Educ-AI-tion Rebooted?

Exploring the future of artificial intelligence in schools and colleges

Toby Baker and Laurie Smith with Nandra Anissa

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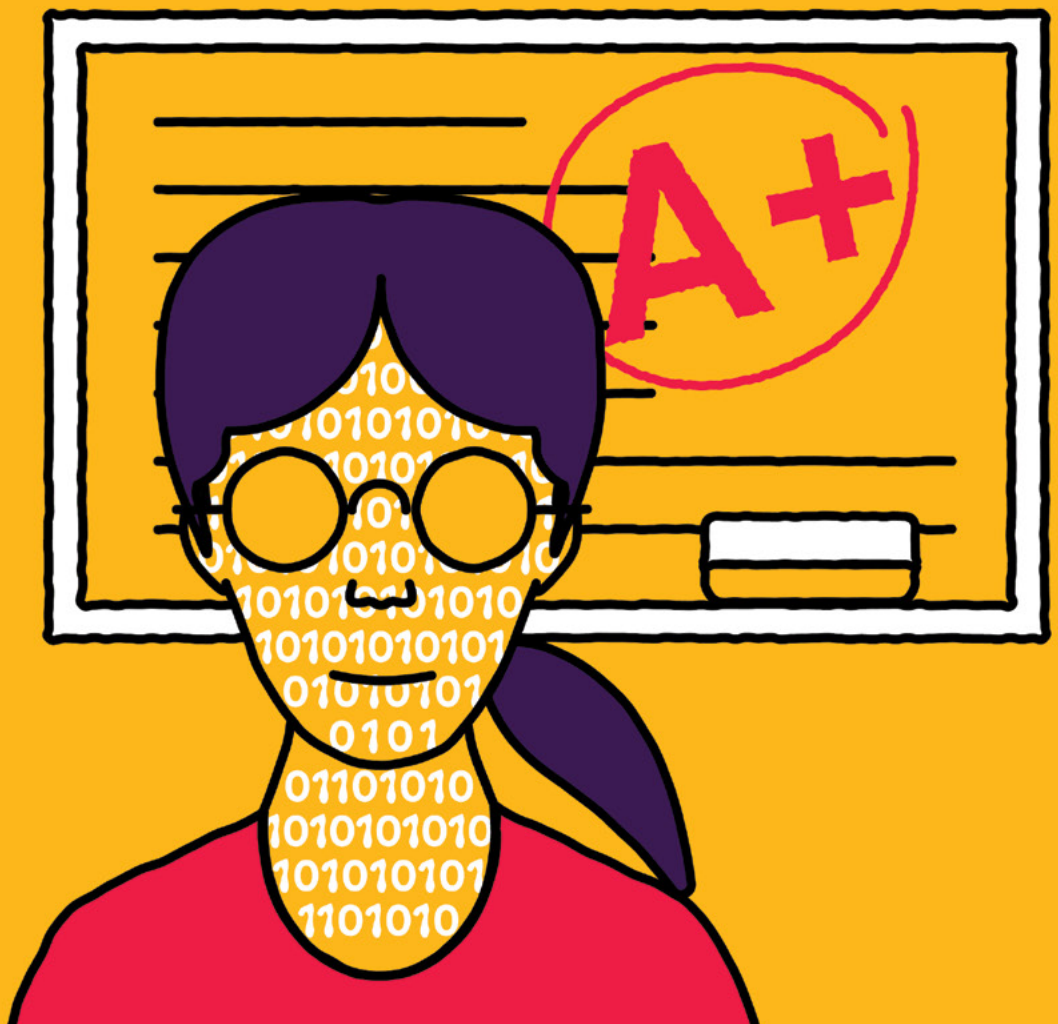

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Foreword

I'm very happy to write the foreword for this brilliant report for four reasons.

Educ-AI-tion Rebooted? is very clearly sighted about the urgency of what is needed.

First, **imagination**. The authors of *Educ-AI-tion Rebooted?* truly understand that artificial intelligence (AI) is on the cusp of transforming schools as well as colleges and universities in Britain and across the world. They understand that this is not a passing innovation like the introduction of photocopying or smart boards, but a once in five hundred year revolution, as I described in my own book published last year *The Fourth Education Revolution*.[1] They see very clearly the British government has yet to comprehend what AI will do in education and how it will be a total game-changer. Whether because they are lost in Brexit, or 20th century mind-sets, or any other factor, those who are steering our national education systems at schools and universities are way off the pace.

Second, **analysis**. The field of AI is vast. Every week, many new publications are published worldwide. Many of them are repetitive and muddled, and do not communicate the subject clearly. But the authors of *Educ-AI-tion Rebooted?* break the entire subject up with admirable clarity into how the new technologies will impact on learners, on teachers, and indeed whole systems. The authors survey the best practice in operation today – which is far more extensive than many realise, before analysing what needs to be done to encourage schools and colleges to adopt the new technologies, and learn from each other.

Third, **optimism**. We hear far too much about how the existing 3.0 digital technologies are damaging young people, and how students should leave their mobiles at home. We are in danger of talking ourselves into a frenzy of fear and ignorance. Yes, there are real risks and hazards with AI in Education, as the authors readily admit. There are hazards too in driving a car, or taking exercise or playing sport. But this does not and should not stop us from driving or playing. The benefits of AI, if we go into it with eyes wide open, as the authors suggest we should, far outweigh the downsides, and we will be much better placed to mitigate for the drawbacks if we start thinking and planning now. A glorious new world of deep education awaits.

Finally, **realism**. The Fourth Education Revolution of AI is fast approaching us across the ocean. Pretending it isn't coming towards us is naive and irresponsible. At present, the factory model of education, which has existed for five hundred years, has resulted in an ever greater obsession with the passing of increasingly meaningless exams, which bear little relationship to the skills and qualities that employers want, that the young need to live meaningful and happy lives, or that society requires if we are all to live together harmoniously.

I salute this report and recommend it as the most important read for all interested in education in 2019 and beyond. It will guarantee to change your understanding and outlook forever.

Anthony Seldon
Vice-Chancellor, University of Buckingham

Introduction

Students, parents, teachers, government and regulators must wake up to the potential of artificial intelligence tools for education (AIEd), because as the world changes – our schools will change too. Artificial intelligence is not just for technologists, and this report is not just a discussion of shiny gadgets or the latest new software.

Overwhelmingly, AI is characterised by its ability to accelerate, exaggerate and amplify issues that surround it – for both good and bad. While consideration of AI in other sectors – from weapons to healthcare – has entered both the public consciousness and government agendas, AI in education lags far behind.

Despite minimal attention, AIEd tools are already being used in schools and colleges in the UK and around the world – today.

We find learner-facing tools, such as adaptive learning platforms that 'personalise' content based on a child's strengths and weaknesses. We find teacher-facing tools, such as those which automate marking and administration (one government-backed pilot in China sees children in around 60,000 schools having their homework marked by a computer). We find system-facing tools, such as those which analyse data from across multiple schools and colleges to predict which are likely to perform less well in inspections.

These innovations are welcome. We desperately need new solutions to tackle the mounting pressures on our school system – from excessive teacher workload to lack of social mobility – and many of the tools described in this report have the potential to dramatically improve our school system.

However, positive change won't happen without a concerted effort, and there remains a considerable gap between the 'hype' of future potential and the reality of practice today. And while there is considerable uncertainty surrounding the future of AI in education, we don't need to sit and wait. There is much that we can do today to shape the future positively.

Much of this action can be initiated by government. The UK is a hub for education technology boasting a strong legacy alongside considerable expertise in artificial intelligence. But without government leadership and public funding, this advantage will be lost.

Similarly, the UK must capitalise on its reputation for taking ethics and the regulation of emerging technologies seriously. There are highly sensitive questions around the sharing of data related to minors, and we must seize the initiative before unwelcome practices become established norms.

We must prioritise the practical implementation of technology and its use by teachers, as they will ultimately choose how AI tools are used. AI does not mean the 'rise of the robots' in classrooms making teachers redundant (in fact, demand for teachers is set to increase, not fall[2]). Instead, we must prepare for the role of the teacher to be augmented and evolve in partnership with the capabilities that AI brings.

The balanced view of parents offers us a cue for how to view this growing field. Parents see the importance of the issue - with 61 per cent anticipating AI will be fairly or very important to the classroom of the near future - but they also see real risk - and many parents are fairly or very concerned about consequences of determinism (78 per cent), accountability (77 per cent) and privacy and security (73 per cent).[3] The rewards of AI are there to be taken, but we must all play an active role to ensure the future of AI in our schools and colleges is one that we have shaped ourselves.

The structure of this report

This report is split into two parts. Part 1 explores 'AI and Education Today', outlining the range of tools used in schools and colleges now, and the major challenges which AIEd is positioned to address.

Part 2 looks to the future, outlining actions we can take now to ensure that we maximise the benefit and minimise the risk of AIEd. These actions are split into four sections, each of which deals with a different question:

- **Growing the AIEd sector**: How can we help the sector grow and scale?
- **Improving AIEd**: How can we improve the quality and effectiveness of AIEd tools?
- **Governance of AIEd**: How should we responsibly use and share the data that drives AIEd?
- **An Education System that Learns**: How can we help our schools and colleges to learn and evolve (just as we expect students to learn and evolve)?

Summary of recommendations

Growing AIEd: How can we help the sector grow and scale? (pp. 27-30)

- Upstream public funding for AIEd R&D through Innovate UK. This funding should prioritise 'teacher-facing' and 'system-facing' tools, which are currently underexplored despite their high potential.
- Downstream support to help growth and adoption of the most promising AIEd tools in UK schools and colleges.

Improving AIEd: How can we improve the quality and effectiveness of AIEd tools? (pp. 31-34)

- Government should mobilise schools and colleges to form an EdTech test-bed to enable companies to test AIEd in real settings.
- Form a clear point of government leadership through which to coordinate support for AIEd.
- Closer collaboration between schools and colleges, AIEd companies and research – with companies providing clearer incentives for teachers to engage.

Governance of AIEd: How do we govern data, opportunities and challenges around AIEdd? (pp. 35-40)

- The Government should publicly declare an ambition to create a system of responsible education data sharing by 2030.
- The bodes responsible for governing AI and data should dedicate time and resource to considering the consequences of these technologies for education.
- When using AI for algorithmic decision making in education the ten questions described in Box 3 should be considered.

An Education System that Learns: How can we help our schools and colleges to learn and evolve (just as we expect students to learn and evolve)? (pp. 41-46)

- Public bodies responsible for exams across the UK should launch an 'AIEd Assessment Challenge Prize' to identify new methods for broadening the scope of assessment reliably.
- Government bodies overseeing accountability systems across the UK should explore how insights from AIEd assessment tools and human expertise can be combined as part of a 'collective intelligence' through pilots in schools and colleges.

Scope and methods

Artificial intelligence and education is a broad topic so to ensure focus we established the following scope for the project:

- **Education in schools and colleges**: Schools and colleges present particular opportunities and challenges for AIEd. However, it is worth noting that AIEd is likely to play a big role in other aspects of education – from online provision of adult learning to the expansion of the university sector around the world.
- **The future out to 2035**: To allow sufficient room for speculation without straying into science fiction.
- **Education in the UK**: Rather than think about AIEd in the huge range of education contexts found around the world, we've limited our scope to the UK where schools and colleges face a similar, although not identical, set of challenges.

For this research we combined a number of different methods, alongside desk research:

- **Futures**: We co-designed some scenarios (stories) through which we could explore the uncertainty around the future of AI and education in collaboration with a range of stakeholders (see Box 1).
- **Data mapping**: Analytics and visualisation of elements of public as well as private funding and investment in AIEd in the UK (see 'State of play: companies, funding and investment').
- **Survey**: Of parents to seek their views on the use of AI in education (see 'What do parents think of AIEd').
- **Conventional research methods**: Including desk research, interviews with experts and focus groups with school children.

Box 1: **Developing scenarios for the future of AIEd**

The future of AIEd is characterised by considerable uncertainty. This makes it an ideal topic to explore using futures research methods. The tool we used is called 'scenarios' - a set of short stories about possible futures. Rather than make predictions, scenarios systematically and transparently explore uncertainty, complexity and the longer term. As described in the scope we looked out to 2035.

At the beginning of the scenario building process we used desk research and interviews to identify important drivers of change - factors such as supply of teachers or public investment in education.

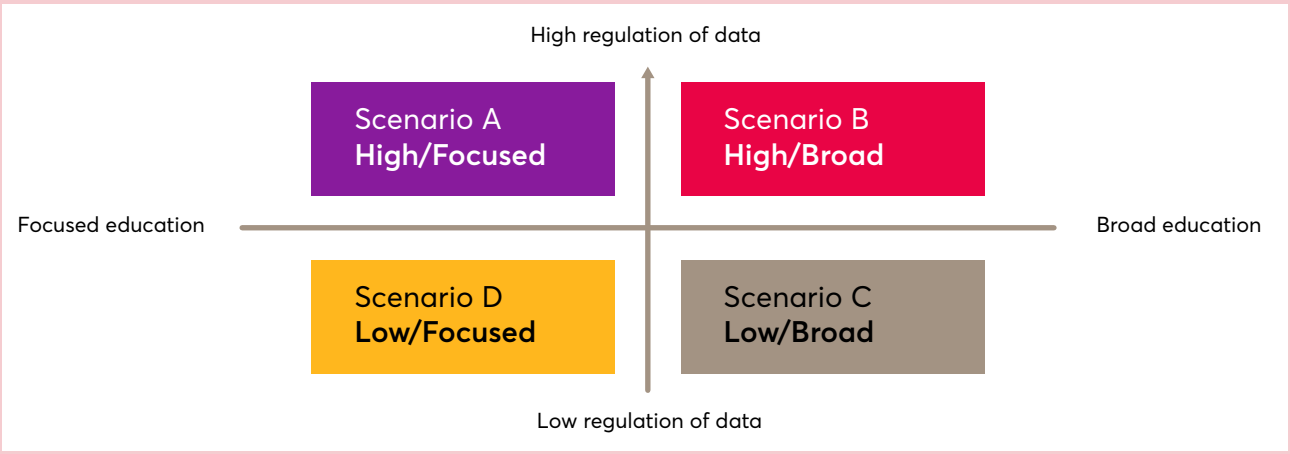
We identified two highly salient drivers to help focus our lines of inquiry (of course these are not the only drivers of change likely to affect the future of AIEd and that we discuss in this report):

Regulation and governance of data (low/high): How data will be regulated and governed is uncertain. Interestingly, both ends of the axis were found by to have 'positive' and 'negative' implications by our workshop participants. 'High' regulation and governance could either be seen as a symptom of government leadership stimulating innovation responsibly, or as restricting the ability of companies to experiment therefore stifling innovation.

Breadth of education (focused/broad): The breadth of education priorities may vary in the future (eg. from a focus on depth of knowledge in a small range of disciplines to placing value on a wider range of skills and competencies). Again, both ends of the axis were found to have 'positive' and 'negative' attributes. For example, a 'focused education' was seen as both offering the greatest immediate opportunities for AIEd to play a role in the classroom with the greatest evidence to support effectiveness of tools, and as limiting the 'life-readiness' of school leavers.

