for life;</p> <p>Create 'industry ethos';</p> <p>Employers as critical partners;</p> <p>Pedagogy supports learning process as well as content;</p> <p>Long term vision;</p> <p>Varied communication strategies;</p> <p>Leadership by example.</p>	<p>Model desired pedagogy;</p> <p>Small steps of change to link new pedagogy to existing approach;</p> <p>Use internal staff expertise to share best practice;</p> <p>Offer teachers stimulating challenges;</p> <p>Trust teachers to take risks;</p> <p>Use problem solving approach with individuals to improve skills;</p> <p>Participate in teacher professional development;</p> <p>Find school governors with engineering expertise to support SLT.</p>	<p>Link rationale for engineering to school ethos; Align desired curriculum change to school ethos;</p> <p>Increase employer involvement in curriculum;</p> <p>Direct employer involvement to meet school needs;</p> <p>Expand engineering-focused ECA;</p> <p>Invite governors to experience the changes in the classroom;</p> <p>Research desired practice, start it off and then hand to others to embed;</p> <p>Build on teachers' existing skill sets;</p> <p>Engage parents using varied strategies;</p> <p>Create a curriculum for teachers to use and adapt to their subjects;</p> <p>Align curriculum change with existing learning habits;</p> <p>Use alumni as models.</p>	<p>Increase flexibility of timetable;</p> <p>Give staff flexibility to deliver the curriculum, but don't relax accountability;</p> <p>Use assessment to value engineering projects;</p> <p>Look for 'quick wins', but not at the expense of the long term vision;</p> <p>Align staff strengths and interests with curriculum needs;</p> <p>Provide supportive environment when staff tackle new challenges;</p> <p>Collaborate with other schools & local community to secure teaching resources.</p>

Figure 10: Centre for Real-World Learning's Leadership for engineering in schools model

attributes combined with three habits of mind that are less well-known: belief in the value of engineering, curiosity about pedagogy and love of professional learning.

5.7 Recommendations

To strengthen support for leaders of engineering education, the engineering community may like to consider the below recommendations in collaboration with the following bodies.

Headteacher organisations

The engineering community should engage with school leadership organisations, for example, the Association of School and College Leaders (ASCL), to focus on pedagogic leadership with regard to education for engineering. This could involve holding a roundtable discussion to begin a national debate about leadership that promotes the value of incorporating engineering in the curriculum and recommends ways of supporting headteachers to develop and implement a strategic vision for engineering.

Engineering professional bodies and subject associations

School leadership issues involved in promoting engineering in collaboration with engineering professional bodies and subject associations should be highlighted. This might involve:

- producing case studies of the different approaches taken by school leaders to embed engineering in the curriculum, each emphasising one of the four leadership functions and including school leaders discussing their approach to the challenges of leadership
- collaborating with STEM Learning to develop CPD resources for all leadership levels that explore the challenges of leading and teaching cross-curricular learning
- discussing with providers of engineering challenges and awards how their success criteria might be aligned with EHoM.

Employers and employers' organisations

Engineering employers should encourage their engineers to support school leadership teams by joining schools' governing boards. Through EngineeringUK, the engineering community could also review guidance for employers on engaging with schools, and develop advice specifically aimed at working with headteachers and chairs of governors.

Government and awarding/assessment bodies

The engineering community should work with qualification-awarding organisations and the Department for Education to explore how examples of how cross-curricular links can be developed using engineering themes across the National Curriculum for computing, D&T, mathematics and sciences.

The engineering community should also work with the Institute for Apprenticeships, in particular the employer panels drafting T-level content in engineering and associated subjects, to explore ways of using the EHoM approach in the new qualifications.

The engineering community might like to encourage awarding organisations to develop GCSE qualifications in engineering based on an activity-led pedagogy and EHoM.

