EDUCATION & TRAINING FOUNDATION

CENTRES FOR EXCELLENCE IN MATHS

Pearson

PRINCIPLES AND PRACTICE

USE OF TECHNOLOGY AND DATA IN FURTHER EDUCATION MATHS

Contents

Published on behalf of the DfE by Pearson Education Limited, 80 Strand, London, WC2R 0RL.

First published 2020

23 22 21 20
10 9 8 7 6 5 4 3 2 1

ISBN 978 1 292 33778 4

Acknowledgements
The publisher would like to thank the Education and Training Foundation and the University of Nottingham for their contribution to the title.

The publisher would like to thank the following individuals and organisations for permission to reproduce their material.

Photos
123RF.com: Varin Rattanaburi; **Education and Training Foundation: etfoundation.co.uk**

Screenshots
Eedi Ltd: https://eedi.co.uk/; **Geogebra: https://www.geogebra.org**; **Pearson Education: https://www.pearsonactivelearn.com/**

Introduction

Programme overview

The Centres for Excellence in Maths (CfEM) programme, funded by the Department for Education (DfE), is designed to deliver a step change in maths teaching up to Level 2 in post-16 settings. A range of expert delivery partners and Centres for Excellence across the country are working together to design and develop evidence-based teaching approaches in four themes:

- an adapted mastery approach for the post-16 sector
- contextualisation – relating maths to real-world situations
- motivating and engaging learners
- using technology and data for maths teaching.

Centres for Excellence and delivery partners

The Centres for Excellence are 21 providers in the Further Education (FE) sector selected to drive innovation and improvement in both their institution and beyond. They are each establishing a network of ten or more partners to share practice across the FE sector. **You can see the 21 centres on the ETF website.**

The Education and Training Foundation (ETF), the national workforce development body for the Further Education and Training sector, is managing and leading the programme, working in partnership with a range of expert partners:

- **Association of Colleges (AoC)**
- **Behavioural Insights Team (BIT)**
- **Eedi**
- **Pearson**
- **PET-Xi**
- **touchconsulting**
- **University of Nottingham**
- **White Rose Maths**

Trials and action research

An important aspect of the programme is to increase the evidence base of what works in maths teaching in the sector. The Centres for Excellence and the University of Nottingham are working together to carry out a range of trials and action research projects looking at aspects of the four themes. The focus of inquiry will change through the course of the programme.

The trials are supported by classroom resources, a professional development programme and collaborative networks. In 2019–20, the national trials are focusing on GCSE resit courses, with the key mathematical concepts outlined below ensuring that they are focused on improving attainment between GCSE Maths grades 3 and 4.

Key mathematical concepts

The Centres for Excellence in Maths programme has focused in on a small number of key mathematical concepts. These concepts aim to provide the maximum potential improvement for students. The University of Nottingham has used anonymised exam data from Pearson Edexcel to identify the concepts that might have the most impact on attainment. Data from diagnostic questions are then used to show teachers where to target their teaching on these key concepts by highlighting common knowledge gaps and misconceptions.

The key mathematical concepts are the same across the four themes:

- working with and understanding number
- multiplicative reasoning
- fractions, decimals and percentages
- basic algebra
- measure (area and volume).

Technology and data

In the technology and data theme, the focus is on using technology to provide students with new insights into mathematical structure. Students will use technology to explore maths through carefully guided activities and teacher questioning, with the technology providing direct feedback and dynamic access to mathematical ideas and structures.

Handbooks

There is a Handbook for each of the four themes. The Handbooks are evidence-based guides for teachers on current research and good practice. They can be used by any post-16 maths teacher looking for evidence-based approaches to teaching. Each Handbook outlines research for the theme, explains why it is important to maths teaching in the post-16 sector, and exemplifies how you might consider developing your teaching to reflect some of what we know from this research.

How to use the Handbooks

Key principles

Each Handbook is structured around key principles. These key principles have been created to reflect both the crucial points from the research and areas where there is the potential to make the biggest difference to teaching. Developed by the delivery partners and teachers from the Centres for Excellence, these key principles provide focus for each theme and allow consistency across the themes and outputs for the programme. They are not meant to restrict how teachers apply the themes to their teaching. Instead, they are intended to describe how well-informed approaches might apply in each theme and support teachers in changing their practice in line with these approaches.