The drivers were arranged in a matrix around which we built four scenarios, see Figure 1.

Figure 1: Matrix of scenarios about the future of AIEd



The scenarios were co-designed and developed through two workshops that included teachers, school leaders, policy professionals, school IT professionals, entrepreneurs, small AIEd companies, large tech companies and academics. Diverse groups are important in scenario building to get different perspectives. This approach also helped bring in voices not often heard in current debate around AI and education. Additionally, the workshop allowed for an exploration of the scenarios from different perspectives, as well as thinking on how the challenges of these different futures might be managed and how their benefits could be realised. The four scenarios are annexed at the end of the report; their insights are woven into the narrative.

Part 1

AI and education today

In this section we explore the development and potential of AIEd in schools and colleges today.

1.1 Defining artificial intelligence

Definitions of AI vary. In this report, we use a broad definition of AI: **'Computers which perform cognitive tasks, usually associated with human minds, particularly learning and problem-solving.'**[4] There are several reasons why we have opted for a broad capability-based definition.

Firstly, 'artificial intelligence' does not describe a single technology. It is now used as a catchall term to describe a range of technologies, from an algorithm or app to machine learning and neural networks. This makes it quite tricky to define through a technology lens alone.

Secondly, the future of AI is uncertain. Since the rapid explosion of machine learning algorithms being used around the world, artificial intelligence and machine learning are sometimes used interchangeably. But there may well be developments in technology in the near future that support artificial intelligence in different ways. Defining the concept in terms of technology-type would limit the scope of our research.

Thirdly, we are interested in the consequences of technology for people. Our definition is rooted in the outcomes of artificial intelligence, not a particular technology type underpinning it.

Finally, although we are confident that large numbers of the AIEd tools in the market now do not harness some of the more complex technologies – such as neural networks or machine learning – it's extremely hard to know precisely what type of algorithms or other technologies specific products are driven by, particularly if those companies themselves self-identify as AIEd. By sticking with an outcome-based definition, we remain focused on the impact on users.

Having said that, we do not want to drift into the realms of science fiction – all case studies in this report describe AIEd tools being used in schools and colleges today. Where we suggest potential applications of AIEd to parts of our education system, we assume modest advances towards a 'narrow' AI – not the 'general' AI of science fiction.

Glossary of Common Terms

Machine learning

Machine learning is one (among many) ways to achieve AI. It is a computer system that learns from data, rather than one that just follows a set of rules. When provided with sufficient data, a machine learning algorithm can learn to make predictions or solve problems, such as identifying objects in pictures or winning at particular games, for example.[5]

Neural networks

Neural networks are a form of AI inspired by the structure of the human brain. They are made up of processing nodes (artificial neurons) which are connected in layers. Each node receives data from nodes above it, and passes this down to nodes below it. Data has 'weight' attached to it by the nodes, which attribute value to the data. If the data doesn't pass a certain threshold, it is not passed on.

Big data

Big data refers to data sets that are too large and complicated to be analysed using simple algorithms and require more complex data analytics or machine learning to understand.

Narrow AI

An AI system that can do one human task.

General AI

An AI system that can do many tasks as well as a human. General AI does not yet exist, and is unlikely to exist in the near future.

1.2 Three categories of AIEd

There are a wide range of AIEd tools being used in our schools and colleges today. We have grouped tools in three broad categories (with the recognition that some products combine features from multiple categories): learner-facing, teacher-facing and system-facing.

1. Learner-facing AIEd

When most of us think of AIEd, we think of learning-facing tools: software that students use to receive and understand new information, which respond to an individual student's needs. Learner-facing tools are often referred to as 'intelligent tutoring systems', or 'adaptive', 'personalised' or 'differentiated' learning platforms, and have capabilities like:

- Curating and staggering learning materials based on a student's needs.
- Diagnosing strengths, weaknesses or gaps in a student's knowledge.
- Providing automated feedback.
- Facilitating collaboration between learners.

Of course, sophisticated AI is not required to do all of these tasks (human teachers have always been 'adaptive') and rules-based computer programmes have offered a form of adaptive learning for some time ('if student completes Question A, move them to Question B'). Dr Wayne Holmes, the Open University's lead for AI in education, observes that:

"Many current AIEd tools are simply variations on adaptive learning platforms."[6]

However, advances in machine learning raise the possibility of a more sophisticated version – rather than having students follow one of a static set of pathways designed by a human, machine learning algorithms try to pick up strengths, weaknesses and gaps in knowledge to build on and scaffold learning appropriately, with the aim of providing a greatly increased level of 'personalisation'.

Learner-facing tools, such as CENTURY (see Case study 1) or Mathigon,[7] benefit students by offering a move away from a 'one-size-fits-all' approach to learning, enabling students to learn at their own pace or tailor learning materials to their own interests. Such tools are used by learners in the classroom, particularly in large mixed-ability classes, where teaching through a single human offering direct instruction may be more difficult. They are also used to carry out homework, or to facilitate flipped learning, where students familiarise themselves with new concepts via the intelligent tutoring system outside the classroom, with classroom time used to develop understanding of those concepts.

Case study 1: **CENTURY**[8]

Learner-facing and teacher-facing

CENTURY is an adaptive learning platform that uses AI to make decisions about the best pathway through learning materials for a specific student. As students learn, answer formative assessments and complete diagnostics tests, the platform's AI gauges their strengths, weaknesses and gaps in knowledge. This enables the platform to provide appropriate scaffolding to support learning.

CENTURY also supports teachers. Its built-in assessment tools can reduce the amount of time spent marking, while insights from data analytics provide insights for teachers on student and class progress. The result is that often teachers are able to provide more effective individual support to those students who need it.

As Charlie Lécuyer, Learning Technologist at Basingstoke College of Technology, said:

"Students are empowered to take responsibility for their own learning through their use of the platform - gaining insights into their own strengths and areas for improvement - whilst teachers are able to utilise time and resources towards one-to-one interventions, rather than blanket delivery."[9]

2. Teacher-facing AIEd

Teacher-facing AIEd can help teachers to reduce their workload, gain insights about students and innovate in their classroom. It supports teachers through a combination of capabilities including:

- Automating tasks (such as assessment, plagiarism detection, administration or feedback).
- Providing insights about the progress of a student or class.
- Helping teachers to innovate and experiment (for example: facilitating different methods of teaching or helping teachers organise students into small groups based on shared characteristics).

Teacher-facing AIEd presents hugely exciting opportunities to evolve the role of the teacher. For example, time saved through the automation of tasks could free up a teacher's time to invest in other aspects of teaching. Insights gained about students' progress could enable

teachers to target their attention more effectively. Virtual teaching assistants could enable teachers to experiment and innovate in their classroom - perhaps through facilitating small collaborative groups, or by planning class seating plans that reduce behavioural problems (see 'Case study 2: ClassCharts').

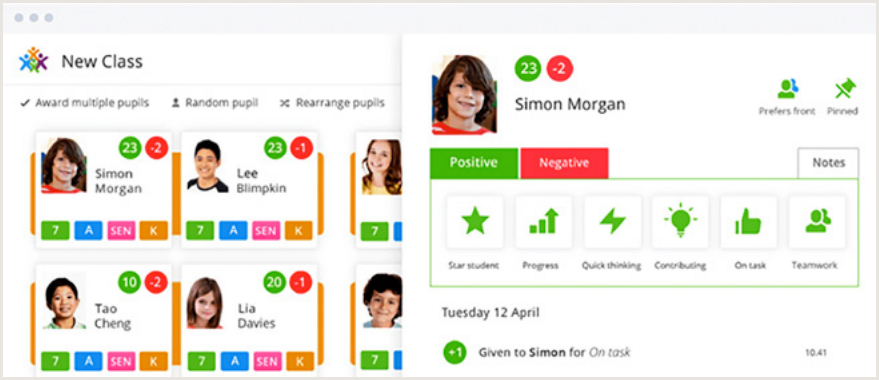
Although AIEd is often seen as seeking to replace teachers (and some CEOs of technology companies are quite open about this aim), our research suggests that this is neither possible (in the foreseeable future) nor desirable. Instead, as Rose Luckin and colleagues note, *"It is teachers who will be the orchestrators of when and how to use AIEd tools."*[10]

Case study 2: **ClassCharts**

Teacher-facing

ClassCharts is an automated seating plan tool and behaviour management software, driven by artificial intelligence. It aims to save teachers time and reduce workload through data rich seating plans that reduce behaviour problems.

The ClassCharts platform allows teachers to monitor pupils' achievements and behaviour, while the ClassCharts technology tracks how pupils influence each other. This allows teachers to create seating charts which are optimised according to pupils' behaviour. ClassCharts was designed by a former teacher.



ClassCharts screenshot. Image: ClassCharts

3. System-facing AIEd

System-facing AIEd helps make or inform decisions made by those managing and administrating schools or our education system as a whole. This is the least widespread category of AIEd, with the fewest number of existing tools identified as part of this research. Often, but not always, system-facing tools require sharing of data between schools and colleges (rather than just within a single organisation) which may in part explain the relative shortage of tools. System-facing tools are used for a wider range of tasks than educator or learner facing tools, with applications ranging from organising timetables to predicting inspections.

The response to this underdeveloped category of AIEd from interviewees working in schools and colleges was positive. As Debbie Penglis, Director of Real World Learning and Partnerships at School 21, said:

"The system-facing tools are particularly interesting as they could help liberate teachers."[11]

Case study 3: **Targeting school inspections**

System-facing

Following a trial run by the Behavioural Insights Team in 2017, Ofsted has been using supervised machine learning to identify which schools should be prioritised for a full school inspection since the Summer of 2018. This involves training an algorithm which uses datasets from across many schools. Using progress and attainment data from the DfE, school workforce census data, and parental view responses, the AIEd is able to make predictions about a schools' performance in an inspection.

This prediction is not used to inform full inspections, but Ofsted claim that AI will 'ensure that our approach to inspection is proportionate and to focus our efforts where they can have the greatest impact.'[12]

1.3 The promise and potential of AIEd

We have explored the types of AIEd tools being used today. But AIEd has huge potential to both address the challenges we face in our schools and colleges today, and ask profound questions about what we would like them to look like in the future.

Certainly, AIEd can accelerate and amplify characteristics of our education system. However, some argue that it may also bring opportunities for a more radical restructuring of education provision – bringing on a *Fourth Education Revolution*.[13]

As our 'Four Scenarios for Schools in 2035' illustrate (see Annex), although the potential for AI to bring change is very high, the exact direction that change will take is highly uncertain. To a large extent that will be dependent on our priorities as we grow, improve and govern AIEd (discussed in Part Two of this report). Rather than make predictions, our case for AIEd's potential is grounded in 'Five wicked challenges' our schools and colleges face today that AIEd is positioned to change.

Five wicked challenges

1. **Teachers burdened with excessive workload, affecting wellbeing, retention and recruitment.**

   Teacher workload is a growing crisis in the UK. Excessive administration is leaving teachers with less time to do what they are trained to do: devote time and expertise to teaching young people. Eighty four per cent of respondents to NASUWT's 2017 survey identified workload as their number one concern.[14]

   Excessive workload impacts on wellbeing, retention and recruitment, for example:

   - Teaching is one of three professions with the highest reports of stress and depression according to the 2017/18 Labour Force Survey.[15]
   - In 2016-17, 9.9 per cent of teachers in England left the profession.[16]
   - In December 2018, the government failed to reach its target for recruitment for secondary schools in England for the sixth year running. In some subjects, this shortfall was dramatic. For example, only 47 per cent of the government's target for recruiting new physics teachers was achieved.[17]

   Used effectively, AIEd can automate tasks that are a drain on teachers' time, from the relatively simple (such as data administration) to the more complex (see Case study 6: Essay marking in China).

   In England, there are indications that the government are keen to support teacher-facing tools that reduce administration. Damian Hinds, Secretary of State for Education, recently said:

   "Teachers should not have to email outside of office hours and should instead embrace innovative technology such as AI to help to reduce their workload."[18]

Case Study 4: **'Ada' and Bolton College**[19]

Student and Teacher-Facing

Bolton College, a further education college in Greater Manchester, have developed 'Ada' - a digital assistant serving their college community. 'Ada' is built using IBM Watson (a computer system that can answer questions) and responds to student enquiries such as, 'What is the hand-in date for my assignment?' or 'When does the library close today?'. For queries 'Ada' is unable to answer, it uses natural language processing to detect the type of query and redirect it to the most appropriate member of staff.

The next stages of the project include plans to help teachers trigger actions using 'Ada' – from messaging specific groups of students, to comparing student performance cards.

2. **'One-size-fits-all' learning, with inflexible learning pathways.**

   The practical constraints of our education system (the number of pupils, buildings, classrooms, teachers, etc.) have limited the ability of our schools and colleges to offer support to students that is personalised to their needs. These needs can range from the pace of learning to social or emotional needs.

   Imagine a classroom in which AIEd adaptive learning platforms provide the opportunity to retain the benefits of learning with a class cohort (social bonds and skills, motivation, learning from the experiences of others, and many more) and those of personalised instruction (the benefits of one-to-one tuition are well documented[20]). As Anthony Seldon and Oladimeji Abidoye write:

   "The 'Holy Grail' would be for every student to have the benefits of personalised tuition for at least part of every lesson, which would ensure that their own needs were individually addressed, and then to have time for group work, when the student can offer contributions and listen to those made by fellow students and the teacher."[21]

3. **Narrow assessment inhibiting teaching and learning.**

   Currently, we assess a narrow range of abilities in our school systems through informal tests and more formal exams. Education should be about more than just passing exams, but our exam-led accountability system asks teachers and schools to prioritise exams, often at the expense of students' other requirements – whether through a narrowing of the curriculum, excluding poorly-performing students, or 'teaching to the test'.

   A narrow focus on assessment also reduces the innovation capacity of highly-trained teachers. As Debbie Penglis of School 21 argues:

   "High-stakes exams and accountability means the system is geared against experimentation, people don't like to take risks under in these circumstances."[22]

   The implications of AIEd for assessment and accountability are discussed in more detail in 'An education system that learns'. While AIEd tools are a long way off being able to assess the whole spectrum of skills and attributes that we would wish to develop in young people - from creativity and wellbeing to problem solving and collaboration - there are promising signs. But importantly, AIEd can facilitate more frequent formative assessment (without adding to teacher workload) and provide more insights into what is actually going on in classrooms (not just test scores).

4. **Difficulty of sharing insights between schools and colleges.**

   In many other sectors, digital transformation has brought about positive benefits through a network effect resulting from a larger and more connected system. While schools that are part of larger multi-academy trusts or chains of schools and colleges do manage to benefit from those close relationships, the majority do not.

   However, the ability to easily gain and share insights – such as best teaching practice (see Case study 5, Third Space Learning) or strategies to tackle behaviour problems of particular groups of students – between individual schools and colleges could develop a network effect.

   There are no technological barriers preventing the development of system-facing AI capable of generating these insights; however, there are significant logistical barriers. For example, the difficulty of data-sharing between schools and colleges which is explored further in the section 'Governance of AIEd' and our scenarios (see Annex). With appropriate systems for collecting and pooling the relevant data, a genuine network effect could become a reality.

