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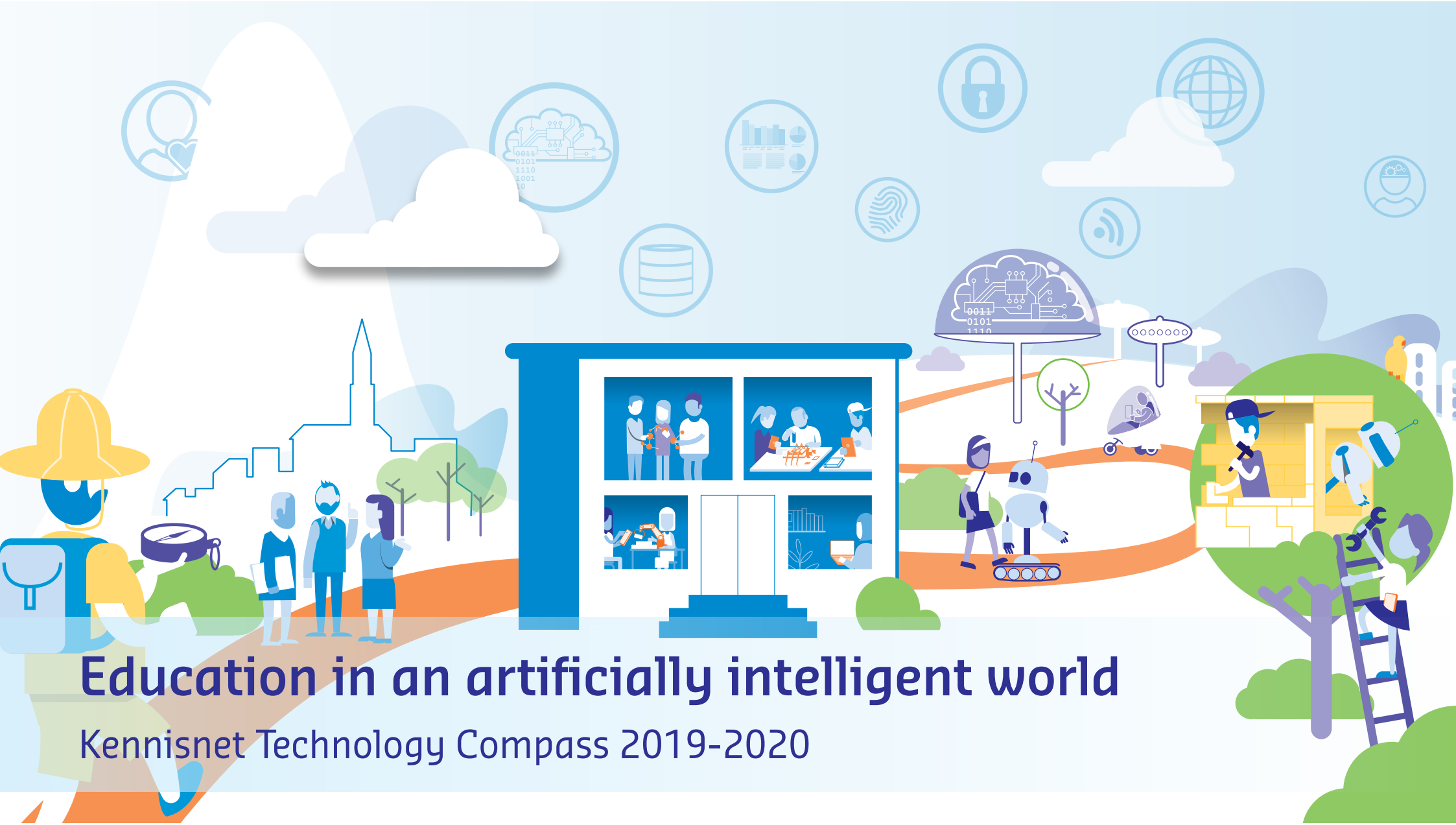

Education in an artificially intelligent world

Kennisnet Technology Compass 2019-2020

Laat ict werken **voor het onderwijs**

Education in an artificially intelligent world
Kennisnet Technology Compass 2019-2020

Please note:

This report is written from a Dutch perspective and with the Dutch educational system and its structure in mind. Please take this into account when reading this report.

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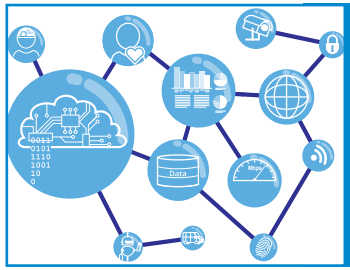


Chapter 1
Contains an analysis of the most significant technological trends and developments. Artificial intelligence (AI) is the most important.

Chapter 2
This insight into the future describes a further development of technologies schools are already using, like adaptive learning materials, in the coming years.

Chapter 3
This insight into the future shows how schools will change in the long term when an artificially intelligent learning environment is available at all times.

What will you find in this technology compass?

If someone had told you 25 years ago – roughly at the time the internet started to rise – that in 2019, you would be swiping on your smartphone for multiple hours a day, and that thanks to the internet you'd know exactly what time your aunt in France was drinking her latte, or that teenagers could become drone pilots during their vocational studies, would you have believed that person? Probably not, as nobody can predict the future. Although technological developments are reasonably foreseeable, the social and cultural consequences they will have in the future are very difficult to predict. For instance, a film from the sixties about the 'office of the future' was pretty accurate from a technological point of view. The only thing missing however was women, as the arrival of washing machines, vacuum cleaners and gas cookers had actually given them more time for office work. How do we prepare young people to live an independent life in a world in which we are continually developing and deploying better, smarter and more efficient technologies? A world where artificial intelligence (AI) helps prevent diseases and domestic burglary, and where robots perform surgery?

The influence of AI and robotics on people and society is profound and far-reaching. In 25 years' time a significant portion of the tasks people currently perform will have been taken over by robots or AI systems. This creates challenges, but also offers new opportunities. We easily come into contact with different cultures via the internet, job security is a thing of the past, and information (or misinformation) is abundantly and publicly available. Life in this kind of society requires skills. Knowledge and cognitive skills remain important, but, more than ever, social-emotional skills are necessary for personal and professional development. The student of today must in the future be able to cooperate in teams of people from different backgrounds and come up with solutions for new issues that we can't even imagine yet.

Technology can't do it completely, but equally, teachers can't do it alone

Schools and teachers therefore have an indispensable role in developing social-emotional skills, in addition to teaching knowledge and cognitive skills. In the acquisition of knowledge and cognitive skills in particular, we see a growing role for technology. With the help of artificial intelligence, it is increasingly possible to personalise education to each individual learner. And with that, something interesting happens: the teacher gets more time and headspace to focus on guiding students in their development of social-emotional skills. And precisely those skills will be very important in this rapidly changing and uncertain future.

Education is geared towards a future in which teacher and technology work together to teach students the knowledge and skills necessary for a meaningful and successful life. Technology can't do it completely, but equally, teachers can't do it alone.

Structure and reading advice

In this technology compass, we outline a future in which teachers and technologies collaborate to teach students the skills they need for a meaningful and successful life. This report consists of four parts. In the rest of this introductory part, we explain the two tools that we use in our trend analysis. Chapter 1 presents our analysis of the most important technological trends and developments. Chapters 2 and 3 each contain insights into the future impact of the technologies in education.

Chapter 1: the most important technological trends
Describes the most important technological trends and developments for education. Artificial intelligence (AI) is the most relevant one. There are a number of other dominant developments that relate to AI as well. We also explain those in more detail in this chapter.

Chapter 2 and 3: insights into the future
Chapter 2 provides insight into how the technologies schools are currently using will be developed further in the coming years. For example adaptive learning materials for students, and dashboards that allow teachers to follow and guide the learning process.

The second insight, in chapter 3, shows how a school changes over the long term into an artificially intelligent learning environment that is always available and that supports personalised learning at the level of individual learning paths.

In both chapters, artificial intelligence acts as the technological catalyst.

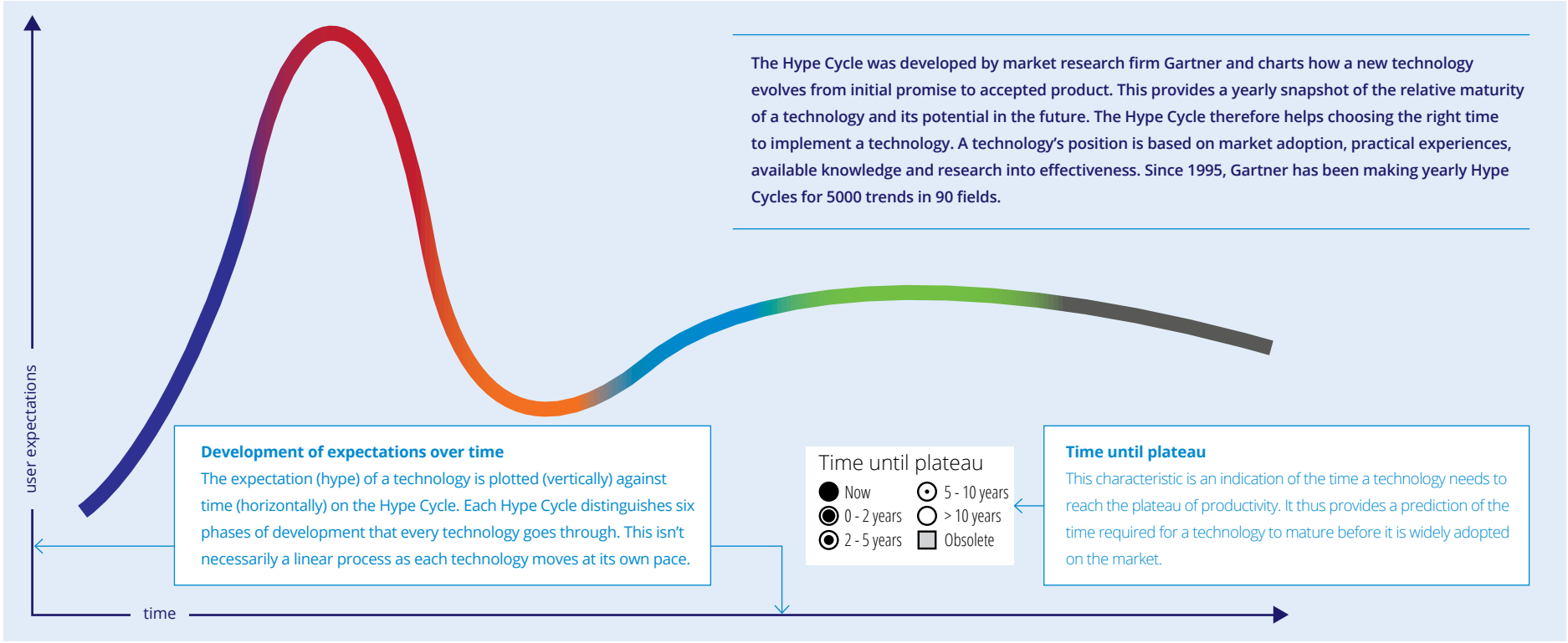
Each chapter consists of two or three sections, from different perspectives.

In a nutshell
We provide a general outline that has relevance for every reader. This is where you can read the most important conclusions and recommendations. ▸ *See 1.1, 2.1 and 3.1*

The technology
Features an analysis of the most important technologies. This enables a greater understanding of the technology, in non-technical language. Especially of interest if you want to know more about the technologies and how they relate to each other. But take note: in 2.2.5 and 3.2.5 there are recommendations that are relevant for all school teams. ▸ *See 1.2, 2.2 and 3.2*

Issues for education
Here we address a number of challenging issues to be faced in education as a result of use of the technology. Especially interesting if you want to know more about the impact of artificial intelligence on the learning process and administration. ▸ *See 2.3 and 3.3*

Hype Cycle: visual representation of market development



Innovation trigger

A potentially groundbreaking technological innovation gets the first media interest through demonstrations and experiments. The technology is not yet generally applicable or commercially viable.

Peak of inflated expectations

A wave of enthusiasm is set off by publicity about the first success stories. These expectations surpass the actual possibilities. This is where the hype is at its highest.

Trough of disillusionment

Enthusiasm makes way for disappointment, due to problems, high costs and low returns. Expectations plummet to their lowest point. This is precisely the period that offers opportunities for new applications, building on the experiences and knowledge of forerunners.

Slope of enlightenment

The first obstacles are overcome and the gains become clear, as do the conditions for successful application. Using the insights of forerunners, there is a growing understanding of where and how the technology can be used effectively.

Plateau of productivity

Now that the actual returns have been proven in practice, more and more organisations dare to use the technology. A period of rapid growth follows, which then sees another decrease as more and more people get involved.

Swamp of diminishing returns

Outdated technology can frustrate, delay or even prevent new initiatives. This means that, in addition to the timely adoption of new technologies, outdated technology should also be replaced in good time.

Benefit Map: balanced ICT portfolio helps achieve educational goals

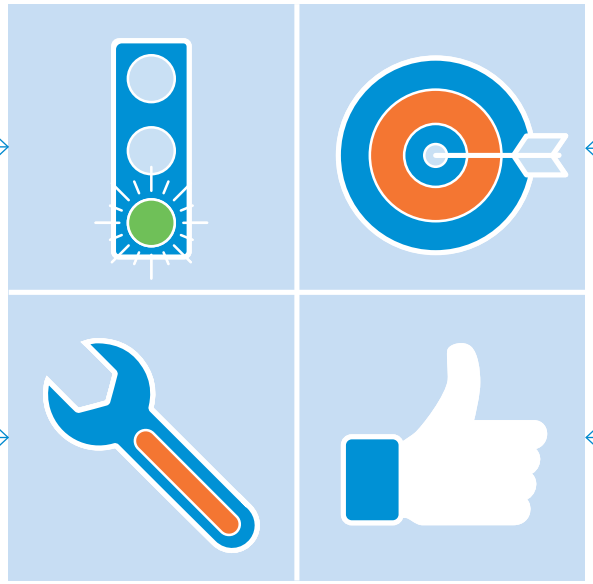
The Benefit Map helps you put together an ICT portfolio with the best balance of risks and returns. Using your educational goals as the starting point, you determine your ICT ecosystem, a set of interconnected ICT building blocks that reinforce each other, and thereby optimally supporting your educational institution. This matrix provides insight into the support for technology from the school administration, as well as from its teachers and students.

Acceptance will be high and implementation will proceed smoothly if the school, teachers and students all see the value of the selected ICT resources. Implementation will be a difficult and slow process if none of them see the importance of a technology. This yields four quadrants, each with its own profile for the technologies it contains.

'Green light'
This technology mainly concerns process-supporting systems such as student information systems. Necessary for the school's administration, but often perceived as cumbersome by teachers and students.

'Enabler'
Technology in this quadrant is not perceived as relevant; this often concerns supporting infrastructure or agreements about standards.

The vertical axis shows the importance that the school organisation attaches to the successful application of a technology



'Hot spot'
Technology in this quadrant is often a variation on consumer technology to support the educational process, such as smartphone apps that offer access to digital learning environments.

'People's choice'
Tends to be (consumer) technology that offers convenience to teachers in particular. However, fragmentation of information and knowledge can arise without investment in organisational security. One example of this is cloud platforms for collaboration.

The horizontal axis shows the importance that teachers and students attach to the successful application of a technology

Hype Cycle and Benefit Map: how they can help you to put together your ICT portfolio

This report provides insight into the currently most interesting technological developments, with educational ambitions as the starting point. But how do you determine which technology will be the best investment for you? What priorities do you set? How quickly do you want to get involved in new technology and what risks are you prepared to take?

Compiling your ICT portfolio is comparable to putting together a healthy equity portfolio. Investing in high-risk technology is attractive if there is a high return in educational value. You have to be wary of getting ahead of yourself and jumping on board too soon, but also of the temptation to 'sell' as soon as you hit a bump in the road. You can wait until the risk is low, but then you also have to settle for a lower return. Finally, in due time, you have to let go of technologies that have become less beneficial.

Moreover, it is rarely a question of a single technology, but rather an ecosystem of mutually reinforcing resources. They will only provide maximum support to educational goals if they are well-connected and mutually reinforce each other. For example, a stable internet connection is required to be able to use adaptive learning materials. Without one, investment in the other is meaningless – and vice versa.

Which technologies can support education in a way that increases the students' learning outcomes and motivation? This was the question we asked ourselves when making this report. In our analysis, we used the Hype Cycle and Benefit Map from research firm Gartner.

A story about how technology contributes to your educational goals

An analysis like this isn't always easy. We had discussions and differences of opinion in our process. In which phase of the Hype Cycle does this technology actually belong? And in which quadrant on the Benefit Map? Are we taking sufficient account of the Dutch educational context? By explaining our different perspectives to each other on why we thought a technology should be in a certain position, we improved our analysis and thus our story to each other and to you, our reader.

As a school board, you also have a story to tell. A story about your ICT portfolio, and how these technologies allow you to fulfil your educational goals. You need to create understanding and support for your investment agenda and implementation plans, with various stakeholders, such as your employees, your students and their parents, the board of directors, the inspectorate and the business community.

Kennisnet developed additional information about the Hype Cycle and Benefit Map to help schools with the creation of their own story to tell. In this, we help you on your way with questions and discussion tips. The completed Hype Cycles and Benefit Maps in sections 2.2 and 3.2 provide inspiration, but are primarily intended as a starting point for discussions within school teams.

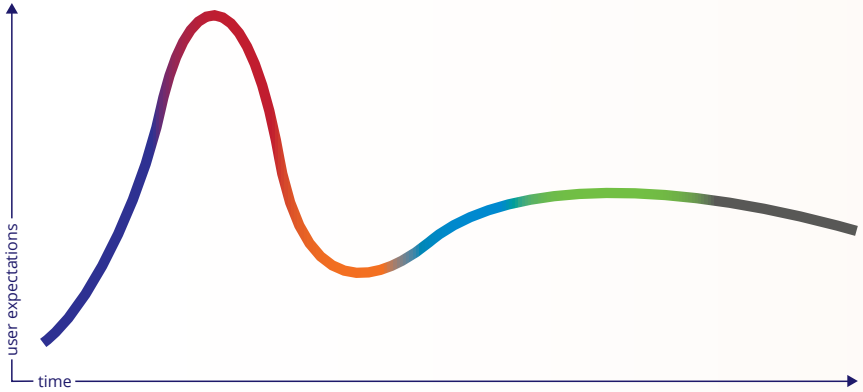
> **Want to find out more about using the Hype Cycle and Benefit Map?** Visit *kn.nu/technologiekompas*

How is this kind of story created?

To give you a sense of the discussions, the struggles and the differences of opinion, you can read three brief overall impressions of a workshop that we held with the board of a secondary school.

Selecting technologies with the Hype Cycle

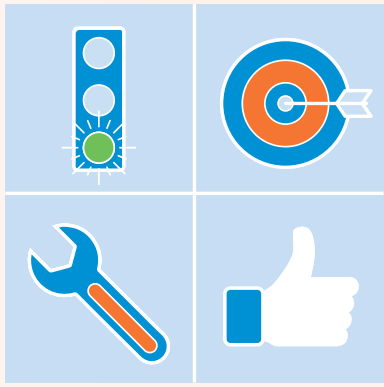
Making a Hype Cycle from scratch is very difficult. This is why we put a set of technologies on the Hype Cycle, with our version as a starting point. We were asked the question: "How can we ensure that adaptive learning materials enter the next phase faster?" The answer was "it doesn't work like that". Each technology goes through its own evolution process – expectations are initially much too high, so we then become disappointed and try to figure out the conditions needed to make the technology a success. Only then does a mature product start to take shape. This caused disappointment among teachers who were already eager to do more with adaptive materials. Fortunately, you don't always have to wait until technology reaches the safe, full-maturity stage. The intermediate phase can in fact provide a great deal of knowledge and experience, which can be of huge benefit to the school. Provided you take the right measures to limit the risks of immature technology. That changed the disappointment somewhat back into enthusiasm.



Understanding each other's priorities with the Benefit Map

The Benefit Map looks simple at first sight, but proves quite difficult to fathom. One of the school directors asked, "Shouldn't everything be in the top right quadrant?" Our answer was 'no'. A typical Benefit Map has technologies in all quadrants. It is a question of the balance between technologies with benefits for the school and with immediate convenience for teachers and students.

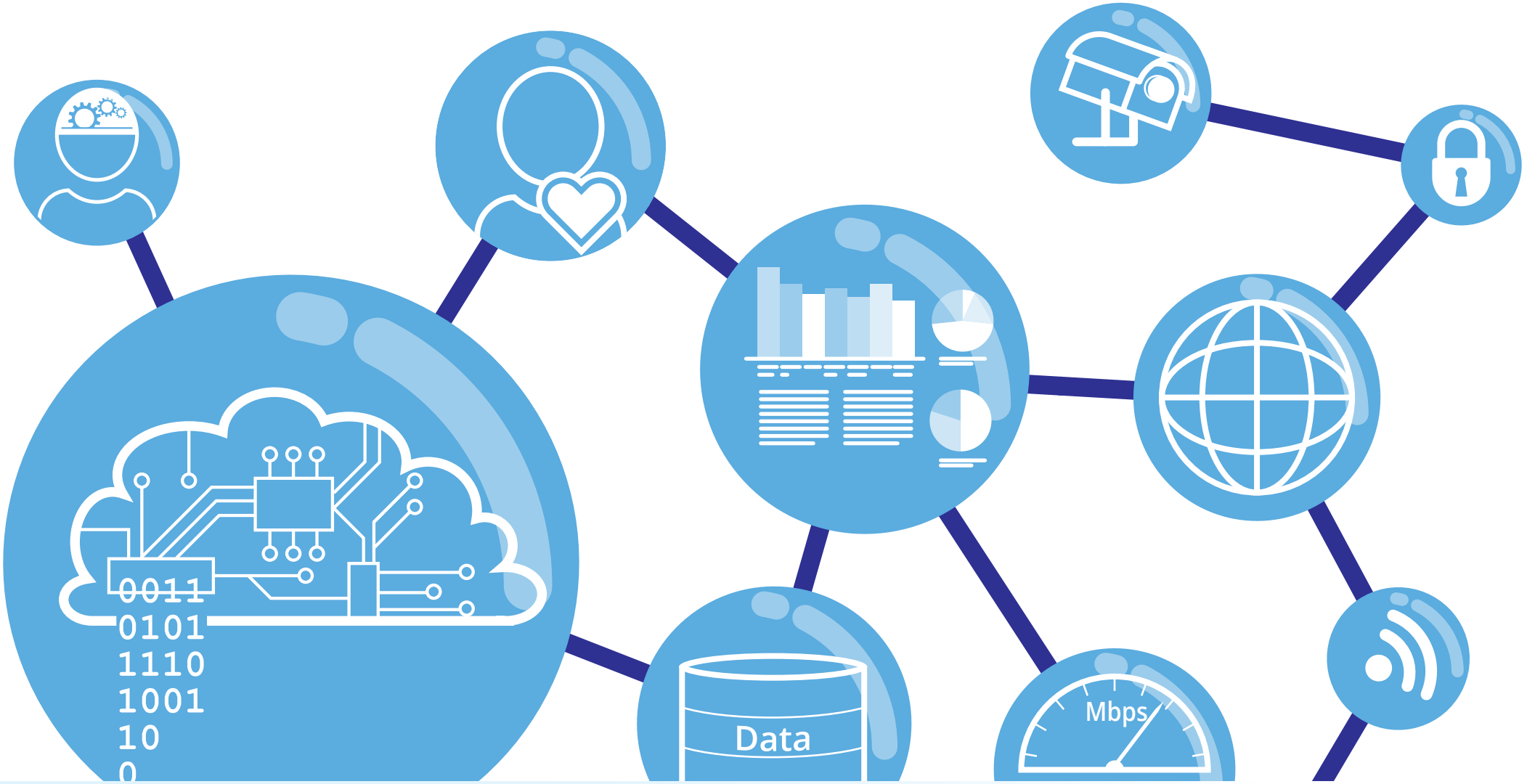
After a short explanation of the axes and quadrants, we placed technologies on the Benefit Map. Adaptive learning materials, devices and dashboards – many did turn out to belong in the 'hot spot' in the top right section. "Have you perhaps forgotten anything?", we asked the group. To this, the ICT



manager retorted: “Fantastic plans, but with the current network, it’s next to impossible!” A discussion followed about the benefit and necessity of a stable internet connection when working with adaptive learning materials on devices. After this conversation, the rest of the group also had a better understanding of how crucial a good internet connection is to achieve their educational goals. We added this technology to the Benefit Map and the Hype Cycle.

Determining interplay and priorities with the Benefit Map

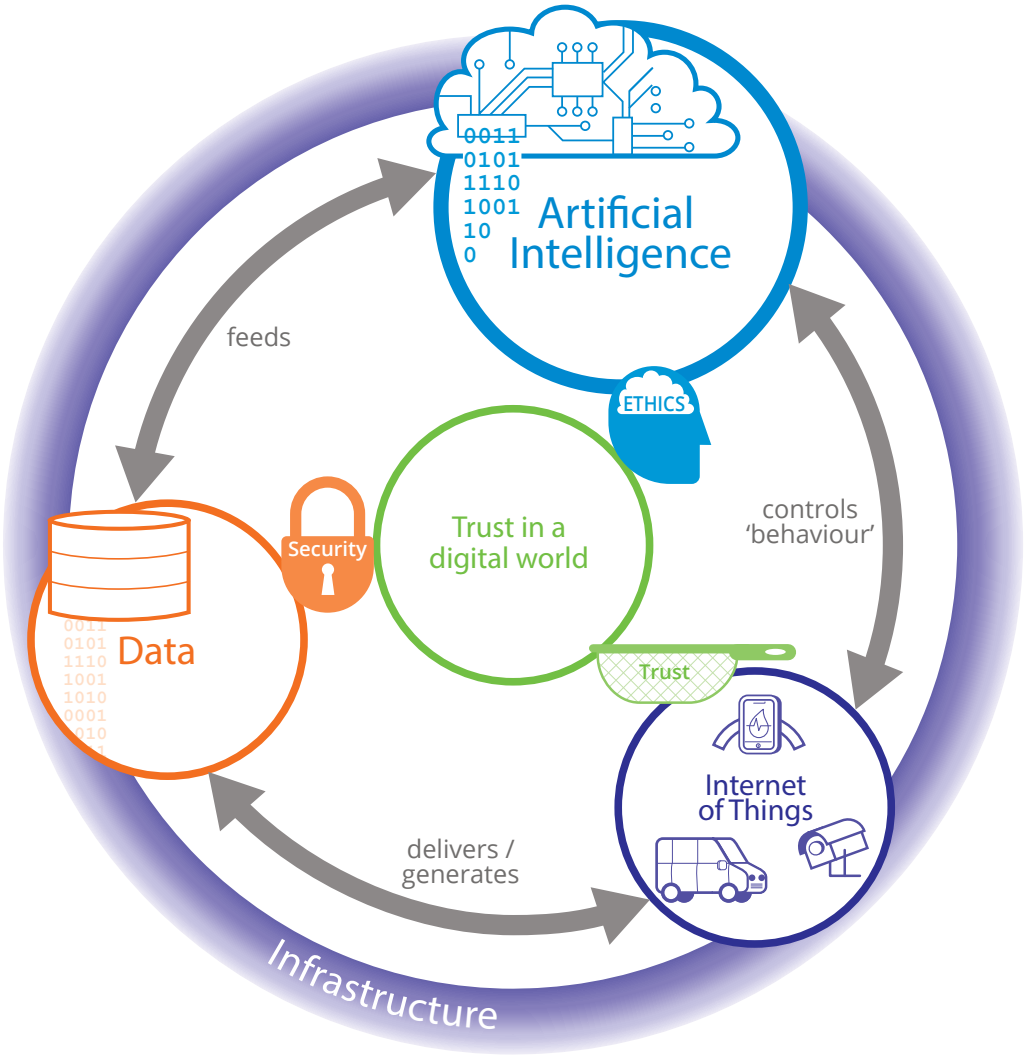
The last exercise we did during the workshop was a discussion of the interplay of different technologies. We asked the group: “Which technologies belong together?” “All of them,” was the first answer. And a logical answer, at that. You need to utilise the whole set of technologies if you want to achieve an educational goal. We then asked, “But are there groups that you could implement separately? Or things you would have to organise first before starting on something else?” After a heated discussion, the group concluded: “Let’s improve our network first, and only then start with structural use of adaptive materials and appropriate types of devices. This will enable the students to work well with the materials, and we also minimise the chance of technical problems frustrating our learning process.”