Find out more

There are lots of links between key principles and between the different themes. 'Find out more' boxes highlight these links.

Key terms and ideas

The most important terms and ideas in sections are highlighted in separate explanatory boxes.

Further reading

The Further reading sections at the end of the Handbooks give you the opportunity to dig deeper into the research. These references are cited throughout the Handbooks, and particularly important documents can be found through hyperlinks.

Note for teachers

At time of publishing, the programs and systems mentioned in this Handbook are all available for use. If you are reading this Handbook and the mentioned technologies are no longer available, an internet search should give you similar products.

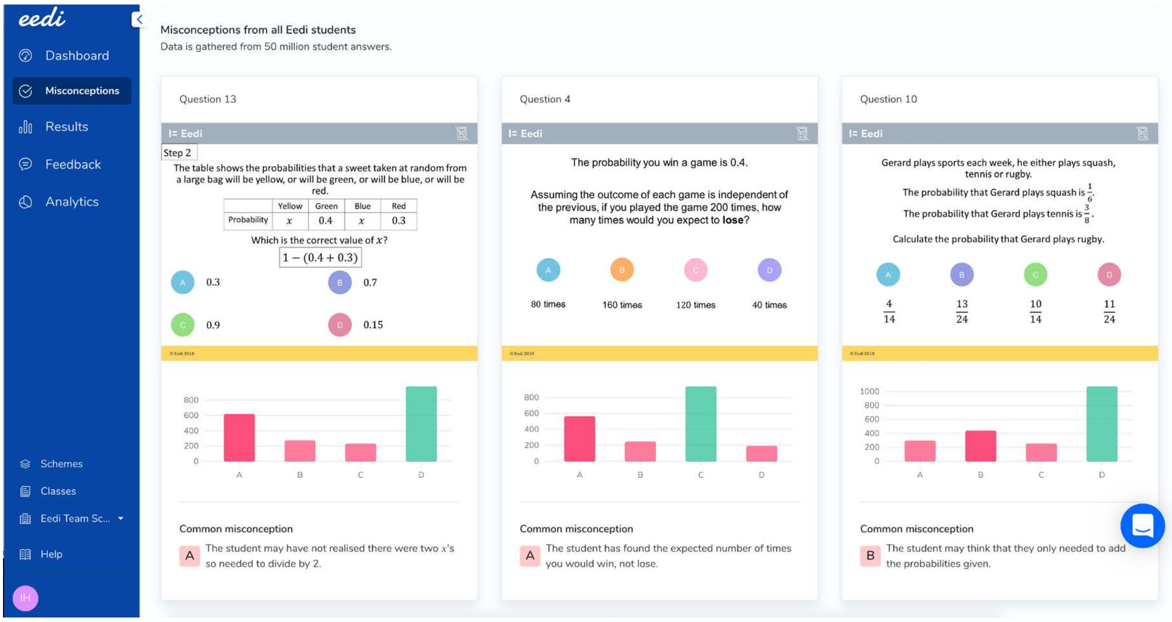
Technology and data

What do we mean by technology and data?

In this Handbook we use the term 'digital technology' to refer to the combination of hardware (computer, tablet, smartphone) and the software (programs, apps) they can run.[1]

Over the course of the academic year, centres and teachers collect data on student attendance, attainment, progress, personal and social information, predictive information, and so on. Technology such as management information systems has automated lots of this data collection and storage, increasing the amount of information teachers have access to. In the CfEM programme, we are focusing on what data could be useful to teachers and how to gather and use them strategically. For example, **Eedi** diagnostic quizzes give you data on your students' misconceptions, and they provide personalised supporting materials to help them progress.

There are lots of different types of hardware that teachers and students can use



Platforms such as Eedi allow you to view data on your students' misconceptions

What does the research tell us?

For over 30 years, educational researchers in maths have been interested in the potential of digital technology to contribute to the teaching and learning of maths.[2] Research suggests that there are many and varied ways in which technology can help.[3,4] However, technology is not used as widely or as well as it might be in many maths classrooms.[5]

Most research related to technology in maths education is set in primary and secondary schools, with a smaller but important set of studies in Higher Education (HE).[6, 7] Where Further Education (FE) studies do exist and are specific to maths, they tend to adopt the same theoretical approaches and interventions as seen in studies set in schools (for example, Adelabu, Makgato and Ramaligela, 2019).[8] While much of what is known is transferable between educational contexts, it is important to consider what might be different for students and teachers in FE colleges. For example, teachers in FE have found it useful for students to experience learning maths in a different way to how they studied it in school.