Case study 5: **Third Space Learning**

System-facing

Third Space Learning provides one-to-one tuition via the internet by connecting students in classrooms with teachers around the world. Students and tutors communicate via a shared screen and headsets. In turn, Third Space Learning collect significant amounts of data, such as recordings of each tuition session, student assessments, and feedback from students and parents.

Since partnering with the UCL Knowledge Lab in 2015, Third Space Learning have been using AI to make sense of this data.[23] Their machine learning algorithm is able to identify patterns around positive teaching outcomes, providing insights into how to optimise teaching interactions. These insights are shared with tutors working across many schools to promote best practice.

5. **Inconsistency of education provision and lack of social mobility**

   The quality of education provision around the UK varies hugely, which limits our education system's ability to increase social mobility. For example, as the Social Mobility Commission reported in 2017, 'Disadvantaged children in the North of England have substantially poorer access to quality secondary schools than in other English regions.'[24]

   AIEd offers opportunities to – at scale – share best practice, improve the quality of teaching and increase access to quality learning materials. For example, children from advantaged backgrounds are currently disproportionately more likely to access a private tutor. Learning-facing AIEd could offer an alternative way to access tuition outside school (assuming the cost of such platforms falls, or is subsidised in some way). However, as discussed in the governance section, under certain circumstances AIEd can drive inequality and lack of social mobility. This uncertainty underlines the importance of engaging with the issue of AIEd now.

1.4 The state of play: companies, funding and investment

A rapid analysis of available data about the AIEd sector has enabled us to build a picture of the 'state of play' of AIEd in the UK. AIEd remains a small – but growing – field, with some interesting characteristics that are described below.

Box 2: An overview of the method behind our data analysis

To better understand the AIEd landscape we integrated data analytics and human judgement. Our data sources were Crunchbase, a platform for finding information on private and public companies, and Gateway to Research, a portal for much UK publicly funded research and innovation. This allowed insights into both private and public investment. In both cases we looked at the UK.

AIEd can be described by different people and organisations in different ways so our first step was to create a list of search terms. We expanded this list with additional relevant terms using machine learning and then used text analytics to identify companies and research grants relevant to AIEd. Inevitably some of the hits concerned companies or grants that were not relevant. The next step was to manually go through all of the hits to weed those out. This human-in-the-loop approach enabled us to improve the model's performance and get a refined list of hits which forms the basis of the analysis and visualisations in this section.

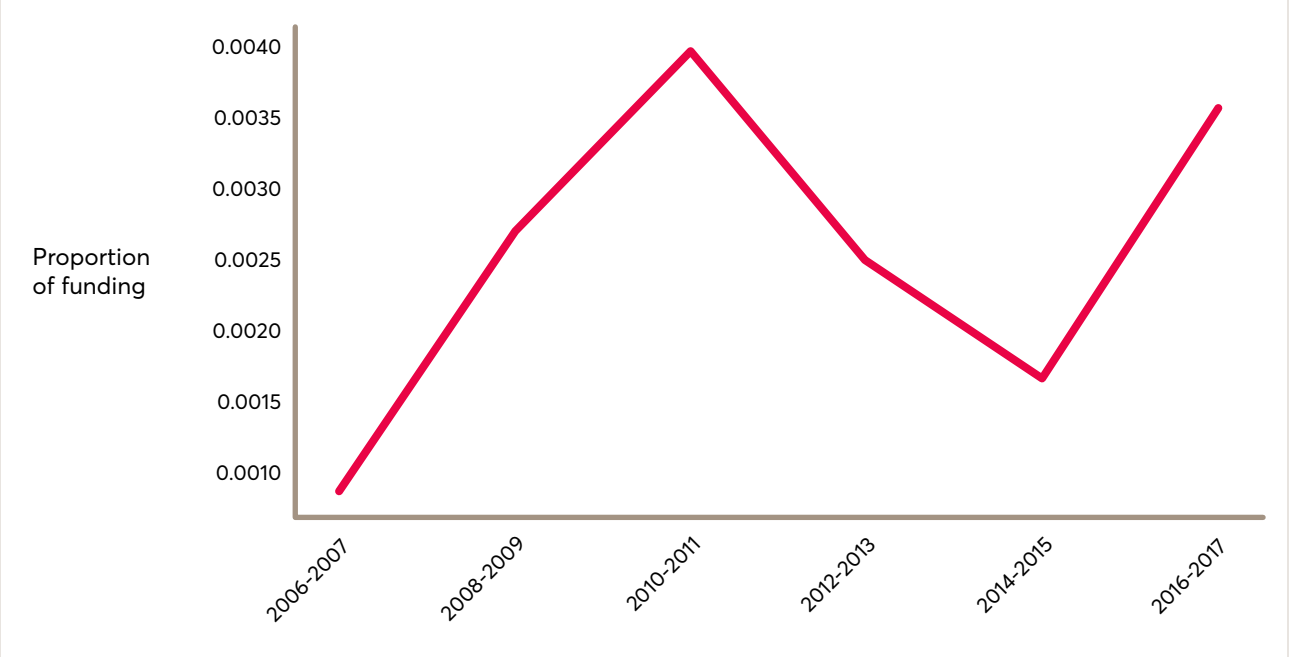
Our approach does have limitations. For instance, despite being a go-to database for technology ventures, not all UK companies are registered on Crunchbase, nor are they obliged to disclose their funding. This might create representation issues, meaning that the data used does not provide a complete view of the UK AI ecosystem. Furthermore, the way businesses use the term 'artificial intelligence' is tricky, and at times contested, even by the tech community. As such, while companies may tag their venture as an AI company, we cannot be certain that they fit with our definition. We are more confident about public funding as Gateway to Research covers a larger proportion of this sort of investment.

Despite the constraints, this approach provides granular data and a better understanding of the state of AIEd in the UK. When used in combination with other sources these insights provide useful guidance for decision makers.

Limited public funding and the growth of private investment

Overall private investment in AIEd has grown (but fluctuated in part due to a few big deals) since 2006/2007, totalling around £112 million between 2006/2007 and 2016/2017 in the 69 companies identified on Crunchbase. The proportion of funding for AIEd companies of all UK companies listed on Crunchbase is given in Figure 2. However, we expect that the total amount of private investment is much higher, given that not all companies are listed on Crunchbase and of those only some will list their investment.

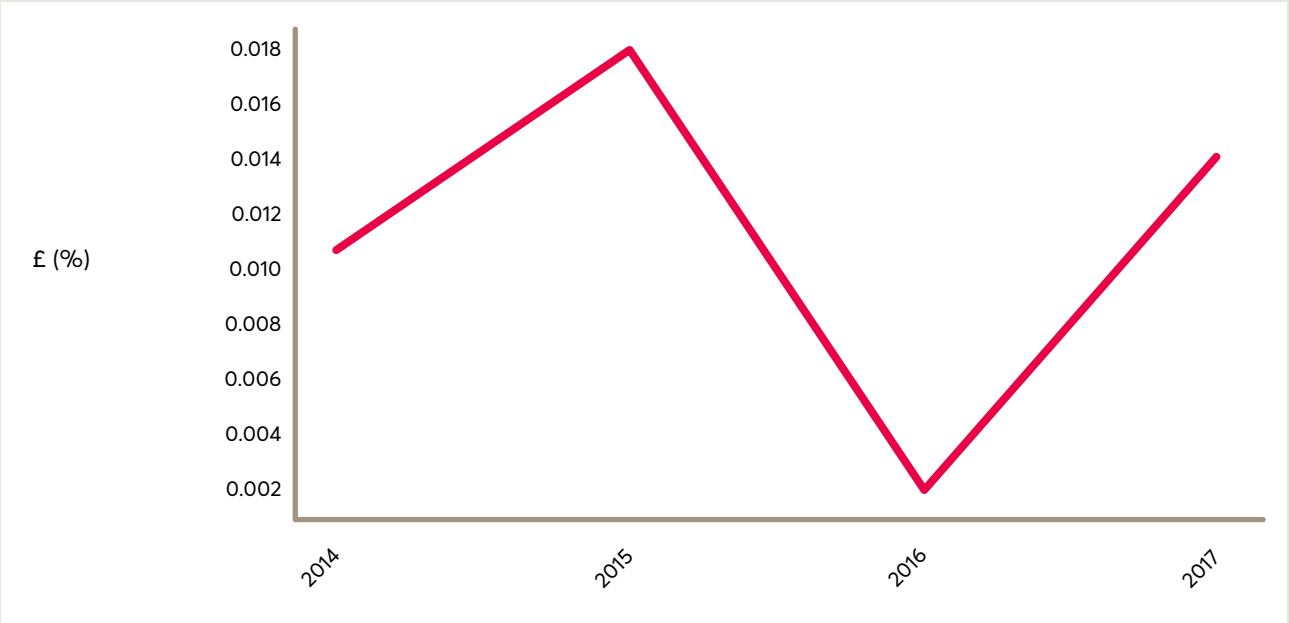
Figure 2: Proportion of funding for AIEd companies of all UK companies listed on Crunchbase



Source: The analysis of Konstantinos Stathoulopoulos in the innovation mapping team at Nesta.

However, public investment remains proportionately small. Between 2014 and 2017 public investment totalled £1 million in nine projects. This is relatively modest when compared to the up to £50 million investment announced for AI and digital systems in healthcare in 2018 by the UK Government.[25] The proportion of Research Gateway grants funding for AIEd by value 2014-2017 is given in Figure 3.

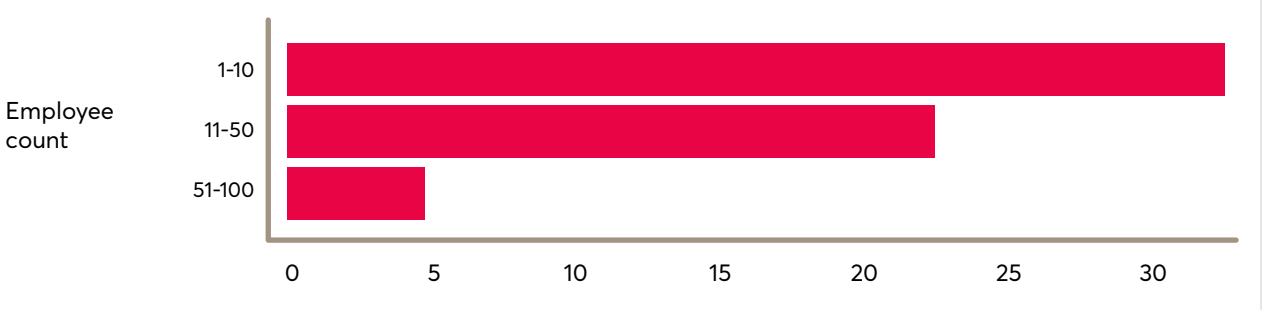
Figure 3: Proportion of Gateway to Research grants for AIEd by value 2014-2017



Source: The analysis of Konstantinos Stathoulopoulos in the innovation mapping team at Nesta.

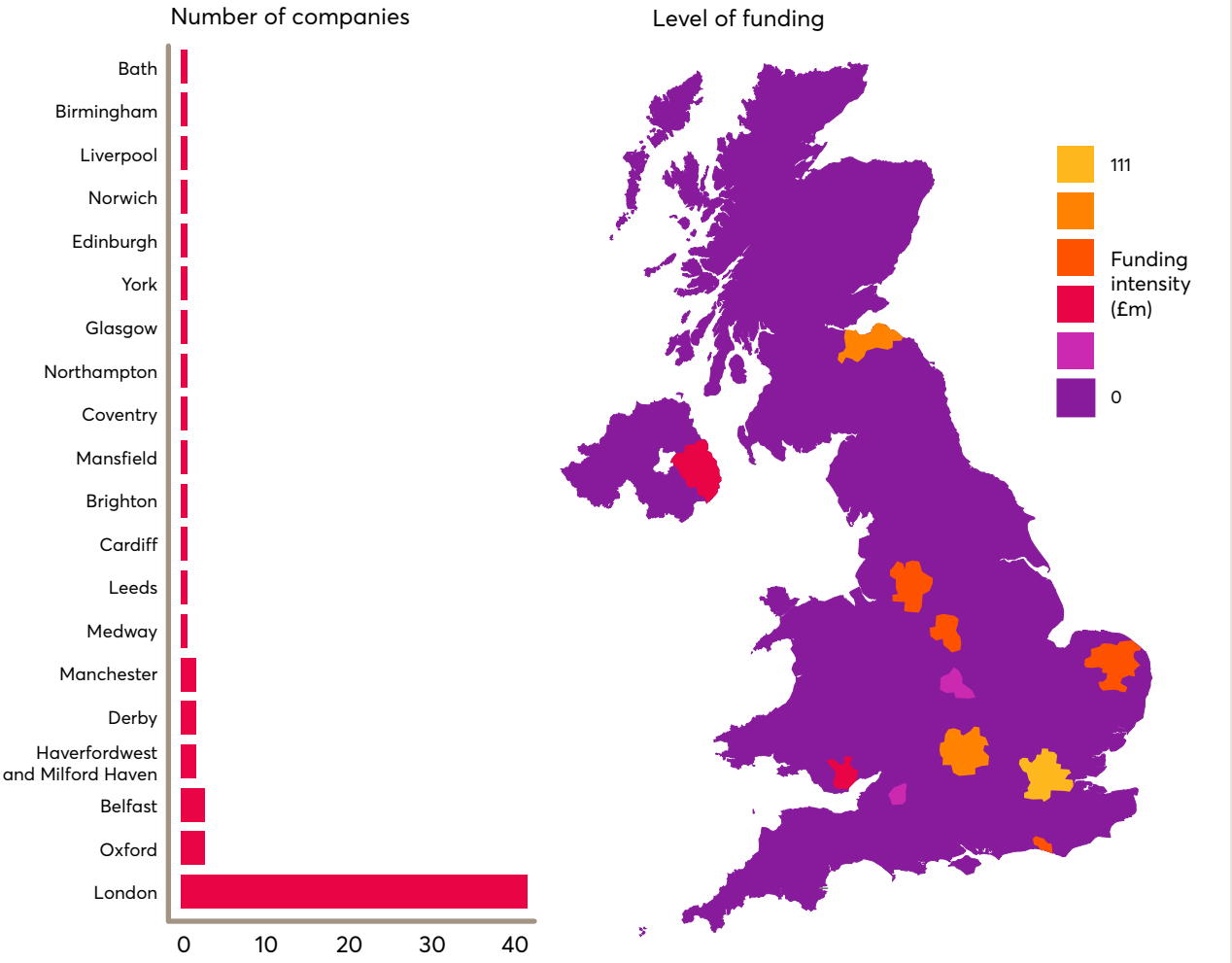
Of the 69 companies identified the majority were micro or small businesses employing one to ten or 11 to 50 people. The overwhelming majority were located in London, see Figures 4 and 5. Public investment is a little more evenly spread with London, Guildford and Aldershot and Bristol with the largest number of projects, see Figure 6.