Chapter 1

The most important technological trends

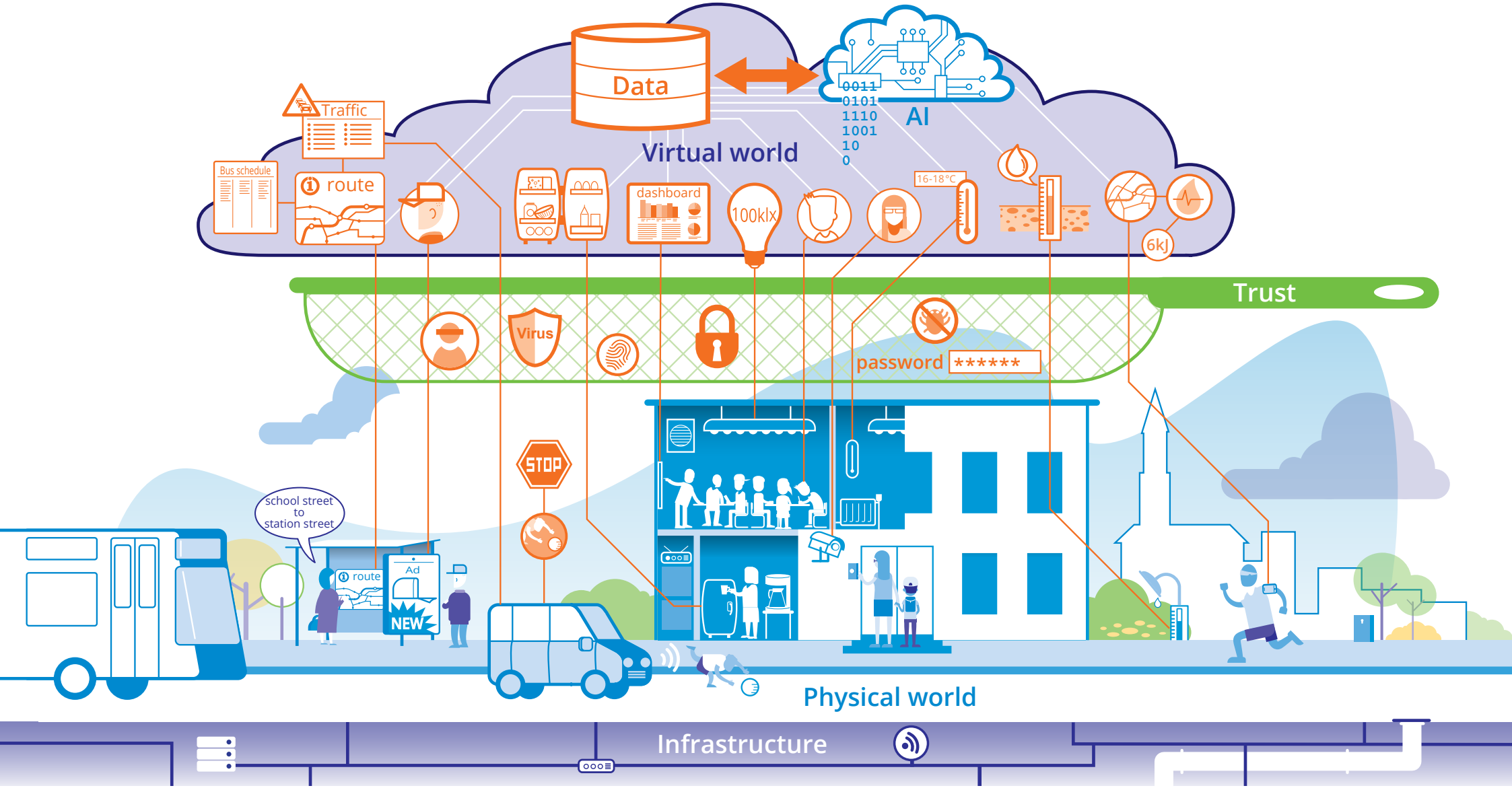
1.1 The universe of trends in a nutshell



Preparing young people for a meaningful life and a successful career, preferably by giving them as much personalised attention as possible. There are different ways to approach this vital task. Our analysis shows that artificial intelligence (AI) is the most promising technology for attaining these educational ambitions. Personal guidance and individual attention are possible without technology, but are very costly and time-consuming. By applying AI, educational professionals can more effectively use the time they devote to each student.

Therefore, the expectations for AI are also high. Schools are already coming into contact with the first applications, for example in adaptive learning resources and tests. We expect that the teaching of cognitive skills will be even more intensively supported by AI in the future. Imagine the possibility of using AI to provide tailored advice for every student's learning path. This is why we have chosen AI as the main topic for this technology compass.

Of course, we haven't just looked at AI alone. We also briefly discuss other important trends such as the Internet of Things (IoT), big data, ICT infrastructure and the increased focus on trust in the digital world in this chapter. We haven't chosen any of these trends as the main topic for various reasons. For example, the impact of the IoT is felt mainly in society and less so in education. And data itself only gains value when AI and IoT applications can derive meaning from it. In the next section, we discuss the relationship between these trends and explain them in more detail.


Data
AI
0011
0101
1110
1001
10
0
Virtual world
Traffic
Bus schedule
route
dashboard
100klx
16-18°C
6kJ
Trust
Virus
password ******
STOP
school street
to
station street
route
Ad
NEW
Physical world
Infrastructure

1.2 The universe of trends: technology

Artificial intelligence (AI) is a very dominant force. This field of study focuses on algorithms that allow machines to display intelligent behaviour. It is inspired by the way that people use their nervous systems and bodies to feel, learn, reason and take action. Due to the increase in computing capacity and the availability of huge amounts of **data**, AI is now undergoing rapid development. Data forms the foundation of the training of algorithms that make AI possible. By processing and analysing this large and varied amount of data, AI can get continually better.

Two of the places where data is collected are in our environment and on our bodies: a development called the **internet of things** (also known as IoT). These are devices with sensors and actuators (something

Artificial intelligence is the most promising technology

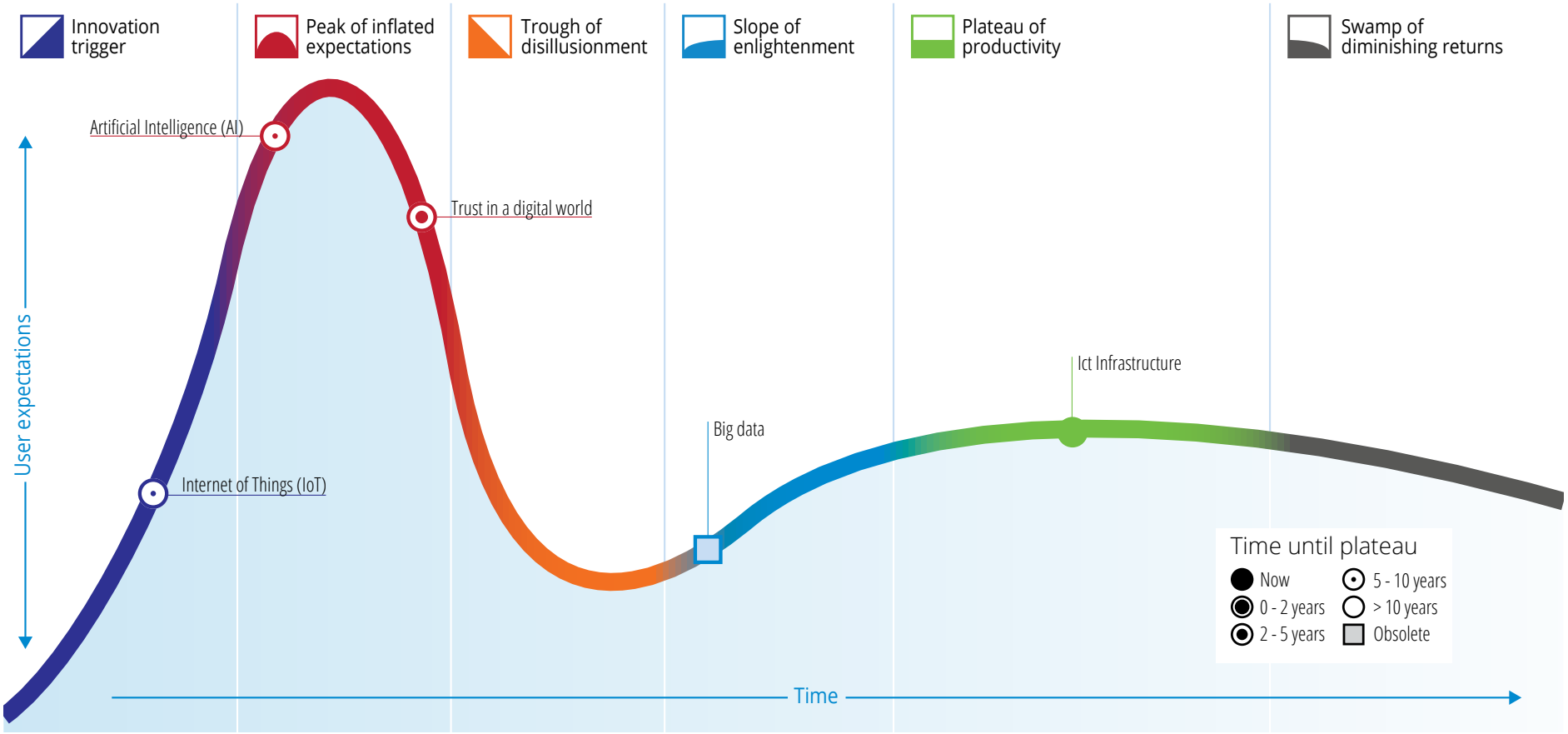
that can be moved or switched on, such as a motor, valve or a program) that are connected to a network. The data registered by the sensors is analysed, decisions are made using algorithms, and physical actions can be carried out by controlling actuators. These devices primarily function autonomously, without human intervention.

Sensors of this kind are also increasingly present in public spaces. Think of smart cities, equipped with smart buildings. With this in mind, the term IoT can seem a little too 'narrow'. Indeed, an environment is created in which computers are always present, observing, analysing and possibly intervening autonomously. This is often referred to as ambient computing.

As a result, more and more data about us is collected and analysed, leading to a renewed focus on **trust in the digital world**. We are increasingly moving towards a world full of algorithms and AI applications. How can we be confident that platforms such as Facebook and Google will appropriately deal with stored, used or shared information about us? And, on the internet, how do you know that parties are who they say they are? Developments associated with this are the growing attention towards privacy and security, the hype surrounding blockchain and the discussions about the platformisation of society.

An education-specific development is the focus on a professional **ICT infrastructure** that ensures that innovative technology can be used unproblematically in the school environment. This is no longer a new trend, but an important development in Dutch education. School boards are realising that a professionally equipped ICT infrastructure is an important precondition for taking the next step with technology in education.

These developments are all at a different stage of development and maturity, as becomes clear when we place them on the Hype Cycle.



In the following sections, we will discuss AI and the other trends on the Hype Cycle in more detail. We only discuss big data in the context of AI and IoT applications because these applications can extract meaning, and therefore value, from data.

1.2.1 Artificial intelligence

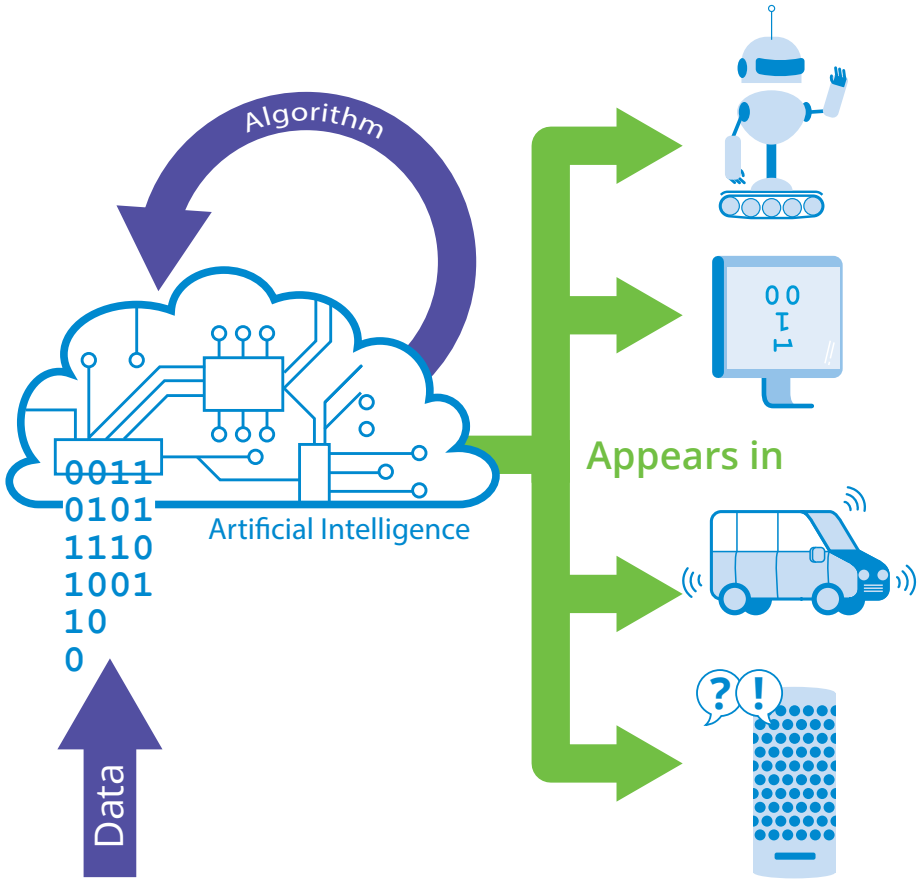
Artificial intelligence is the ability of computers to perform tasks that require humans to use their intelligence, like: observing, recognising, interacting with the environment, analysing, reasoning, solving problems and making predictions. For example, you can find AI in voice assistants on smartphones, self-driving cars or in robots that compile orders in large warehouses. But it can also be found in programs that, without any human intervention, can write factual accounts about annual figures or produce diagnoses of medical disorders. A huge range of different manifestations, but they all use AI as their foundation.

Inspired by the human brain but not the same

Artificial intelligence does not have to mimic the functioning of the brain in order to be effective, in the same way that an aeroplane can fly without having to move its wings like a bird. Due to the rapid development of chip technology, AI can store, process and analyse many times more data than a human brain. However, not all human capabilities can be approximated

Artificial intelligence doesn't have to mimic how the brain works

with brute computational power at this time. An AI system that can mimic a complete human being, otherwise known as artificial general intelligence, still has a long way to go. Task-specific artificial intelligence, on the other hand, is already all around us. You can find it in a wide variety of products. However, AI technology of this kind must be made suitable for a specific market or field of activity. For example, there are great expectations for AI in education, but for the time being, we see it only to a limited extent in tangible educational products.



Robots – predominantly for physical work and specific tasks

We regularly see impressive videos of robots effortlessly navigating all kinds of obstacles or answering a range of questions. As a result, there are high expectations. Does this mean that robots, powered by AI, will soon be able to take over all of our physical activities? No. Robots may seem smart, but they aren't. A walking robot only functions in a controlled environment. If you were to put that robot outside on the pavement, it couldn't function at all, and would pose a danger to the humans around it.

Recently, British parliamentarians asked a talking robot a number of questions. On the basis of its comprehensive answers, you might think that the robot understood the questions and could therefore answer any random question. In reality, the answers were preprogrammed. Robots are therefore not yet suitable for physical and cognitive interaction with our complete, complex reality.

Cooperation between people and robots

Robots that can behave entirely like humans are still a long way off. However, they can perform specific tasks, thereby complementing people. For example, robots in the warehouses of major online stores bring racks filled with items to the human order picker. Because no space is required for people, the storage racks can be built closer together. The order picker then picks up the ordered items by hand from a rack, because robots aren't very good at handling a variety of objects with different shapes or weights. What is very intuitive for people can be very complicated for robots.

Robots are also used in surgical procedures, which has led to significant changes to how people work in the operating room. The surgeon no longer does the cutting himself, but controls the robot from behind a screen. Incisions thus become smaller and more precise, resulting in less scar tissue. Moreover, the communication between the surgeon and his assistants has become much more important because they are physically further apart. But, after the operation, there is no robot at the patient's bedside to tell them how the operation went; although robots can very successfully simulate empathy and create the illusion that they understand us, that is still the work of a human, who can demonstrate true empathy.

Robots particularly complement people when it comes to heavy physical work, or when an activity has to be performed with great precision. This is one of the reasons why it is important that vocational education focuses explicitly on robotics – robots will have an increasing influence on our work and our lives, but not in tasks where our human capabilities and strengths play an important role. As an object of study in basic education, robots are interesting for students, and they will definitely play a role in the students' future occupations. But for now, a robot in every classroom is still very much a pipe dream.

How does AI work?

Artificial intelligence essentially consists of two components: a self-learning algorithm and data. An algorithm is a series of instructions that leads to a certain result. In computers, this takes the form of a computer program. One example of an algorithm that you encounter and use in everyday life is a *recommender system*. Based on your viewing behaviour, video streaming services make recommendations about other videos that you may find interesting. To be able to make these recommendations, data is needed. In this case, the data is your own viewing behaviour and that of others. Data is the raw material that allows AI to work. By analysing more data, the algorithm can make better recommendations.

An important difference between other programs and those that use AI is the ability to learn. Think of a chess program. You could program it with every possible strategy, decision and rule, prepared in advance. In terms of possibilities, the end product then remains limited to what the programmers have told the program about effective strategies. With an AI chess program, you don't come up with all the steps in advance, but you make an algorithm that is capable of learning from data. You 'feed' it millions of chess games that people have played. The algorithm analyses everything and then extracts strategies, rules and decisions. It would be impossible for people to analyse so much data, but an AI program is able to. After the algorithm has been trained, it can play chess against people in the form of a computer program.

Programs that are trained with AI don't necessarily learn constantly. It is a snapshot, as it were, of all knowledge and experiences acquired up to that point. Its functioning is as good or bad as the quality of the devised algorithm and the data with which it was trained. The algorithm makes decisions based on what it has learned before you can eventually use it as a program. Of course, the program also collects new data as you use it. To make the AI even better, this data must first be processed and a new snapshot can be made. You can compare this new snapshot with a software update.

Bias in AI

Just like people, AI systems sometimes have prejudices, although these often arise unintentionally. The developer can consciously or unconsciously program them in the algorithm. It is also possible that the dataset with which the algorithm is being trained is incomplete, polluted or incorrect. As AI systems start carrying out more and more tasks for us, we must be wary of these biases. Later in this report, especially in section 3.3.2, we will further discuss this bias and the implications it can have in the educational context.

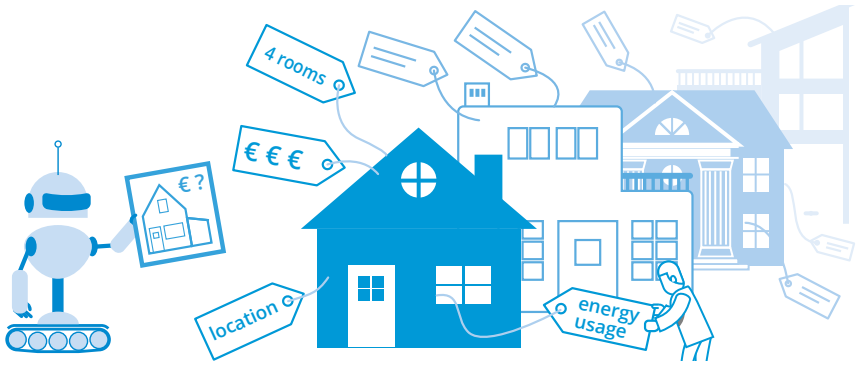
Forms of AI

There isn't one specific form of AI. The different forms of AI use different approaches, each with its own strengths and opportunities. AI products and services use one or more forms of AI. Here, we will discuss the four most commonly used forms.

Supervised machine learning

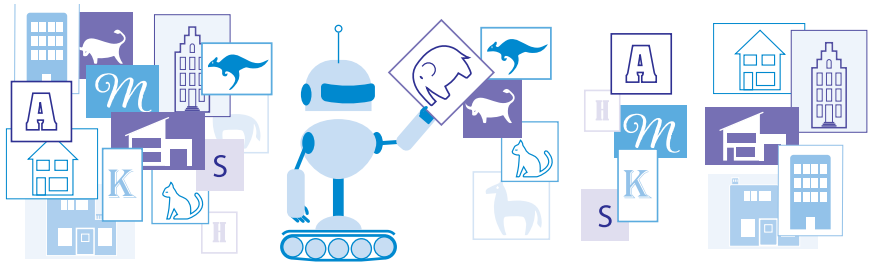
With this form of AI, you know in advance what the correct outcome is and you teach the algorithm the relationships between various data. All of the data used is labelled by people, in much the same way that you would indicate the meaning of each column above the columns of

a spreadsheet. The algorithm doesn't have to figure out what the data means or which data groups belong together. By feeding the algorithm more and more data, the results become more and more accurate. As an example, think of determining the selling price of a house. By giving an algorithm lots of historical data of sold houses with their final selling price, plot size, location and other features, it gets a better understanding of the relationships between the factors. This allows it to more accurately determine a selling price.



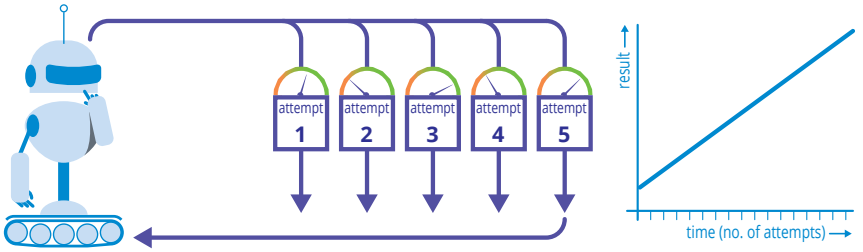
Unsupervised machine learning

With this form of AI, you don't program what the right outcome is and exactly which data is relevant, but you ask an algorithm to cluster the data by finding patterns in a dataset. Algorithms like these can be used if you don't want to or are unable to classify all the data yourself, or because you want to discover new connections and clusters. One practical example is a video service that recommends other videos that are likely to be of interest to you. In this case, you don't want to think up every single category in advance, but you want the system to determine them, and to keep recognising and updating them.



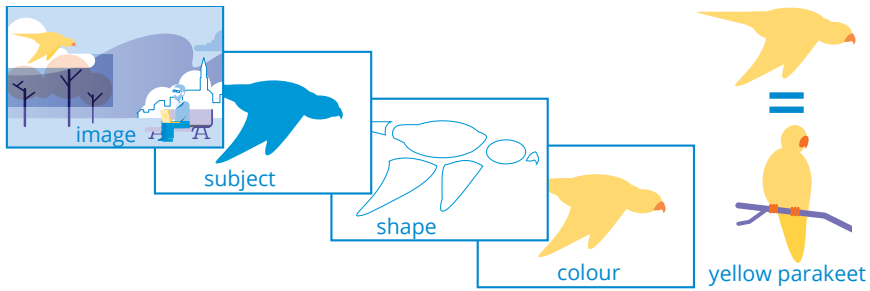
Reinforcement learning

In this form, the algorithm learns to perform a task by getting rewarded for actions that provide the right outcome. You can use this type of algorithm if there is little data available. It is comparable with training a dog: if the dog does something right, you give it a reward, otherwise, no reward. The algorithm then learns what the desired actions are that contribute to achieving a specific goal. These types of algorithms are also used in self-driving cars so that, learning from the driver, they can make better decisions. Or, in the case of a robot learning to walk, it learns by trial and error how big the right step has to be.



Deep learning

You can use this form with 'unstructured data' such as images, videos or sound recordings. Compared with the other forms, it needs much more data, but it may yield even more accurate results. Deep learning algorithms consist of different layers. Each layer learns new and more complex properties of the data. For example, you can create an AI system that recognises animals. By providing it with lots of examples of different birds, the system learns to recognise various characteristics. For example, one layer of the algorithm analyses the shape of the object. By recognising wings and a beak, it knows that this particular object is a bird. Another layer analyses the colour of the bird and recognises that it is a yellow bird. Based on the combination of these characteristics, a subsequent layer could also recognise the specific type of bird, for example a yellow parakeet. If you show the algorithm a new bird that wasn't in the training set, it can still recognise the bird on the basis of its characteristics.



1.2.3 Internet of Things

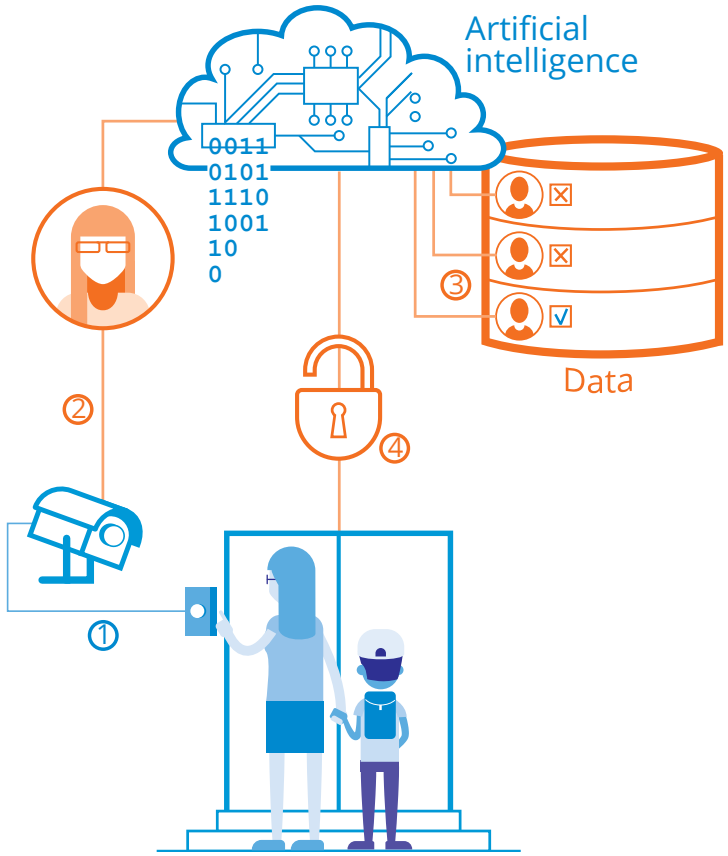
The Internet of Things (IoT) consists of objects in our daily environment that are connected to a network such as the internet. These are often objects that we wouldn't necessarily expect. IoT devices contain sensors that observe their environment and use AI algorithms to analyse the recorded data. As a result of this analysis, the IoT devices can then act independently in the physical world.

Devices collect, analyse and intervene

For instance, a camera can warn security personnel when a threatening situation is detected, and immediately sound an alarm or preemptively close a door. A smartwatch can instantly warn its wearer of an unusually high or low heart rate, or immediately alert emergency services after you've taken a fall. Over the longer term, our lifestyle habits will be analysed and we can receive advice on healthy exercise and adequate rest, taking our daily and weekly routines into account.

Processing of data, both locally and in the cloud

IoT devices continuously collect data on their environment and send this to online cloud platforms. This enormous amount of data is partly responsible for the rapid improvement of the algorithms used by AI, as described in the previous section. Previously collected data is used to train the AI algorithms that IoT devices apply locally and that cloud platforms use to determine appropriate actions based on current data. Data improves these artificial intelligence processes in iterations, however not at the moment of data collection. Determining the right intervention and being able to execute it as quickly as possible is the priority at that moment. Self-driving or semi-autonomous cars will



therefore analyse the data independently if immediate action is required, for example braking or avoiding an obstacle on the road. Locally analysing data and acting on this is also known as edge computing. Here, *edge* refers to the edge of the cloud. Actions that don't require intervention within milliseconds, such as determining the best route based on current traffic levels and other relevant information, can be coordinated with a central cloud platform.

Seamlessly integrated computer environment

There is a very diverse collection of devices that can now function without any human intervention now that items we use every day such as lighting, doorbells, refrigerators and washing machines are connected. For this reason, we often don't recognise them as 'computers'. They create an extra layer around the physical world, which is also referred to as ambient computing by working ever more closely together. While IoT revolves around the devices, ambient computing refers more to the experience of ubiquitous, seamlessly integrated computer support in everyday life and work.

Safety is not a given

Alarm bells may have gone off for some readers with regard to the various vulnerabilities in the functioning of IoT devices. For example – what if false data is fed to algorithms? What happens if sensors are manipulated? Or if the communication between an IoT device and its cloud client is intercepted and distorted? In many cases, this could lead to unwanted and sometimes life-threatening situations.

Unfortunately, the fundamental conditions for secure ambient computing aren't yet in sight. As yet, there is no integration between suppliers, and agreements about encrypted, secure communication still don't receive much attention. This is due in part to the early stage in which IoT finds itself on the Hype Cycle. But it also says something about the broader, practical applicability, which is low, for the time being.

Opportunities for education lie further down the road

All signs indicate that IoT devices will enable a world of *ambient computing*. Applications in specific situations are promising, such as analysis of facial expressions and behaviour on security cameras. Smart buildings that can enable more efficient energy consumption have also been on the rise for a number of years. In society, we see IoT applications increasingly becoming a part of our daily living and working environment. And thus it also has an influence on education. We also note, however, that productive contributions to important educational goals, such as personalised learning, aren't currently under discussion.