Most research reports are on small-scale, qualitative research. These reports provide valuable insights into the experiences and learning of teachers and students, many of which are relevant across educational contexts. Where larger-scale experimental studies exist, digital technologies in the teaching and learning of maths have had a small positive effect, particularly with lower-achieving students. However, as Drijvers et al. suggest,[9] the low uptake of digital technologies for the teaching and learning of maths could be partly explained by the lack of research evidence into the benefits of digital technology for student learning in maths.

While digital technologies are widely used to gather and analyse student performance in maths, little research exists as to how, and how well, the data are used. There are some recent studies in this area, for example, Ngo and Kwon (2015),[10] who investigated the use of data to inform decisions about the maths courses on which to place college students.

How can technology and data help in the classroom?

The table below shows some areas of the classroom where technology and data can help. These are based on some of Becta's core pedagogic principles that underpin effective teaching and learning.[11]

In the classroom	How can technology and data help?
Inclusion and access	• Offers flexibility by adapting to different students' needs.
Engagement	• Provides different opportunities to make learning more fun and enjoyable. Teaches the same content in new, innovative ways.
Effective learning	• Technologies that enable students to manage the pace, time and place of their learning add real value to the experience of learning.
Formative assessment	• Automatically provides personalised feedback to students.
Summative assessment	• Retains performance data that can be accessed over time as evidence of progress.
Ease of use	• Creates transparent digital learning resources with appropriate guidance. • Makes appropriate assumptions about the technology skills of both students and teachers so that it does not obstruct learning.

Find out more

More on how you can use Becta's core pedagogic principles can be discovered in Key principle 3: Adding value.

Key principles

Key principle 1: New and insightful maths experiences

1. Supporting students to experience maths in ways that are new to them and which allow new insights into mathematical concepts and structure

Students entering post-16 education have already been introduced to all the topics they will be covering. Many have a negative attitude towards learning maths. To overcome this, it is important to introduce students to new ways of thinking and working in maths to allow new insights into mathematical concepts and mathematical structure.

Key principle 2: Independent learning

2. Supporting students' independent learning both in and outside the classroom

Digital technologies can engage students with maths in new ways that provide a private space in which to learn maths with instant feedback. The use of digital technologies can be used to support independent learning in this way both in and outside of the classroom, where it is increasingly available to students.

Key principle 3: Adding value

3. Adding value to learning rather than using technology for its own sake

Using technology because it is there will not in itself raise attainment. The teacher, in partnership with the students, should make an informed choice on what tools are most helpful to the learning process.

Key principle 4: Using data strategically

4. Optimising diagnostic assessment and other data for strategic and easy use

Teachers using data diagnostically can reveal large amounts of information, which could be useful to themselves and students and help identify learning needs. This can be used strategically to plan the learning journey the student will take.

Key principle 1: New and insightful maths experiences

Engaging students using technology

It is important that students experience a different way of learning from how they were taught in school. In order to engage them, maths can be presented in a new and insightful way. Technology can help achieve this, even where students have used some technology in school. For example, automating the mathematical process allows students to focus on the bigger picture of what is happening rather than spend their time 'doing' the maths. This can be done by using, for example:

- graphing software that shows the effect of changing the variables in an equation rather than drawing the graph by hand
- geometrical modelling that allows the impact of changing a shape on its dimensions to be seen without the need to draw the shape by hand.

GeoGebra, **Desmos** and **Autograph** are widely used, freely available, examples of software that allows students to do both of these.