Figure 4: Number of UK AIEd companies on Crunchbase by employee count



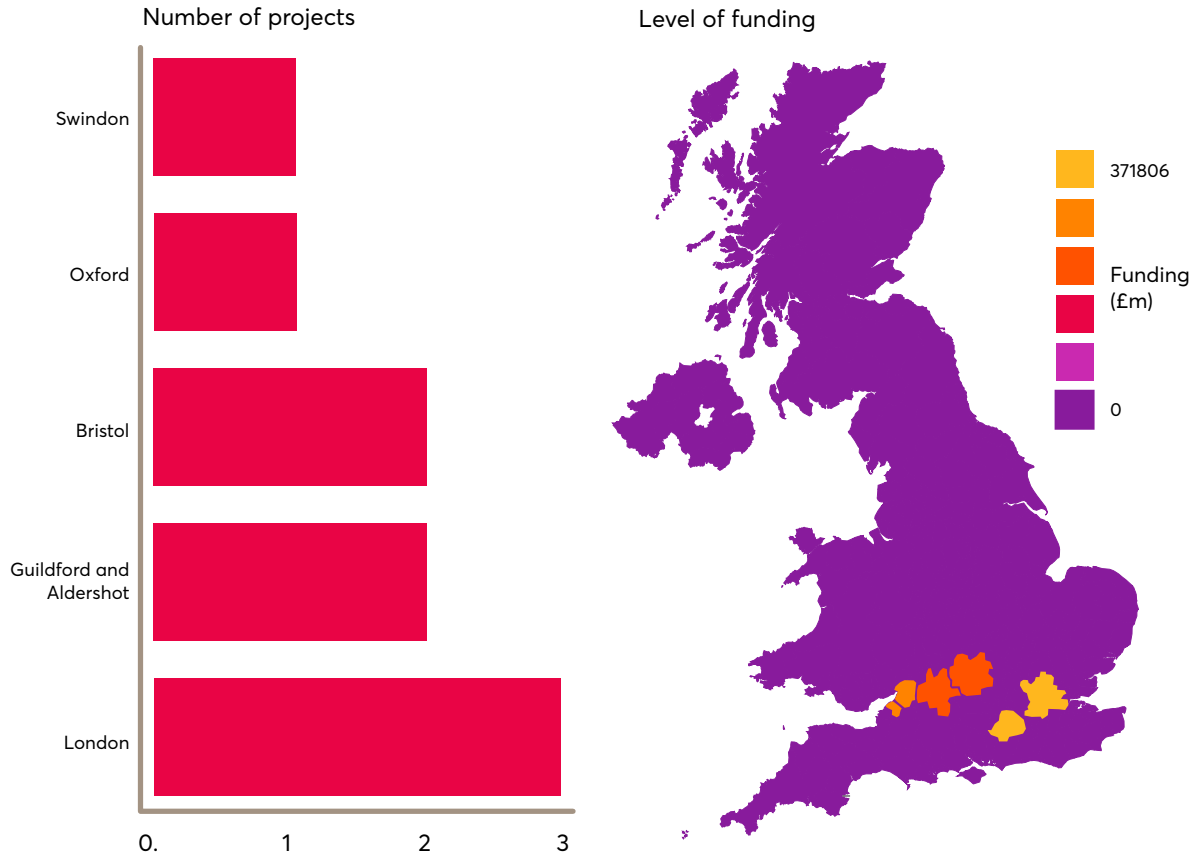
Source: The analysis of Konstantinos Stathoulopoulos in the innovation mapping team at Nesta.

Figure 5: Number of UK AIEd companies on Curnchbase by locality



Source: The analysis of Konstantinos Stathoulopoulos in the innovation mapping team at Nesta.

Figure 6: Number of UK AIEd projects on Gateway to Research by locality



Source: The analysis of Konstantinos Stathoulopoulos in the innovation mapping team at Nesta.

Investment focused on learner-facing tools

Although the AIEd sector remains small, AIEd activity and funding is skewed towards learner-facing tools, rather than educator or system-facing tools. Of the 69 AIEd companies identified during this research, 52 were 'learner-facing', with only 14 'educator-facing' and three 'system-facing' tools. This bias can be traced through the history of AIEd research, with an overwhelming focus on 'creating systems that are as effective as human on-to-one tutoring'[26] – seen by some as the 'gold standard' of education since the publication of Harold Bloom's 'two-sigma problem' in 1984.[27] In some cases, where learner-facing tools have been introduced in schools, students have gone on strike to protest what they felt was a computer replacing their teacher.[28, 29]

Delving into AEd companies

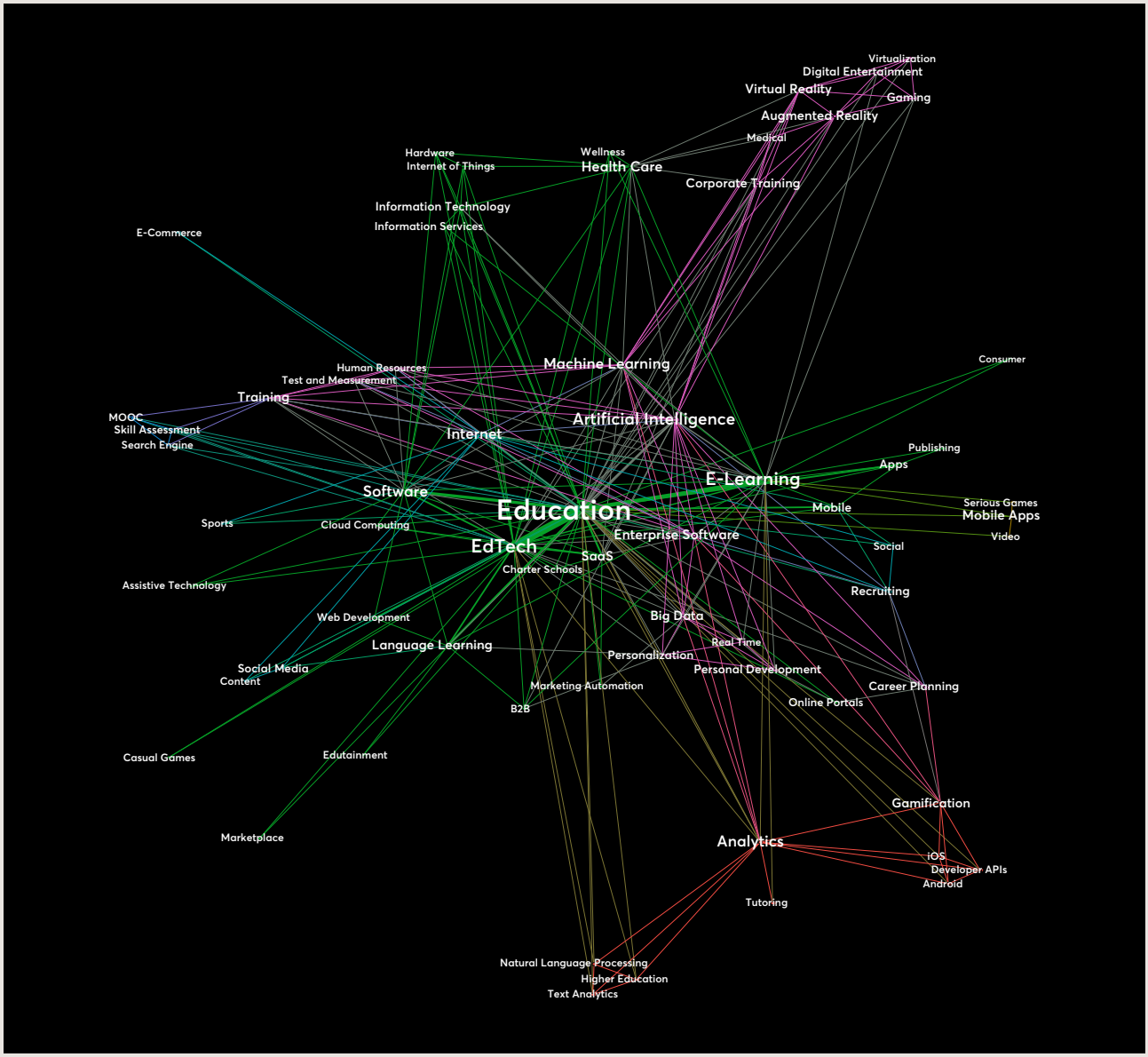
We also analysed how else the AIEd companies we identified described themselves in an attempt to dig deeper into this industry. When registering on Crunchbase, companies adopt various pre-defined labels such as 'education', 'e-learning' and 'software.' These can be used to show relationships between companies that label themselves in different ways. A relationship map of the AIEd companies we identified is in Figure 7. The figure shows the co-occurrence network of Crunchbase categories the AIEd companies have used. For example, if a company has used two categories, artificial intelligence and health, a link between them will be drawn.

The most linked categories appear at the centre of the graph and are related to Education and AI since the co-occurrence network was created using the AIEd subset of the data. Three interesting features of the map reveal associations with:

- Other aspects of education, such as corporate training and higher education.
- Other digital technologies, such as virtual and augmented reality.
- Other sectors, such as healthcare and sport.

This shows that companies involved in AIEd in schools and colleges are part of a wider ecosystem that touches on other markets and technologies. For example, investment in supporting AIEd in the online adult learning market is likely to have positive impact on AIEd in schools.

Figure 7: Relationship map of co-occurrence network of Crunchbase categories the AIEd companies have used



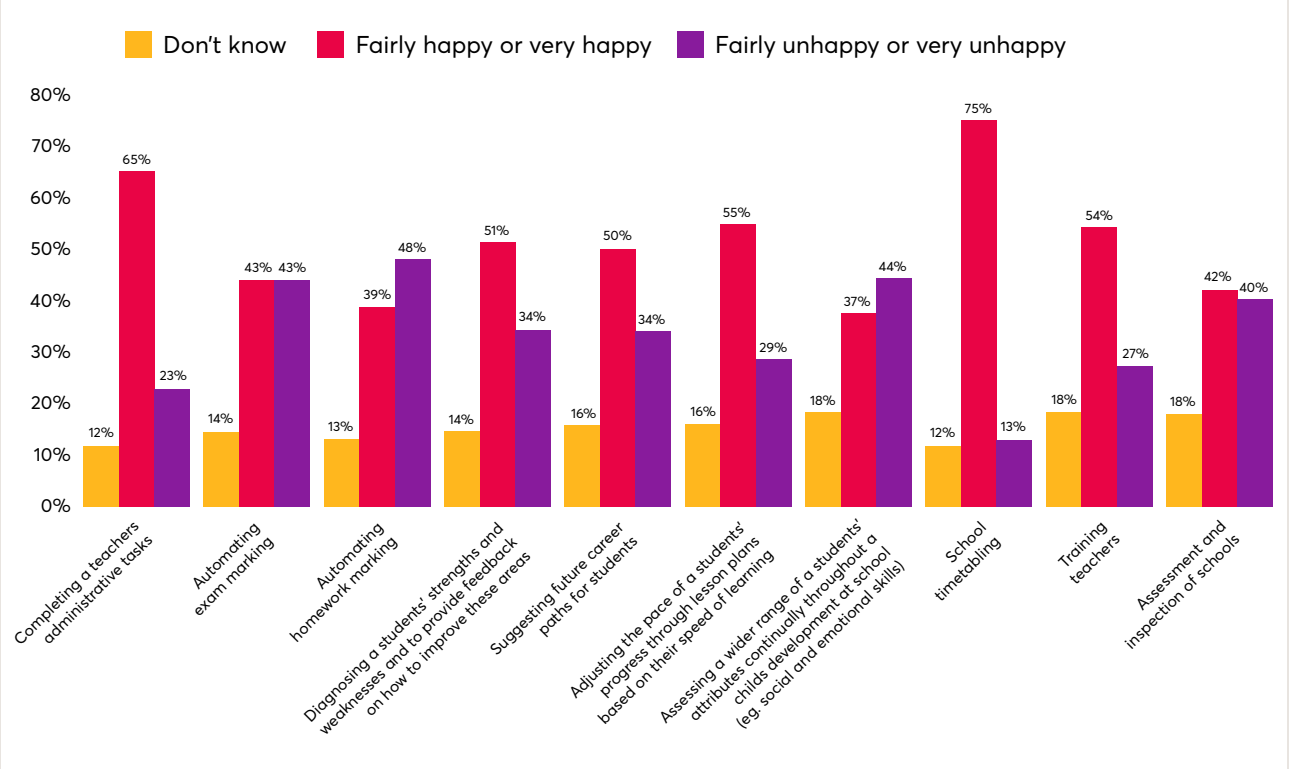
Source: The analysis of Konstantinos Stathoulopoulos in the innovation mapping team at Nesta.

1.5 What do parents think of AIEd?

To obtain the perspective of parents on AI and education we commissioned YouGov to undertake a survey of 1225 GB parents with children aged 18 and under.[30]

The survey showed (see Figure 8) that a large proportion of parents surveyed would feel fairly happy or very happy for AI to be used for a number of different educational purposes such as school timetabling (75 per cent), completing a teacher's administrative tasks (65 per cent) and adjusting the pace of a student's progress through lesson plans based on their speed of learning (55 per cent). There was greater scepticism about other tasks such as automated homework marking where 48 per cent of parents with children aged 18 and under would feel fairly unhappy or very unhappy with AI having a role.

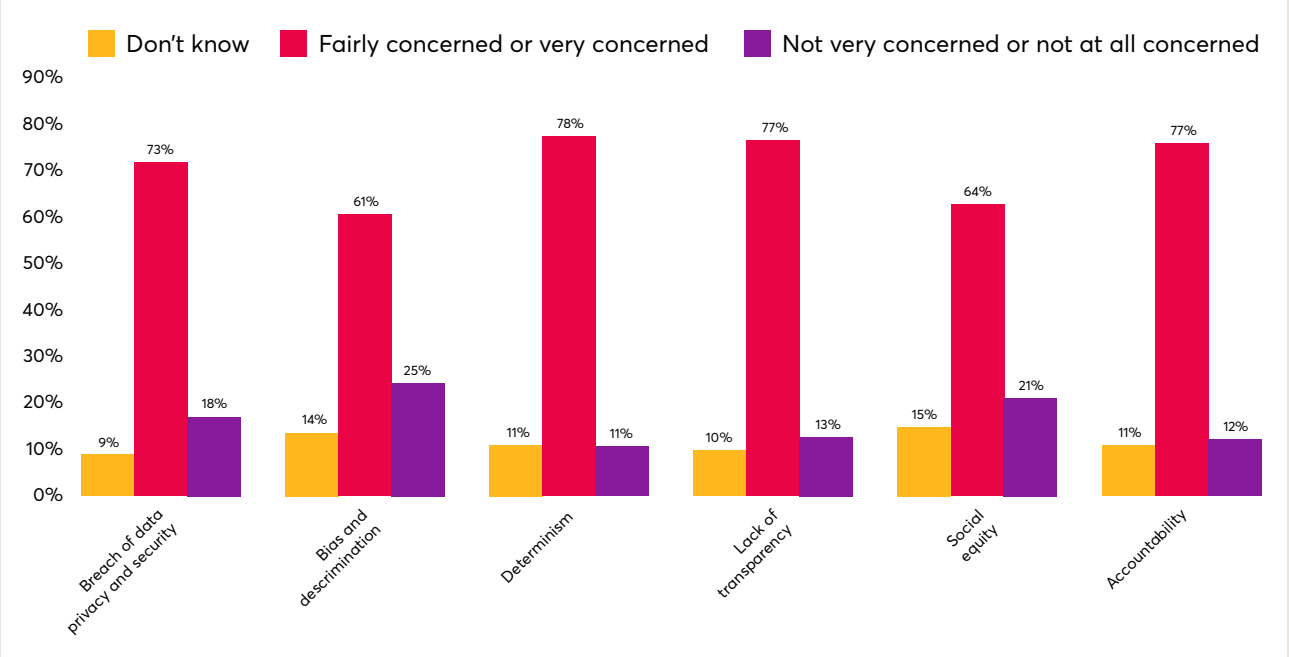
Figure 8: Happiness or unhappiness of parents surveyed on use of AI in their children's school for certain tasks



Source: YouGov. AI in schools. 2019. Survey commissioned by Nesta.