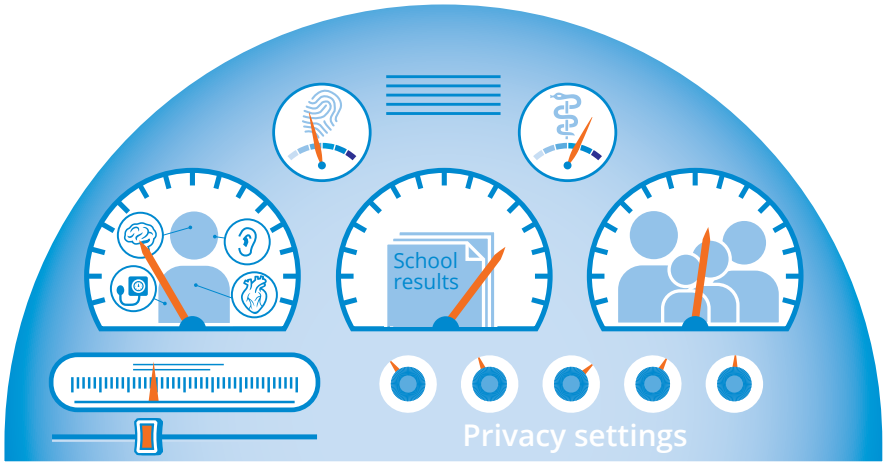
1.2.4 Creating trust in a digital world

Phishing, hacking and other forms of digital fraud are increasingly being used to successfully take people's money and data, or to perform other actions with bad intentions. This is why it is so important that we continue to make efforts to ensure that others can't access or use our property. Measures are needed to make technologies safe to use in the digital world as well.

Technology can never completely resolve issues of trust. Think of the lock on your front door, for example. A long time ago, people wouldn't have been able to imagine that it would be necessary having to lock your home. Now, it is standard for everyone to do so. You are considered either careless or naive if you don't. However, the technology (the lock) never completely prevents thieves from entering. Increasingly sophisticated locks and alarm systems are appearing on the market, and even 'smart locks' exist that can allow timed entry to persons with suitable identification, such as postal or delivery services, but remain locked for the rest of the day. Nevertheless, burglaries still take place.

Trust is still a human process

In short: technology can help us to create trust, for example by providing us with information that allows us to better assess whether our trust is justified. But technology can never completely encapsulate the trust process, as this remains a process between people. The limits of what technology can and cannot do for us however leads to a renewed dialogue about ethical issues. What do we consider to be acceptable, comfortable, and fair as human beings? These ethical issues are also highly relevant in the educational context. We highlight a number of these in this report, particularly in sections 2.3 and 3.3. For instance, think of how career guidance will manifest as AI is increasingly used in



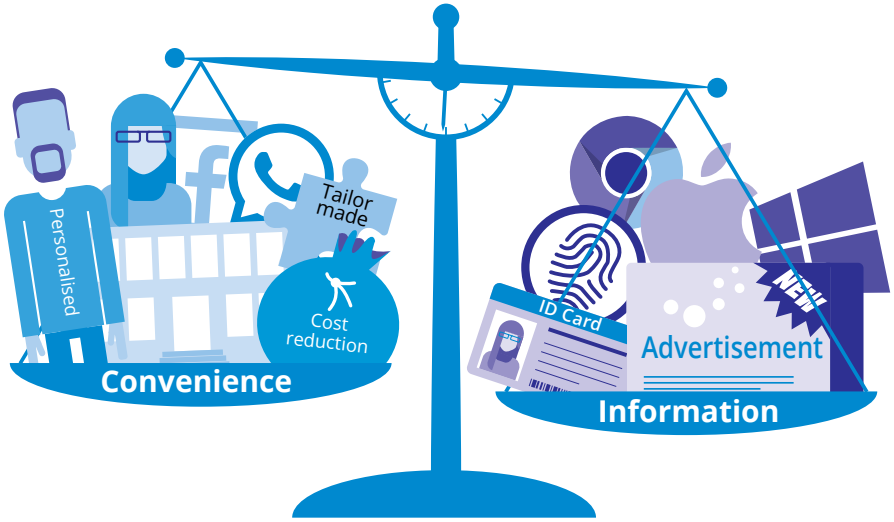
the analysis of learning paths: does AI or a person make the final decision? And as for the usefulness and necessity of collecting IoT data in students' learning environments: do we really need all that data in order to make adjustments to the learning process?

Differences between the physical and digital world

We relied on personal interaction, experience and reputation to determine whether we could trust a person or an organisation before the existence of the internet. In the digital world however, we are less able to rely on this physical personal interaction. For this reason, we have to look for other structures to determine whether we are about to do business with real people, whether they are who they say they are, and whether their intentions are good. People base their trust on an assessment of competences, integrity, and good intentions; for example, what have they learned from their own experiences or those of people close to them, or from information in the media about the relevant person or organisation?

AI technology demands a renewed dialogue about ethics

A growing number of interactions in the digital world take place via an AI analysis of available data. The competence and reliability of these AI algorithms can be assessed objectively: does the analysis lead to the right outcome in comparable situations? However, evaluating the intention of an algorithm is more difficult: is an online shop offering you the hardback edition because it's more expensive, or because your



previous three purchases were also hardbacks? As the digital world is increasingly controlled by the analysis, advice and decisions of algorithms, the discussion about securing trust in the digital world intensifies. How do we organise and facilitate that trust, and can technology play a role in this?

Platforms organise trust

Peer review platforms that operate on the basis of unedited experiences and reviews is one way in which technology can organise trust. This enables us to confidently do business online with people whom we don't know at all in the physical world. We rent houses or book taxi rides through platforms that facilitate the trust process for us. Does the driver have 5 stars? If so, then he received this rating based on reviews from

real customers. People like you and me. Is there a structural problem in a holiday apartment? Then it will be apparent on the platform – the host can't simply remove or delete this feedback. This creates trust and makes people willing to provide information and pay for services.

Privacy and security measures evolve

There are also other ways to organise trust. Privacy and security measures have been in use for some time and are steadily becoming more advanced. Take the example of pseudonymisation, which allows you to disconnect data from people; one use of this is in providing student data to AI applications in order to improve adaptive learning materials. Another example is advanced encryption to protect the data that schools need from theft or manipulation. In section 2.3.2 we also describe privacy by design, where educational systems are designed from the outset to safeguard the

Blockchain in education

The increasing digitalisation of education presents us with new challenges in ensuring that digital components work together seamlessly, especially when dealing with data, and the devices on which it is collected and used. A logical question, then, is whether new, promising technologies such as blockchain can also help us to organise safe, trusted cooperation in educational situations. However, key features of blockchain mean that effective application of the technology is not as obvious as it would appear at first glance. For instance, consider the permanent storage of (transaction) data. One fundamental principle of blockchain is that the removal or modification of once-recorded data is impossible, because it is designed to serve as a permanent record of all transactions. This isn't always the intention in education, because data sometimes needs to be changed, for example when adjusting an incorrectly calculated figure, or if a diploma needs to be withdrawn in the event of fraud. Moreover, permanent storage is at odds with the right to erasure, or 'right to be forgotten'. Another important problem that blockchain sets out to solve is the lack of a trusted third party overseeing the reliable recording of data. In education, however, such third parties are readily available, in the form of school boards or parties such as the Department for Education, sector councils, SURF and Kennisnet. Otherwise, the trust problems are such that they cannot be solved with blockchain because they occur in a process that precedes their being recorded in the blockchain, for instance in the wrongful awarding of a diploma. This makes blockchain unnecessarily complex or burdensome in the vast majority of educational situations.

Want to find out more about blockchain technology?
Read our publication "A study of blockchain technology for education" via *kn.nu/technologiekompas*. This publication also contains a checklist that allows you to assess whether a use case benefits from blockchain technology.

privacy of students and teachers. Secure access to systems is ensured by using two-stage identification, meaning that, whenever a user logs in from a new location, an extra code is sent to the user's registered mobile number, and this code must be entered to complete the log-in process. This makes it possible to adequately secure the students' administration, while still keeping it accessible for teachers and students.

There are few concrete applications outside of the Bitcoin network

Blockchain as a mechanism for trust and transparency

There is a great deal of hype surrounding blockchain in the trust domain. This technology is the basis for Bitcoin transactions and replaces third party trust, because all of the participants in the blockchain network always have an exact copy of the register in which all transactions are stored. All participants jointly determine whether a Bitcoin transaction actually took place before it is recorded in said register. Everything that has ever been recorded can never be changed and is fully accessible to the public. This makes blockchain completely transparent. According to experts, this transparency leads to trust, and is a solution if the participants do not trust a third party; in the case of the inventors of Bitcoin, the third party they didn't trust was the banking system. Although there are a lot of expectations for this technology we still see few concrete applications outside the Bitcoin network.

1.2.5 ICT foundations for AI in education

ICT infrastructure is no longer a trend, and therefore doesn't feature extensively in this report. We do, however, briefly outline what it means to set up a safe, reliable and future-proof ICT infrastructure. This forms the natural foundation for all ICT applications in education, including AI. Without that foundation, ICT cannot be used effectively and responsibly in the primary process, and it won't be possible to achieve the future potential that we sketch out in this report. Furthermore, new developments such as IoT bring with them new requirements for ICT infrastructure.

> **Want to find out more about designing ICT infrastructure?**
> See ***www.kennisnet.nl/ict-infrastructuur***

Radical investment in mature technology

The organisation of a modern school, with its complex planning and scheduling, demands professional digital support and a reliable ICT infrastructure. And, once the choice has been made to use digital learning resources on a structural basis in the primary process, there must also be radical investment in ICT infrastructure, without hesitation or reservation. Otherwise, digitalisation won't pay off. Take, for instance, investments in flexible, effectively managed mobile devices for students and teachers, and a reliable (wireless) network in schools. An internet connection with high availability and guaranteed capacity for all locations within the administration is also vital.

Direct and manage, but think of ICT infrastructure as a utility

Because ICT infrastructure consists of mature, fully developed technologies, a school can make investments here without risk. This doesn't mean that putting together a reliable ICT infrastructure is easy, but it is to say that reliable products and the right knowledge and experience are available. As an educational facility, it is best to think of this infrastructure as a utility that market participants can take care of for you, while you direct and manage to ensure it is properly aligned with the educational process. To be able to

manage effectively, you must therefore invest in expertise on a tactical and strategic level. Operational ICT tasks don't belong in education.

Coherent application landscape in the cloud

Effective support for both the primary and secondary processes in your school requires a well-organised, integrated application landscape. Administration systems, learning systems and learning materials must be able to efficiently (re)use each other's information, without manual data transfer, double storage of data or any other frustrating, risk-increasing, time-wasting side effects of badly organised ICT.

Without reliable ICT infrastructure you will not reap benefits

An excellent place to start is a 'cloud first' strategy for generic education applications. Exceptions are only justified if essential functionality is missing or if privacy cannot be guaranteed in a cloud platform. Functional compromises are inevitable in order to avoid expensive customisation and in-house facilities as much as possible.

Organise ICT to serve education

When the foundations are solid, you have a stable basis on which to introduce, use and manage new applications. By establishing robust control of those foundations and carefully selecting applications that support the educational process, you will have a successful and dependable ICT infrastructure. If the deployment of ICT in education – the information management role – is organised and arranged thoughtfully, this will create the space to concentrate fully on the application in education. This frees resources that can be allocated for teachers to be professionally advised and guided in how to use ICT effectively in their daily education process, and for initiating innovation and modernisation when this is necessary or seems promising.

Chapter 2

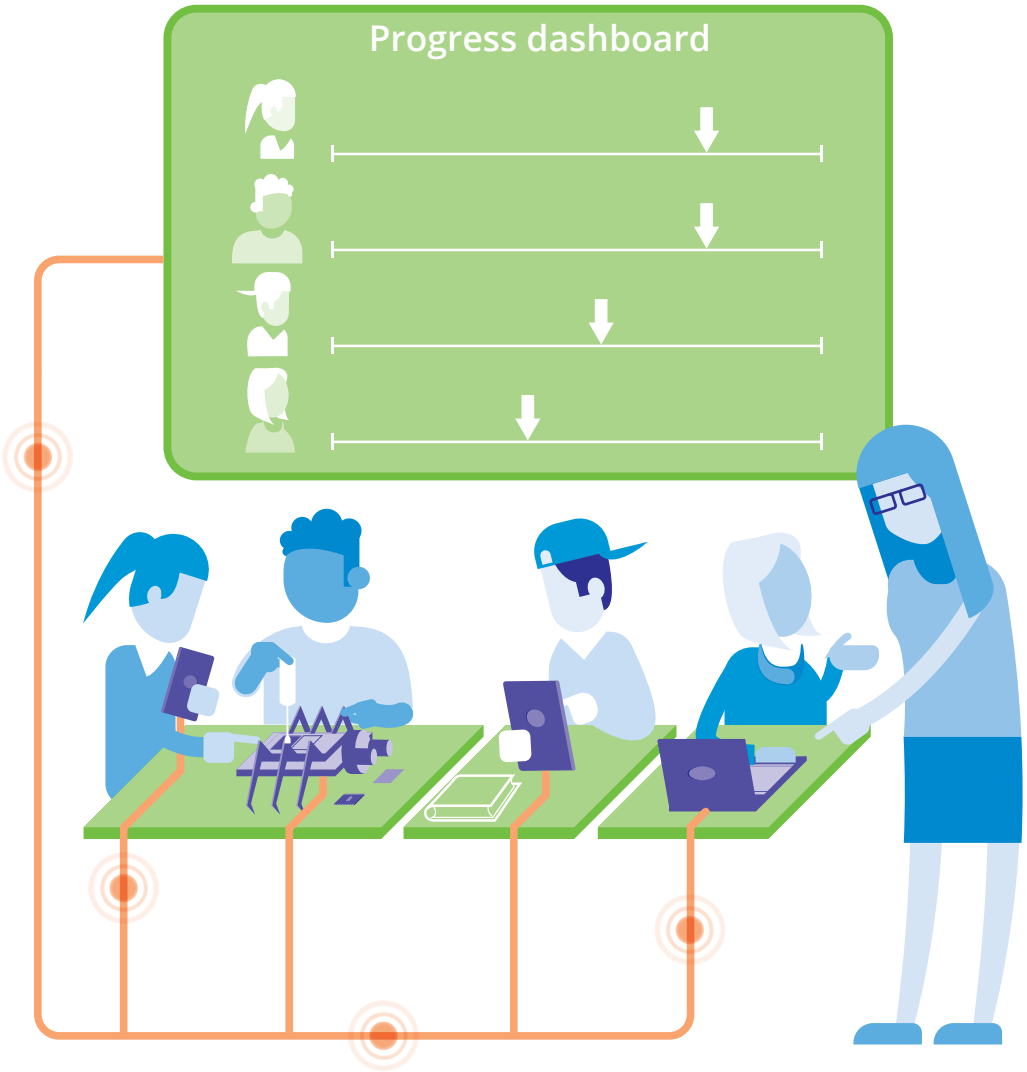
Personalised learning at an individual level

2.1 Personalised learning at an individual level in a nutshell

2.1.1 Transformation of the learning process with the use of technology

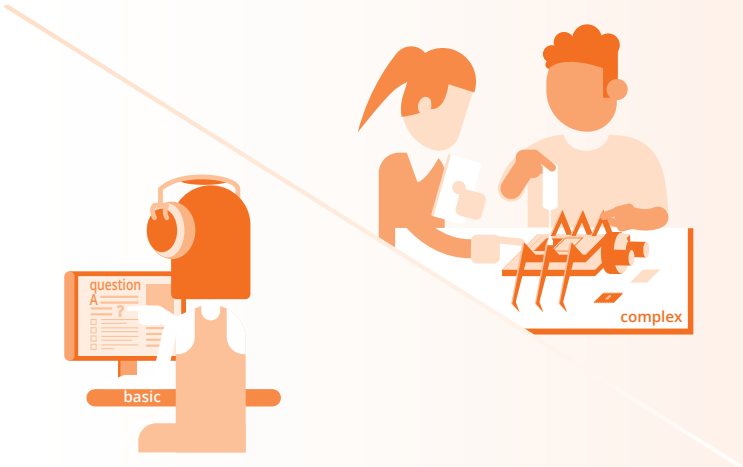
Paying attention to the specific needs of each student is a long-cherished ambition of education. Most schools have already established some form of differentiation for this purpose. Teachers can respond to the diversity in their students' needs, while maintaining feasibility and ease of organisation in their teaching by putting students into groups. The next step is personalised learning at an individual level. This doesn't mean that students are isolated in their learning, or that they only do what they want to, but rather that they are offered exactly what they need to enhance their learning in a given moment. Think of personalised instructions, practising at your own level, and direct, meaningful feedback – which are important elements of effective education.

Personalisation doesn't mean that students only do what they want to



Technology for personalised learning at an individual level

The use of technology, such as adaptive learning materials, is essential in enabling individual personalised learning. It offers students the opportunity to learn at their own pace and at their own level, whenever and wherever they want. The data from the learning activities is collected, analysed and used to evaluate and adjust the individual learning process. By clearly summarising and displaying this data for every student, teachers can give targeted instruction and pay greater attention



Basic versus complex cognitive skills

In taxonomies of proficiency levels, such as Bloom's, we find a useful organisation of cognitive skills, from basic to complex. With basic cognitive skills, we are referring to skills such as memorising, understanding and applying. Education has built up decades of experience with proven effective mechanisms for developing these skills. In the form of adaptive learning material, AI offers an opportunity to automate this well-established approach. With complex cognitive skills, we mean skills such as analysing, reflecting, evaluating, and applying existing knowledge and skills in new situations. It is difficult to mould these skills with adaptive technology, and education is still in the process of discovering an effective approach to this. Technology only plays a minor role in this context.

to the coaching, nurturing and well-being of their students. Because the teaching of basic cognitive skills is covered by budding AI technology, the teacher can give more attention to complex cognitive skills. Technology supports the teacher, broadens their repertoire and takes over a portion of the tasks traditionally assumed by the teacher. This offers opportunities for the relationship to deepen between student and teacher.

How does AI technology help to achieve personalised learning at an individual level?

That is the subject of this chapter. First, we will provide an outline of how personalised learning at an individual level changes the learning process within a school and, on the basis of this, we will offer some mindful advice. We will then explore the technology behind personalised learning in detail, analysing the most important technologies that you can use as a school to enable individual personalised learning in the near future. We will demonstrate the potential impact on your school and give advice on important preconditions, such as guaranteeing privacy and embedding personalised learning in your school organisation. relationship to deepen between student and teacher.

A story about personalised learning: a year in the life of Mr Theo

3 September

A new school year and a new class, how exciting! Who will be a joy, who will be bouncing off the walls... how tough is this year going to be? At the start of the day, I quickly notice that, once again, there are big differences in their holiday stories – some children were with relatives in America, others made day trips to nearby cities.

24 September

Numeracy definitely isn't Lucy's favourite subject. She has problems with it, which gnaws away at her self-confidence. She does the exercises, but her pace is a bit slower and she can't quite keep up with the programme. We'll often start a new topic before she has fully got the hang of the last one. How do I get her back up to speed? Jack is very quick with math, and is getting bored because he can't go any further. Of course, the annual plan states that the school wants to tailor programmes to serve students individually... but I find it very difficult to do this in practice. In the autumn holiday, I'm going to make a plan – I want to be able to vary the practice time available to each child.

27 October

Pffff my autumn plan to let my children work at their own pace just doesn't fit into our weeks. On 'average', the class is up and we're on schedule, but of course, 'average' doesn't actually refer to the individual children. And I see too many kids struggling, grrrrrrr... I want to do something about it, but what?!

3 November

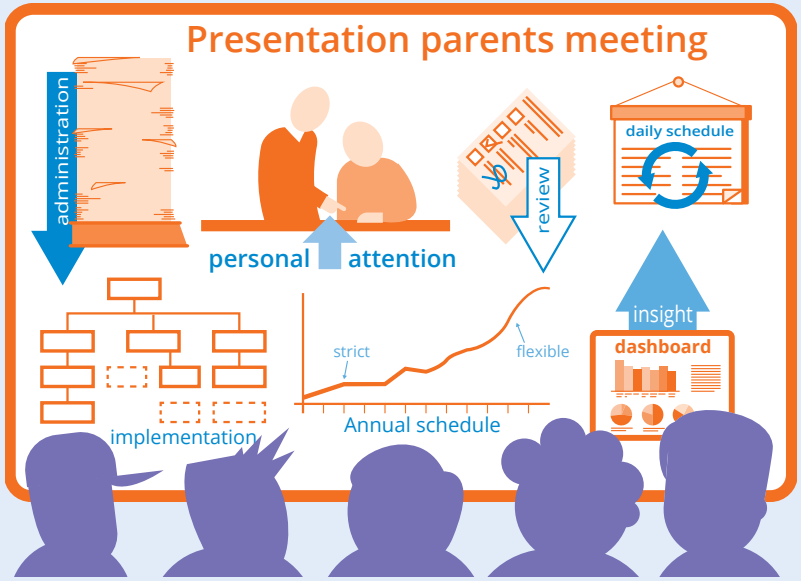
After the PE lesson, I told my students about the history project we're going to be doing. I saw Lucy perk up immediately! She already had a topic in mind: the Renaissance. Unfortunately, I have very little time to help the class with how to approach it. To be honest, they will pretty much have to figure it out for themselves. I know that Lucy gets help at home, but I wonder if Javi is getting on OK. He already speaks Dutch well, but his parents don't yet. I'm afraid they can't really help him...

14 November

René, our ICT coordinator, recently told us with great enthusiasm about a new digital method that allows children to do literacy and numeracy exercises at their own pace. I know he wants to help me, but it sounds complicated. Am I going to have the time to delve into that?

22 December

René sent round a hilarious Christmas film where he explains what his plans are for the new method and how it works in the classroom. It's cool how you can see how fast each child is working and which parts they're getting stuck on! I think I'll get the hang of it if he accompanies us one afternoon a week – he has really thought about how to handle this. I am going to try to vary how much time each child has for the exercises.



27 February

We're about to start with the new method, super exciting! There was a lot of criticism from parents when we explained the plan after the Christmas holidays – the information evening was hectic. But, luckily, 'my' parents were quite positive and some even offered to help.

16 March

I notice that I don't have to spend as much time on corrections with the new method. I can use that time elsewhere, which is great. Many colleagues agreed with me when I suggested: "We could get a lot more out of it if we stick less rigidly to the tight annual schedules." But there was also some resistance. "By the end of primary school, we really do need to have covered everything," Mr Don said, annoyed. "Do we have to change everything at once?" Of course, that doesn't seem wise to me either. I proposed that, as a first step, we free up two hours per week for students to work on individual activities. We have agreed to start this, and evaluate how it's going after the May holiday.

2 May

The May holiday is here again. This method is really cool, but man what a change to get used to! Suddenly I'm looking at screens instead of workbooks. But the children like it, and happily work through everything. I think I'm making good use of the two hours of individual activities, but I also find it hard to really trust what the dashboard of the learning material says. I'd like to discuss this in our weekly team meeting next Wednesday afternoon – I understand that Pascal also has questions about this.

7 July

Lucy now gets more time to practise numeracy. Although it still isn't her favourite subject, her self-confidence is growing. She does it in her own way and at her own pace. So lovely to see! Without this new technology, I don't know if she'd have come this far...

Because I don't have to spend as much time on corrections, I finally found some time to guide students in putting together their project, because it can be a challenge to search for, evaluate and analyse information in order to write a good piece of work. Especially for pupils like Javi, who can't simply fall back on the help of family at home.

During the team meetings, there's still a lot of talk about the overviews, and how we can use them collectively to best cater to the differences between children. But we're learning a lot from each other, and I see that the students are really benefiting, too. Next year we will expand the individual time for each student. But first things first, let's enjoy the summer holidays!

2.1.2 Future insight: personalised learning at an individual level in education

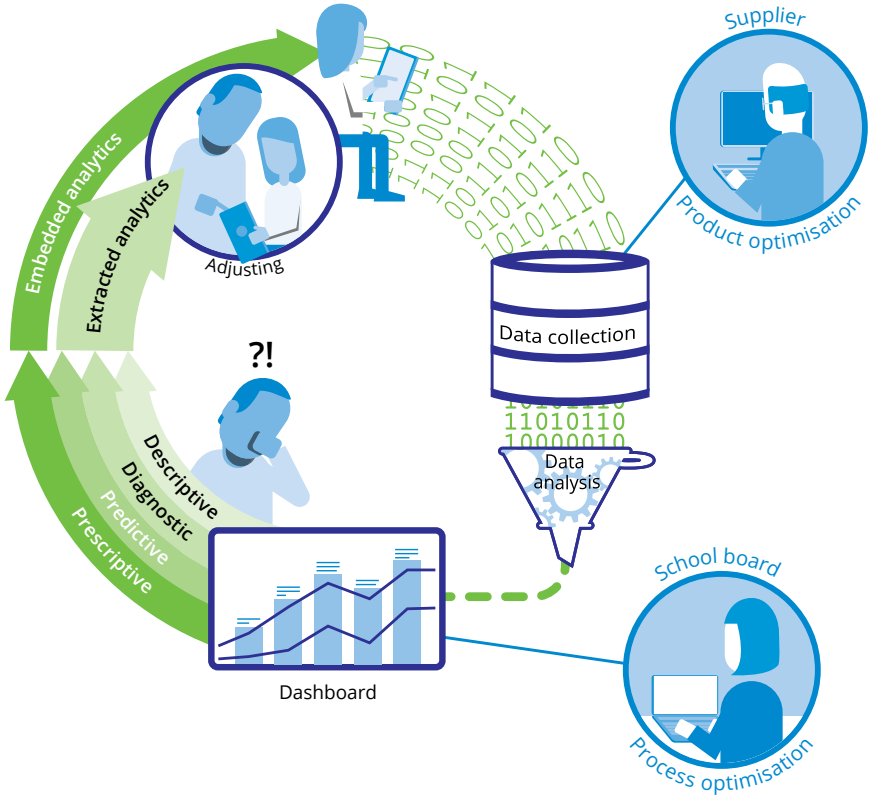
Technology is offering opportunities to fulfil ambitions in personalised learning in the near future. But we're not quite there yet. The technology that supports personalised learning is still under development. Schools, developers and suppliers still need to collaborate to acquire a great deal of knowledge and expertise before adaptive learning materials can be widely applied. But we're certain that this development will happen rapidly. An average school day will soon look very different, as this future insight shows.

Practise at individual level, make immediate adjustments

A student picks up his tablet and starts his exercise program. The program generates all kinds of data based on the tasks he completes: how long does it take him to finish a task? Which answers did he get right, and where did he struggle? What is (fundamentally) missing? The program immediately determines the most effective follow-up steps and provides the student with immediate task-oriented feedback. Perhaps, the difficulty of the tasks then increases, or the program decides to offer additional explanation. The adaptive learning tool continually analyses all data about the learning behaviour of all the students using this learning tool, and therefore gets better and better at serving students on an individual level. The teacher offers books and other non-digital forms of learning materials, effectively blending traditional resources with adaptive learning material.

Space for complex cognitive skills

On their screens, teachers see a dashboard with data that is collected



from exercises, tests and feedback given from different systems and learning tools. This provides them with a coherent picture of a student's progress. On this basis, they define targeted follow-up steps. This makes

Technology saves teachers time that can then be spent on teaching students other skills

it possible for one student to spend more time on numeracy, while another receives more literacy assignments. Administrative work, such

as manual checking of exercises and documenting the results, is largely automated. This, coupled with standards for data exchange, has ensured quality improvement and accountability within and outside the school. The time that teachers save here is then used to support working methods that develop students' complex cognitive skills, such as analysing, reflecting and evaluating. Technology is still rather limited in its ability to analyse the data from these working methods. However, technology does help teachers to efficiently plan and organise the learning process, by recording, collecting and assessing the assignments aimed at developing complex cognitive skills.

Transformation of the educational process

Teachers have gradually changed and improved the learning process by working daily with adaptive learning tools, exchanging experiences and gradually making adjustments based on this exchange of feedback. However, they have noticed that existing preconditions and frameworks within the school and the limited flexibility of the educational process have hindered the optimal use of adaptive learning tools, and that additional steps are needed for further optimisation. At present, therefore, monthly meetings are planned with the board, school leadership and other involved parties regarding how to gradually transform the education system and

how they can create support for this throughout the organisation. The school has recently started experimenting with getting rid of existing frameworks such as the class system, annual planning and timetables. These consultations and experiments form a process of phased, concrete, planned and continuous development, allowing the full potential of the technology to be attained.

2.1.3 Advice on achieving personalised learning at an individual level

Many of the consequences of personalised learning are not yet fully known. There is as yet no long-term experience of personalised learning technology and its impact on the learning process and the school. Nevertheless, we do see that personalised learning is playing an increasingly important role in the educational process. But where do you start? And how should you approach it?