Using technology in the classroom can help engage students

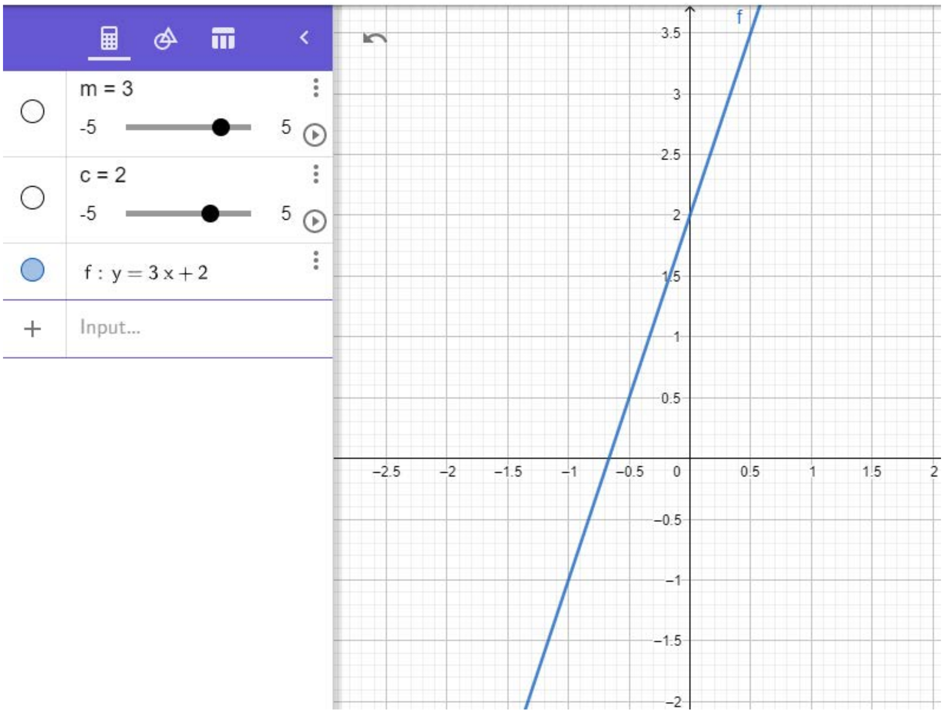
What does the research show?

Research shows that teachers can offer new and insightful mathematical learning experiences, supported by technology, in a number of ways. Some technology can be used to perform mathematical processes (or 'do the maths') for the user.[4, 9, 12, 13, 14] This can enhance the learning experiences of students. The technology can shift focus from students carrying out the low-level mechanics of the maths to focusing on mathematical patterns, generalisations and structure. For example, students can create a range of graphical representations using graphing packages and then focus on the characteristics of different graphs in order to draw out common features and patterns.[3, 14, 15, 16] Technology that 'does the maths' is used to varying degrees in Level 2 maths teaching. While students routinely use calculators in maths,[17] there is not always an effective use of other technologies such as spreadsheets and computer algebra systems.[15]

Using technology in the classroom

Drawing graphs

It is usually not enough to ask students to draw a set of graphs in a graphing package such as GeoGebra and ask them to explore the effect of either changing the equation of the graph on the shape of the graph or vice-versa. Students tend to need highly structured activities that direct their explorations and draw their attention to the features you want them to notice. For example, students can be shown a graph such as $y = 3x + 2$, predict what will happen if they change the 2 to a 1, and then to try it out.



Graph of $y = 3x + 2$ on GeoGebra, with sliders for students to change the gradient and y-intercept

Using spreadsheets

Spreadsheets such as Microsoft Excel or Google Sheets can be used as simulators. Spreadsheets can generate thousands of results in a very short time. An example is using a spreadsheet to simulate the rolling of a dice by using the formula '=RANDBETWEEN(1,6)' and using a COUNTIF formula to count the results. The **Microsoft Excel support site** can be used to find more guidance on how different formulas can be used.

By doing this activity with students, they will be able to see that as more results are added, the probability of rolling any given number will become closer and closer to one in six. It is unlikely that this will lead to any meaningful mathematical learning by itself. Consider what you want students to learn and how the simulation will help. You could demonstrate the difference between theoretical probability and actual results by stopping the simulation after 50 rolls of dice and looking at the distribution, which is unlikely to be even across all numbers. You could then look at the distribution after 100, 200, 500, 1000 rolls of the dice and discuss how the distribution changes.

Key principle 2: Independent learning

What is independent learning?

The term 'independent learning' has come to have a wide range of meanings in the educational literature. Several other terms are also used with equally diverse but similar meanings – for example, autonomous learning, independent study, self-directed learning and student-initiated learning.

We are using 'independent learning' to mean that the student or student group takes some responsibility for their learning. This can mean students deciding on the next question to tackle in order to achieve a set goal, setting a personal learning goal, or identifying learning resources to use and the pace at which to work. Independent learning does not remove the need for you as a teacher, rather it changes your role from being solely the 'director' of the learning to one where you play more of a supporting and guiding role.