Despite the support for the use of AI in education for some tasks, parents with children aged 18 and under seem to be concerned about a number of consequences of these technologies, particularly determinism (78 per cent), breaches of data privacy and security (73 per cent), a lack of transparency (77 per cent), and accountability (77 per cent), see Figure 9.

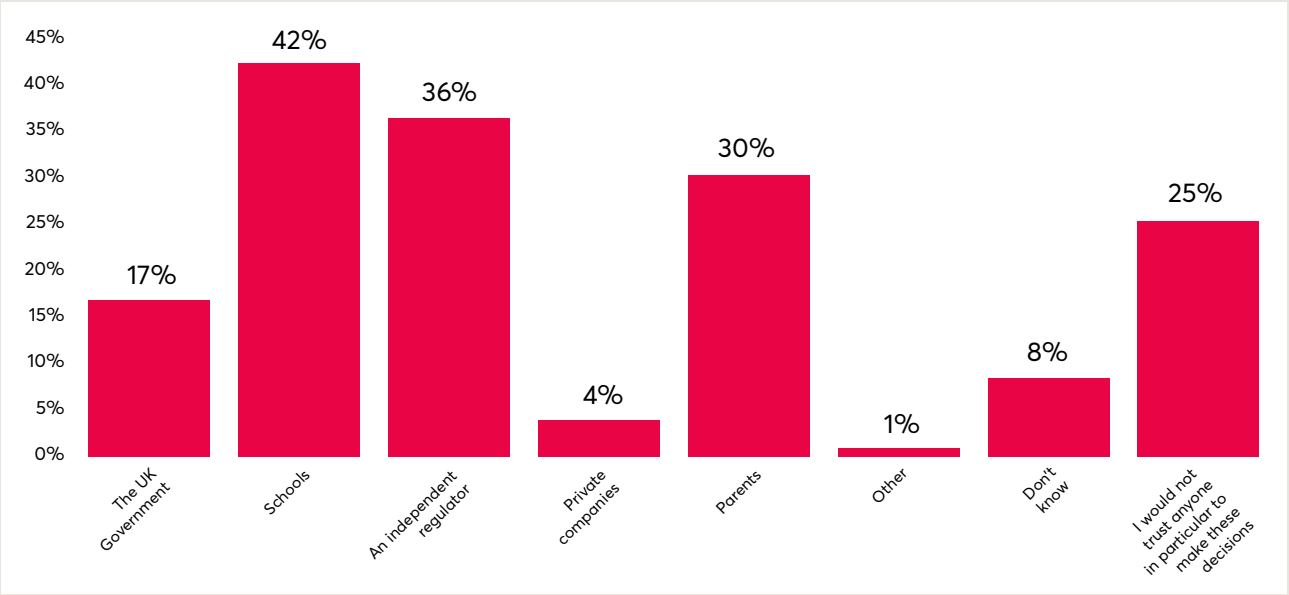
Figure 9: Concern of parents surveyed about potential consequences of the use of AI in UK schools



Source: YouGov. AI in schools. 2019. Survey commissioned by Nesta.

On the issue of collecting and sharing their child's personal data, which is important to many forms of AI, 42 per cent of the parents most trusted schools to make decisions about this, followed by an independent regulator (36 per cent) and parents themselves (30 per cent), see Figure 10.

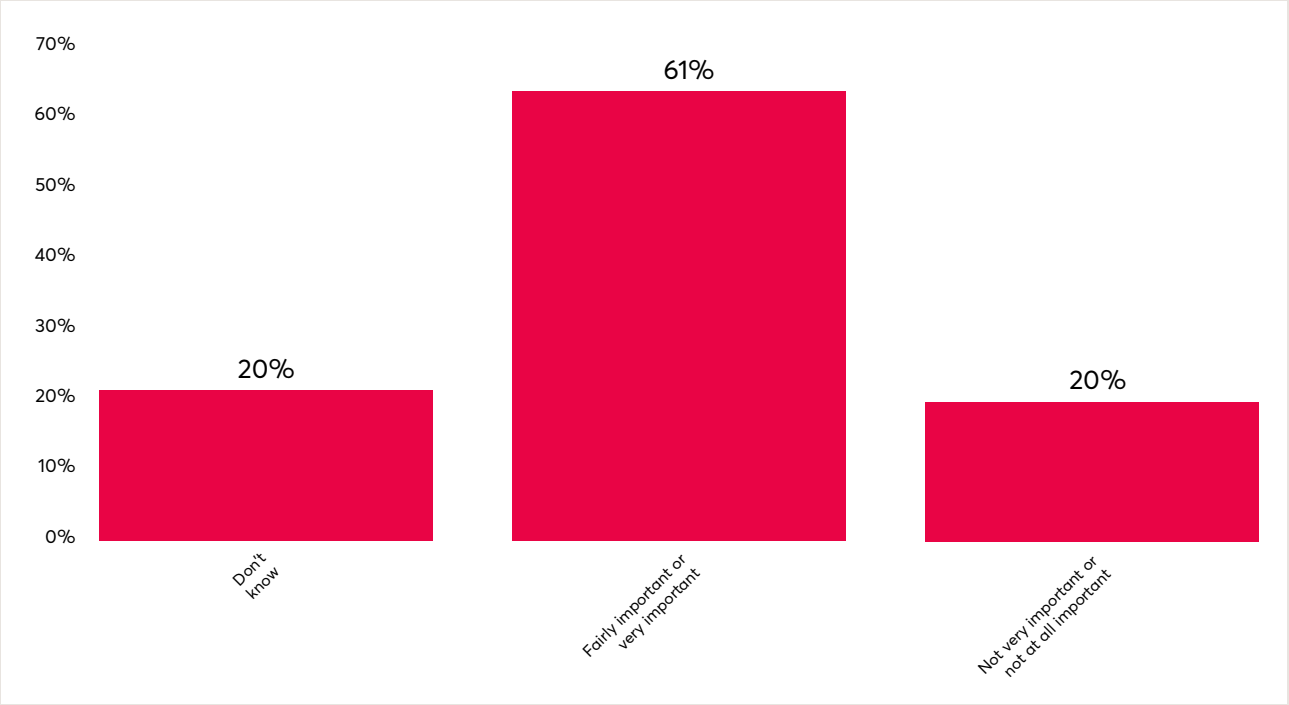
Figure 10: Trust of parents surveyed in different groups to collect and share their child's personal data



Source: YouGov. AI in schools. 2019. Survey commissioned by Nesta.

Irrespective of their concerns, a clear majority of parents with children aged 18 and under (61 per cent) thought that AI would be fairly important or very important in the running of the school classroom in 2035, see Figure 11.

Figure 11: Views of parents surveyed on whether AI and education will be important in schools in 2035



Source: YouGov. AI in schools. 2019. Survey commissioned by Nesta.

Part 2

AI and education tomorrow

Part 1 has outlined the development of AIEd in schools and colleges today, and made a case for its potential. In this section we look to the future and outline actions to maximise the benefit and minimise the risk of AIEd.

2.1 Growing the AIEd sector

Despite high potential to address some of our education system's most stubborn problems (see 'The promise and potential of AIEd'), the AIEd sector is underdeveloped. This section outlines how to grow the AIEd field, making a case for government intervention, and describes how investment can be used to broaden the range of AIEd tools in the market, particularly to unlock the potential of teacher-facing and system-facing tools.

AIEd is a nascent field. Our research identified only 69 AIEd companies listed on Crunchbase. Of those companies, the majority were micro or small, employing between one to ten and 11 to 50 staff. If AIEd is to evolve from a cottage-industry and fulfill its potential, it needs support.

The case for public investment and government support to grow AIEd

The potential for AIEd to tackle some of the school system's biggest challenges that we have already outlined is a strong incentive to support the development of new AIEd tools, and help existing proven products to grow their impact. However, there are three further arguments that make a case for the specific importance of public investment and government support:

1. Demand and supply-side market failures preventing development and maturity of AIEd

The education sector presents unique challenges for companies bringing products to market, with both demand and supply side failures preventing the maturity and development of tools. These challenges are difficult to overcome without public investment and government support.

AIEd market challenges:

- **Cost of entry**: Complex technologies used in many AIEd products require high upfront R&D costs.

  "Building AI is expensive; it is far more than web development, and requires data scientists and data engineers."[31]
  Priya Lakhani, Founder and CEO, Century Tech

- **Fragmented marketplace and complicated system**: Other markets present easier opportunities for companies to generate a return on AI investment. Public investment in AIEd can incentivise development of AIEd products, support growth of existing AIEd products and pivot technology companies to the education market and particular customer groups.
- **Pressure on school budgets**: Shrinking budgets reduce the ability of schools to purchase AIEd. The latest figures from the Institute of Financial Studies (IFS) found total school spending decreased by 8 per cent between 2017-18, driven by 55 per cent cut to spending on services by local authorities, and over 20 per cent cut on sixth-form funding. Education for 16-18 year olds has lost out most from education spending cuts over the last 25 years. At the same time, school costs have risen faster than inflation since 2015-16.[32]

- **Lack of single point of government leadership**: EdTech and AIEd leadership used to fall under the remit of the British Educational Communications and Technology Agency (Becta). Since government funding was discontinued in 2011, responsibility for AIEd has been split between the Department for Education and the Department for Business, Energy and Industrial Strategy.
- **Lost learning**: Siloed research funding and difficult routes to market prevents some of the best AIEd ideas from developing beyond the research laboratory or lecture theatre to reach maturity.
- **Education expertise**: Successful development and implementation of AIEd in real contexts requires both technological expertise and education expertise. Without government leadership, there are concerns that technology companies will not prioritise education expertise, undermining the quality of tools and trust of AIEd.[33]
- **Scaling and growth**: Alongside stimulating new entrants, support is needed to help promising existing ideas to grow and scale.[34]

2. The UK's competitive advantage in AIEd

The EdTech sector as a whole (of which AIEd is part) is set to grow globally to $252 billion by 2020.[35] The UK EdTech sector, home to around a quarter of Europe's EdTech businesses, is the largest in Europe[36] (in part thanks to its long history of pioneering education technology – for example through initiatives from the Open University[37] and the BBC[38]). The UK is also a global hub for artificial intelligence development.

These factors gives the UK a strong competitive advantage to capitalise on the benefits of a growing AIEd market. However, other countries around the world are beginning to support AIEd (and EdTech more widely) through ambitious systematic support. For example, the Chinese government has announced it will invest $30 billion in EdTech by 2020.[39]

Without further government support the UK risks giving up its competitive advantage.

There are also implications for investing in skills. The future development of AIEd relies on a pipeline of talent. More is required to both boost the digital skill development in young people and the diversity of those entering careers in technology.

3. Public R&D funding for AIEd is low, and lags behind other comparable sectors

There is very little public R&D funding to support AIEd in the UK. Our analysis identified just £1m spent across three years. This total appears even lower when compared with other sectors. For example, the government announced £50m in funding to support AI in healthcare through the Industrial Strategy Challenge Fund.[40]

How to support the growth of AIEd through public investment?

1. Upstream public funding for AIEd R&D, particularly focused on teacher-facing and system-facing tools.

Analysis of funding data and company listings in the 'State of play: companies, funding and investment' chapter has provided valuable insights about the state-of-play of the AIEd sector currently, which are supported by qualitative understanding of the market. We can say with confidence that:

- Public investment in AIEd is very low, with no systematic support.
- The AIEd market is skewed towards 'learner-facing' tools, with opportunities for 'teacher-facing' and 'system-facing' tools far less exploited.

There is a need to stimulate the development of new AIEd tools, particularly those which are teacher and system facing. Upstream public R&D funding from Innovate UK would lower the cost of entry to the AIEd market, and ensure that the best ideas were supported to develop from research laboratories into the marketplace.

Shaping emerging technologies upstream is particularly important for applications that have the power to transform our public services. Indeed, there are concerns that the private sector alone cannot be trusted to shape the future direction of AIEd. For example, a partnership between Facebook and a charter schools network in the US called Summit Public Schools,[41] has seen the rollout of an adaptive learning platform in many schools across the country. However, concerns about the role of Facebook in the partnership have led to protests against the platform in several schools.[42]

Public funding to set an agenda, with ring-fenced funding reserved for for teacher and system-facing tools, will help to develop a more diverse set of tools that are capable of tackling the range of challenges described in 'The promise and potential of AIEd' and more palatable to parents.

2. Downstream support to help growth and adoption of most promising AIEd tools in UK schools and colleges

Even with the stimulation of more AIEd tools upstream, this does not guarantee growth and scaling of tools. The Department for International Trade, working with organisations such as the British Educational Suppliers Association (BESA),[43] is doing valuable work to help UK-based companies to sell overseas. Indeed, many international markets present more appealing opportunities for companies, with more centralised purchasing and more students. Help is required to ensure the benefit of AIEd tools is felt in the UK.

The Department for Education and the Department for Business, Energy and Industrial Strategy can address this by offering direct support for AIEd tools with strong supporting evidence to gain traction in UK schools and colleges, and to grow their businesses. This funding could be designed to stimulate demand and uptake in schools (falling under responsibilities of the Department for Education – for example, through subsidising certain products or staff time to help schools to implement products in their school context) and provide resources for companies to grow (falling under the responsibilities of the Department for Business, Energy and Industrial Strategy). This could be achieved through grant funding programmes.

3. Obtain a more comprehensive picture of AIEd research and market activity through further analysis.

Our research has analysed funding data and information about companies listed on Crunchbase and public funding through Gateway to Research. However, further research could provide a more comprehensive view of the sector. For example, analysis of academic publications may reveal trends in AIEd research which are not currently captured. Similarly, more comprehensive mapping of company registrations or patents may paint a clearer picture of exactly where public investment is most needed.

Diagnosis	Recommendation
Public investment in AIEd is very low, with no systematic support and the AIEd market is skewed towards 'learner-facing' tools, with opportunities for 'teacher-facing' and 'system-facing' tools far less exploited.	Provide upstream public funding through Innovate UK for AIEd R&D. This funding should prioritise 'teacher-facing' and 'system-facing' tools, which are currently underexplored despite their high potential.
Promising AIEd tools struggle to gain traction in UK schools and colleges.	Downstream support to help growth and adoption of most promising AIEd tools in the UK.
We undertook some exploratory data analytics of UK AIEd but more extensive public information on this topic is needed.	Obtain a more comprehensive picture of AIEd research and market activity through further research.

2.2 Improving AIEd

It is not enough just to grow the AIEd sector. The quality and effectiveness of AIEd must also be improved.