1. Establish where you are, where you want to go and how you'll get there

As a school, you first need to determine, based on your pedagogical vision, what your ambitions are for personalised learning at individual level. Working with your teaching team, establish the correct application, role and weight of personalised learning technology in the learning process in your school. Determining an appropriate, mutually reinforcing blend of digital and non-digital learning resources and working methods is also a key part of this. Have you and your team determined your educational frameworks, and worked out where you want to be in three or five years? You can then create a roadmap or implementation plan based on this, clearly describing the steps you will take in the coming years.

2. Set out on a journey and adjust your ambition if necessary

Many schools are already acquiring the necessary knowledge and experience with adaptive learning tools. Make it possible to compare these experiences within your teaching team by determining in advance how and under what preconditions and frameworks a digital learning resource will be used. Discuss these experiences with each other periodically so that teachers can gradually and continuously optimise the learning process. This also entails thinking about what data you need in your learning process in order to plan, monitor and improve education. You also need to examine whether the software you're using can provide that data and exchange it with other systems. When investing in personalised learning technology, interoperability of systems

Seamless data exchange is essential for personalisation

and standardisation of connections is essential so that you only have to record data about group classification, profile choices or achieved results once, and can properly reuse this data when organising personalised learning. Are certain choices about resources, teaching or data collection not having the desired effect? Then adjust your roadmap, and maybe even your destination, accordingly.

3. Arrange the preconditions for your journey

To be able to realise your ambitions for personalised learning on an individual level, you will need a reliable, secure ICT infrastructure to serve as the foundation. This means uncompromising investment in wifi, internet connection, cloud platforms, devices and mobile device management.

Your user experience with personalised learning technology should never be marred by a faltering internet connection, for instance. Investments in ICT infrastructure aren't necessarily cheap and the implementation isn't necessarily easy, but the technology is mature, so a successful roll-out is possible. Make sure that your information security and privacy policy are well-structured. To be able to deliver customised services, you will be recording more information about students and sharing it in the cloud. Make the proper arrangements with your suppliers in this regard, so you can embark on your journey with confidence.

2.2 Personalised learning at an individual level: the technology

Which technologies help us to offer a tailor-made learning process for each student? Which underlying technology requires attention to enable this? Where do we draw the boundaries between technology and people? In this chapter, we illustrate the relevant technological building blocks with three tools that make individual personalised learning possible.

The **Hype Cycle** shows the maturity of each technology. We can see a clear divide. On the one hand, we have a group of technologies consisting of (parts of) the adaptive learning materials themselves. These technologies are still under development and therefore aren't yet fully mature. The second group consists of stable, mature technologies that form the necessary ICT foundation for the effective use of adaptive learning materials.

The **Benefit Map** shows the connections between technologies. We see three clear chains that build on each other: the personalised learning technology that is visible and used in the daily education process; the technology 'under the bonnet', which supports the personalised learning technology with the exchange, interpretation, analysis and application of data; and the ICT foundation of technologies that ensure the smooth functioning of personalised learning technology.

In the **SWOT** we map out the strengths and weaknesses of personalised learning technology and the opportunities and threats it poses for education. Adaptive learning material enables targeted individual interventions and diversity in learning opportunities for basic cognitive skills. Complex cognitive skills and other aspects such as well-being are difficult to measure, but are also crucial in a student's growth. With the help of adaptive learning materials, time and headspace are freed up so that education can pay even more attention to these areas.

We conclude this section with advice that will help you get to grips with an investment and implementation plan to achieve individual personalised learning with technology.

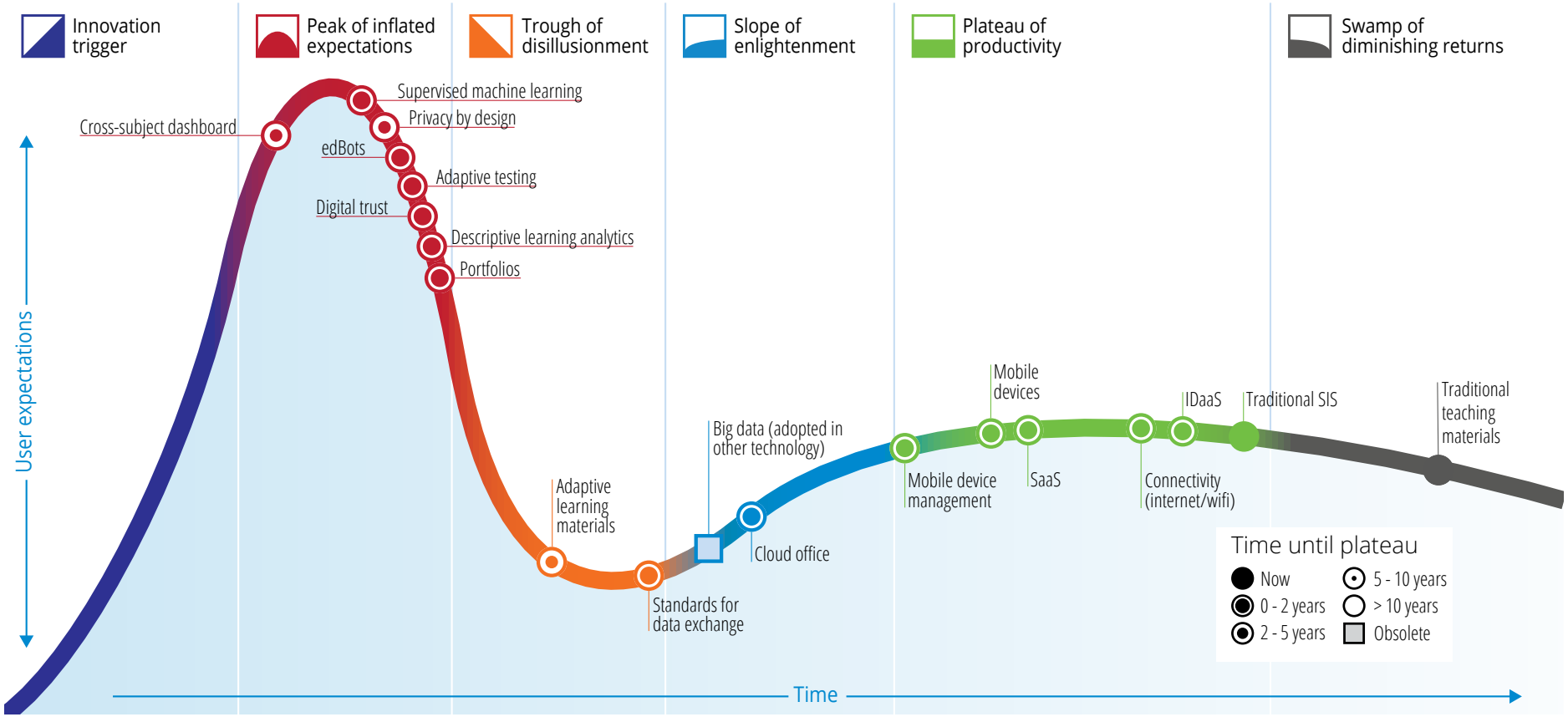
Need a refresher on the Hype Cycle and Benefit Map?
Have another look at the explanation in the introduction.

2.2.1 Hype Cycle for personalised learning at an individual level

The Hype Cycle below displays all the technologies that are important for personalised learning. The location on the Hype Cycle shows a snapshot of the relative maturity of a technology and its potential in the future.

The Hype Cycle helps you choose the right time to start using a technology and what risks are associated with its deployment within your school.

The Hype Cycle below is the result of an analysis of various studies and existing Hype Cycles.



Innovation trigger: first introduction of innovative, new technology

In this phase, we tend to see experimental or conceptual technologies that are not yet ready to be dependably used in practice. This personalised learning scenario doesn't contain any technologies that are still in this trigger phase.

Peak of inflated expectations: hyped technology doesn't yet meet high expectations

Here, we see technologies that are still under development, but which a number of schools are already trying out in practice. Think of **cross-subject dashboards** that aim to meet the need for insight into the learning process at schools where many digital learning tools are being used. For this cross-curricular insight, many agreements are needed between suppliers, together with teaching staff, to be able to connect and exchange information properly. Supervised machine learning is also used, but for the time being this is limited to fairly simple artificial intelligence applications that don't always have a self-learning system behind them. Supervised machine learning learns from data, but does so on the basis of fully pre-programmed rules. This technology is mainly used to teach basic cognitive skills, rather than complex cognitive skills.

Trough of disillusionment: high expectations not fulfilled, disappointment prevails, potential is underestimated

This phase is dominated by disappointment, due to problems in using the technology. Expectations are not met and some schools turn away from technologies such as **adaptive learning materials** and **descriptive learning analytics** due to high costs and poor returns. Nonetheless, in this stage, you learn a huge amount about the preconditions for using a technology productively and effectively. **Portfolios** can play a role in the recording and collection of assignments aimed at complex cognitive skills. It is noteworthy that we have to indicate **big data** as 'obsolete before plateau'. Although (big) data as a raw material is essential for 'training' and improving all forms of machine learning and learning analytics, the broader concept is now too general and uninformative without the context of application.

Big data: obsolete before plateau

In our analysis, we have indicated Big Data as 'obsolete before plateau' on the Hype Cycle characteristic 'time until wider adoption'. Our estimation is that the technology in this form will not reach large-scale implementation. Is that the end of Big Data in education? Definitely not. However, data only becomes valuable when AI applications derive meaning from it. It is therefore of more interest to look at AI and to then consider data via that route.

Slope of enlightenment: obstacles are overcome, preconditions become known, benefits become visible

Much of the supporting technology for personalised learning is or will soon become mature. **Cloud office** is a special case because the ever-expanding functionality of these important platforms (G Suite for Education, Apple Classkit/Classroom and Office365 for Education) isn't always mature. Due to expansions, the technology sometimes makes a *leap backwards* on the Hype Cycle. However, basic functions such as calendar, email, editing documents online, chat and video functions,

assessing assignments and recent *classroom* functions for planning and organising mature quickly and can be fully deployed.

Plateau of productivity: proven benefits, widening adoption, acceleration of growth

Technologies such as **SaaS** (the technology that enables digital resources to be web-based), **mobile devices**, **mobile device management (MDM)** and **connectivity (internet/wifi)** form the reliable foundations for personalised learning. However, this doesn't mean that it is always straightforward to put these facilities in place. Investments in time and resources are required, but luckily, the necessary knowledge and mature products are available in the market.

Swamp of diminishing returns: watch out for new goals getting frustrated due to technologies of decreasing value

In addition to identifying valuable new technologies that support educational ambitions, it is equally important to identify which older technologies are becoming a hindrance to said ambitions. **Student information systems** in their current form are a good example of this. They are still important for administration and accountability, but need to be further developed and renewed in order to support personalised learning and thereby return to the *plateau of productivity*. **Traditional teaching material** also has declining added value in its current form, because it only makes a limited contribution within a school. For instance, automatic registration of the learning process and adaptivity are not possible with these resources. By using a purposeful blend of adaptive learning materials where possible and existing traditional teaching materials where useful, education will still be able to make good returns from traditional resources for some time to come. When the market consciously designs learning resources as a set of digital and traditional teaching materials that complement each other, the value of

An effective blend of digital and folio material is essential

traditional teaching materials will once again increase. This will cause it to disappear as a separate technology on the Hype Cycle and return as an integrated part of learning materials.

2.2.2 Benefit Map for personalised learning

The Benefit Map is a tool used to make decisions about interrelated technologies and to generate support for the choices and agreements that you make. It gives a sense of where the interests and concerns of the school lie, as well as the interests and concerns of teachers and students. It also makes it possible to discern the mutual connections and dependencies of technologies. By positioning the technologies from the Hype Cycle on the Benefit Map, we can clearly demonstrate which technologies are important to whom (teacher/student or school) and for what reasons.

This Benefit Map has been devised on the basis of dozens of conversations with schools about personalised learning and the underlying technologies, thereby constituting our estimation of an 'average' school. Depending on differences in educational ambitions and other concerns, your organisation may place technologies in different quadrants.

Hot spot: shared interests/importance

The Hot Spot contains technologies for which the school, teachers and students all have high expectations, and therefore find very important. Some examples are adaptive learning materials that are used every day, or cross-subject dashboards that provide an overview of the digital aspect of the learning process.

Enabler: the difference between wishful thinking and reality

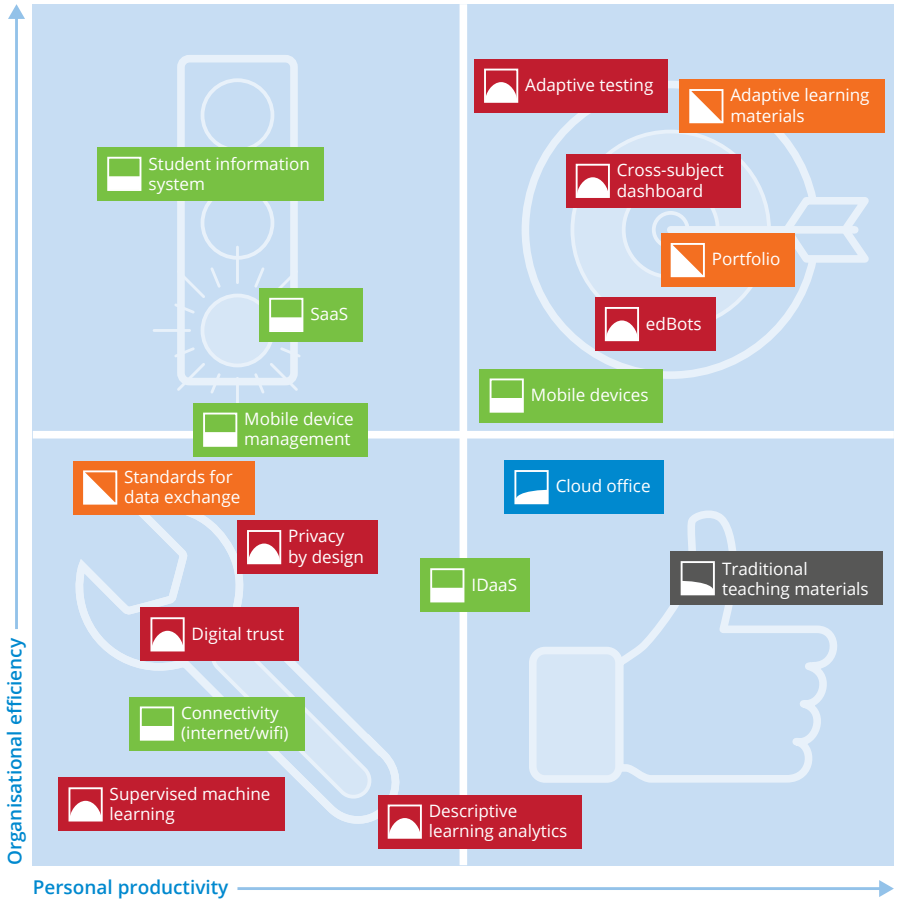
The Enabler quadrant contains a significant number of technologies that students, teachers and the school alike find less interesting. There is low willingness to devote structural attention and resources to these because all three parties don't see the direct importance of them. Nevertheless, the high expectations for Hot Spot applications can often only be realised if they can rely on the enablers. Namely, strong ICT foundations and data exchange.

Green light: the organisation has responsibilities

The Green Light quadrant contains technologies that are particularly important to the organisation because they guarantee processes and information provision. As an example, each educational organisation has (legal) obligations and must be accountable for performance and resources. Student information systems are one example of a technology that is of great interest to the school board, while often regarded by teachers as a chore. After all, filling them in doesn't immediately contribute to better lessons.

People's choice: teachers and students prioritise the learning process

The People's Choice quadrant contains technologies that are particularly



important to users because of the direct benefit to their everyday learning experience. Teachers and students naturally focus on the technologies that specifically support them in the daily education process. Cloud office (email, calendar, shared documents) and traditional teaching materials can therefore be found in this quadrant, and usually so can applications that allow the student or teacher some freedom of choice.

2.2.3 Interplay of technologies

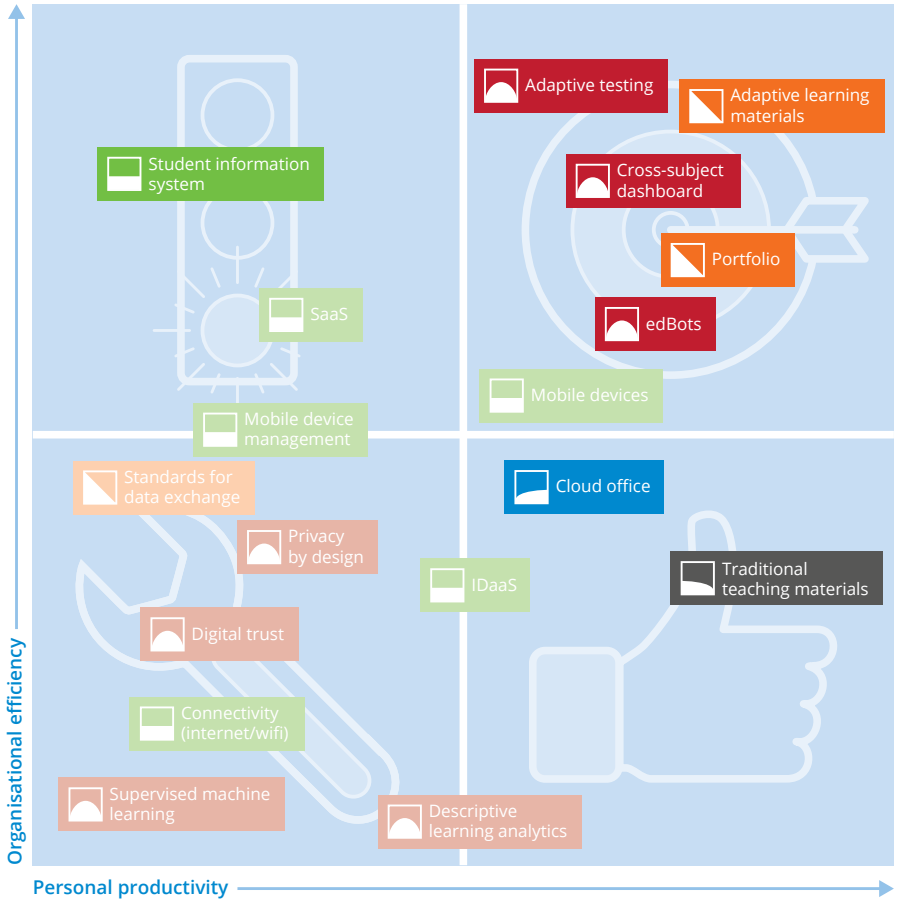
Once the technologies have been positioned, you can look at how they relate to each other. Often, a certain technology can only work safely and effectively if there is also investment in a different technology. By linking these technologies, a chain is created. We found three chains in our analysis: one with the technologies that you experience as a user (the 'front end'), one set of technology 'under the bonnet' and finally a chain containing the technological foundations.

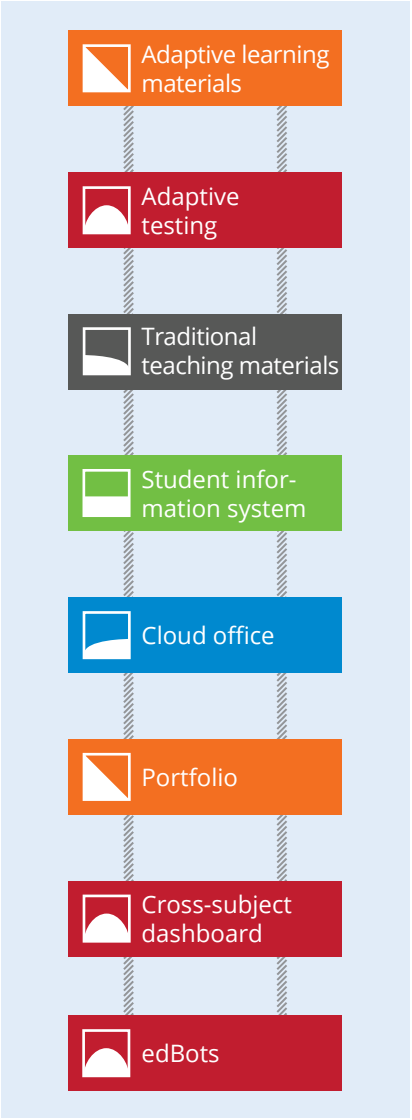
The front end: technology that is visible in the daily education process

In this scenario, students use technologies that offer personalised learning in their everyday learning environments. Teachers thus have insight into the daily learning process of students and can offer individual support based on this.

1. With **adaptive learning materials** and **adaptive testing**, students can work at their own pace and level, whenever and wherever they want. The learning material adapts in real time based on students' actions and achievements, offers task-oriented feedback and makes connections to prior knowledge and preferences. This technology is limited to training and testing basic cognitive skills such as memorising, understanding and applying. It gives a teacher time and space to interact with the students and support their acquisition of complex cognitive skills such as analysing, evaluating and applying existing knowledge in new situations.

2. Although digital learning resources are developing rapidly, **traditional teaching materials** and non-digital working methods and activities do still add value to the learning process. The teacher must then record progress and results separately in the **student information system**. Also, more instruction and direction from the teacher is needed to be able to offer personalised learning. After all, traditional teaching material offers limited differentiation, doesn't collect data about the learning process, and offers no adaptivity. Within the context of work





Chain 1. Technology visible in the daily education process

pressure and efficiency, traditional teaching materials therefore remain limited to the places where they really add value or where there isn't yet a digital alternative.

3. With **cloud office** (for example, G Suite for Education, Apple Classkit/Classroom or Office 365 for Education) the students work on assignments and papers and communicate with the teachers or fellow students with whom they are collaborating. These systems can be used to organise activities that focus on complex cognitive skills, thereby supplementing adaptive learning resources. The **portfolio** provides insight into the approach to assignments, helps to monitor the process and (automatically) redirects the manual assessment of products to the student information system and a cross-subject dashboard.

4. This **cross-subject dashboard** provides an overview by (automatically) bringing together information on progress and results from various learning resources and environments. Using the student information system as its basis, the dashboard offers the student and teacher a cross-subject view of the student's development and their learning process. This saves the teacher time, which then enables them to give appropriate attention to each student. This cross-subject snapshot then forms part of the basis used by the teacher and student to plan interventions.

5. **EdBots** relieve teachers by providing students with routine information or guidance. For instance, they can proactively send text messages and clickable links to the students at useful moments, providing them with information about lesson planning, dashboard insights, timetable changes and other notices concerning day-to-day teaching and learning. These simple chat applications provide AI-generated answers to questions. Companies use chatbots to answer their customers' most straightforward questions via WhatsApp and Facebook in order to reduce their customer service costs.

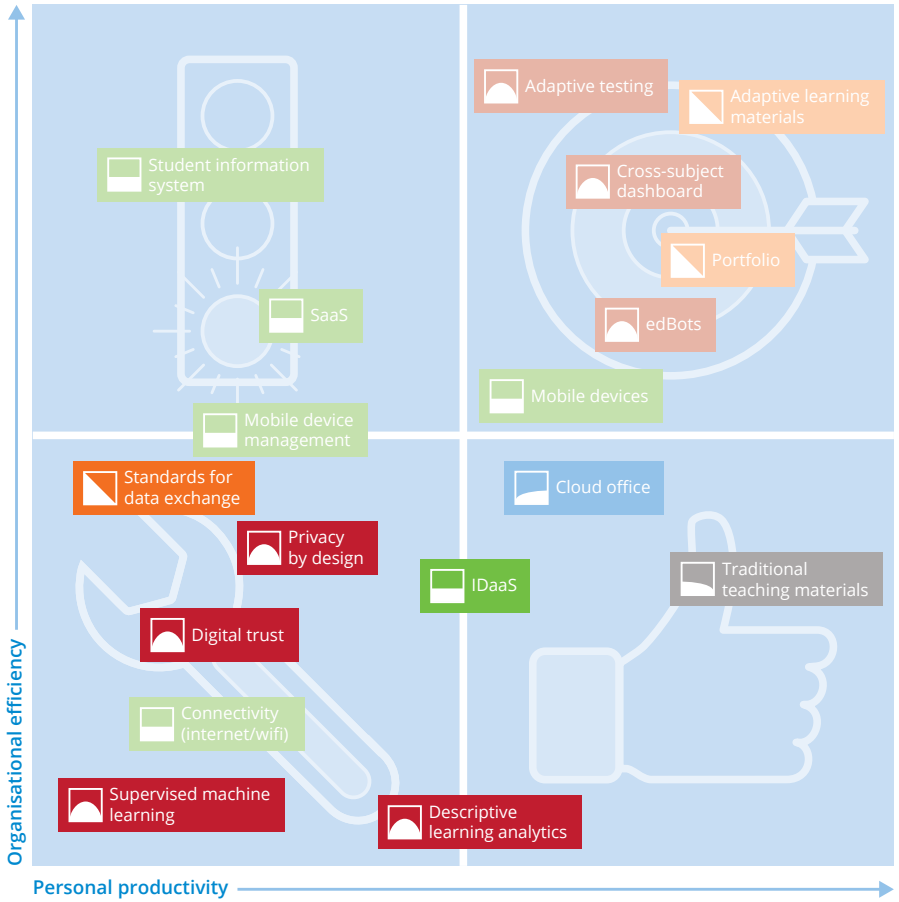
Under the bonnet: automatically collect and analyse information from the digital learning process

Personalised learning technology makes extensive use of real-time data from the learning process. Technologies 'under the bonnet' efficiently handle this with their smart and automatic collection, sorting and analysis of the relevant data.

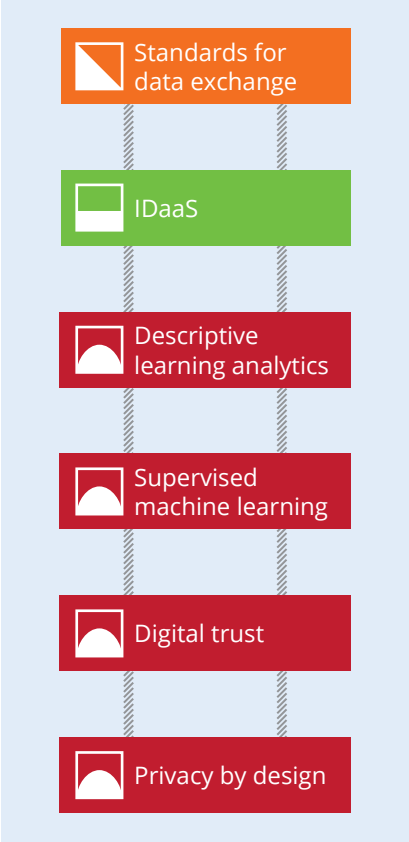
1. The intelligence in adaptive learning materials and tests and the insights into progress on the cross-subject dashboards rely heavily on current data from the learning process. With the consistent use of applicable **standards for data exchange** – for example, grouped information about progress towards a learning objective – relevant data about the (results and progress of the) student can be collected quickly (and automatically) and can be viewed by both teacher and student. For example, Edustandaard's UWLR (Exchange of Student Data and Results) standard for the Netherlands sets out the guidelines for the exchange of students' data and results.

2. Personalising the learning experience of each student requires information on an individual level. Students sign up using their own, unique identity in all the learning resources and applications that they use. **IDaaS** (identity as a service) refers to services that allow students and teachers to log in unambiguously and only once (also known as SSO – single sign on) so that they can access all digital learning resources and applications used by the school without any problems.

3. The data collected in each student's learning process is analysed with **descriptive learning analytics** so that the cross-subject dashboard



can demonstrate what the student has done so far and the results to which these actions have led. This form of learning analytics simply looks back on the learning process, and doesn't draw any conclusions. It is up to the teacher to do this.



Chain 2. Automatically collect and analyse information from the digital learning process

4. The same data is used by **supervised machine learning** (a form of artificial intelligence) to improve the periodically adapted or self-learning algorithms in adaptive learning materials and adaptive tests. For example, resources with new data are better programmed to adequately respond to the learning needs of students and to appropriately deal with situations that arise in the learning process. These algorithms make small pedagogical decisions in each student's learning journey.

5. Collecting as much data as possible per individual student and using it every day in the educational process rightly raises questions about how the **digital trust** of students, teachers and parents can be guaranteed. This trust is essential for acquiring and building support from them for digitalisation in the educational process. The school protects the privacy of students and teachers by safeguarding the confidentiality, correctness and limited accessibility of data, thereby earning their digital trust and, crucially, complying with legislation and regulations.

6. **Privacy by design** is when the design, development, selection or implementation of a process or software proactively address how you wish to regulate privacy and information security. Privacy by design is a legal obligation arising from the GDPR that affects software providers, but also any schools that 'design' their educational process. As a school, you must ensure that the data generated in your learning process is only available to those who require it. This means that the data is to be preventively protected against unauthorised use. Providers of digital learning systems must build their products in a way that guarantees their users' privacy. By using pseudonymisation, the student's identity is only visible when and to whom it is relevant. With suitable encryption, data can only be read by persons who are authorised to do so. As a school, you are legally responsible for careful organisation of such measures, even if you invest in suppliers to implement them.