Technology can support independent learning as it can give students access to the necessary data to make an informed decision on the next steps in their learning and provides the resources they can use to progress, for example, short video clips or online practice questions.

Technology can also support independent learning through the **flipped classroom** approach.

Key idea

In the **flipped classroom** students discover new content before the lesson from videos at home or other resources outside of the classroom so that lesson time is used for activities and developing understanding. Essentially, traditional classwork and homework are 'flipped'.

What does the research show?

Technology can support independent learning in a variety of ways.

Online homework

Roschelle et al. (2016)[18] found that when students worked independently using an American online homework tool called **ASSISTments**, along with relevant professional development of the teacher, student achievement was higher than for those who did not work in this way. This was especially the case with students with lower prior achievement.*

Students can work independently on a device to answer practice questions or complete homework

*This is one example of an online homework tool. There are many other platforms with similar functions. More examples can be found under Setting practice questions on page 11.

Online questions

Technology can provide students with the opportunity to practise answering maths questions independently.[19, 20] Sophisticated programs provide adaptive questions. If a student provides a correct answer, they are then given a more difficult question. If their answer is incorrect, they are given another question at the same level of difficulty.[21] These technology-based practice applications are sometimes termed 'drill and practice' exercises. They can be used to build confidence and fluency in students, which can improve engagement and increase motivation. Roschelle et al. (2016)[18] says that building confidence and fluency is important, and the non-judgemental feedback given by the technology can provide an ideal environment for their mathematical practice. Kehrer et al. (2013)[22] says that when given feedback immediately, students learned more than when receiving the same feedback later.

Flipped learning

Research suggests that a flipped classroom approach can have a positive effect on students.[23] For example, before a lesson students might watch videos which present mathematical content to introduce the topics to be covered in the lesson. Students will generally make notes from this activity. In the classroom, time is then spent on developing their understanding. This allows more class time for activities that help students make connections or for practising exam questions, crucially, with the support of their teacher and each other.[24, 25, 26] Other benefits include more time for mathematical discussion and better peer learning.[24, 25] Students can also use the videos at any time, for example they could be used for revision as well as for preparing for lessons. The idea of flipped learning has been around for many years. Bergmann and Sams (2012)[27] and Khan (2011)[28] have contributed to its increasing popularity. Research has shown that implementing a flipped approach to learning can improve student motivation, attendance and raise achievement.[29]

Putting independent learning into practice

There are a number of strategies to help support students in becoming independent learners. The first step to putting this into practice is to foster a classroom culture in which students can see they are making progress, part of which is encouraging a 'growth mindset'. Students who believe they can achieve their goals are more likely to do so.

Find out more

A growth mindset is the belief that intelligence can be developed.[30] More on growth mindsets can be found in the CfEM Motivation and Engagement Handbook.

Setting practice questions

When using technology to set practice questions, research shows it is important to use software that gives students immediate, non-judgemental and private feedback on their performance. This can help to build students' fluency and confidence but should not be used for all of their mathematical activity. Students can be engaged in learning through the feedback by talking with you about what they think the feedback is telling them, what areas they did well in and where they struggled.

There are a range of companies who provide practice questions but they do not generally focus on the post-16 sector. Popular free examples in this country include **Eedi** and **DrFrostMaths**, with **Hegarty Maths** and **ActiveLearn** available as subscription services. **Century Tech** is an example of a platform that uses artificial intelligence to provide adaptive routes through practice questions, and **Blutick** an example of one that provides immediate feedback at every step of a student's answer.

It is important that you talk with students about the automated feedback they receive

Flipping the classroom

Preparing students

For the flipped classroom, students need to be prepared for the potentially challenging shift to taking control of their own learning. They may also prefer asking questions as they learn, instead of waiting for the class.[29] Oakes, et al. (2018)[26] noted that a common disadvantage for students was not being able to ask questions. Students felt the approach worked well for some topics but not all topics as you sometimes want to ask questions as you go along. Expectations of student responsibilities should be clearly set, as students will be used to mathematical content being introduced during the lesson. This includes ensuring students have reliable access to the videos or other resources. Research suggests that the majority of students are positive about the flipped classroom, as it allows them to feel more prepared for lessons, and gives their teachers more time to help them overcome difficulties.[31]