"Edtech is often not informed by pedagogy and the design of interfaces often lack user-centricity - putting hurdles in the way of teachers, rather than empowering them."[44]

Carla Aerts, Director of the Tmrw Institute.

There are a number of barriers to improving AIEd, many common to the EdTech sector as a whole, although AIEd has some unique characteristics. In this section we outline three major barriers to improving AIEd tools - evidence, accessing expertise and information, and teacher confidence and skills – and propose practical steps to address them.

Evidence

As with the EdTech sector as a whole, the collection and presentation of evidence for AIEd tools is inconsistent. Dedicated research organisations (eg. Education Endowment Foundation), investment funds (eg. Nesta Impact Investments), accelerator or support programmes (eg. EDUCATE) and teacher networks (eg. ResearchED) have worked hard to increase the status of 'evidence' in the education sector as a whole. However, more needs to be done. For example, education myths - such as the importance of 'learning styles' – remain commonly cited by companies and schools.[45]

There are two main barriers to better use of evidence to support the development, purchasing and implementation of AIEd:

1. Testing products in 'real' conditions - in schools and colleges - is extremely hard. Some large companies – such as Google, Microsoft or Apple – have dedicated 'certified educators' to experiment with products in the classrooms, but startups do not have the same resources or status to enable this.
2. There is a need to collate evidence about the efficacy of AIEd in consistent ways. This would enable AIEd products with strong foundations in evidence to differentiate themselves from others, and help AIEd purchasers to make more informed decisions.

The need to test tools rigorously in real settings is particularly important for AIEd as it has problems of 'intelligibility' (see 'Governance of AIEd').

Accessing expertise and information

Applying a particularly complex technology to a complex set of problems within a fragmented and difficult education sector is challenging. Although we have well developed pools of knowledge and understanding about our education system and technology, these are not sufficiently joined up.

On the one hand, AIEd companies often don't have access to experts with understanding of our education system to design the most effective products or identify the greatest needs and opportunities for AIEd. This encompasses expertise in both the mechanics of how our education system works, and research into the theory and practice that explains why an

intervention or approach may be successful. At the most simple level, companies should have a clear theory of change that shows an understanding of where their product sit in the complex education ecosystem of schools, colleges, students, teachers and parents, enabling them to interrogate the assumptions made about how their product creates impact.

On the other hand, professionals in our school system - school leaders, teachers and IT purchasers – do not have access to sufficient information about AIEd to be able to make informed decisions about the products that a classroom or school may, or may not, benefit from.

Teacher confidence and skills

Teacher confidence and skills using technology remains a major barrier to effective use of AIEd in schools. A survey by Promethean found that less than 5 per cent of teachers believe they receive full training and support on new technologies, and less than 36 per cent of teachers believe their training is adequate.[46]

Of course, teacher training and effective use of Continuing Professional Development (CPD) is an issue which extends beyond technology. The Education Policy Institute's 2016 report on teacher workload found that teachers in England spent an average of four days on CPD opportunities, compared with an average of ten point five days across the 36 jurisdictions studied (and 40 days for teachers in Shanghai).[47]

However, given the growing importance of AIEd - and the critical role that teachers will play in deciding how and when to use these technologies – insufficient mechanisms for teachers to develop their understanding, confidence and skills with AIEd are a major barrier to its effectiveness. Improving teacher confidence and skills in AIEd may, in turn, also stimulate downstream demand.

What can we do to improve quality and effectiveness of AIEd?

1. AIEd should be tested in 'real' settings as part of an EdTech Test-bed, with follow-on funding for products which have been tested

The Department for Education should mobilise groups of schools and colleges to provide a test-bed for promising AIEd tools. This should be done in such a way that enables participating schools and colleges to access new products and provide evaluation and feedback, while AIEd startups would be able to test and improve their ideas in real settings. Through this process, companies could be incentivised to address specific priorities which are underserved by the market currently. Of course, schools and colleges cannot be expected to engage with such a test-bed without clear benefits – financial or otherwise.

Of course, an EdTech test-bed in any country of the UK would need to be tailored to that system's particular challenges. However there are examples around the world that offer inspiration. New York's iZone for example, allowed participating companies to take part in 'Short Cycle Evaluation Challenges' which saw products tested and iterated in schools across 16-week cycles.[48]

Crucially, this must be combined with better collation about the efficacy of AIEd. This will enable the best products to differentiate themselves from competition, and empower teachers to make more informed decisions about the technology that they purchase.

2. Government coordination of AIEd, with a clear point of leadership

Responsibility for AIEd within government is fragmented. For example, the Department for Education, the Department for Business, Energy and Industrial Strategy, the Office for Artificial Intelligence and the Centre for Data Ethics and Innovation each have some interest in the sector, but there is no clear point of leadership.

In practical terms, each different government department or office has different responsibilities for a different slice of AIEd - from public R&D funding or governance of data, to teacher training and improving efficiency of school purchasing. Although each of these responsibilities will remain separate, a clear point of leadership straddling the departments and organisations involved would improve the ability of government to take longer-term strategic decisions to support the growth and implementation of AIEd. This single point of leadership would also present opportunities for organisations (such as BESA or the newly formed Institute for Ethical Use of AI in Education) to engage with government and provide external expertise on this issue during a critical phase in its development.

3. Closer collaboration between schools and colleges, AIEd companies and research - with companies providing clearer incentives for teachers to engage.

Better collaboration between schools and colleges, academia and AIEd companies is essential to improving the quality of AIEd products, and making sure the right products are used in the right setting.

Too often, AIEd products are designed without sufficient input from their intended users - teachers and learners. As Rose Luckin observes:

"It is educators who understand what is to be taught, how their students learn and what types of system are likely to work in the hustle and bustle of most educational environments."[49]

Similarly teachers, faced with a range of different EdTech products available to them (often with competing claims and varying methods for articulating evidence), have insufficient tools and opportunities to understand which products will suit their needs in their school. The reality is that there are many teachers across the UK who are very keen to understand more about how AIEd can improve their school, but their time is under great pressure and there are few easy ways to engage with companies usefully.

The EDUCATE project (housed within the UCL Institute of Education and run in partnership with Nesta, BESA, F6s and UCL Engineering), a business and research training programme offering EdTech start-ups access to expertise in relevant academic literature and business mentoring, is taking steps to involve schools more closely in the programme.

Individual companies can take action too. For example, Sparx Maths Homework, a product that sets personalised maths homework to students based on insights from their teacher and the pupil's learning data, have spent eight years iterating their product through close collaboration with three schools in Exeter. Such close collaboration is possible, but more must be done to facilitate these types of collaboration, with clear incentives for schools and colleges to take part.

A teacher and child using the Sparx platform. Image: Sparx

While companies have clear incentives to engage with teachers (not least, they are potential customers), incentives for teachers are less clearly articulated. Nesta will convene experts in the next six months to explore solutions to this problem and test appetite for a cross-AIEd working group to support better collaboration between schools, colleges and AIEd companies.

Diagnosis	Recommendation
Testing AIEd in 'real' conditions is very hard, and there is little consistency in the collection and collation of evidence about its efficacy. Products with a strong grounding in evidence find it hard to differentiate themselves.	AIEd should be tested in 'real' settings as part of an EdTech Test-bed, with follow-on funding for products which have been tested.
Responsibilities for different aspects of AIEd are split between multiple government departments and bodies, meaning that coordinated and long-term strategic support is difficult.	Form a clear point of government leadership through which to coordinate support for AIEd.
There are few opportunities for educators and academics to engage with the design and development of AIEd, and few opportunities for AIEd to learn from educators.	Closer collaboration between schools and colleges, AIEd companies and research - with companies providing clearer incentives for teachers to engage.

2.3 Governance of AIEd

What needs to be governed

Artificial intelligence creates huge opportunities and challenges for education both of which need to be governed in a manner that is considered ethical and trustworthy by citizens. The technologies that underpin many recent advances in AI, such as machine learning, generally require enormous data sets so governance of AI in education should be considered alongside that of educational data.

The general aspects of both AI and data that need governance have been discussed in a number of recent reports, such as those by the House of Lords Committee on Artificial Intelligence, the Royal Society, the British Academy and Nesta.[50, 51, 52, 53] Many of these issues also feature in the scenarios generated for this project (see the earlier section that describes the AI and education landscape and the Annex). These include:

Bias

If the data used to train certain types of AI are biased then the results produced by these systems may be correspondingly shaky. Prejudice can creep into algorithms in many ways. Data may be unrepresentative or reflect undesirable discrimination embedded in deep society. For example, an AI may learn from the data on which it is trained that more men than women hold a particular job so incorrectly give careers advice to students that being male leads to success in that role.

Even if certain sensitive attributes are excluded from training data, others can sometimes act as surrogates through links such as the one between parental birthplace and ethnicity. Alternatively the algorithms may also intentionally or unintentionally reflect the preferences and biases of their creators, a concern that was raised in one of our scenarios.

Bias is also a concern for parents, whose acceptance of AIEd will be a major factor in its use in UK schools. Sixty-one per cent of parents in our survey were fairly or very concerned about bias.

Bias can lead to inequality which can also stem from AI for other reasons, such as uneven distribution of the technology whereby only some groups experience its benefits or harms. For example, more limited digital infrastructure in some parts of the countryside could reduce access to certain AI technologies.[54] Sixty-four per cent of parents were fairly or very concerned about social inequality stemming from AI in education.

Intelligibility

The reasons why certain types of AI, such as deep learning, arrive at particular conclusions can be very difficult to understand because of the complexity of the underlying model. This has been described as the 'black box' problem. The consequences are that it is harder to explain why a decision was made, to predict the behaviour of an algorithm under different circumstances or to improve the technology in the future.

Seventy-seven per cent of parents expressed concern about transparency. This was echoed in one of our scenarios where low regulation and a broad curriculum meant that few algorithms were properly understood. The impetus for making AI intelligible has been increased by the General Data Protection Regulation (GDPR) that contains provisions for individuals to have a right to an explanation as to how a decision was reached under certain circumstances.

One potential solution to intelligibility is technical transparency so experts can examine the underlying software. But simply knowing the software architecture offers limited insight into how an algorithm has understood and interpreted the training data that forms the basis of its decision. Artificial intelligence systems are being created that can explain how particular conclusions are reached. However, there can be trade offs between transparency and accuracy. What is more human decisions can also be opaque and biased in their own way, and are frequently the alternative to decision making by AI.

Accountability

One challenge presented by many current forms of AI is who is responsible when they fail. The way in which some systems work means that they may reach conclusions or decisions that are very difficult for their creators or users to foresee. For example, if a driverless school bus powered by AI had an accident, would the driver, manufacturer or some other party be responsible?

In our survey 77 per cent of parents were fairly or very concerned about accountability.

Privacy and surveillance

When combined with large quantities of data the analytical capabilities of AI can generate insights that could not be obtained before. This has important consequences for privacy. The distinction between more and less sensitive data has become more porous as information can be teased from datasets that were previously considered banal. Anonymisation offers less security when AI can be used to help re-identify individuals.

One concern raised in our scenarios was the possibility of surveillance where classrooms retrofitted with sensor technologies for continuous assessment might be used by parents to watch their childrens' every move. Advances in this direction are already being seen such as the use of eye tracking in education research to assess learners' interests, motivation and engagement levels.[55] A similar worry is described in the report *Intelligence Unleashed* that raises the possibility of AI teaching assistants being used as classroom spies to report any perceived poor performance by teachers.[56]

This uneasiness about privacy and security was also reflected in our survey of parents where 73 per cent were fairly or very concerned.

Data access and availability

Since data is so crucial to the current generation of AI, access to this asset is important for whomever wishes to develop these sorts of technologies. Data becomes more valuable when brought together but this can be difficult as it is often siloed or stored in different formats. Frequently data is of poor quality or simply does not exist. Many organisations and individuals

hoard data for their own benefit or because of concerns around privacy. The complexity of legislation and regulation can be daunting so legitimate uses of data may not even be attempted. Tej Samani, Founder of Performance Learning,[57] said:

"Schools which are aware of the rules and regulations around the usage and sharing of data post GDPR, feel more confident in collaborating with external providers to assist them in the usage of that data to drive uplifts in performance."[58]

In combination these factors leave much of the potential public value of data unrealised and those with limited access to data less able to innovate.

The controversy surrounding the illegal sharing of Royal Free Hospital data with Google Deepmind illustrates the potential for scandal from poor governance - similar risks exist in education if not well-managed.[59] To help the public sector tackle some of these issues Nesta has developed a set of ten questions to answer before using AI in algorithmic decision making that are given in Box 1. These questions should be considered by those thinking about the use of AI in education.

Box 3: **Ten questions to answer before using AI in public sector algorithmic decision making**

Source: Source: Copeland, E. Ten questions to answer before using AI public sector algorithmic decision making. Available from: https://www.nesta.org.uk/blog/10-questions-ai-public-sector-algorithmic-decision-making/ Accessed Feb 3, 2019.

Education has a distinct combination of properties

Education has a number of properties that in combination make it distinct from other sectors where AI might be applied such as employment, finance or transport. These properties include:

The involvement of children: Who are regarded as more vulnerable than other members of society due to inexperience and immaturity so require greater protection. Legally, minors are often treated differently from adults, which can have consequences for AI and data. For example, the GDPR requires consent for the processing of personal data for children under 16 to be obtained from the holder of parental responsibility not the child themselves. There are also governance issues around data ownership when the child becomes an adult, and in control of their own data.

Determinism: Young people are more malleable than adults so there is a danger that the predictions made by certain applications of AIEd could lock them into undesirable future educational, employment or life pathways.[60] This concern was raised by Debbie Penglis of School 21:

"Biases within AI could accidently lead children down a narrow educational path."[61]

For example, we can imagine AIEd tools making recommendations for future education or career pathways which could reinforce and replay whatever social inequality is reflected in the data on which an algorithm was trained. A form of determinism was played out in one of our scenarios where a rosy future was mapped out for a student when he was a toddler, which then informed the students' and parents' expectations. It has also cropped up in other reports that describe the possibility of a learning companion that follows students throughout their lives meaning they can never escape past mistakes.[62]

Schooling is mandatory: which in practice, when combined with near monopoly provision of education by the state, could mean that children (and their parents) have limited choice about whether they encounter AI in education if these technologies were widely deployed. While children can be educated at home, the majority are taught in schools and opt out from particular lessons or activities within schools may become increasingly difficult if AI is widespread. In one of our scenarios a small minority of parents become 'data hermits', removing their children entirely from the state school system in favour of the private sector or homeschooling.

Fragmentation: the UK education system involves diverse providers such as academies, local authority maintained schools, grammars, independents and colleges; each with their own organisational arrangements. Such differing institutions potentially presents challenges to the pooling and coordination of data that strengthens some types of AI, and to the even and coordinated regulation of the potential challenges generated by these technologies.

Contested goals: education has many purposes - training a future workforce, individual wellbeing and building future citizens are but a few. The relative importance and priority of these objectives is not always agreed upon, making the introduction of powerful new technologies such as AI into this setting potentially challenging.

A long term and high impact endeavour: school-age education takes around 13 years and this learning can last a lifetime. The stakes when introducing AI into education are therefore high as the impact is large, long-term, uncertain and takes considerable time to emerge. The scalability of many forms of AI exacerbate these challenges.