Adaptivity with algorithms

An algorithm is a set of rules leading to a predetermined objective when its steps are executed in the correct order. It is comparable with a recipe. The rules are the cooking instructions, and the goal is the meal that can be made from the various ingredients by following these instructions. In the same sense, for adaptive learning materials and adaptive tests, algorithms are processed by a programmer. The purpose of this is to determine the student's level and to adjust what is offered to them each time their level changes.

Algorithms in adaptive learning materials and adaptive tests can be grouped into three forms.

Multistage testing

With this form, a student gets one set of tasks after another. Based on the answers, the algorithm re-estimates the student's level and prepares a subsequent set of tasks that is appropriate for said level. These sets of tasks have been put together in advance by the developers and have been classified into particular levels.

Computer adaptive testing

In this form, the algorithm selects the next task based on the student's answer to the previous task, steadily getting a more accurate sense of the student's level. This continues until the algorithm reaches a predetermined level of measurement precision. The algorithm retrieves the task from a database of tasks that the developers have already catalogued by level.

ELO rating system

With this form, the level of the tasks is not determined in advance. The tasks are linked to a topic or core goal. Based on the answers that the student gives, the algorithm determines their proficiency level. Are the student's answers correct? Then their score increases for those topics or objectives. This then leads them to work on tasks where they are less proficient.

All these forms of adaptivity can be found in digital products. Sometimes only one of the three occurs, but there is usually a combination. Adaptivity is still under development. We therefore deemed it wise to inform you in advance about how adaptivity is applied. The way that a learning resource or test has been put together shouldn't be a black box to the teacher (or the student).

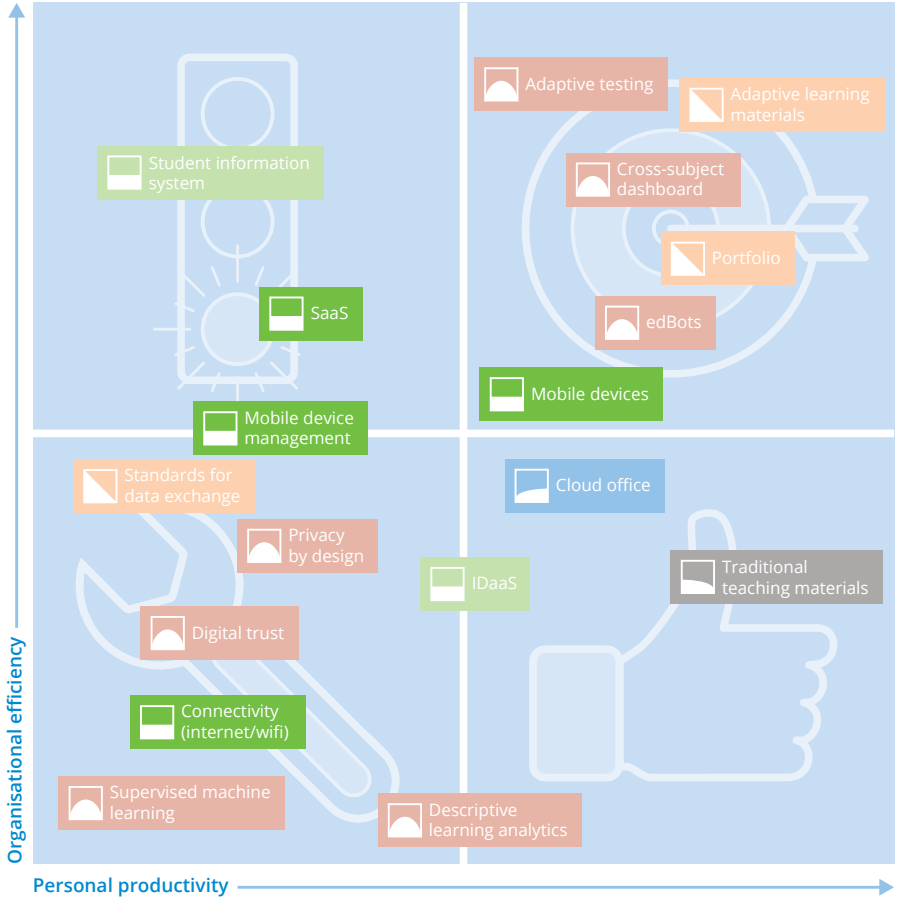
Privacy from a personalised learning perspective: the transaction

The ambition of personalised learning is at odds with the obligation to guarantee the privacy of students and teachers. After all, personalised learning requires detailed information about the student's needs and the teacher's skills to determine an optimal approach to using adaptive learning resources and effectively guiding the learning process. How do you maintain the right balance to deliver the best possible education? The guiding principle must be that any recorded information provides a demonstrable contribution to personalised learning for individual students. It has to be a fair transaction: any recorded information must improve the student's education.

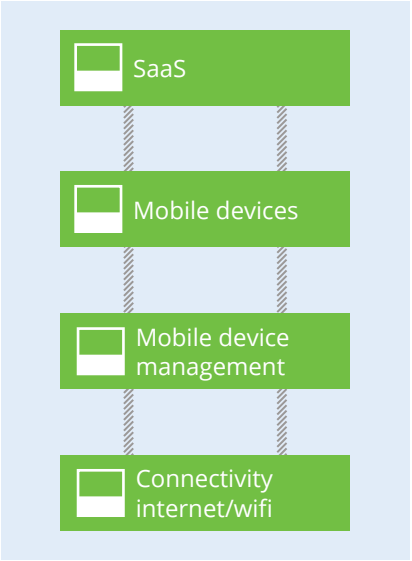
The foundation underlying all digital applications

Need a refresher on ICT infrastructure?
Re-read section 1.2.5.

All software and learning materials in this scenario are now cloud-based. The daily dependence on these technologies in the primary process therefore requires a reliable, scalable and secure ICT foundation that, just like electricity, becomes an invisible and assumed part of the school landscape.



1. **SaaS** (software as a service) has rendered facilities requiring a great deal of knowledge and capital, such as in-house servers and data centres, obsolete. The service provider is responsible for managing availability, scalability (more or fewer users), reliability and maintenance. This frees up a school's time and investment for tasks that are more closely related to education.



Chain 3. ICT infrastructure as a foundation for all digital applications.

2. Because students use digital learning resources every day in their learning activities, they have appropriate **mobile devices** (tablets, Chromebooks and/or laptops) suitable for that form of work.

3. To assure the correct functioning of the mobile device, and that it has the right settings and applications, **mobile device management (MDM)** is used, wherein the school manages the design and use of mobile devices in the educational process and can allocate flexible (management) responsibilities to students, teachers and ICT support staff. For instance, MDM can allow a school to remotely provide temporary settings to mobile devices for a test.

4. Full dependence on access to cloud applications for mobile devices in the education process requires reliable, scalable and secure wireless **connectivity (internet/wifi)**. This enables students and teachers to independently work anywhere, at any time, from any device, without time-wasting disruptions.

2.2.4 SWOT analysis for individual personalised learning

There are pros, cons, ifs and buts in the successful implementation of technology for personalised learning. A SWOT analysis is a great tool to help organise and weigh up the pros and cons of this scenario. We see a number of strengths and weaknesses of the technology, as well as opportunities and threats for education.

Strengths of the technology

1. Facilitates individual personalised learning with targeted interventions.
2. Increases objectivity and equity by taking an unbiased view of students.
3. Provides more guidance thanks to comprehensive documentation of the learning process.
4. Reduces reliance on time and place because learning is possible anywhere and at any time.
5. Offers flexibility in the learning process by making it possible to organise education in a different way.

Weaknesses of the technology

1. Does not support valuable aspects of education such as complex cognitive skills or well-being, because they are difficult to model and measure.
2. Reduces objectivity and equity due to outdated (organisational) frameworks, assumptions and biased data.
3. Only supports personalised learning to a limited extent when cross-subject insight is lacking.
4. Complicates the collection and assessment of meaningful information due to fragmentation, low quality and poor interpretation of data.
5. Reduces flexibility and freedom of choice in your ICT environment due to interdependence of components.

Opportunities for education

1. Increases students' learning outcomes by allowing them to practise at a suitable level and receive direct, effective feedback
2. Supports ambitions for personalised learning via flexible organisation and better documentation of the learning process
3. Reduces workload by automating administrative and routine tasks
4. Creates space for the teacher to focus on developing students' complex cognitive skills
5. Offers opportunities for extensive quality improvement due to detailed insight into the learning process

Threats to education

1. Potentially increases blind faith in technology, thus reducing variety in education
2. Demands new (ICT) skills from teachers, otherwise the learning benefits of personalised learning lag slightly or significantly behind
3. Teaching can come across as impersonal due to unsubtle emphasis on cold technology
4. Explicit attention must be paid to making good use of the freed-up teaching time, otherwise the extra benefits of personalised learning are limited
5. Increases resistance among students/parents if the school is not transparent about data use and measures to guarantee privacy

Strengths

Adaptive learning resources enable targeted interventions and offer opportunities for broadening the scope of education in schools. Objective testing can ensure equal opportunities, and learning can take place anywhere and at any time. With the help of the comprehensive data produced during the learning process, a school can better guide the organisation thereof. By working with adaptive learning resources, it becomes clear where the sticking points are in current educational frameworks, and how your educational process can be made more flexible.

Opportunities

Adaptive learning resources support the ambition of personalised learning in two ways. On the one hand, students are free to flexibly organise and plan what they need to do and when, and on the other hand, the resources offer comprehensive documentation of what students have already done. Practising at their own level and receiving direct, effective feedback increases the students' learning outcomes while reducing the teacher's workload because routine and administrative tasks are taken care of automatically. This creates space for teachers to devote more time to the development of complex cognitive skills such as analysis, evaluation and creation. The detailed documentation of the learning process offers opportunities for quality improvement for all processes in the school.

Weaknesses

Not everything that adds value to or offers insight into the learning process can be modelled or captured in data. For instance, it is hard to quantify insights into students' solution-finding strategies, or influences outside of school that are affecting their results. Another problem is that data collection is difficult and the collected data is often of low quality. The unconscious biases of developers or the use of unrepresentative data can also diminish objectivity and equity in education.

Threats

Excessive use of technology can diminish the overall educational experience and reduce variation in teaching and learning. Without investments in developing teachers' new ICT and analysis skills, there is a chance that the learning potential enabled by personalised learning will not be reached. In addition, teachers won't necessarily fill the vacant space created by use of adaptive learning materials with activities focused on complex cognitive skills. The stereotypical image of personalised learning as an impersonal technology could then gain the upper hand. Also, a lack of transparency in data handling can generate resistance, particularly if students and parents feel that their privacy is at stake while the educational benefits remain unclear.

2.2.5 Advice for the implementation of personalised learning technology

Adaptive learning resources offer many opportunities, but if you don't use them in the right way, they have the potential to reduce the quality of education. Considering all of the strengths, weaknesses, opportunities and threats: what can you do in the coming year, while minimising the risks, and without going down a dead end? And what preparations can you make now so that you will be able to realise your ambitions for personalised learning in the coming years?

1. Establish where you are, where you want to go and how you'll get there

Before you can get started on any changes, you first have to decide, as a school, where you are right now and where you want to go. This will prevent you from setting goals that are unrealistic or unmanageable. There are a number of steps you can follow to do this:

A. As a school, you first need to determine, based on your pedagogical vision, what your ambitions are for personalised learning at an individual level. Do you want to be a digital pioneer? Or would you prefer to wait a little longer?

- **Tip:** make use of tools and resources if you find yourselves struggling to obtain a clear idea of your vision or to get the conversation flowing. For example, on kennisnet.nl, you'll find our helpful 'ICT puzzle for education' and 'vision accelerator'.

- **Pitfall:** as much as possible, avoid discussions at this stage about the easy topics, such as how many devices you need or which dashboard is best. In this step, the priority very much lies in the way you want to shape education and what role you want technology to play.

B. Working with your teaching team, establish the correct application, role and significance of adaptive learning materials in the learning process. This will include a discussion about what data you want to collect and how it will be used, both during the educational process and to improve the educational process. Determine an appropriate, mutually reinforcing blend of digital and traditional teaching material and activities.

- **Tip:** establish your long-term learning resources policy. Is it in line with your vision for education? At what rate does the blend change? And what are the consequences of this? For instance, what is the impact on your ICT infrastructure, and which (additional) skills will be required by teachers?

- **Pitfall:** the discussion on which technologies are needed can still get bogged down if the earlier discussion about your pedagogical vision for personalised learning has not been completed. To illustrate: if someone is fiercely opposed to tablets, it may be because the use

of tablets doesn't fit into their image of 'good education'.

C. Have you and your team determined your educational frameworks, and worked out where you want to be in three or five years? To do this, create a roadmap or implementation plan together with your ICT manager, clearly describing what you will do and when.

- **Tip:** divide your implementation plan into small, clear and manageable steps. Set ambitious but achievable goals for each school year and incorporate clear deadlines for evaluation. Be informed and inspired by the technologies from the completed Hype Cycle and their relationships as shown on the Benefit Map.

- ▲ **Pitfall:** don't be put off by everything that needs to happen – you can choose to stagger the implementation of some items.

2. Set out on a journey and adjust your ambition if necessary

Many schools are already working with adaptive learning resources and acquiring the necessary knowledge and experience. You want to be able to compare these experiences within your teaching team so that you can learn as much as possible from each other. Structure this process as follows:

A. Determine in advance how and under what preconditions and frameworks an adaptive learning resource will be used.

- **Tip:** think in advance about what information is needed in your learning process in order to plan, monitor and improve your education, as well as which (type of) learning resources can be

used to securely retrieve said data.

- ▲ **Pitfall:** (excessive) collection of data without a clear goal and without linking it to possible interventions in the learning process. Consider who is going to do what and when with the available information.

- ▲ **Pitfall:** continuing to wait for the ultimate learning resource that will solve all your problems or attempting to build the ultimate dashboard yourselves. It is better to make a start sooner and to learn on the basis of technology that is already here and that you might be able to improve. You can also benefit from this process.

B. When investing in personalised learning technology, consider the interoperability with underlying systems and standardisation of connections, so that you only record data about group classification, profile choices or achieved results once, and can properly use this data when organising personalised learning.

- **Tip:** determine requirements for products that you select and research whether they can deliver the data you need. Also, thoroughly investigate whether exchange with other systems based on standards is supported. In time, this should become an explicit part of your purchasing policy and must then be guaranteed with every investment, so that you can ensure that systems cooperate smoothly in the long term.

- ▲ **Pitfall:** don't expect all educational software to support standards as a matter of course. The exchange of learning results and obtaining an overview in a dashboard particularly depend on this process. You must therefore make prior agreements regarding standards for data exchange. This will prevent your supplier from charging unexpected costs or failing to cover this.

C. Make sure you can compare practical experiences, and avoid conducting isolated experiments. Aim for broader implementation, for example in one subject over one school year. By doing this, you will gradually and continuously optimise the learning process.

- **Tip:** give your teaching team the time and space to optimise the learning process. One way of approaching this is to hold a weekly consultation involving as many teachers as possible. It is vital that these consultations are used as an opportunity to discuss and evaluate the objectives that you formulate for personalised learning, and that you make agreements about any necessary adjustments to the strategy.

- **Tip:** if things go well, adaptive learning resources ensure that teachers have more time available because the resources take care of some of the teachers' usual tasks. Discuss with them how they can utilise this time to devote attention to issues such as complex cognitive skills or deepening the student-teacher relationship.

- **Tip:** formulate your plan in small steps, so that your path isn't set in stone, and allow yourselves to learn from the insights gained along the way and to adjust your goals and/or plans accordingly.

- ▲ **Pitfall:** discussing practical experiences without assessing whether objectives are being achieved or whether actual improvement measures are being linked to the identified hurdles. This stagnates optimisation of the learning process.

D. Modify your roadmap if it becomes apparent that certain choices of resources, teaching or data collection are not having the desired effect. Accept that you may also have to adjust your target destination.

- **Tip:** set up a process within the school board that will allow you to continuously learn from practical experiences, observations and other findings at other schools, which you can use as a basis to adjust your roadmap. A conventional long-term plan offers insufficient flexibility for this.

- ▲ **Pitfall:** stubbornly adhering to the plan and not providing any scope to utilise newly gained insight and adjust the course.

3. Arrange the preconditions for your journey

You can only realise your ambitions for personalised learning technology if everything around that technology functions optimally. A reliable, secure ICT infrastructure is a crucial foundation for this.

A. This means uncompromising investment in wifi, internet connection, setting up cloud platforms, devices and mobile device management. You can then be certain that the user experience of personalised learning technology will not be marred by a faltering internet connection, for instance.

- **Tip:** formulate a cloud migration strategy. Ask yourself the following: which applications are already running in the cloud and are they well integrated? Are there any applications that you need to migrate? What kind of multi-year planning do you have in place so that any duplicated licence costs or technical provisions are resolved as quickly as possible? Does this planning take sufficient account of your other ambitions?

▲ **Pitfall:** the implementation of infrastructure technology is complicated and not necessarily cheap, and for this reason it often gets postponed. However, you can and must organise it proactively and comprehensively, by making use of professionals, relying on their expertise and know-how, and using business-quality products that are appropriate for the school's level of dependence on these technologies.

B. Ensure that your information security and privacy policy are effective and well-structured. Make the proper arrangements with your suppliers in this regard.

- **Tip:** make sure your suppliers have signed the privacy agreement, and that you have a data processing agreement with every supplier.

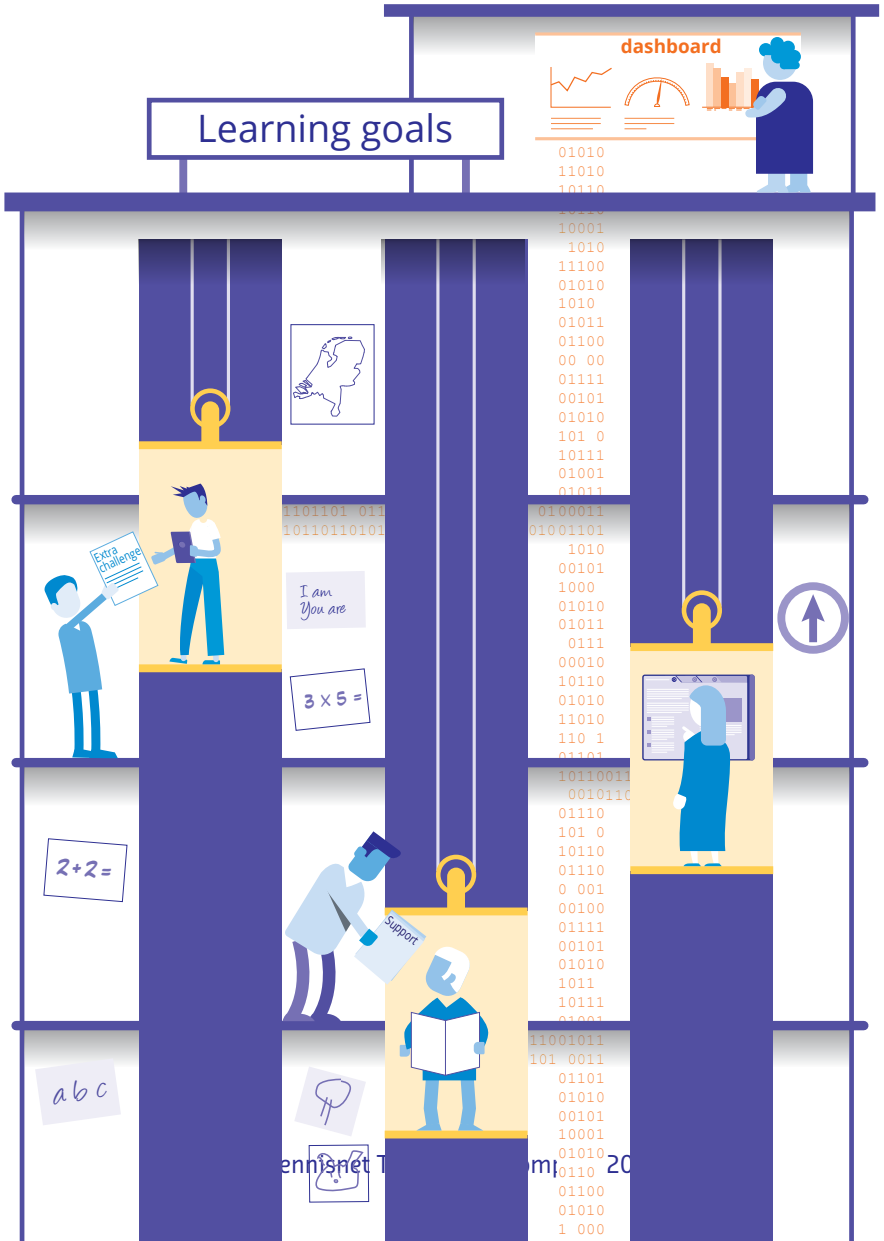
- **Tip:** prevent teachers from independently choosing to teach using any app that stores students' personal data if there is no data processing agreement between the school and the selected app. This is not permitted and the school is responsible for this. Clearly inform teachers as to which apps are permitted.

▲ **Pitfall:** do not assume that it is the end of the story once you have signed or made agreements. You must maintain awareness throughout the entire school organisation.

2.3 Personalised learning at an individual level: issues for education

Personalised learning – and the technology that supports it – has a notable influence on how education is organised, first by optimising the current educational process, and later by relinquishing this process and transforming it into a more flexible educational system. This optimisation, and subsequent transformation, evidently has consequences for the learning process and the education process, as well as the skills of people in different roles and the overall ICT configuration.

In this section, we will outline the most important issues and the consequences that they entail. Of course, we are not dictating what your educational process should look like, but rather touching on the issues that schools may face.



2.3.1 Do you want to differentiate the amount of time that individual students spend on different subjects?

Within the foreseeable future, a student's relevant data from all the digital learning resources they use will be clearly displayed in a cross-subject dashboard. A potential insight that could be brought to light by one of these dashboards is that a certain student should be spending more time on numeracy than on literacy. A timetable in which each student has to spend the same number of hours on each subject does not meet this need. In these situations, the role of a learning resource is limited to offering the student exercises at their level. Ultimately, this could simply intensify the differences between students. Do you truly want to offer

personalised learning on an individual level? Then, as a school, you have to make a decision about how to vary the amount of time students can spend on a subject in order to reach a certain level.

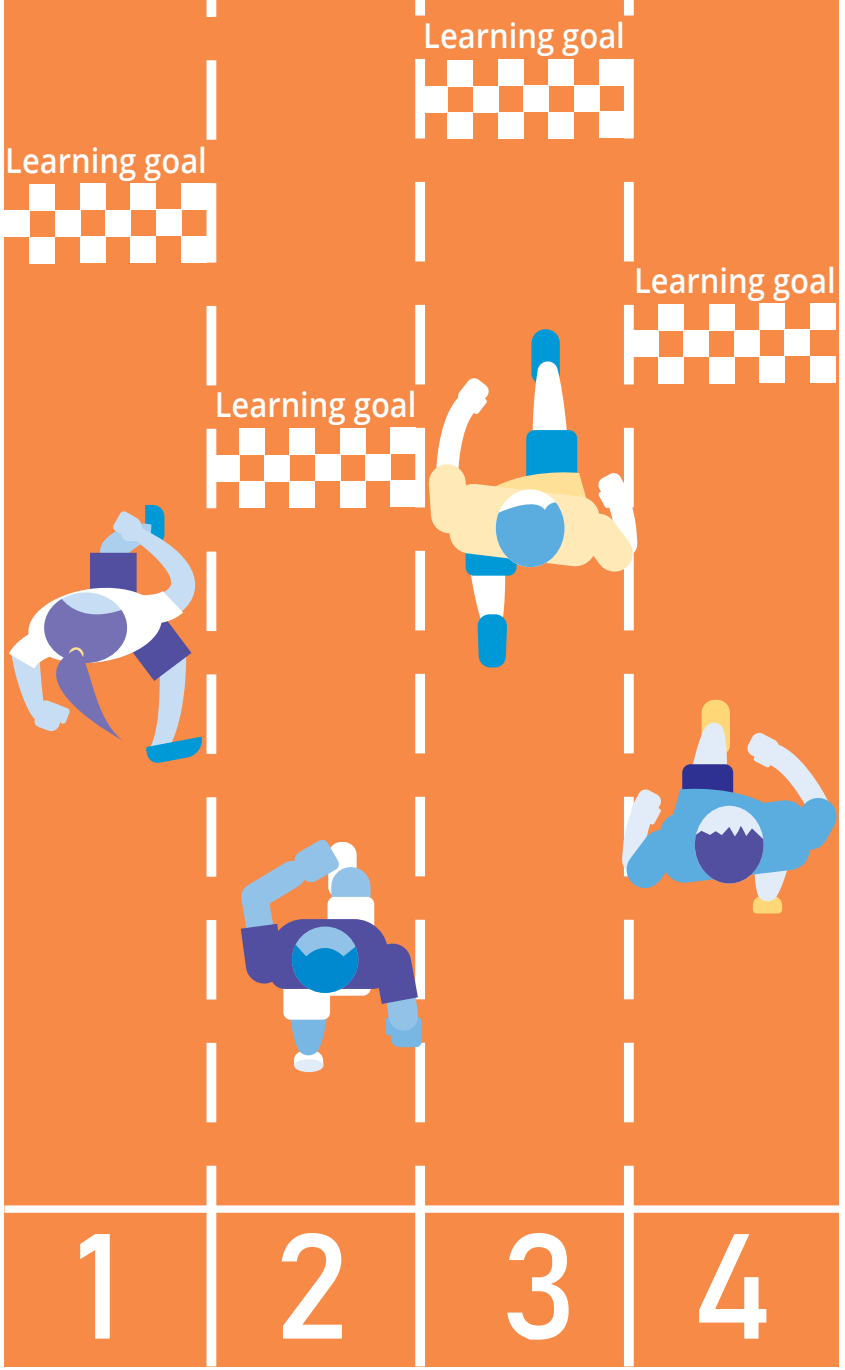
Consideration: think about how you want to organise and facilitate personalised learning

For example, you can offer students the opportunity to stay at school longer, or if a student has achieved good scores in literacy, for instance, they can spend less time studying it. You can also opt to vary the final target level for each student based on their talent and ambition.

2.3.2 Do you want students to be able to learn at their own level and pace and in their own way?

Some students need more time and guidance to understand the study material than others. Adaptive learning materials and cross-subject dashboards help to elucidate these differences. Is there already a fixed timetable for the year that determines what will be covered in different periods and when the tests will be? If so, this severely limits the extent to which students can work through material more slowly or quickly. This means that at the end of the year, every student has to be at the same end point in terms of learning objectives, so that the next teacher can build on this in the following year. If you want to offer more personalised learning, you should also consider getting rid of this kind of organisational structure.

In education, we distinguish two main types of differentiation. Convergent differentiation is where teaching is focused on the different needs of students to allow them all to achieve the same learning objective.



In divergent differentiation, on the other hand, students work towards different learning objectives. Both forms of differentiation have a positive effect on students' educational performance.

Divergent differentiation requires the biggest changes in how education is organised because you increase, rather than minimise, the differences between students. This can mean that students of the same age are working towards entirely different learning objectives. Documenting and monitoring the learning process and organising appropriate learning activities for individual students can be very demanding for the school. Technology can assist by offering tailor-made exercises. A clear overview of student progress in cross-subject dashboards is then crucial to keep track of each student's progress and current level. You can then make smaller, more frequent decisions based on current insights into their progress, and place much less emphasis on sticking to a fixed schedule. However, research also shows that convergent differentiation can be motivating for students. This effect even seems to be greater than in education that only focuses on divergent differentiation. One possibility is to apply convergent differentiation in some learning domains and divergent in others.

Personalised learning forces us to reconsider existing organisational structures

Legal frameworks and the transitions between tiers of education mean that you cannot completely move away from the use of convergent end points. They limit the scope of decisions that you can make. But in the years a student spends at a school, there is room for other choices to be made.

Consideration: ensure good communication between team members

Have you chosen to move away from with convergent end points? In this case, teachers who work with a student later on can no longer count on students having been engaged with the same content at the same time as each other. A comprehensive handover from teacher to teacher thus becomes an essential part of the process. This no longer applies simply per class, but per student. Therefore, you must thoroughly document the learning process and the individual level of each student and ensure that you make clear agreements about how to transfer this information.

2.3.3 Do formative and summative assessments correspond with each other sufficiently?

Adaptive learning materials use formative assessments to provide you with continuous insights into each student's performance and proficiency level. These formative tests occur frequently during the learning process and are used to determine how best to steer said process for a particular student. The test results, combined with the student's daily experiences, provide a comprehensive overview of a student's learning process across several years. Nevertheless, summative tests remain necessary, not only because of the value that society and the education system attach to standards, certification and accountability, but especially because the likelihood of good learning outcomes increases when summative and formative assessments are considered and developed in conjunction.