Videos

You can find resources for flipped learning online, for example the free Hegarty Maths videos available on **www.mathswebsite.com** or the free videos on DrFrostMaths, but the approach is more effective when you create the videos yourself. Creating your own videos means you can anticipate the problems your students will have, allowing you to pre-emptively answer questions and help with misconceptions that would normally take up time in a lesson. The videos should not be longer than three or four minutes.[26]
It is also worth noting that longer videos take longer to download and require more data. This is relevant for students using their own data to watch videos. It can be challenging to get the materials ready on time, and getting used to the technology required to create your own video lessons can be difficult. This becomes easier with experience.[32]
Alternative options to save time and ease workload are:

- working across the department with other teachers
- combining your own new materials with online resources
- creating or using existing presentations and using screencasting software to make videos'
- building a bank of videos or hyperlinks – this will allow you to replace generic, online content with more personalised content over time.

Find out more

For more information on how a flipped classroom approach can be put into practice, please see the *Technology and Data Practice Study – Using a flipped learning approach*.

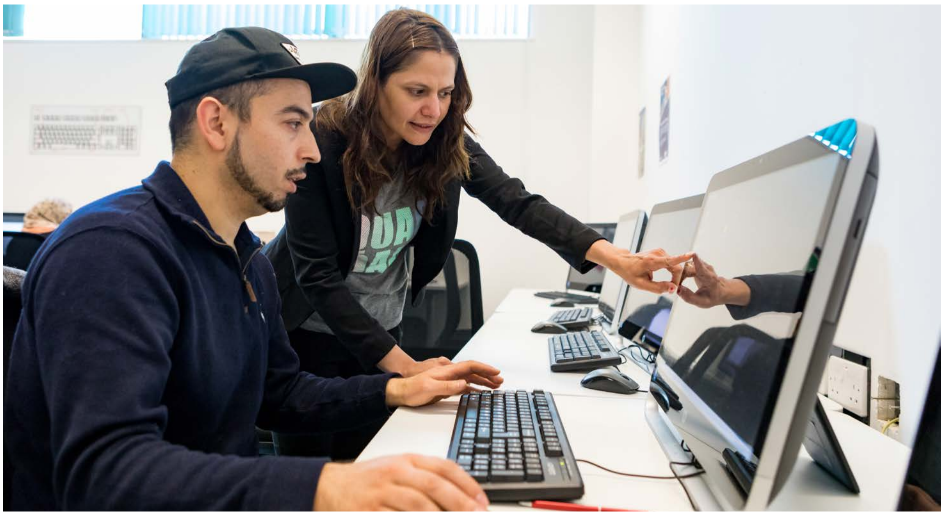
Key principle 3: Adding value

What is the evidence for using technology effectively?

Technology used well can support students and there are many tools available to help them achieve their goals. It is important that teachers support students in finding the right tools that can help them build mathematical fluency, reasoning and problem-solving ability. By using the power of technology, teachers can engage students, deepen their understanding and ultimately make them better mathematicians.[33] It is not solely the technology that enables learning, but the strategic use of the technology by effective teachers. Access to technology is not enough, the teacher and the curriculum are still important for delivering effective use of technological tools. [34, 35, 36, 37]

The key question any teacher or student should ask when considering using a resource is 'What value will be added to the learning by using this resource?'.

Technology should not be used when teaching just for the sake of it. A common example is where a maths class is timetabled to be in a computer room and so the teacher will come up with an activity students can do using the computer. The activity might not be relevant to the maths the class is currently learning, but is used because students are in the computer room. An example might be a lesson planned to be on index notation, where the students go straight to exploring quadratic and cubic graphs in GeoGebra while they have the computers.



The teacher plays a crucial role in using classroom technology effectively

Choosing which technology to use

When using any tool for learning, especially one involving technology (which will likely come with a financial and, at least initially, time cost), first consider whether it is the right tool for the job. Becta's *Quality principles for digital learning resources*[11] can help you choose the resources that match your needs. Decide which of the core pedagogic and design principles are important in what you want the tools to do – these principles will then support you in making informed choices about technology.

It is also worth noting that there is an increasingly large number of platforms and tools that are free to use, such as the **Desmos Classroom** activities and **Geogebra Classroom Resources**, as well as the platforms mentioned in Key principle 2. These principles should still be considered when choosing what to use, to ensure the technology gets the most out of you and your students' valuable time.