Many of these characteristics exist in other fields where AI might be applied, particularly in the public sector. For example, children use health services where they are often treated differently to adults, although they make up a smaller proportion of participants than in education.

What makes education distinct is the particular combination of these properties and the way in which they are manifest. This does not make education special, merely in some ways different as many other sectors are in their own way. The US State of California has already acted with the implementation of the Student On-Line Personal Information Act (SOPIPA) in 2016, which restricts the use of students educational data. The situation in the UK is very different from the US but bespoke legislation specific to the use of data in education can be seen as an acknowledgement of the novel characteristics of this sector.

There are already various governance arrangements for AI and data in general, such as the Centre for Data Ethics and Innovation and the General Data Protection Regulation.[63] While education is within the remits of many of these systems education does not feature prominently in debates about the governance of AI and data when compared to other sectors. A welcome recent development is the launch of the Institute for Ethical Artificial Intelligence in Education that will hopefully help inform future governance through its research.

Parallel governance arrangements unique to education could make data governance even more complex. This might create a situation like the many sets of similar ethical standards and principles for AI and data. Instead the governance of AI and data in education should take place within existing arrangements and be viewed through the lens of the distinct properties of this sector. The bodies responsible for governing AI and data should dedicate specific time and resource to considering the consequences of these technologies for the practice of education through the lens of the distinct combination of properties this sector exhibits.

Data collaboration

The capability of many AI tools can be improved when data is brought together at scale. In education this could allow new proficiencies. For example, our scenarios considered the possibility that AI could identify patterns in complex data that would allow funding, such as the pupil premium, to be directed toward those with greatest educational need rather than providing blanket funding to students from the poorest families, which currently serves as a poor proxy for educational and social disadvantage (some of the current challenges of spending pupil premium funding effectively are discussed in a series of blogs by Rebecca Allen, Co-founder of Teacher Tapp and ex-professor of education at UCL).[64]

Already, certain types of educational data are being brought together and linked at scale. For example, the Longitudinal Education Outcomes (LEO) database links educational and HMRC data to better understand transitions from education to the workplace.[65] If managed responsibility, in the future a combination of AI, educational and other data could create a much smarter education system that provides insights for students and society, such as clearer pathways through school to employment, and what pedagogies and curricula work.

A portion of educational data is available through resources, such as the National Pupil Database, Find and Compare School Performance and data.gov.uk. However, much is accessible only to some groups, is fragmented or is hard to reach, such as some homework or internal school assessments. Personal data which is attributable to identifiable individuals can provide important insights, but is tightly controlled for privacy reasons.

Many of the barriers to bringing data together are practical and apply across sectors. Ways of surmounting some of these barriers in local government have already been proposed by Nesta and others;[66] with shared standards and interoperability highlighted as being important for education.[67] As Mohit Midha, CEO and Co-Founder of MangaHigh said:

"Technologists and educators need to work together around responsible data sharing."[68]

As with many other sectors, there is a tension in the governance of educational data between realising the wider public value and protecting the individual. Often, data governance focuses on the latter rather than the former. If anything in education, the problem is lack of sharing rather than too much, although this should be undertaken responsibly.

In a recent thought piece,[69] Nesta described a framework which aimed to open up the debate on data governance, encouraging us to recognise the twin goals of greater control for citizens and greater value for the public as a whole. The piece argues that, since the primary task of data governance structures is to build trust, the nature of the task will be different in different fields. Different institutions need to be designed and experimented with depending on the example, ranging from the very specific to the very general. Educational data was identified as a complex example because both the potential public and private benefits are high.

The potential benefits of responsibly sharing and coordinating educational data for use in AI and other purposes are so substantial that the Government should publicly declare an ambition to create a national system of responsible educational data sharing by 2030. Our survey of parents showed there is more of an appetite for public than private bodies to take a role in collecting and sharing educational data, so the public sector should play a prominent role in such arrangements. For example, 42 per cent of the parents trust schools and 36 per cent trust an independent regulator to make decisions on this matter while only 4 per cent trust private companies.

There are considerable practical, ethical and legal challenges to this aspiration. For example, much educational data is sensitive so access might need to be in some ways restricted through tools such as anonymisation or substitution with synthetic data. Decisions would need to be made as to whether the system was centralised or federalised, the extent to which data collection was mandatory and which models of sharing, such as trusts, co-ops or commons, are most suitable for which aspects of education. Consideration should be given to the risks from bringing data together, such as from criminals that might to try to exploit this sort of resource.

The potential long term public social and economic benefits are significant enough to justify the attempt. There needs to be further thought on the models that are suitable for education, and future research involving a wide range of stakeholders. A few of the properties such arrangements might exhibit include:

- Engendering trust: through security, privacy, independence, accountability, transparency and thick connections with varied communities connected to education.
- Maximising benefit and minimising risk: through consideration of the net public and private, near and long term benefits and challenges of sharing data in the round.
- A collective approach: that brings together data from many sources and involves clearly identified and appropriate incentives for schools and colleges to share data.
- Developing good governance: through identification of governance arrangements suitable for the purpose of the data sharing and helping to develop and adapt ethical, regulatory and legal frameworks for sharing educational data.
- Capability: through expertise, managed integration with other data sources and resource to store, manage, handle and clean data in a secure manner.

Diagnosis	Recommendation
Many forms of AI need data, so mechanisms are needed to responsibly share and coordinate educational data.	The Government should publicly declare an ambition to create a national system of responsible educational data sharing by 2030.
Education has a combination of properties that are distinct from other sectors and need to be considered when governing AI and data in this field.	The bodes responsible for governing AI and data should dedicate time and resource to considering the consequences of these technologies for education.
The use of AI for algorithmic decision making in education presents complex questions around issues such as ethics, oversight and impact.	When using AI for algorithmic decision making in education the ten questions described in Box 3 should be considered.

2.4 An education system that learns: AIEd's role in assessment and accountability

Just as AIEd can help learning in a classroom, it can also help our whole education system to learn and improve. Hallmarks of good learning in a classroom - such as useful feedback, appropriate support, and healthy two-way communication - should also apply to the system as a whole.

At the heart of this is assessment and accountability, and the role of government bodies overseeing overseeing our accountability system – such as Ofsted, Estyn, Education Scotland and the Education Training Inspectorate of Northern Ireland. Through assessment – from formal exams to informal tests – we understand, measure and compare the progress and achievements of individual students. However, assessment of individual students is also one of the key ways that we understand, measure and compare - through accountability systems – the progress of schools and colleges themselves and the health of our whole education system.

This dual function has important implications for the treatment and potential of AIEd assessment tools which are discussed in this section.

AIEd innovating assessment

Artificial intelligence is impacting on assessment in exciting ways, changing both how we assess students and also what capabilities of a student we can assess at scale. The need for innovation here is great - with narrow assessment contributing to both excessive teacher workload and a narrowing of what students learn in many schools (see 'Five wicked education challenges').

Changing the 'how' of assessment

Automated marking of multiple choice questions has been around for some time (through Google Classroom, for example), but increasingly sophisticated AIEd tools are now able to automate marking of much more complicated questions – such as tools using natural language processing to mark extended essays and provide formative feedback, offering judgements on both the content and the style of prose.

However, of course, the process of assessing work is just as important for a teacher as the outcome of that assessment. The best formative assessment generates actionable insights that can be used to inform planning and teaching on a daily basis.[70] AIEd assessment tools must ensure that this aspect is given due consideration as they take on increasingly complex assessment tasks.

The ability of AIEd to automate complex assessment - that would otherwise require a lot of human effort – has implications on how assessment is physically done, but also how it can be used.

Continuous assessment, monitoring how students progress at frequent intervals and providing feedback, will be possible without placing an extra burden on teachers. This is an opportunity to radically transform informal assessment (such as daily or weekly check-in tests) and more formal assessments (such as exams). Exams are a crude measure of how students perform on a single day in a narrow set of disciplines, with many well documented flaws. AIEd may see the end of exams as we know them.

Case study 6: **Essay marking in China**

Teacher-facing

One in every four schools in China (around 60,000 in total) are part of a government-led trial of essay marking AIEd. According to reports, the technology claims to able to 'understand the general logic and meaning of the text and make a reasonable, human-like judgment about the essay's overall quality'.[71] As well as grading the essay, it offers feedback on writing style, structure and theme.

Changing the 'what' of assessment

AIEd also presents opportunities to broaden the range of skills and aptitudes that can be tested across large numbers of students. If assessment becomes more flexible, with AIEd used to analyse a student's learning continuously, assessment can be built into a wider range of learning activities in different contexts. For example, rather than test a child's maths abilities in an exam hall, they could be tested through a collaborative project using knowledge to solve problems and work with others.[72] In this example, data collected by AIEd tools could be used not only to understand how well a child can apply a mathematical theory to a problem, but also a range of aptitudes – from collaboration and problem solving, to confidence and concentration. For example, Edulai (see Case study 7), a tool being piloted in the higher education sector, uses AI to assess skills such as critical thinking, problem solving and communication.

The importance of these wider skills and aptitudes (alongside vital core knowledge) is set to grow. Nesta's analysis of trends in the labour market finds that interpersonal skills, higher-order cognitive skills and systems skills are likely to be in greater demand in the future.[73] However, these are skills which, currently, are very difficult to measure. Data collected by AIEd in the types of flexible and continuous assessment scenarios that AIEd assessment tools may enable in the future, present an opportunity to assess a much broader range of attributes, at scale.

Case study 7: **Edulai**[74]

Teacher-facing

Edulai is an assessment tool being piloted in universities in Italy to develop and assess 'employability skills', such as critical thinking, problem solving, communication and leadership. Students learn from materials provided through the platform and communicate with others to collaborate on group projects. This data is collected by the platform. Edulai have combined this data with student self-assessments and teacher assessments to train an algorithm. This algorithm is able to place students within one of five achievement levels (from 'basic' to 'master') on a skills assessment framework for each of the target skills.

AIEd and accountability

If AIEd can transform how and what we assess, what does that mean for our accountability system? It is hard to overstate the importance of student outcome data - such as exam results - to our school system today. Not only do they define if a student has done well, but for governments (through Ofsted and others) they help to define whether our schools, colleges, headteachers and teachers have done well.

A rigorous accountability system has many benefits, but the narrow-scope of exam-led accountability has led to a number of well documented negative side-effects – from 'teaching to the test'[75] and a narrowing curriculum available in many schools,[76] to prioritising whole-school results over the needs of some of our most disadvantaged individual students[77] and removing or excluding poorly-performing pupils from school entirely.[78] As Dr Tim Rudd, CEO of LiveLab, said:

"There is a fetishisation of exam results and league tables."[79]

In England in particular, there is recent recognition of this growing criticism. Ofsted recently announced that its new school inspections will downgrade the importance of outcome data in its assessments of schools in favour of broader measures, including 'personal development' and 'behaviours and attitudes.'[80] As Luke Tryl, Ofsted's Director of Corporate Strategy commented:

"We are not saying outcomes don't matter, but we have reached the limits of what data alone can tell us."[81]

The shortcomings of outcome data under our current accountability system might lead to a temptation to relegate the role of data entirely. However, given the potential of AIEd to dramatically broaden the range of assessment that is possible at scale in the near future, this would be a great shame and jeopardise the potential of AIEd to transform assessment and accountability.

The question for governments and regulators is: How can AIEd assessment tools (and the outcome data they provide) be used without creating yet-more-data-metrics for teachers to meet?

To empower or control?

Aspects of our future scenarios reveal clues. They describe dramatically different future roles that AIEd could play in assessment and accountability. AIEd can either control or empower.

'Control' in our scenarios was typified by high-stakes testing, reverence to data at the expense of qualitative judgement, an emphasis on data-led targets, and feelings of being observed. As Professor Renee Hobbs, Director of Media Education Lab at the University of Rhode Island, observes:

"It [AI] will amplify a focus on assessment, and it will focus on and amplify tracking behaviour, monitoring and surveillance behaviour [...] And that, of course, gives me concern."[82]

'Empowerment' in our scenarios was typified by more frequent low-stakes testing, an emphasis on formative assessment over summative assessment, the recognition of qualitative expert human judgement alongside insights from data, and the ability of data to provide easily actionable suggestions on how to improve practice.

To ensure that AIEd empowers, rather than controls, we must ensure that assessment data is treated responsibly and is combined with the insights of humans - that might include students, teachers, parents or school inspectors. Nesta's ongoing work exploring the design of 'collective intelligence' through the Centre for Collective Intelligence Design[83] offers a conceptual solution. Collective Intelligence is the mobilisation of human intelligence in combination with data to solve problems - either through better understanding of a situation, generating new solutions, making better decisions, or learning more quickly.

Methods for pooling insights from data and humans (a collective intelligence) must be developed to harness the insights from AIEd assessment tools in ways that empower teachers to take positive action to improve their practice, and for schools and colleges as a whole to learn and improve. Emoti-OS (see Case study 8) is an example of what an experiment of this kind looks like.

Through appropriate treatment of data alongside the expertise of teachers and inspectors, collective intelligence offers a route to ensure that our whole education system learns and improves – just as we expect students to learn and improve.

Case study 8: **Plymouth School of Creative Arts and Emoti-OS – Towards a collective intelligence?**

System-facing

Emoti-OS,[84] developed as part of a collaboration between Plymouth School of Creative Arts[85] and iDAT,[86] measures and visually represents the wellbeing and 'mood' of pupils and staff in the school. It's made up of two parts: a chat-bot and an emoji-based interface.

The chat-bot acts as a channel for pupils and staff to express how they feel about their learning environment, school community and other issues. The emoji-based interface allows students to directly record their feelings by pressing the appropriate emoji button. The collective mood of the school at any given time is reflected on a large screen in the school atrium.

The Emoti-OS chatbot in action.
Source: Plymouth School of Creative Art

In its first four weeks in the school there were over 20,000 conversations with the chat-bot, based on a series of daily driving questions suggested by students (such as 'What would make your school better?' 'What or who inspires you?' or 'How do you feel about your future?'). These conversations are retained as transcripts. Through analysis of the transcripts, staff are able to gain insights into the wellbeing of individual pupils (conversations that contain keywords are flagged by an automatic safeguarding system, enabling human teachers to provide support) and common concerns across the school. From this information, staff are able to make decisions about how best to improve wellbeing (and other issues).

In this model, insights gained from data collected by AIEd are combined with insights from staff in the school to create a collective intelligence, to enable decision making that brings together the views of students and staff.

Where to begin?

1. Public bodies responsible for exams should launch an 'AIEd assessment challenge prize' to identify new methods for broadening the scope of assessment reliably

Organisations responsible for regulating the qualifications taken in the UK - Ofqual, The Scottish Qualifications Authority, Qualifications Wales and the Council for Curriculum, Examinations and Assessment - should actively seek to support AIEd that would enable them to reliably assess a wider range of attributes, at scale.

Challenge prizes are a funding tool used to incentivise a wide range of innovators (with different methods and expertise) to address a specific problem. An AIEd assessment challenge prize[87] will stimulate the development of reliable and sophisticated AIEd assessment tools.