For a summative final test, you must first define attainment targets, core objectives and the intended learning impacts. In other words: what should students know and be able to do by the end of primary school, or upon completing a programme of study? You can operationalise this by

developing and determining an examination syllabus with standards and test items. That is the summative process. Having defined these attainment targets, core objectives and learning impacts, they can form the basis for the educational programme in your organisation. You then map out how they can be achieved: this is the formative process. These decisions lead you to make choices about resources, methods and format, which in turn result in the curriculum.

Consideration: ensure that summative testing is well matched with the formative process and vice versa

If summative tests and the formative process are well attuned to each other, this minimises the potential for differences between the outcomes. Over time, this would allow schools to reduce the frequency of summative tests, and the results would be much more in line with each other. Therefore, start by drawing up the objectives that you want students to demonstrate in the summative assessments. Then, for each objective, consider which resources you want students to use to achieve those objectives. This will require the use of a combination of resources, working methods and activities. After all, adaptive learning materials can only be used effectively for basic cognitive skills. Summative tests are not only used for final assessment, but also to aid in designing the formative process.

2.3.4 Does the skill level of your teachers match the resources you are using for personalised learning?

Providing personalisation with the use of adaptive learning resources demands more than a basic level of ICT skill, knowledge and experience. Teachers must be able to work with the resources, but also to interpret the information from them and convert it into effective actions.

Algorithms make small pedagogical decisions in each student's learning journey

Consideration: ensure that teachers know how to use the monitoring information on the dashboards in adaptive learning resources and be sure to exchange experiences and learn from each other

To illustrate: smart use of a dashboard gives teachers a quicker view of progression in the classroom. This serves as their basis for more effectively selecting and planning the right interventions. Simply buying the technology is not sufficient - teachers also need to know how best to use the dashboard to then choose appropriate interventions. A short training session at the start of the school year is not enough. It is important that time be allotted for training during implementation as well. Time also needs to be set aside for staff to understand the resource in practice and to exchange their experiences with colleagues.

2.3.5 Does the skill level of your ICT support team match your vision for personalised learning?

Individual personalised learning requires a thorough approach in many different aspects. If the underlying technology doesn't work or doesn't align well with personalised learning, this has a direct impact on the learning process. This also changes the role of ICT managers within a school or board. Their job is no longer simply solving small daily problems, nor even answering the question of which devices to purchase. That is too limited. Their remit instead becomes: what combination of technologies can we use to implement our vision for personalised learning? It is up to the ICT manager to find out about these matters and to come up with an investment and implementation plan.

Consideration: invest in ICT expertise and think about the changing role of your ICT manager

In addition to improving the skills of your teaching team, you also have to invest time and money in professionalising your ICT expertise. Working in cooperation with the school leadership, the ICT staff must think, at policy level, about how they can support the school's educational ambitions with

It is up to ICT managers to come up with an investment and implementation plan

the proper use of ICT. Moreover, they must guide and support teachers in the implementation of ICT in the school's learning process. The ICT policy plan detailing this must be reviewed annually to see whether it is in line with the organisation's ambitions for education.

Chapter 3

Living, learning and working with artificial intelligence

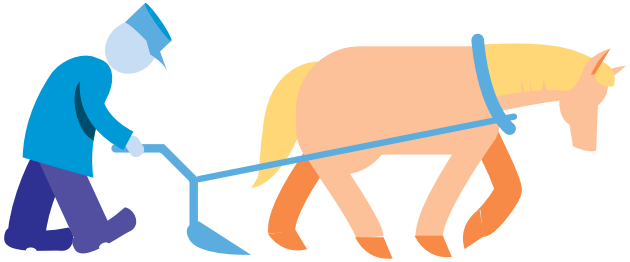
3.1 Living, learning and working with artificial intelligence in a nutshell

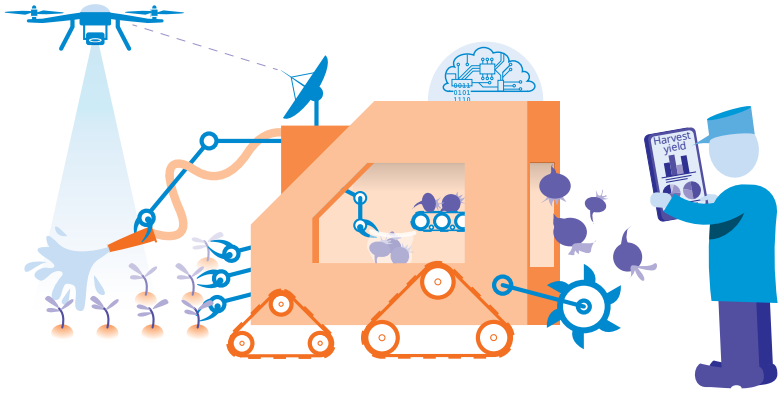
3.1.1 From 'doing machines' to 'thinking machines'

Since time immemorial, we have used tools to supplement our physical strength. Sometimes, a tool is so fundamental that it becomes a starting point for a myriad of new innovations. Think of the invention of the wheel, or more recently, the introduction of the steam engine or electricity. Artificial intelligence (AI) constitutes another such breakthrough. But this time, the tools are able to extend our brainpower, rather than our physical power.

We are educating students to live a meaningful existence in a complex world

Artificial intelligence is on the rise, with far-reaching consequences in our society and our education. Although there is still a long way to go, the impacts in specific tasks and professions are already visible. Existing professions are changing, and new ones are appearing. In education, too, adaptive learning resources have already assumed routine teaching tasks. And that's just the beginning: AI applications can more and more completely monitor a student's learning process and, based on analyses and predictions, provide targeted feedback and propose changes in their learning path. As a result, teachers can focus even more of their time on guidance and coaching, for example in the acquisition of social-emotional skills, which students will need more than ever before. In this way, we are educating students not only to have a profession, but also to live a meaningful existence in a complex world. AI thus has the potential both





to make education better and to make the teaching profession more attractive.

> **Need a refresher on AI?** Re-read section 1.2.1.

Thinking machines need frameworks

Every new tool that improves our lives brings with it a number of risks. Alongside offering convenience in the household, electrical appliances constitute a fire risk. Cars offer mobility, but they also claim traffic casualties. By making agreements - fire safety standards and traffic rules – we can safely use these tools with an acceptable level of risk. These kinds of agreements are also required for AI. Because AI is still very much in development, the frameworks within which this technology can and may act are still insufficiently defined. In education, too, we can exert influence by holding discussions on an appropriate division of roles between people and technology. This will enable us to use the power of AI fully, and in an ethically responsible way.

Artificial intelligence in society: living and working

Artificial intelligence is everywhere. It helps the police to predict domestic burglaries, and it assists doctors in choosing the most effective treatment method for cancer patients. The influence of AI and robotisation will increase in the future. For example, robots will perform surgery and algorithms will predict the consequences of new government policies. The work carried out by people will predominantly be those tasks and functions where machines are not yet profitable or effective, such as picking objects up carefully - applying the right amount of pressure to different objects is very complicated for a robot, for instance.

Professions will change, especially in situations where there are routine or even complex tasks that can be captured effectively in algorithms. Think of tax consultants, warehouse staff and accountants. These professions are supported by AI analyses so that people can focus on differentiated activities, such as decisions and actions in which empathy and moral awareness are important.

In 25 years, robots and AI systems will have taken over many tasks

Artificial intelligence in education: learning

The impact of AI on society will also be visible in education: in what we learn (the content of the curriculum), how we learn (in what way and with what resources) and how we organise education (at which place and at what time) as well as the choices we make about students, courses and schools.

Learning content prepares for a society with AI

Students need to acquire the knowledge and skills that will prepare them for a society full of AI. They have to understand what it means to be human in a world in which you come into constant contact with AI, and how they can manage the suggestions provided by AI analyses. This has a large number of implications for education. What foundation for living and working do you want to give students in primary education? Which professions do you focus on in secondary education? How are vocational curricula developed and organised, taking into account the impact of AI on jobs and professions? And what perspective does that give students for a career in that discipline? These questions aren't easy to answer, but they are pertinent to today's school boards.

Cognitive versus social-emotional skills

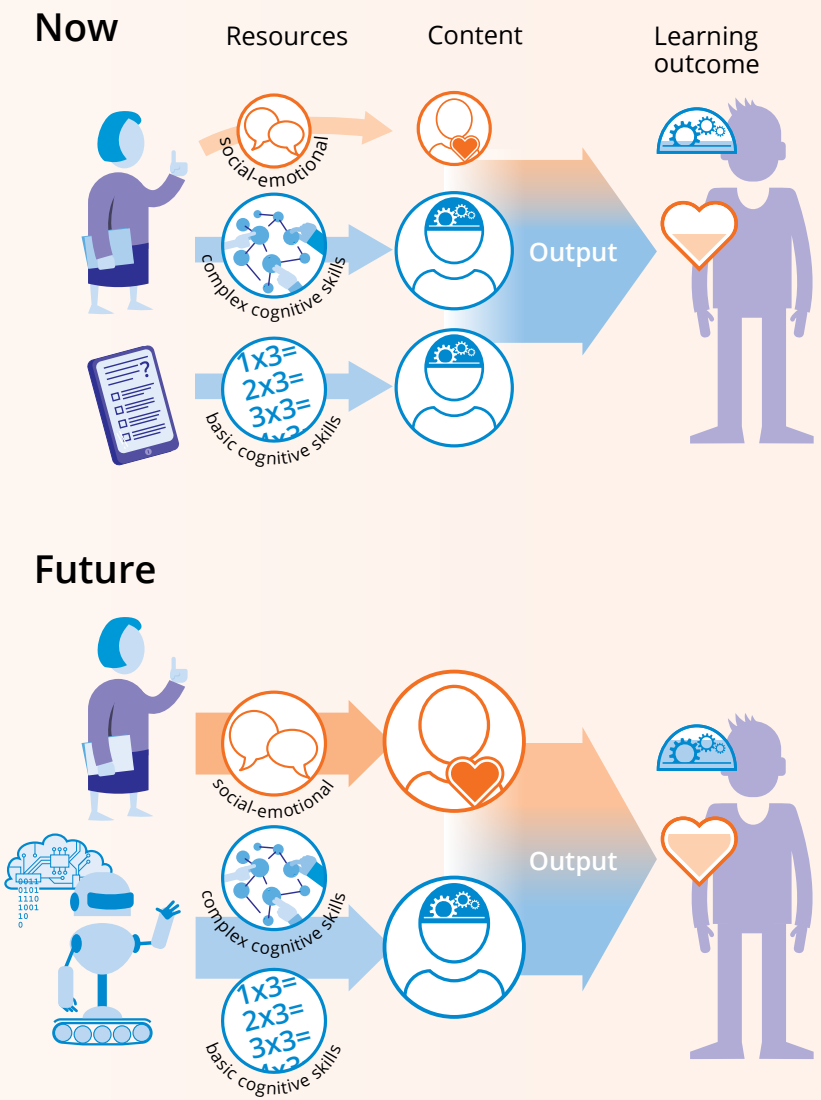
Adaptive learning materials are limited to basic cognitive skills, such as remembering, understanding and applying. For instance, they can automate the learning of spellings and arithmetic.

In this chapter, we extend the discussion to future AI systems that have detailed knowledge of a field, and that 'understand' what students are saying or writing, thereby enabling them to analyse and support a broader pallet of learning activities. This would see AI becoming involved in complex cognitive skills, such as analysing, reflecting, evaluating and applying existing knowledge in new situations. Even when AI can support the learning of the entire range of basic and complex cognitive skills, there will still be important tasks for teachers to fulfil, for example, the development of social-emotional skills, guiding students in their learning process where necessary, and organising authentic, contextually relevant learning experiences; these experiences enable the students to better understand how the knowledge and skills they acquire can be used and applied in the world around them.

When automating a complex task such as teaching, it is important to carefully consider which subtasks the AI system will assume and which subtasks will be carried out by the teacher. Care must also be taken to ensure that no subtasks inadvertently fall through the cracks. To illustrate: hand dryers in public toilets mean that you can always dry your hands, and there is no longer a need to stock paper towels. However, this now makes it much more difficult to wash and dry your face if you want to freshen up.

If you observe that an important element of the teaching process is falling by the wayside, you can put additional measures in place. Or simply choose not to automate that particular task. An AI system could provide independent feedback on structure and use of language when writing a formal letter. But the skill of giving effective oral feedback, and the art of receiving negative feedback, can only really be learnt when you practise with each other, face to face. How do you deal with a classmate who bursts into tears when she receives negative feedback on her letter? Did she interpret it differently than you intended? Could you have phrased it another way? A teacher can help students to hold up mirrors to each other and discuss the strengths and weaknesses of their feedback or delivery. This is just one example of a situation where teachers are essential for students' development.

The expectation is that AI will gradually progress towards supporting more and more skills: from adaptive learning resources that are limited to basic cognitive skills, we will see them increasingly support complex cognitive skills. First, this will occur per individual subject, but later they will integrate multiple subjects. Eventually this support will be supplemented with information about social-emotional skills.



Learning materials support more complex cognitive skills

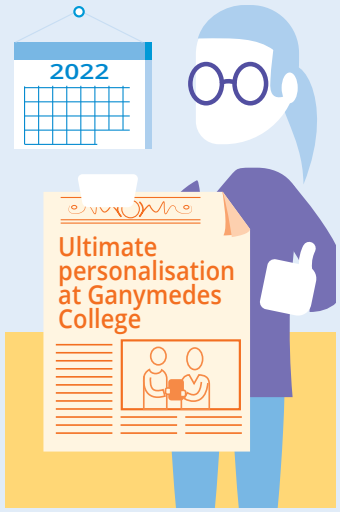
Adaptive learning materials now offer personalised learning at an individual level, supporting the development of basic cognitive skills. Artificial intelligence is developing rapidly, and will increase the capabilities of learning materials to better monitor and understand the student's thinking process, thereby offering personalised solutions at an individual level. AI technology is already being used in niche products for support in checking open assignments. In this sense, AI can already read technically, but not yet comprehensively. For example, it can count words and check grammar, but it cannot assess the intention, justification or structure of a writing exercise. There are, however, already experiments with this in mind. It is only a matter of time before we find the acquisition of more complex cognitive skills in mature Dutch educational products as well.

Teachers can make better decisions and spend more time on guidance and coaching

Learning process is supported at the level of the individual's learning path

Currently, adaptive learning materials offer opportunities for personalisation at the level of a learning resource or subject. But, looking further into the future, we can see a development towards personalisation at the level of the individual student's learning path. Based on analyses of behaviour and results, and predictions about where this can lead, the AI gives targeted feedback to each student, makes recommendations for follow-up steps and helps to nip potential development risks in the bud.

Director Mrs Kepler's farewell speech, June 2042



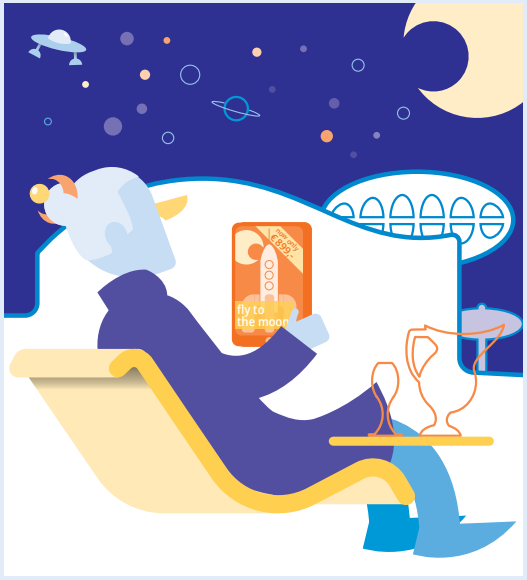
Dear colleagues, students and parents – what a great time I've experienced here. Do you remember that there was a time when personalised learning was only an emergent movement? It may be hard for you to imagine, but when I started out as a teacher, we taught the same lesson to 30 students at the same time. They sat in one classroom, learning the same subject for 80 minutes. This all changed in the 10s and 20s. Thanks to new technology, students no longer had to do the same lesson at the same time and in the same place. We were one of the first schools to support individual learning paths. And we were so proud to be highlighted in the press for it!

But this didn't all happen automatically. Students discovered ways to fool the systems. There was a lot of back-and-forth about protecting student data. And some teachers struggled to get used to the fact that they were no longer able to talk about their subject for 80 minutes straight. With a heavy heart, I had conversations with colleagues who didn't want to carry on in the profession. Or who simply couldn't keep up with the changes.

I still vividly remember the discussions during one of our away days. I can still hear Rob say: "I don't want those smart things in my house, with everything in the news about hacked data. I don't want to be constantly spied on at home. And I don't want that for my students either!" I felt the frustration of some colleagues over what they considered to be a naive attitude toward AI technology. And vice versa – advocates of the new tech were frustrated about what they saw as doom-mongering. Our ideas were still miles apart.

I flipped the discussion during the next away day. I asked everyone to think of three possibilities why using AI technology in our school could go wrong. After having explored all these possibilities, we were able to look for measures to prevent them from happening. That helped to get everyone on the same page. Once we'd named the preconditions together and got used to the technology, things really took off fast! We were, however, still mainly using the technology for the transfer and application of knowledge. And digital skills became increasingly important. Yes, folks, I used to take smartboard lessons. You know, that thing we keep in the drama space as a prop!

In the 30s, we experienced another huge growth spurt in the technology. We were able to get overviews that included not only data per subject, but information across all subjects. And not just about factual knowledge and level, but also about skills like reflection, creativity and collaboration. To assess factual knowledge, we started working with microphones and cameras that the AI systems used to analyse the knowledge level of students, then translated this information into individual lesson recommendations. This technology is soon to have a breakthrough for social-emotional skills. I notice that we're getting excited about it again, but I'm curious to know where it's going to lead.



I also remember how much fuss there was about those microphones and cameras. Parents didn't want them. And privacy activists insisted on a referendum in the Houses of Parliament. Still, I'm so glad that we finally found a way to handle this data properly. Because without these insights, we wouldn't be able to spend so much time on student guidance. In my early days as a teacher, I never would have dreamed that we'd be able to support the students' development in the way that we can now. Because it's so valuable to be able to apply knowledge in modern society – and to interact with the other members of it.

And yet, I did also occasionally curse the new systems when they didn't quite do what we expected them to, or I would heave a heavy sigh if it turned out that newly graduated colleagues hadn't been properly prepared for the job. I remember when I went cycling with Aisha, who had recently graduated as a teacher in the philosophy of science. She told me how she was struggling: "I want to bring students into a dialogue, start discussions, but I do find it hard when I have to work with all these systems."

I told her that I had also really struggled with that, but that I quickly noticed that the systems mainly took over the annoying parts of my work: repeatedly confronting students about what still needs to be done and checking whether they are keeping to schedule. My role as a teacher shifted to being much more of a helper: why is a student getting stuck in a certain subject? What could we do differently? Aisha knew what she could do: "Ask questions about the philosophy of science – that I can do!" she laughed.

When I myself was in primary school, I spent my time chanting times tables. After secondary school, I had no idea what I wanted to do with my life. And as for the job I chose, I only really understood how it worked once I was actually working in it. My grandchildren are now discovering their talents and interests during their time at school, without any prejudice from their environment about what they should be able or willing to do. We're not only training them for a profession, but, crucially, for a meaningful existence in this incredibly complex world. And that brings me so much joy!

We jumped into the deep end, and gradually learned how to swim. Over time, we became increasingly familiar with this formerly unknown landscape, and somewhere along the way we reached a point where we could no longer imagine how things had been before. I'm delighted that I've been able to live through these developments with you all. In the years to come, I'm going to travel and reflect on my time as a teacher and director at this school. Maybe I'll be very old-fashioned and write a book! Or I'll go on holiday to the Moon. I read that there are some new offers.

When teachers are supported in this way, they can make better decisions and pay closer attention to guiding and coaching their students. It will be vital that we bring together data from different systems with different scoring scales into one integrated overview. And although it is complicated, steps are already being taken in this direction.

Educational organisation better substantiated by data and analysis

A learning process in which data and analysis play a major role calls for different roles for teachers, school leadership, departments and administrators. As manual review of assignments and administration of figures largely become a thing of the past, time is freed up that can be spent on better-informed consideration of interventions at student level, subject level or even institutional level. We can process, analyse and present all the available data from AI-based learning resources, enriched with additional information from the teacher, in dashboards at student, school year, class, school, programme or institutional level. With this information, we can plan and monitor at different levels. This creates a learning path for the student that will best enable them to achieve their potential.

The student follows a learning path that best enables them to achieve their potential.

Departments, school directors and administrators can make better-informed decisions at a more overarching level. For instance, when starting a new educational programme, or closing a branch location based on declining student numbers, local residence or student progress.

How is AI going to support us in life, education and work?

This will be the subject of this chapter. First, we sketch a picture of what an average school day may look like in the future. After that, in section 3.2, we analyse the most important technologies for artificial intelligence and how they can support better, more personalised education. In section 3.3, we discuss the impact AI has on school management, teachers and students.

3.1.2 Future insight: living, learning and working with AI

No one knows exactly how the world is going to look in the future. But we know for certain that AI will have a big impact. To get a more concrete sense of the impact, allow us to paint you a picture of a possible future day in the life of a vocational student, his teacher, and a programme director.

The student

The virtual assistant wakes the student at 7.30 and walks him through his daily schedule. He has an online meeting with a fellow student at 8.30 so they can prepare for their joint presentation later that day. At 11.00, he has to be at school for a dress rehearsal for a play about the end of the Cold War, and at 13.00 he is giving a presentation about his internship at a manufacturer of self-driving cars. The domestic robot has already laid out clothes based on the student's daily schedule and the weather forecast. A cup of tea and a sandwich are ready and waiting at the kitchen table. During breakfast, he speaks with his dad about his schedule, as well as that of his mum, who has already left for the day. They agree who will be cooking and what time they will eat together in the evening. Meanwhile, the domestic robot puts the groceries, delivered by Bertie the drone, into the fridge and pantry.

8.00: The student's virtual assistant indicates during breakfast that his online meeting is in 30 minutes' time. First, the student chats with his English AI tutor in his room via the adaptive learning environment to discuss the improvements in his essay. By asking questions the learning resource assesses to what extent the student really understood the previously discussed study material, and addresses the points where he has done less well. The resource also uses text and speech recognition to provide feedback on the student's pronunciation during the conversation.

10.00: The student is sitting with his dad in the self-driving car, which departed at 9.57 based on traffic information, available routes and schedule so it would be able to drop them both off at their destinations on time. While en route, they call the student's grandmother, who at that moment is lifted out of bed by her personal care robot and then assisted with washing and getting dressed. The student goes to school early because he has agreed to meet his best friend.

10.55: After thoroughly discussing yesterday's football game with his friend, he walks to the room where he has his dress rehearsal. Afterwards, he walks to the supermarket. His drink is paid for automatically, while he walks back telling his mother how excited he is about the rehearsal.

12.10: Back at school, his virtual assistant suggests that he finish his internship report in self-study room 3A, because tomorrow is the deadline. His AI tutor gives him feedback on language use, grammar and the structure of his report. His score for the chapter about transmission is still too low, so with the help of a link to an in-depth article, he improves and then delivers his report. On his way to his presentation at the internship company, he watches a video message from his father and grandmother in the park.

The teacher

The teacher is woken up at 8.00 and jumps in the shower, then at precisely 8.15 he and his partner drink espressos served by their domestic robot. He then has a look at his integrated dashboard to see how his students are doing and where they need help. He answers some video messages from students asking specific questions.

8.40: He also checks the feedback and assessment that the AI tutor has given for the essays his students had to write. He schedules a conversation with a student who has performed less well this week and who has also been in school less often. For another student who is still having problems with grammar, he schedules a progress appointment with the Dutch language expert. For the rest of the students, he examines the steps that the AI learning resources are advising within the subject, but in particular he reviews the analysis that the AI has made per student profile for the entire learning process, and the advised learning path. He looks at assessments and feedback from learning resources and what students have done with it, checks social-emotional progress and makes personalised suggestions for each student.

10.25: The teacher goes to school, where he has a discussion with the English language expert and ten students about the business letters they wrote this week. All students have been instructed in advance to select three letters by other students and to provide verbal feedback to each other. This is then discussed as a group. During this activity, students learn how certain feedback – both positive and negative – can come across to others. The teacher supervises the process, acts as a mirror for the students, and gives them tips on how to properly substantiate their feedback.

12.30: The teacher has lunch at school and asks his virtual assistant to schedule a video call with other colleagues to discuss the progress of his mentor students. In preparation for this meeting, he looks at the insights and advice from the integrated dashboard.

The programme director

After breakfast in his office at home, the programme director uses his dashboard to look at the programmes' rates of return in preparation for the Board meeting tomorrow. He also prepares for appointments that team members have scheduled with him.

8.50: He sees that the Warehouse Manager programme is still popular, but knows that there is less and less prospect of a job in that field. During a business visit last week, it was apparent that robotisation in warehouses is

continuing to grow strongly. By contrast, there is an increasing demand for good, creative chefs. The cookery programme could be updated by better integrating new technologies. He also sees that chefs' personal branding is becoming increasingly important.

9.21: Crisis! A data leak in the adaptive learning environment – fortunately, through a short video call he learns that the ICT department acted quickly. The leak must be reported straight away to avoid fines and negative publicity. The programme director immediately dictates a letter for students and parents to his virtual assistant.

10.25: In the online team environment, he asks the teaching team of the cookery programme to investigate the extent to which it can grow and what changes are needed in its content. His virtual assistant is already planning the discussion of the proposals.

13.00 Evaluation of the AI learning resource that was used for the first time this school year is on the agenda for the English team meeting. He asks about their experiences and observes that certain aspects of the original learning method worked better. In collaboration with his teachers, he will investigate whether this is an acceptable trade-off, and what compensatory measures are possible.

3.1.3 Advice for the journey towards AI-supported education

The expected impact of AI on our society and education is far-reaching, and is already visible today. What opportunities does AI offer for achieving ambitions and educational goals? How can it help you realise your educational vision? What is a suitable distribution of tasks between teachers and digital tools for you and your team? With your teaching team, consider the future role of AI technology in your school. And make an inventory of the risks associated with it so that you have a jointly drafted framework to use when making decisions about digital resources in the future. Because the transition to a school organisation where people and technology work together seamlessly means a process of change that requires difficult decisions to be made.

1. **Discuss how AI can strengthen your teaching in specific terms**
   By discussing both utopian and dystopian scenarios with the teaching team, you are making a commitment to reflect on uncomfortable questions related to AI's impact on day-to-day education. At the same time, it functions as a reality check. Do your colleagues see the

Discuss how AI can strengthen your teaching in specific terms

   same allocations of task and role for teachers and AI as you do? With the team, for each teaching task, critically analyse whether and how automation via AI could improve or impair the development or well-being of students or teachers. For example, what effect could the use of AI have on the year group system currently used to organise subject matter – how could it offer room for more individualised learning paths? By doing this exercise together, you are already generating support among the teaching team for the necessary changes.

2. **Investigate the concrete impact of AI products on the school and organisation**
   Imagine that your educational goals are reducing workload and making better-informed decisions. How can you utilise AI technology to achieve

these? Research what the consequences of specific AI products are for your institution and whether they contribute to your goals. Start with AI technology that is already being used and that influences the pedagogical decisions in the learning process. Then, expand your research towards more advanced technology. Assess and evaluate investments in new digital tools based on expectations and objectives that have been formulated explicitly and in advance. Use experiences of what works well to develop a testing framework and to establish preconditions. Use research results and case studies, as well as experiences and expertise from other school boards, and involve market players as well. As a school board, implement a continuous, cyclical process to hone and specify the role that AI technology can play in achieving your educational vision.

3. Preconditions for the effective application of AI

You can already start to establish a number of important preconditions. Allowing an AI-enhanced adaptive learning environment to flourish at the level of individual learning paths requires current data from the learning process. This means that systems need to be able to exchange sufficient and immediately usable data. Therefore, one precondition is that, as much as possible, you choose digital learning resources and tracking systems that support data exchange. So that you have an integral picture of the students and their learning paths. In addition, it is important to make clear agreements about how personal data is used, both internally and by third parties. By doing so, you facilitate the appropriate use of educational data and prevent privacy incidents that violate legislation.

3.2 Living, learning and working with artificial intelligence: the technology

How is artificial intelligence (AI) going to change how we live, learn and work? How will people and technology work together so that the learning process can become as effective as possible? In this chapter, we will use three tools to shed light on the technologies relating to AI that will transform the learning process in the coming years.

The **Hype Cycle** shows the maturity of each technology. It is clearly visible that almost all AI technology is still under development, especially in education. Although a concrete translation into education is difficult and brings with it many uncertainties, the impact in terms of living and working is already clearly noticeable.

The **Benefit Map** shows the interplay between technologies. There are three chains that, when used in combination, enable education to take full advantage of AI-based technology. An artificially intelligent learning environment that organises an individualised learning process for every student. The cognitive services that bring this learning environment to life. And the ICT foundation that allows the learning environment to function safely and reliably.