Ofsted

The Academy should encourage the Ofsted lead inspectors for STEM subjects to reflect on the ways in which inspection, specifically at upper secondary level, is 'bending the curriculum out of shape'. There is an opportunity for Ofsted to reinforce the messages learned from earlier research about the teaching of engineering using the EHoM approach. Equally it is a moment to take stock of the ways in which the EBacc may, unintentionally, be making it more difficult for schools to teach important areas such as engineering and consider how breadth and balance may be maintained across the curriculum.

International organisations

The Academy might like to approach the OECD, building on the OECD's recent decision to introduce a new PISA test of Creative Thinking in 2021, to explore opportunities to develop thinking in 2024 or 2027 for a new kind of PISA test of engineering, which would be of use, formatively, to schools.

Glossary

ACER	Australian Council for Educational Research
Academies	Publicly funded schools in England that receive money directly from the Department for Education and are independent of local authority control
ASE	Association for Science Education
CPD	Continuing professional development
CRL	Centre for Real-World Learning, University of Winchester
DfE	Department for Education
D&T	Design and technology
Distributed	When applied to leadership suggests shared, collective and extended practice that builds capacity for change and improvement
EBacc	English Baccalaureate
EHoM	Engineering Habits of Mind
Free school	Schools in England, often set up by parents, community or faith groups, that receive money directly from the Department for Education and are independent of local authority control
Grey literature	Materials and research produced by reputable organisations outside of mainstream academic or commercial publishing channels
GCSE	General Certificate of Secondary Education
KS	Key Stage
MAT	Multi-academy trust
NGSS	Next Generation Science Standards (USA)
OCR	Oxford, Cambridge and RSA Examination Board
OECD	Organisation for Economic Cooperation and Development
Ofsted	Office for Standards in Education, Children's Services and Skills
Pedagogic	When applied to leadership suggests an understanding of teaching and learning, sometimes called instructional leadership
PISA	Program for International Student Assessment – an international assessment managed by OECD that measures 15-year-old students' reading, mathematics, science and problem solving
STEAM	Science, technology, engineering, arts and mathematics
STEM	Science, technology, engineering and mathematics
T-level	Defined pathways to gaining post-16 technical qualifications in 15 specified employment sectors, beginning September 2019
Transactional	When applied to leadership suggests a focus on day-to-day organisation, management and performance
Transformational	When applied to leadership suggests a conscious desire to make significant changes in the interest of learners
UTC	University technical colleges are schools in England for 14 to 19 year olds delivering technical education as well as the core curriculum

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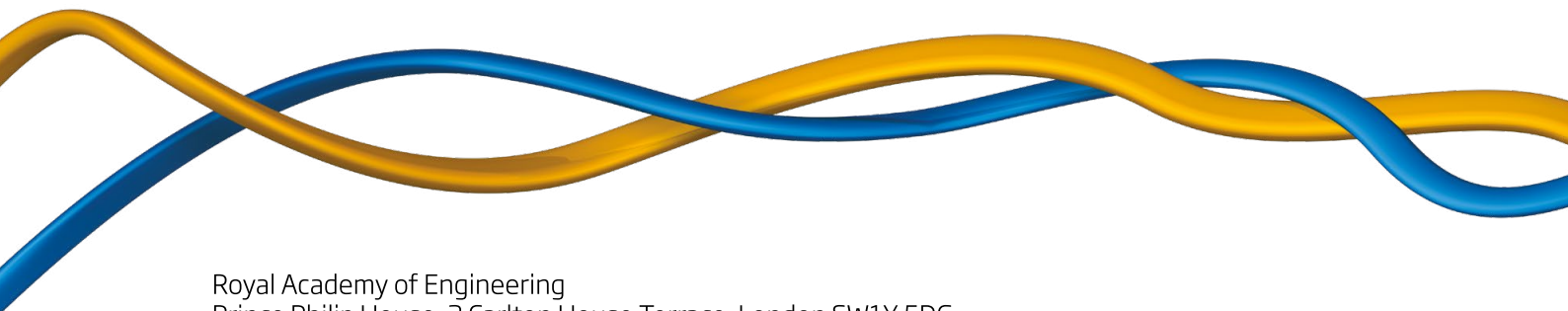
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