Key principle 4: Using data strategically

What do we mean by using data strategically?

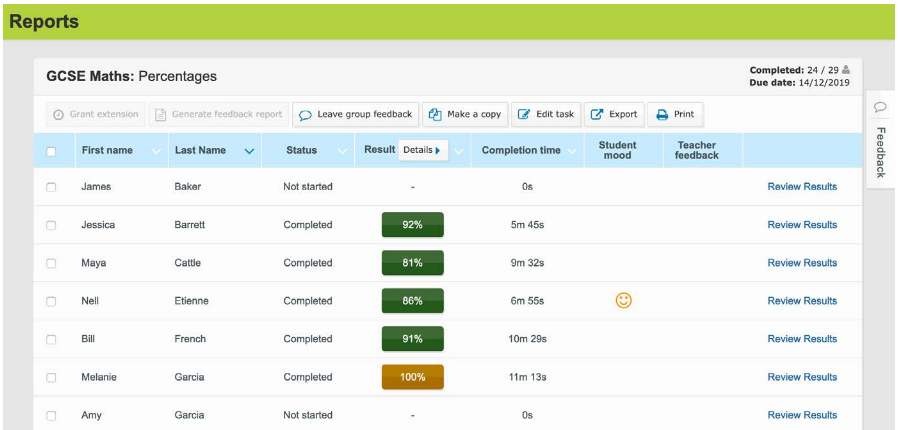
Centres have access to huge amounts of data about their students. Examples include:

- attendance data
- diagnostic data on student misconceptions
- attainment data, including data on past performances in exams as well as from any online questions completed
- data on student progress.

The amount of data available can be a challenge. It is easy for teachers and students to become overwhelmed because of the quantity of data that can be generated very quickly.[38] Using data strategically means focusing on where data can have the most impact.

What does the research show?

Teachers can use technology to gather and analyse data about their students' performance.[39] For example, technology can provide data on how many questions students have answered correctly, which questions they appeared to find difficult and how quickly they answered the questions.[15, 40] In order for these data to be useful, the questions need to be well-designed so that the diagnostic data generated can be used to pinpoint students' mathematical misconceptions.[18] These diagnostic assessments can be used in formative ways to provide follow-up activities for students to address their misconceptions. Some technology even provides suggested activities bespoke to each individual student.[16, 41]



On the ActiveLearn platform you can see how students have fared with the questions they have been set, including how long it took them to complete the questions

Putting strategic use of data into practice

When using any student data, consider whether you are using them ethically as well as whether you are using them strategically. Jisc's **Code of practice for learning analytics** gives examples of how to ensure that data are used effectively, while respecting student privacy and access and minimising adverse impacts.[42] The table shows some suggestions from the code of practice of what you need to consider.

Area of importance	Considerations
Responsibility	You need to allocate specific responsibility for: • collecting data • anonymising data where appropriate • analysing data.
Transparency and consent	You must explain clearly to staff and students: • where the data has come from • the purposes of analytics and the metrics used • who has access to the analytics and how to interpret them.
Privacy	Access to student data and analytics should be restricted to those identified as having a need to view them.
Validity	You should ensure that: • any inaccuracies in the data are understood and minimised • the implications of incomplete datasets are understood • the optimum range of data sources is selected.
Access	Students must be allowed to see the data about them if they ask.

Data will never give a complete picture as they can sometimes ignore the personal situation a student is in, so you need to remember to take that into account. Data should not bias staff perceptions or behaviours towards students, nor reinforce discriminatory attitudes.