The prize and associated funding should prioritise efforts to:

- Assess skills and aptitudes that are associated with occupations that are set to be in greater demand in the future. Box 4 shows the top 15 skills identified by Nesta's research into labour market trends and employment in the year 2030. These skills and aptitudes are particularly hard to assess at scale using traditional techniques, but AI may prove an important tools in better understanding and modeling how these skills are developed.
- Generate new metrics that could be considered within Ofsted's new inspection framework, particularly focused on 'personal development' and 'behaviours and attitudes'.

Data, such as sample examination scripts, anonymised test scores or a set of synthetic answers might be released alongside the challenge to participants to incentivise participation and improve the quality of products developed. This is an approach that has worked successfully in prizes in other sectors, such as Open Banking.[88]

Box 4: O*NET variables ranked by importance to future demand for UK occupations[89]

1. **Judgement and decision-making**
2. **Fluency of ideas**
3. **Active learning**
4. **Learning strategies**
5. **Originality abilities**
6. **Systems evaluation**
7. **Deductive reasoning**
8. **Complex problem solving**
9. **Systems analysis**
10. **Monitoring**
11. **Critical thinking**
12. **Instructing**
13. **Education and training**

2. Government bodies overseeing accountability systems should explore how insights from AIEd assessment tools and human expertise can be combined as part of a 'collective intelligence' through pilots in schools and colleges

Ofsted, Estyn, Education Scotland and the Education Training Inspectorate of Northern Ireland should support experiments to understand how to design a Collective Intelligence that harnesses new insights from AIEd assessment tools within their accountability measures.

These pilots and experiments should prioritise the skills and aptitudes which are currently hard to measure and assess using exam results and other outcome data, but which are important for a child's future - such as social and emotional skills. The ongoing work of Nesta's Centre for Collective Intelligence Design[90] is working to better understand how such experiments can be designed in different contexts.

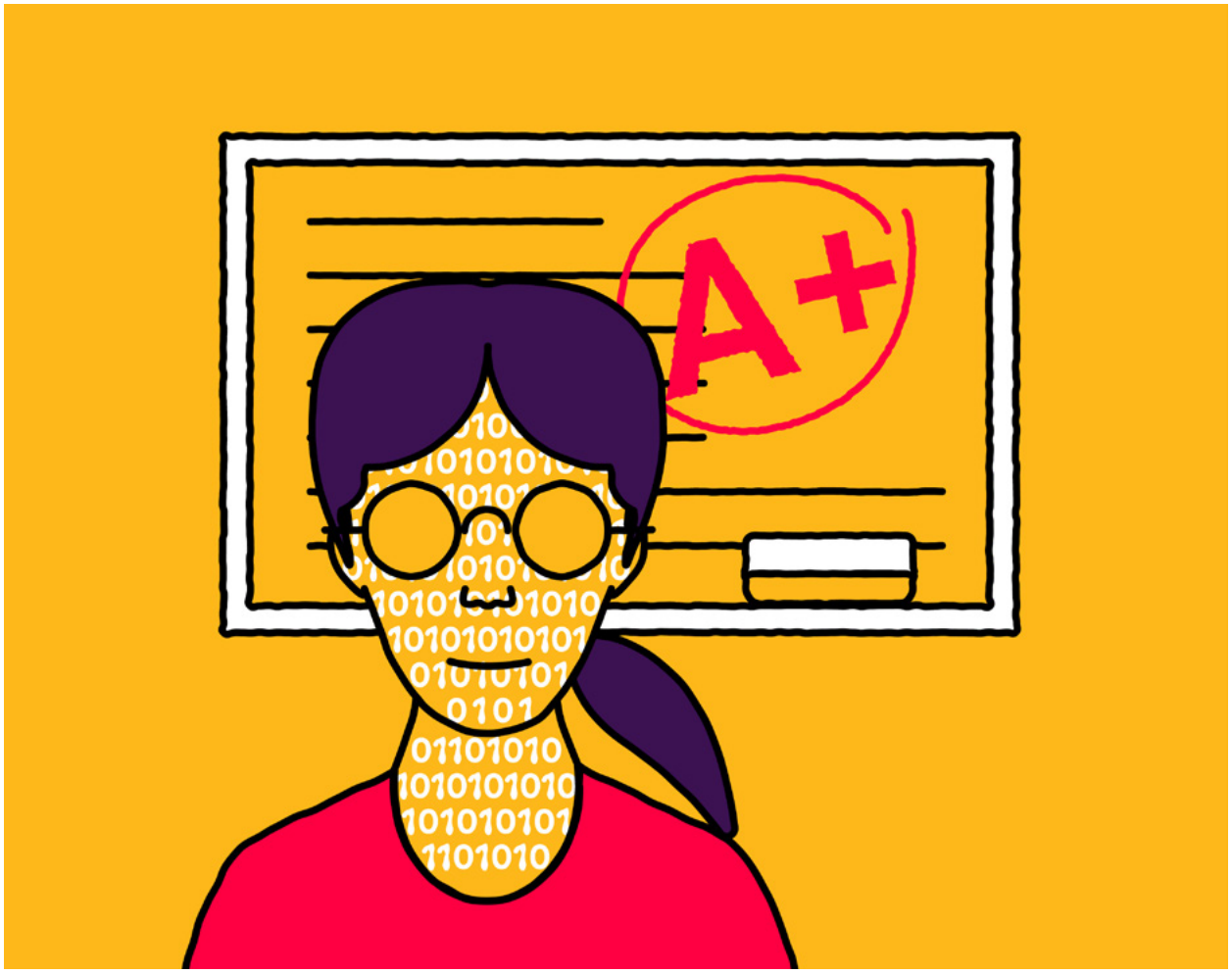
School pilots will pave the way for more sophisticated accountability in the future which is capable of tracking the improvements of both students and our schools towards developing complex skills and aptitudes.

Diagnosis	Recommendation
The potential of AIEd to innovate assessment is unfulfilled, and the scope of assessment in schools is too narrow.	Public bodies responsible for exams should launch an 'AIEd Assessment challenge prize' to identify new methods for broadening the scope of assessment reliably.
An over-reliance on outcome data has led to a narrow schooling for many young people, skewed by the need to meet certain targets. There are few sophisticated mechanisms to combine human expertise and insights from AIEd.	Government bodies overseeing accountability systems should explore how insights from AIEd assessment tools and human expertise can be combined as part of a 'collective intelligence' through pilots in schools and colleges.

Conclusion

AIEd promises much to be excited about. This report makes a strong case for the potential of a wide range of different tools – learner-facing, teacher-facing and system-facing – to change our schools in profound ways. More importantly, it describes actions we can take to help fulfill that potential while minimising risk.

But interestingly (and outside the focus of this report) the impact of AI elsewhere in society is affecting the type of world – experiences, relationships, and professions – that our schools should be preparing young people for.[91] Given AI's ability to accelerate, exaggerate and amplify, we must be careful that we do not just use AIEd to reaffirm the priorities of our schools today. Instead, AIEd can serve as a platform that enables us to re-imagine the design of our education system so that it is fit for the future.



Annex

Complete scenarios

The complete scenarios that were co-designed as part of the project are below. Each scenario consists of a description of the future of AI and education in the UK in 2035 and includes a description of the future from the perspective of a learner. The process for generating the scenarios is given in Box 1.

The scenarios intentionally consider quite extreme futures to better understand the potential consequences of choices made today. When considered alongside the results of our other research we favour a future with:

- **A broad education**: For reasons beyond AI, though these technologies implemented in the right way might help achieve this goal.
- **Higher (though not too restrictive) regulation**: Though only if this is implemented in a manner that would facilitate innovation (see 'Governance of AIEd').

Scenario A:
High regulation and governance of data/Focused education

A focused education prioritises retention of knowledge in a small number of core subjects. Children learn from adaptive AI learning platforms which tailor content to their pace of learning using mastery pedagogy. Assessment is automated and continuous. With the majority of 'teaching' and marking carried out by AI, teachers are more focused on behaviour management and pastoral care. A new cohort of Gen Z teachers are passionate about bringing data analysis to the role.

The government has shown leadership through regulation which supports the use of AI in schools. High regulation of data and strictly enforced consistent data standards across schools enable Ofsted to carry out data-led inspections. A government 'Office for AI in education' has introduced rules ensuring that the state retains ownership to any valuable pupil data collected by private companies. The government makes anonymised sections of this data available to startups in an effort to help them compete with internet giants.

Public attitudes towards AI are mixed. A small minority of parents – 'data hermits' – have chosen to remove their children from the school system entirely in favour of non-digital education through the private sector or home schooling.

The learner

"Congratulations, Angus, you have reached level 97! Can you beat Eun-Kyung, aged 14 from Democratic Unified Korea, in this race to solve for 'x'?"

Angus suppressed a groan. He knew all his friends were on level 114, at least. Why was he so bad at maths? He looked out the window at the clear sky and thought about the weekend. A loud pop in his headphones alerted him to an incoming message.

"Mr. Stewart: Are you looking out the window again? You have not answered a question in the last four minutes and your monitor's facial tracking sensors have lost eye contact. Please begin the next level or request a break."

As he began the first challenge on level 97, Eun-Kyung's avatar appeared on the right of his screen.

"Hello, I live in Korea. What's it like in Cornwall?"

"Well, it's beautiful outside but this classroom is so boring"

Angus mumbled into his headset, but his message didn't send. He'd lost 6G connectivity, so his translation software was struggling.

Angus looked out the window again. He was going to try and persuade his parents to home school him. They didn't understand data, so maybe he could scare them into opting out. How was any of this going to help him get a job in conservation?

Widespread use of a small number of adaptive learning platforms have increased the consistency of education provision, although a small number of schools in remote areas suffer from sluggish connectivity. Smaller schools struggle to capture enough pupil data to perform more sophisticated data tasks (such as predicting where students will struggle, targeting resources to education disadvantage and monitoring pupil wellbeing), which has led to the rise of 'Mega-Schools' of 10,000+ students in large cities. Shared data standards across schools mean school inspections are now carried out entirely through reporting of data, with no human inspectors visiting schools.

Although the attainment gap in schools is closing, this has not translated into increased social mobility. Despite high academic achievement, employers complain noisily that school leavers are not equipped with the skills they need to succeed in the workforce. The UK arts and cultural sector has suffered a slow decline as young people stay away from arts venues in favour of online communities.

Scenario B:
High regulation and governance of data/Broad education

High regulation limiting collection and use of children's data has slowed the introduction of AI learning tools in classrooms (with companies preferring to market products to universities and companies instead). There are very few adaptive learning platforms tackling subjects and skills that are more complex to model such as art, although adaptive learning platforms are used by a number of schools in a small set of subjects that are easier to model within software or which have particular teacher shortages such as mathematics.

A broad curriculum has led to more variety in learning experiences, although only a proportion are carried out using technology and therefore capable of being assessed by AI. This has led to increasingly sophisticated parent-school engagement tools collating both automated and teacher-led assessments. Uptake of these products among parents is widespread thanks to relatively high public trust in AI and strong regulation restricting data sharing. Platforms also provide incentives to parents to use the programmes regularly. Most schools have appointed a specific 'data lead' to ensure their use of data is in line with regulation and to manage parent-school engagement tools. Demands on teachers are extremely varied – from understanding insights from data analytics tools and providing feedback online, to providing pastoral support and leading varied learning activities.

The learner

"There's seven fallen rocks. But I can see marram grass and new shoots of dwarf gorse!" Called out Agata to her project team from the base of the cliff. Her class were tracking the impact of cliff subsidence on the habitat of the local sand lizard population.

Her e-learn tablet chimed inside her bag. It would be her dad. Every since Educ-8 offered e-shopping points to families that used the learning platform twice a day, he had been regular as clockwork.

"Message from Dad: 89 per cent on the new science module! Gratulacje! Although Mrs Wood has written that you need to be more confident in your group problem solving activities. Is everything ok?"

Ofsted holds schools accountable to many different outcomes with equal weighting, from academic performance to personal development, mental wellbeing and skill development. This is reflected in reformed 'league tables' which now rank schools under a number of different categories. As a result, schools have developed particular specialisms and brand themselves on that basis. There is an increased emphasis on the importance of school choice, with house prices around popular schools inflated by as much as 400 per cent.

Scenario C:
Low regulation and governance of data/Broad education

This is a world where limited regulation of data and a broad education have led powerful AI to capture and analyse more educational data than ever before. Classrooms have been retrofitted with advanced sensor technologies that are controlled through speech and gestures. Exquisitely detailed continuous assessment of a wide range of skills and knowledge have made examinations all but redundant and parents can observe their children's progress in real-time. Light regulation means that few algorithms are properly understood, particularly as the curriculum is so wide ranging. Many suspect that the machines contain the same biases as their creators.

The learner

Jess couldn't switch her brain off.

New learning coach tomorrow and he isn't going to be impressed by her stats.

She turned her pillow over hoping the cool side would be more comfortable.

She couldn't blag it, the academy bot knows exactly what's going on.

She threw off the sheet.

Working super hard now wouldn't help this late as it's average performance that matters.

Anyway how to do you argue against a machine no one understands?

A drone buzzes by outside.

A few of the other kids even have bots from unis sniffing around their data trails.

She can dimly hear her sister's game - she's such an hakikomori locking herself away like that.

At least her parents already knew everything through the Learning Odyssey app. And that one good score in kindness might get her a care home job - lots of roles there these days.

The teaching profession has evolved into a small multidisciplinary group of superstar content setters and many more learning coaches who form teams to work with large classes supported by AI teaching assistants. Rich insights from AI in schools allows universities and employers to actively seek promising students and staff long before they have completed their education. The same technologies mean more extensive surveillance of matters beyond education such as disposition to extremism or criminality. In cities schools have become more specialised because of the broad curriculum but this is not an option for their country cousins due to the distances students would have to travel. This has led to an urban-rural split, exacerbating inequality.

Scenario D:
Low regulation and governance of data/Focused education

This is a world where focused education and lightly regulated data has made education highly competitive and deterministic with only one route to success, which can easily be analysed and predicted using AI. Students now progress more quickly along a narrow academic pathway. Instead of using the extra time to widen their experiences most students double down on focused learning, with 'Tiger moms and dads' pushing ever harder for success. Advances in AI and other digital technologies mean learning is more continuous, personalised and less tied to the classroom.

The learner

"You're not going and that's final."

Tom marched out onto the balcony.

"But dad."

Billy said weaving through the flat.

"My rolling average marks for the last six weeks have been over 98."

"They haven't in sim. And if your teacher's off learning about the next bit of tech then responsibility for your education is on me."

"Josh's big sister says we're not learning the right things anyway."

"It's a game. Do you want to stay here the rest of your life?" he said gesturing to the shabby estate.

"But the algos predicted ages ago I'd do tops at toddler school. And they were right."

"Only 'cause of all that screen time at home."

"But dad."

"No more buts. What use are philosophy classes these days anyway."

Educators are finding that the focused curriculum is allowing powerful AI to encroach on their traditional role making many of them distrust this technology, despite having to do less marking and admin. The skills and knowledge learnt by students is sometimes out of date or less relevant to a fast changing workplace leading to the growth of lifelong learning to compensate. The highly competitive educational environment pushes up educational inequality but this is pulled down by AI being better able to identify those with greatest educational need. A focused curriculum also means that the development pathway of AI technology is relatively predictable and the AI itself is relatively explainable and transparent.

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