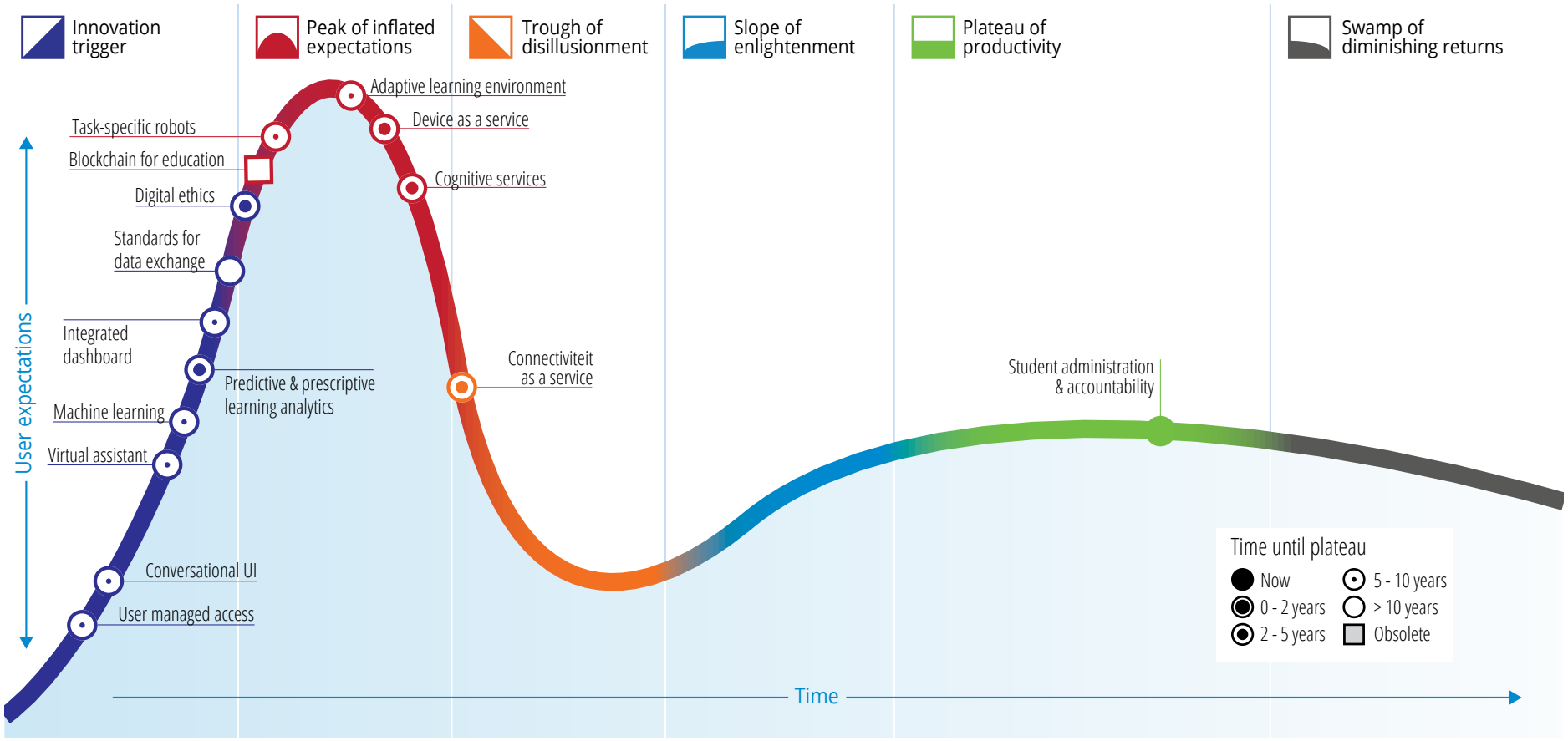
In the **SWOT analysis**, we map out the strengths and weaknesses of AI technology and the opportunities and threats it poses for education. An adaptive learning environment gives teachers a deeper and more objective insight into the learning process, and – because AI takes over routine tasks – also gives them time to focus even more on creating guided, contextually rich learning experience. Provided that the AI is based on correct, relevant information and that teachers are able to make the step towards a new interpretation of their duties.

The analysis is the prelude to our concluding advice in this section. It will help you to make preparations straight away. So that you have a better sense of the process that you will have to go through as a school to use AI responsibly and correctly in your educational institution.

> **Need a refresher on the Hype Cycle and Benefit Map?**
> *Re-read the explanation in the introduction.*

3.2.1 Hype Cycle for living, learning and working with AI

The Hype Cycle below depicts AI technologies that will give shape to living, learning and working in the future. Their locations on the Hype Cycle show a snapshot of the relative maturity of the technologies and their potential in the future. The Hype Cycle helps you choose the right time to start using a technology and see what risks are associated with its deployment within your school. This Hype Cycle is the result of an analysis of various studies and existing Hype Cycles.



Innovation trigger: first introduction of innovative, new technology

We find various types of technology in this phase: technologies containing the intelligence behind educational applications, such as **machine learning** and **user managed access**, but also technologies that enable students to interact with learning resources via speech and text, such as **conversational UI**. Additionally, we see **standards for data exchange** that need to be further developed in order to support **integrated dashboards**.

Although many of these technologies are at an early stage of development within education, this doesn't mean they aren't already fully in use in society. For instance, think of the use of voice assistants in the home and robots in nursing facilities.

Peak of inflated expectations: hyped technology doesn't yet meet high expectations

We already see the technologies in this phase being used to a limited degree in education. Cognitive services provide some of the universal building blocks of AI. For example, they enable developers of **adaptive learning environments** to make their product accessible via natural language without themselves having the expertise and resources to develop and improve that kind of functionality. With **device as a service**, hardware suppliers relieve the burden of rapidly digitalising education by allowing schools to flexibly upgrade or retire digital devices. **Task-specific robots** are already widely used in transport, care, security and other sectors. For instance, there are now factory buildings where no light is needed because only robots work there. With all its complexity, including intensive human interaction, the school environment is a setting that poses many challenges to robots, meaning they are still a long way from being used in the learning process. Applications at the moment focus on the robot itself as an object of study.

No high-impact role yet for robots

Robots are mainly effective at performing specific physical tasks. That is why we are seeing robots taking over tasks in healthcare and logistics, for example. For this reason, robotics is an essential topic for vocational education. Furthermore, robots can notably generate the illusion of empathy, as is the case with some of the robots used in healthcare. But they still don't come close to a human's capacity for empathy. Robots are therefore relevant as an object of study, but not as a substitute for the teacher.

Need a refresher on robotics?

Re-read section 1.2.1.

Trough of disillusionment: high expectations not fulfilled, disappointment prevails, potential is underestimated

AI-related technology has not been used long enough to bring problems to light. At the moment, we mostly see opportunities and aren't yet disappointed or disillusioned. There is only one underlying technology in this phase: **connectivity as a service**. The network infrastructure within schools and the connection to the internet come under heavy pressure due to accelerated digitalisation. The market does offer services, but doesn't yet provide education with a decent level of service

provision, scalable capacity and security at an appropriate price-quality ratio.

Slope of enlightenment: obstacles are overcome, preconditions become known, benefits become visible

The slope is empty because there hasn't yet been any wide practical experience with the stated technologies. We therefore don't yet know what works and what doesn't work, let alone how we can avoid risks and overcome obstacles.

Blockchain: obsolete before plateau

In our analysis, we have classified blockchain as obsolete before plateau on the Hype Cycle characteristic of 'time until wider adoption'. We estimate that the technology in this form will not reach large-scale implementation.

Will that be the end of blockchain technology in education? Not necessarily. Technology trends with the breadth and impact of blockchain will be reflected in various sector-specific applications that take account of the frameworks and characteristics of that sector, such as education.

Need a refresher on blockchain?
Re-read the box in section 1.2.4.

Plateau of productivity: proven benefits, widening adoption, acceleration of growth

The functionalities for **student administration** and a**ccountability** remain necessary in an artificially intelligent learning environment. It could well be that the technology or functionality that supports these activities becomes part of a larger system that also includes an integrated dashboard, for instance, or an adaptive learning system. But as a functionality itself, it is in the plateau. In addition, new perspectives on accountability will come about under the influence of technology. For instance, ethical frameworks for the use of AI in learning and recent privacy legislation both provide frameworks for the processing of student data in digitally supported education.

3.2.2 Benefit Map

By positioning the technologies from the Hype Cycle on the Benefit Map, we clearly demonstrate which technologies are important to the school, teachers or students, and for what reasons. This generates support for the choices and agreements that you make. It gives a sense of where the interests and concerns of the school lie. It also demonstrates the interests and concerns of teachers and students, and illustrates the underlying connections and dependencies of the technologies.

This Benefit Map is inspired by various reports and analyses of the impact of artificial intelligence on our society. On the one hand, there is the direct impact that AI technology will have on the design and organisation of education. On the other hand, AI will bring about a transformation in the allocation of tasks between people and technology in life and work. This has an indirect impact on the content that will be required in education.

The Benefit Map below offers a starting point for a conversation within school boards and schools.

Hot spot: shared interests/importance

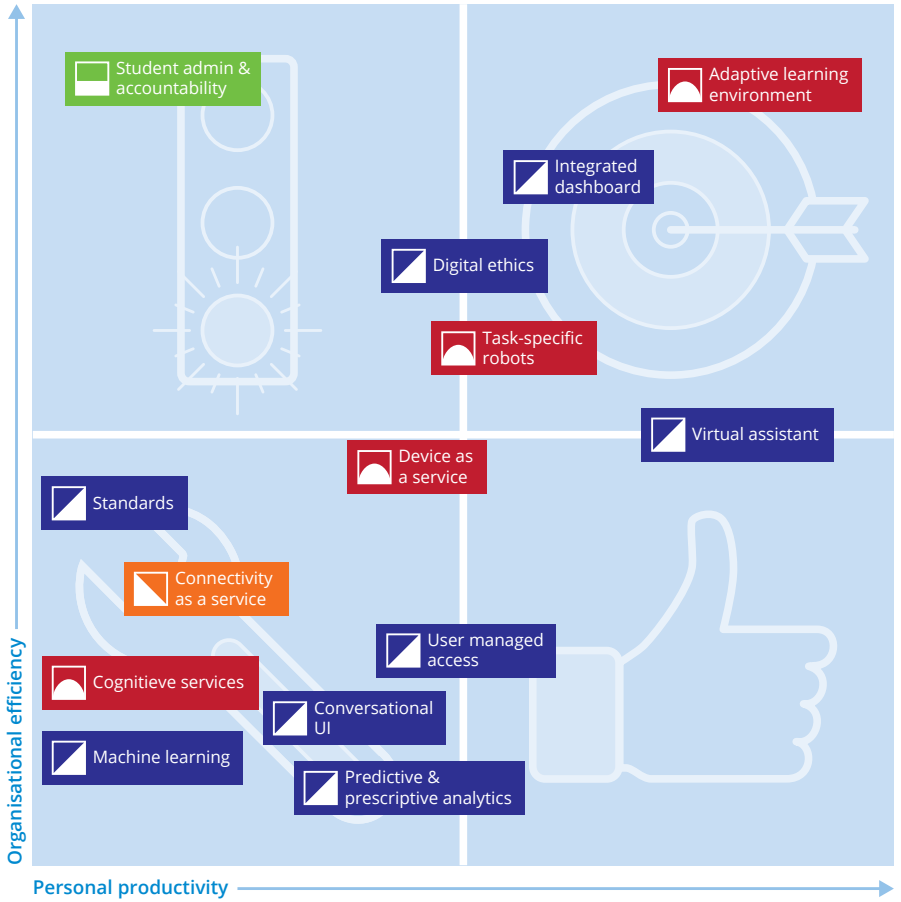
The Hot Spot contains technologies for which the school, teachers and students all have high expectations, and therefore find very important. Examples include the adaptive learning environment and integrated dashboards that we can use every day to organise personalised learning and to be able to respond flexibly to findings on a weekly or even daily basis if desired.

Enabler: the difference between wishful thinking and reality

The Enabler quadrant contains a significant number of technologies that students, teachers and the school alike find less interesting. There is low willingness to devote structural attention and resources to these because all three parties don't see the direct importance of them. Nonetheless, we can only achieve the high expectations of the Hot Spot of an adaptive learning environment when we have seamless ICT infrastructure. And secure handling of the data from the learning process and information derived from AI building blocks functioning as the enablers of flexible learning paths.

Green Light: the organisation has responsibilities

The Green Light quadrant contains technologies that are particularly important to the organisation because they guarantee processes and information provision. As an example, each educational organisation has legal obligations and must be accountable for performance and resources. The basis for that accountability is formed by the student administration system, supplemented with consolidated information on student performance. This is requiring less and less manual work thanks to enabler technologies.



People's choice: teachers and students prioritise the learning process

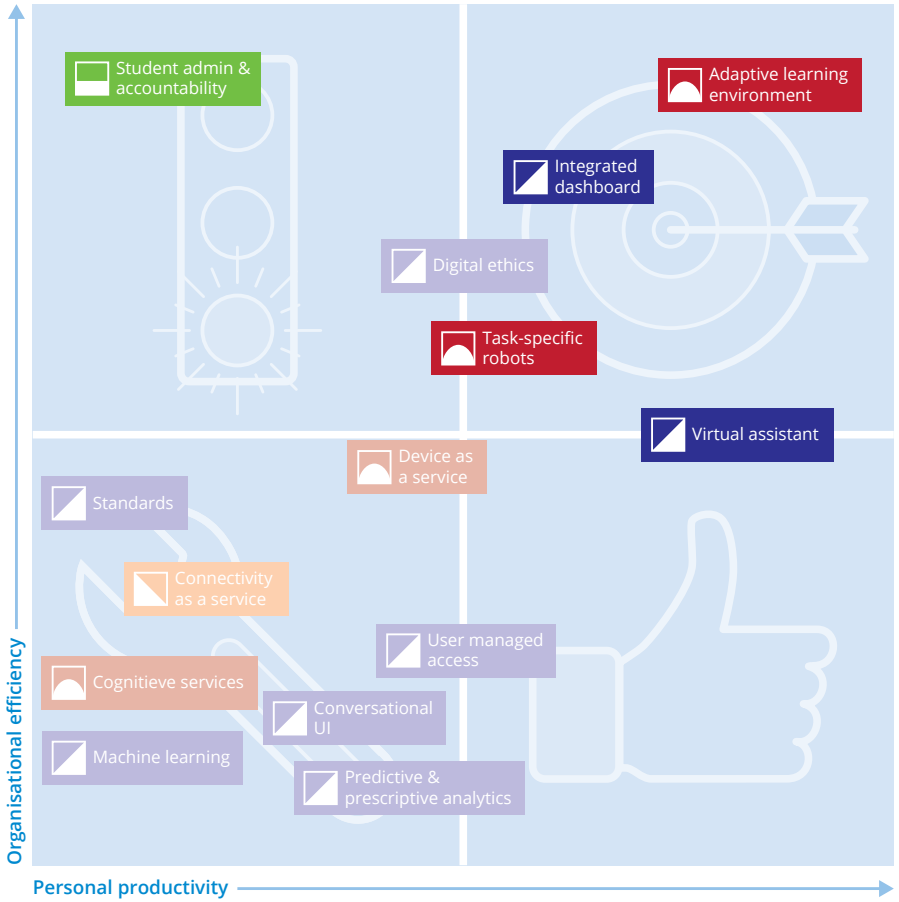
The People's Choice quadrant contains technologies that are particularly important to teachers and students because of the direct practical support they provide in the daily education process. For instance, think of virtual assistants that offer individual support when using systems and devices. And user managed access that gives users control over who can use their data and for what purpose.

3.2.3 Interplay of technologies

Once the technologies have been positioned, you can see how they relate to each other. Often, a certain technology can only work securely and effectively if there is also investment in a different technology. By linking these technologies, a chain is created. We found three chains in our analysis: one with the technologies that you experience as a user (the 'front end'), one set of technology 'under the bonnet' and finally a chain containing the technological foundations.

The front end: the artificially intelligent learning environment prepares students for life and work

In this sketch of the future, a learning process for students is organised with an artificial intelligent learning environment that is tailored to individual needs. Students are provided with precisely what they need on a daily basis, teachers keep track of the progress of individual students and are supported in the effective design and organisation of both shared learning moments and individual guidance.



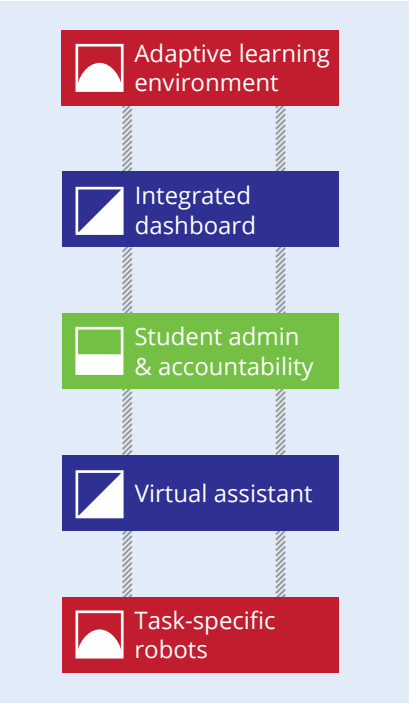
1. An **adaptive learning environment** offers advice on steps that students can take within a subject, but particularly on steps to take within the integral learning process. In this learning environment, students are offered a learning path that fits their pace and level for

each subject and takes account of their preferences in the composition of their school day. For instance, they can choose to adjust the time and sequence of proposed learning activities, the learning method that suits them best, and whether an activity can take place at home or on location. Furthermore, the learning environment includes the teachers' additional manually entered observations on the students' social-emotional development. These observations are also taken into account in the daily modelling of the learning path.

2. The **integrated dashboard** is a further development of the cross-subject dashboard that can help to analyse the progress of students. It presents the adaptive learning environment's predictions about the progression of the entire learning process. It offers students and teachers insight into all available progress information and achieved results from different learning resources, environments and contexts. Furthermore, it displays the developments in social-emotional skills that have been manually recorded by the teacher. It thus forms an objective, collaborative basis for a conversation between teacher and student. Together, they discuss the system's suggestions for possible steps to take next, whether changes to the learning path are required to reach targets on time, and if the targets themselves need to be adjusted.

3. The **student administration system** forms the basis for the student's file and is supplemented with a consolidated view of the student's performance. With this combination of data, the school has **accountability** for the education provided and the return achieved.

4. **Virtual assistants** provide solicited and unsolicited advice to students and teachers in the form of homework reminders, tips or other instructions. This helps students and teachers to do timely preparatory work for a lesson tomorrow. Or it ensures that they don't forget the necessary follow-up of learning activities. Students can use a chat or speech interface to be quizzed to see whether they have thoroughly understood the material and which passages would benefit from extra study. By analysing available data from the learning environment and the dashboard with AI and proactively considering any advisable interventions, the virtual assistant actively supports the learning process. It's as if each student and teacher has a human personal assistant keeping an eye on all the details, making life more straightforward for them.



Chain 1. The artificially intelligent learning environment prepares students for life and work

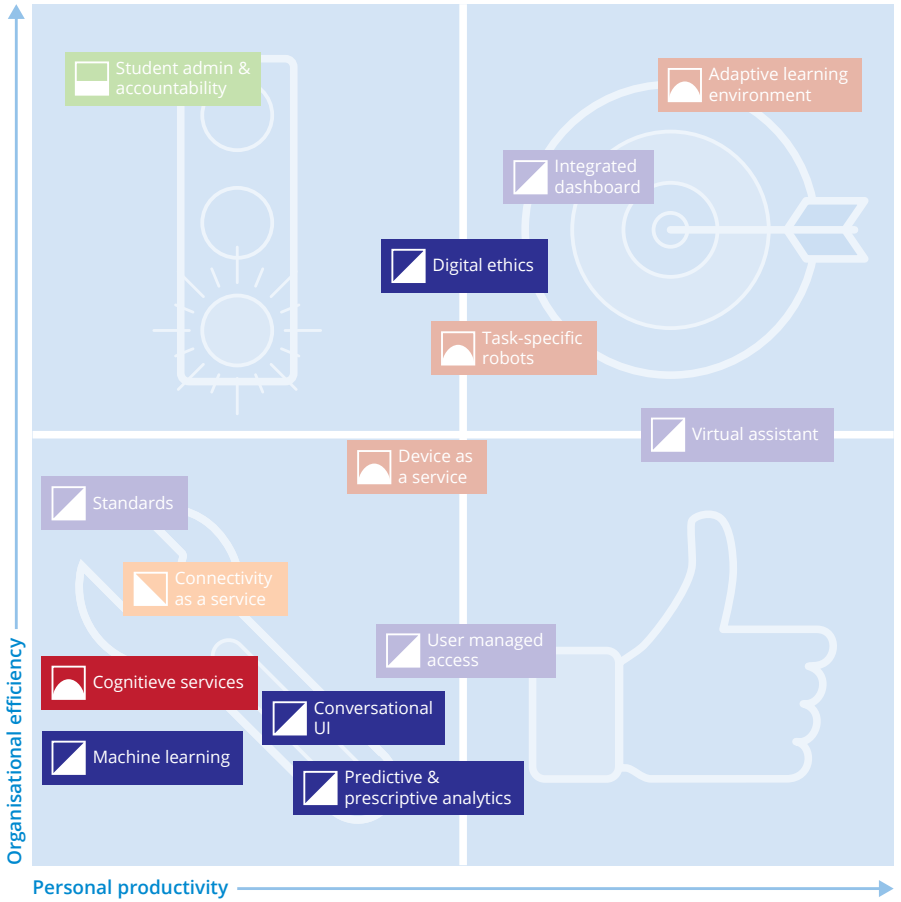
5. In the broader context of life and work, **task-specific robots** support people in heavy, dangerous or unpleasant work. This is already having an impact on the knowledge and skills required by students.

Under the bonnet: cognitive services bring the artificially intelligent learning environment to life

The artificially intelligent learning environment derives its intelligence from a diverse collection of AI-based services. Alongside the specialist analytical engine, there are various cognitive services that make the environment as human-friendly to work with as possible.

1. For instance, a **conversational UI** (user interface) allows users of the environment to ask questions, in natural language, to a system such as an integrated dashboard or learning resource. The systems, in turn, respond in language that users can understand. For example, asking: "show me the results of Christopher Smith in 8C" will provide an overview of all the results of this Year 8 student. And the follow-up command: "just for maths and French" will limit the list to those two subjects.

2. Interfaces of this nature are made possible by **cognitive services** that are able to interpret spoken and written natural language and process it as a demand within the system. The answer to that question can then be presented to the user in the desired form, for example as text, image or spoken word. Similarly, images, gestures or other input can be used to query or command the system. These widely applicable services have taken off because we can train the algorithms used by AI with the unprecedented amount of data that is available online, such as images, sound recordings, text and videos on YouTube and other platforms. Product developers can then use these universal AI building blocks in specific sectors, for example in an intelligent learning environment.



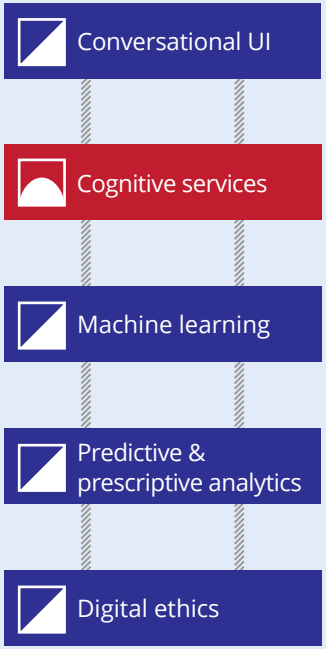
3. **Machine learning** is at the core of these types of AI applications. These forms of artificial intelligence autonomously improve in order

to successfully solve a problem. For example, recognising objects in images. Data is used both to develop the algorithms and to test which algorithm is most successful in carrying out the intended task. These algorithms are also applied in the adaptive learning environment. In addition to the daily analysis and improvement of students' learning paths, the data within the environment is also used by developers to improve the algorithm in new versions of their products.

> **Need a refresher on AI and machine learning?** Re-read section 1.2.1.

4. The data available from the learning process for each student is analysed with **predictive & prescriptive learning analytics** and presented in the integrated dashboard. Based on a student's previous actions, activities and performances, a (predictive) forecast is made about how their results will develop over time. On this basis, (prescriptive) advice is given to help maintain good results or to prevent poorer results or study setbacks. This form of analytics makes it possible to look ahead and advise or immediately carry out proactive interventions on the basis of predicted outcomes.

5. The application of the technology described above raises necessary ethical questions that are addressed under the label of **digital ethics**. In our educational context, one such question could be: "Under what conditions and within what frameworks can AI independently make decisions about a student's learning process?" In a broader context, important questions arise about who can, may or must take responsibility for decisions that are made or independently carried out by AI. This issue is literally close to our hearts because AI systems are already successfully making medical diagnoses and recommending treatment plans. Who can follow the AI's analysis process and authorise its suggestions? For example, consider the responsibility for an intelligent learning environment in which so many decisions have to be made every day that an educational institution can only provide preconditions in advance. The institution does, however, remain responsible for the learning paths recommended to students and the success rates of the programmes.



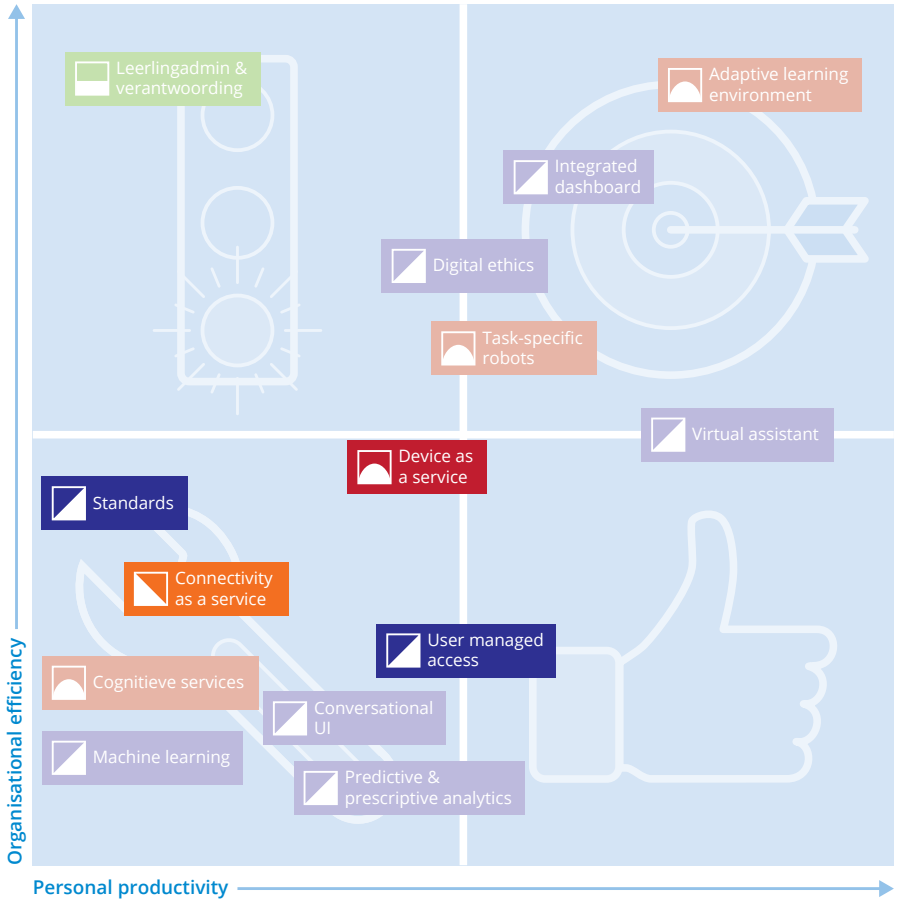
Chain 2. Cognitive services bring the artificially intelligent learning environment to life

The foundations for the artificially intelligent learning environment

There are three components that enable the artificially intelligent learning environment to function reliably and securely. A reliable, secure and sustainable underlying ICT infrastructure. Technology to handle data effectively and securely and universal AI building blocks to be able to learn and analyse it. And the seamless exchange of all the information required for this.

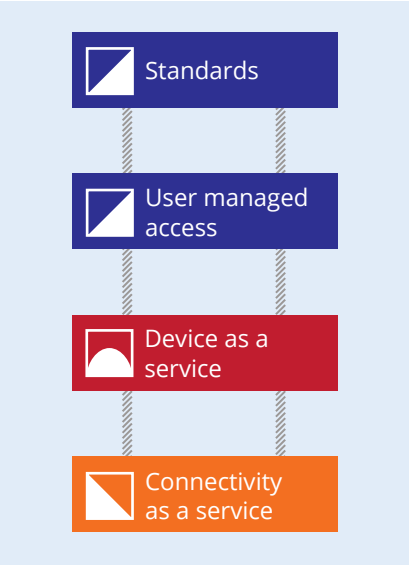
1. The adaptive learning environment makes full use of data from the learning process. This data comes from various digital sources such as learning resources, test environments and various platforms that students use to work on or collaborate on assignments. To collect this data efficiently, **standards** are needed that clearly describe the meaning and context of the exchanged information. Only then can different digital components work together, without human intervention, to collect, organise and interpret information.