Examination data

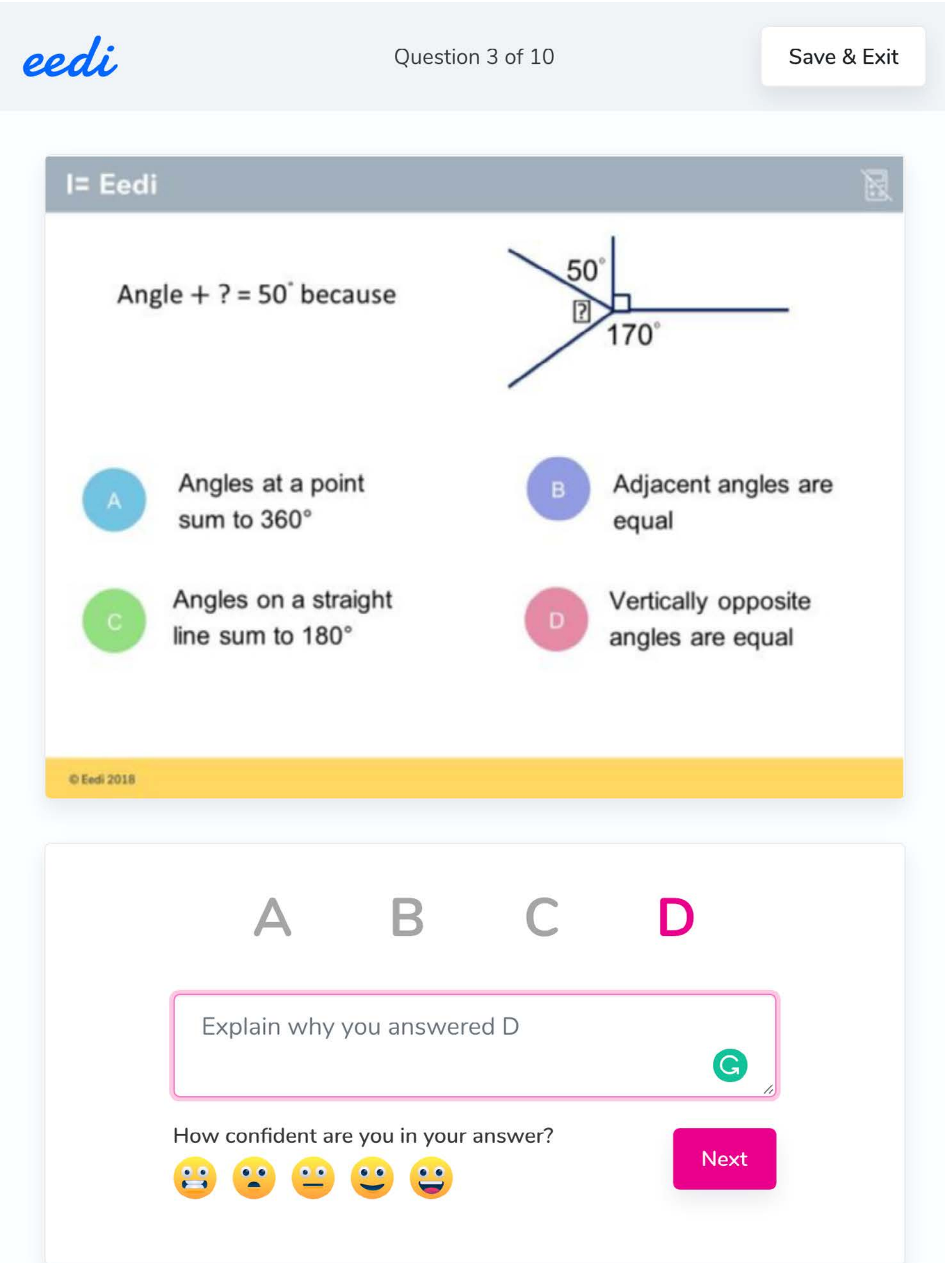
It is possible to retrieve and analyse detailed exam data for incoming students, but this may require considerable effort as they have to be retrieved from the centre at which the students sat their examinations. It is possible to use these detailed examination data to pinpoint the exact areas where students have succeeded previously. It is still important to ensure they have understood the underlying mathematical structure in these topics so that the success can be repeated, but it is motivating for students to know what they can do successfully and have opportunities to both celebrate and build on what they know.

Exam data can also be used in conjunction with diagnostic assessment to focus teaching and learning on common areas of misconceptions and where students need to improve.

Diagnostic data

Rather than cover the whole maths curriculum, you can use regular diagnostic assessment data generated through tests, quizzes, and so on, to identify specific learning needs. This allows you and your students to focus on what will lead to success rather than covering elements of learning that are either already understood or do not support the achievement of their goal.

Depending on the lesson length, diagnostic questions can be asked at different points during lessons to provide up-to-date information for the teacher and student of their progress through lessons. When you find misconceptions through these questions, address them with students to help them understand where their misconception may have come from. When planning lessons, use your knowledge of your students' previous misconceptions to anticipate where they may need support.[43]



Students can complete diagnostic questions on the Eedi platform which generate misconception data

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