2. **User managed access (UMA)** offers the possibility to organise data access in a way that is transparent, manageable and in accordance with laws and regulations. This method gives control of the data to the person whom the data concerns and provides tools to efficiently request permission for access to data in a specific context or application at appropriate times. Every year, the students (or their parents/guardians) will be routinely asked for permission, in accordance with their choice of subjects, to give the teachers and mentor of that year access to their file, their previous results and other relevant information for that year. If it is apparent before the autumn holiday that a student would benefit from maths tutoring, this student would be asked to give the tutoring centre permission to access their mathematics file until Christmas. Personalised learning per student will also demand personalisation in terms of data access; use of UMA can make this transparent and manageable.



3. The adaptive learning environment requires that every student and teacher have access to a secure, reliable, well set-up device that carries their digital learning resources and educational applications. With **device as a service** – a kind of lease agreement for devices – suppliers make life easier for students and teachers by keeping their personal device in good working order, taking appropriate security measures and installing and maintaining the software required by the educational institution.

4. Modern devices are now entirely reliant on cloud platforms to store data and applications and to access them when and where needed. To this end, **connectivity as a service** is essential for maintaining a reliable, secure connection between the device and the internet. This requires professionally organised and managed infrastructure within the school, between school locations and to the internet. So that availability is guaranteed. Reliability must be secured with adequate measures to limit malfunctions and minimise the impact of hacks, DDoS and other attacks. Services of this kind require structural attention as well as hard-to-find technical expertise, which is why schools have to outsource them to the market.moeten uitbesteden.



Chain 3. The foundations for the artificially intelligent learning environment

3.2.4 SWOT

There are pros, cons, ifs and buts in the successful implementation of AI-supported learning. A SWOT analysis is a great tool to help organise and weigh up the pros and cons of this scenario. We see a number of strengths and weaknesses of the technology, as well as opportunities and threats for education.

Strengths of the technology

1. Provides new insights into progress by analysing the entire learning path together with individual insight per subject.
2. Increases flexibility due to continuous insight into and rapid intervention in the learning process.
3. Reduces boring, dangerous, repetitive work, supports people and compensates (physical) limitations via automation and robotisation.
4. Can be successfully combined in products with education-specific knowledge and functionality thanks to modular composition of cognitive services.
5. Offers human communication with and understanding of the behaviour/ decisions of machines by using cognitive services in the conversational UI.

Weaknesses of the technology

1. Makes yields and conclusions vulnerable due to dependence on the objectivity and representativeness of underlying datasets and the resulting algorithms.
2. Good, integrated overviews are difficult to achieve because comparisons of data from different sources are not necessarily valid.
3. Can only be developed, improved and used effectively by a few large players because a great deal of accurate data, computing capacity and hard-to-find expertise is needed.
4. Makes (public) infrastructure and society vulnerable due to complexity of outsourced, intelligent services.
5. Makes potentially incomprehensible decisions due to inimitable, non-transparent, complex algorithms.

Opportunities for learning, living and working

1. Enriches education thanks to a better balance of automated practice and teacher-led, contextually rich learning experiences.
2. Supports the educational goal of individual learning paths by making organisation and guidance of the learning process more flexible.
3. Enriches human interaction and enhances comfort and safety thanks to machines that take over boring, routine and dangerous work.
4. Provides better insight into biases and preferences by analysing human assessments and the data on which they are based.
5. Offers opportunities to make teaching an attractive profession because teachers can focus their attention on more interesting didactic/pedagogical and thus more highly valued tasks.

Threats to learning, living and working

1. Puts the educational organisation and team under pressure due to the (radically) different organisational requirements of individual learning paths.
2. Eliminates (elements of) human tasks through automation and robotisation and has potential to diminish education if teachers can't adjust to the new range of tasks required.
3. Increases risk of data-dominant education and self-fulfilling prophecies due to people lacking the time or expertise to assess the AI's suggestions.
4. Increases opportunities for inequality due to limited access to the resources and knowledge required to use the technology.
5. Conflicts with the right to be forgotten because society runs on the data required for AI to improve.

Strengths

Artificial intelligence is capable of analysing more and more information and insights from the broader learning process. This gives new insights into students' progress. Because this insight is available almost immediately, you can make adjustments in the learning process as soon as necessary. AI applications also take over routine tasks in education, strengthened here by the use of conversational UI that uses cognitive services to make interactions with technology increasingly human-friendly. Thanks to the modular composition of those services, innovations can be quickly integrated into educational products. The underlying infrastructure and mobile devices form a utility that requires less and less attention and that, using AI, can respond intelligently to the needs of education.

Opportunities

AI makes it possible to individualise learning paths and can enrich education thanks to a better balance of automated practice and contextually rich learning experiences. The use of adaptive learning resources that are equipped with human-friendly interfaces, such as bots that can recognise and analyse speech and text, enables task differentiation. They take over boring and routine work, thus allowing teachers to focus more on teaching social-emotional skills, something that learning resources cannot (yet) do. This may have a positive impact on the teacher shortage because teachers can devote themselves to didactic/pedagogical tasks that make the profession more appealing and give the teacher greater job satisfaction. AI analysis also promotes objectivity: by analysing human assessments, it helps to avoid any unconscious biases about students. Thanks to applications in the domain of user managed access, students and their parents have more control over their own data and how it is used by third parties.

Weaknesses

AI applications carry out analysis and make decisions based on collected data and information that has been enriched by humans. But if the underlying datasets are not representative, objective or sufficient or if other relevant information is not included in the algorithms, these decisions can be (partially) incorrect. There is potential for major, undesirable consequences for the educational process. Another risk is that algorithms become so complex that you can no longer find out how decisions or conclusions come about and you don't always feel confident trusting them. Our infrastructure and society will only become more vulnerable as the services that utilise AI become more complex and the knowledge of how they work is in the hands of a limited group of people. To limit these risks, clear agreements and frameworks are needed.

Threats

The commitment to individual learning paths is only brought to life when an educational organisation can transform into a data-driven learning environment where teachers enrich student data with data on their social-emotional development. Is this not happening (sufficiently)? Perhaps because teachers are struggling to adjust to their new range of tasks? In that case, the use of AI can actually cause the quality of education to diminish. There is a definite risk of data-dominant education if people make too little time or expertise available to assess the machines' suggestions. In addition, AI increases the risk of a dichotomy in our society because not everyone has access to resources and knowledge in the field of AI. Because an AI society runs on data as a raw material, there is a potential conflict with privacy considerations.

3.2.5 Advice

Artificial intelligence has a lot to offer to education. Bearing in mind the ambitions of education, it is the most promising technology. Yet it can feel like it is a long way off. So why should you start thinking about it right now? Because this technology is already affecting how we live, learn and work.

Toddlers are already growing up with virtual assistants like Siri and Alexa at home, self-driving cars on the roads, and drones flying around everywhere. At the same time, the consequences for specific tasks and professions are already visible. Administrative processes are increasingly automated and adaptive learning resources are already taking over some teaching tasks. What does that mean for the distribution of tasks between teacher and digital tools, and for teachers' workloads? How can AI contribute to achieving your educational vision in a world in which AI can no longer be ignored?

To be able to answer these kinds of questions, it is vital that you consider the role of AI technology in your school and discuss this with your team as soon as possible. So you can create a solid, shared foundation for future decisions about digital tools. The next three steps will help you to manage that process effectively.

1. Discuss how AI can strengthen your education and make your ideas concrete by coming up with future scenarios

Discuss future scenarios (both dream and doom scenarios) with each other. This forces you to consider uncomfortable questions, for instance, what the role and tasks of a teacher are. By doing this, you will be better prepared for any future dilemmas, and you will create understanding and support for the change because you are including your teaching team in the change process from the very beginning.

A. Think about who you want to be involved, how often, which scenarios you want to work out and to what level of detail.

   - **Tip:** sketch out both dystopian scenarios, such as data-driven robot education, and the utopian dream scenarios, which could be different for everybody. Does your dream scenario look the same as your colleague's?

   - **Tip:** in this phase, focus primarily on each other's arguments, starting points and principles. No one can predict the future precisely, so discussions about probability are irrelevant.

   - ▲ **Pitfall:** watch out for polarised dialogue when a teacher has a romantic view of a technology that is only bad. Explore different viewpoints without labelling them as right or wrong.

B. For each specific teaching task, consider the extent to which automation by AI could enrich or damage the development or well-being of students or teachers.

   - **Tip:** be aware of the role that AI plays in learning resources and the influence that algorithms have on the learning process. How do we handle the pedagogical decisions that algorithms make in learning resources?

▲ **Pitfall:** don't look solely at the big picture, for example 'by 2025 we will all work with a personal virtual assistant'. But also discuss practical dilemmas, such as how the year group system currently used to organise subject matter could gradually offer room for more individualised learning paths.

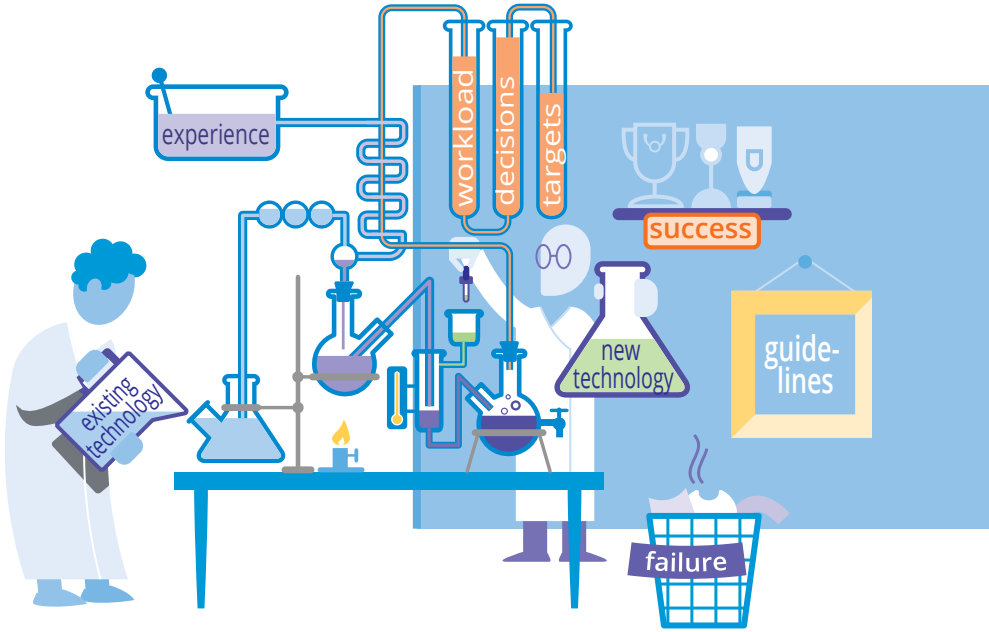
2. Investigate the concrete impact of AI on the school and organisation

Determine which intermediate steps will yield results in the shorter term. How will you use AI technology to make work more enjoyable, reduce workload, make better-informed decisions? What is the preferred division of roles between teacher and technology in your institution? This step is in fact a continuous, cyclical process. As a school board, you construct an increasingly concrete vision of how AI technology can play a role in realising your educational goals. Below are some specific tips:

A. Examine the consequences that various AI products may have for your educational institution.

- **Tip:** start with the current situation. Consider which AI technologies are already being used to make or support pedagogical decisions. Ask each other the question: which tasks and decisions is this technology already taking over from us and how do we expect it to develop in the future? Only extend your investigation to more advanced technology when you are ready to do so.

- **Tip:** in this step, make use of the opportunities and threats mentioned in the SWOT.



▲ **Pitfall:** stay away from discussions about the development speed and (im)possibilities of systems and technologies. It is up to other people to follow this closely. It is much more important to agree on a common language and framework, for example about the value of developing students' social-emotional skills. This enables you to formulate requirements for your adaptive learning environment.

B. Determine whether the use of AI products contributes to the educational vision and goals you want to achieve. Assess how you can evaluate this based on predefined expectations.

- **Tip:** your goals don't have to be quantifiable, but it is important to evaluate whether your investments are having the expected results.

Explicitly define your expectations for new learning resources or methods in advance. So that you can retrospectively confirm, and substantiate, whether the intended goals have been met.

- **Tip:** use your experiences with (new) AI technology as the basis for determining what works and documenting this in agreements, frameworks and preconditions. Also, stipulate the areas that you do or do not want technology to support. Either temporarily or permanently. By doing this, you will develop a test framework for new learning resources with possibilities that we can't yet imagine.

- ▲ **Pitfall:** don't be afraid to abort a chosen path if it turns out not to bring you closer to the intended destination, but do try to learn from it.

C. Take advantage of the experiences of other school boards and the expertise of market parties. It takes a lot of time to investigate what does/doesn't work and discover how to overcome certain obstacles.

- **Tip:** as a school board, have discussions with other school boards, and embark on this journey with suppliers of learning resources. Doing this enables learning resources to improve faster, and also teaches you the methods and preconditions needed to make the best use of them.

- **Tip:** existing initiatives and have discussions about agreements and standards so that you can consider solutions and stay up to date with developments.

- ▲ **Pitfall:** don't rely solely on quantitative research results. Sometimes, a set of qualitative case studies can also give a valuable indication of results. Are no research results or case studies available? Then ask schools that already use or have tried the technology.

3. Preconditions for the use of AI

During the process we described in step 2, you lay down various frameworks based on your experiences with AI technology and establish your preconditions. There are a number you can establish already without any risk.

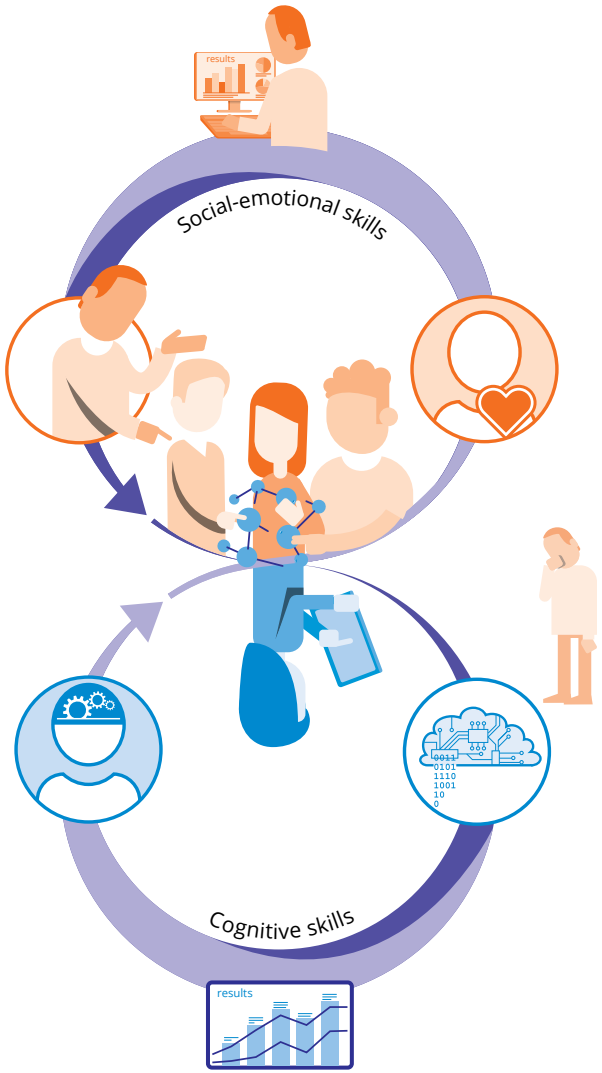
A. Pay close attention to the preconditions surrounding data. Algorithms in AI technology can only improve by training and testing with data. They can then analyse current data from the learning process. Therefore, systems need to produce sufficient, usable and exchangeable data.

- **Tip:** invest as much as possible in digital learning resources and student information systems that support data exchange. When the exchange of data runs smoothly, you can build up an integral picture of the student and later the learning path in the adaptive learning environment.

- ▲ **Pitfall:** remember that AI applications usually work with personal data. Make clear agreements with suppliers of AI applications about data use so that you don't violate privacy legislation. In this way, you can direct the appropriate and effective application of educational data.

3.3 Living, learning and working with artificial intelligence: issues for education

People currently in their thirties hadn't even heard of cybersecurity 20 years ago, but many of them now have a job in the field. Meanwhile, many administrative functions have changed drastically in five years. The same applies to a large number of tasks carried out by accountants and warehouse staff. Nobody knows AI's precise impact on our society. We do know, however, that simply waiting for the future to unfold is unwise. Education must prepare children as well as possible for life in a society where AI is ubiquitous. There are several important issues to which we can and should pay attention in the short term. We have listed these issues in the present chapter.



3.3.1 What does AI mean for students who will be working in the future?

In the future, students will have to work with AI systems and machines. They need to understand the distinct differences between people and machines and how they exchange information, how results and suggestions from AI analysis arise and how they can and should be used. For a large proportion of students, reading and interpreting data overviews and dashboards will also become an aspect of their work. How does that work if you can no longer find out how an AI application made a decision?

Faced with the disappearance of existing professions and the emergence of new ones due to AI and robotics, vocational education needs to answer the question of how its range of programmes should develop. And how

this will be regulated if it wishes to continue to offer students the prospect of a job or career. Perhaps vocational education institutions also need to restrict their intake of students for professions that will only require a limited number of people in the future.

In secondary education, you can think about how you guide students towards professions in which AI will undoubtedly play a role. How do you stay up to date about all of the programmes on offer and the opportunities they will lead to in the labour market? In primary education, too, the emphasis may shift to particular knowledge and skills that are important for successfully preparing students to live and work in a society surrounded by AI and robotics. Digital citizenship is essential. Where we currently teach children how our legal system works, perhaps in future this will be a combination of how decision support systems work and how the judge adds humanity during the trial.

Consideration: start having conversations about the changing world now

With your team, discuss which skills you want to particularly emphasise among the students. Also think about conversations you can have with students about AI's impact on their lives. Potential topics of discussion are the profession they want to start practising and how this will develop in the future, what machines will be able to do in future and how students will be able to supplement these abilities with their specialist knowledge. Another key subject is what it means to have to put increasing faith in the advice and decisions of AI systems. For example, the aforementioned AI support for judges could be a rewarding topic during a lesson about social studies, citizenship or career orientation.

3.3.2 How do you ensure that pedagogical decisions made about students are correct and unbiased?

As AI systems become smarter and carry out more and more tasks for us, we need to be wary of bias. These are biases in the systems due to the way they have been developed. The developer can consciously or unconsciously program these biases into the algorithm. It is also possible that the dataset being used to train the algorithm is incomplete, polluted or incorrect. For example, an automatic soap dispenser only became activated by hands with a light skin tone because the dataset probably contained no or too few photos of hands with a darker skin tone. Very embarrassing, but can't be put down to malicious intent. An AI system can also make you aware of your own biases. For instance: as a teacher, what should you do if your assessments always deviate from the system's for children from a particular neighbourhood, or with a certain accent?

Even if an AI system has been made to be unbiased, not all of the problems have been solved yet. Because AI systems will provide advice and make predictions, for example, about how students will perform in the coming year or even in their careers. We know from research that a teacher's expectation about a student's performance has a major influence on their actual performance. If the system predicts a certain level, this influences the teacher and thus the student, making it impossible to escape the effects of that prediction. All while the current state of AI means that we cannot yet find out exactly how the algorithm arrived at that conclusion.

There is an ethical question closely related to this: to what extent can you still afford to deviate from the AI's advice without getting into trouble with

students, parents or school management, as is already sometimes the case when it comes to the results of a final test? Predictions based on historical data and learning outcomes will only become more accurate in the future. If we can no longer judge whether we agree with this prediction, the danger is that we will either not, or will blindly, trust the advice of AI systems. The question is whether you want that. It is possible that AI systems will then be developed that provide insight into some of the reasoning behind the decisions, or AI systems that can explain the lines of reasoning of other AI systems. Similar to the four eyes principle that has been applied to assessments for years.

Consideration: discuss the pedagogical decisions that AI can and should make

Have discussions with your team about the decisions being made, both implicitly and explicitly, by the systems you are already using. For example, adaptive learning materials and dashboards for management information. Then discuss whether you think this is justified. Determine what kind of explanation or substantiation you expect from AI systems and take this into account when selecting future learning resources. Also discuss the extent to which AI's decisions influence your own biases as a human being. So that you are aware of them and can mitigate any unwanted effects.

3.3.3 What does the arrival of AI mean for the teaching profession?

Teaching is complex. However, this complex task is made up of subtasks, some of which can be taken over by machines. For example, AI systems can instruct students in acquiring cognitive skills. They can also set and check assignments and provide feedback. In the future, AI applications will be able to support assignments where more complex cognitive skills,

such as analysis, are required. For instance, there will be systems that can provide feedback on assignments that are more open-ended.

This will give teachers more time to focus on the tasks that provide more satisfaction and make the profession more fulfilling and appealing. Such as devising, designing and delivering contextually rich assignments where explicit attention is paid to cross-subject skills such as collaboration. So that the relevance of acquired cognitive skills is made clear to students. Another example is carrying out didactic interventions in the learning path advised by the adaptive learning environment based on progress information about cognitive skills and their own perceptions about a student's social-emotional development.

Because the average working day of a teacher is going to change, this will call for new knowledge and skills that are hardly present in a teacher's current remit. For example, interpreting the analysis and overviews in dashboards. What does this analysis say about the student and the class? And for the school leadership and director: what does it say about the school or the school board? As an education professional, you must be able to critically view an AI system's line of reasoning, make a judgment based on this and then act accordingly. Not only the teacher, but all educational professionals will have to find a way to cooperate effectively with AI, just as a pilot cooperates with the autopilot in an aeroplane and relies on the instruments in his cockpit.

There is already a shortage of teachers, and on top of that, almost all of them experience the burden of an excessive workload. With AI, we can support those teachers in more routine tasks. The hope and expectation are that this will lead to a lower workload and make the profession more appealing. It is the education sector's responsibility to investigate this.

Consideration: what skills will your future teachers need?

Have discussions with your team about how they intend to use the freed-up time – so that education improves, the teaching profession becomes more creative and attractive, and more time and information is made available for better quality mentoring conversations, for instance. Also consider the new skills that teachers will need if they want to continue to work effectively in the future. Don't immediately reject an AI application if it appears to reinforce a certain teaching task but doesn't completely replace it, but rather discuss within the team about how the AI technology and the teacher can complement each other and what that will mean for students.

3.3.4 What does a future with AI mean for school leadership?

Due to the arrival of AI, how schools are organised will look increasingly different. With different processes and different roles for employees. Teachers may experience this as a threat. In the 19th century, factory workers smashed weaving machines because they were taking away the workers' jobs. This may happen less abruptly in education, but automation can definitely cause turbulence. The school leadership must pay attention to this.

For you as a director, it isn't just a question of what people and machines are going to do in the future. What is perhaps more important is how you create the headspace to figure it out as a team, and how you make difficult decisions. The key question is how you can create the best possible combination from the available resources, people and capital.

This economical way of looking at things, which has been commonplace in industry for many years, still isn't sufficiently implemented in the education sector. Although education revolves around guiding young people, rather than maximising profits, it is still important to ensure that students achieve optimal learning outcomes and that employee productivity increases.

To form an integral picture of a student, which will form the basis of their personalised learning path, even closer cooperation is needed between schools, parents and internship companies. For example, agreements about the exchange of confidential information about the student with those parties. Or a dialogue with internship companies about the design of vocational training and internships.

And how do conversations between the school board and the education inspectorate change when a large proportion of the learning activities has become measurable? Perhaps the inspectorate will become a kind of inspection service for AI systems and AI functionality, so that these systems and the tasks they take over can be scrutinised and held accountable. In the future, it is possible that inspections in schools will increasingly focus on results that are harder to measure, such as the students' social-emotional development.

Consideration: as a school board and school leadership team, prepare yourselves for the changing organisation and new relationships with partners

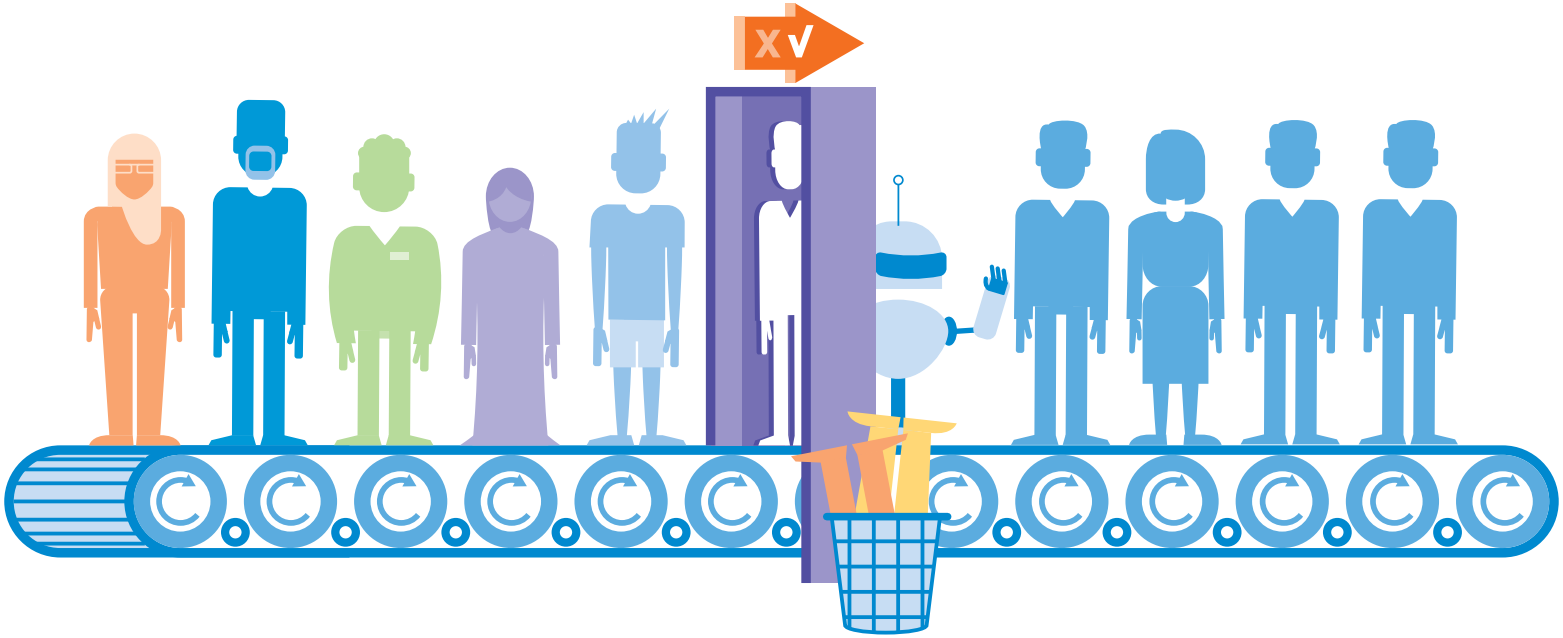
Making the transition to a school organisation in which people and machines work together seamlessly means managing a change process where difficult decisions have to be made. For example, about the ideal mix of people and machines and the relationship between them, whether you want to be an early adopter or would rather wait longer before investing in AI applications, and how to shape the corresponding dialogue with the inspectorate, internship companies and parents. You have to create space in the school organisation to think about these kinds of issues. Encourage

The change process towards education with AI demands strong leadership

critical thinking and discussion about complicated topics. Gradually create space for these conversations during regular meetings. Look at good examples outside your own school or school board and get inspired by discussions happening at a national level. Also involve your educational community, for example, students and their parents, or internship companies in the case of vocational education.

3.3.5 How do you ensure that AI enriches education and doesn't diminish it?

Artificial intelligence has a great deal of potential to enrich education. By using AI to teach both basic and complex cognitive skills, teachers can focus more on the development of social-emotional skills. After all, educating students is about much more than teaching them to do long division or how to speak a foreign language. Education also has a socialising objective. It teaches children to explore the boundaries of their own and others' prescribed frameworks, how to deal with successes and setbacks, and the differences in our diverse society.



These educational tasks cannot be easily summarised in algorithms and data. Moreover, if you allow everything in the learning process or in your life to be determined by algorithms, you will in fact continue to operate within the framework of that algorithm, the 'filter bubble'. When it is in fact valuable to come into contact with other ideas and opinions, and learn how to deal with them respectfully. In addition, students need authentic, contextually rich activities so that they can understand and feel the relevance and function of acquired knowledge. Especially in vocational education.

Another risk of AI and data-driven education is the emphasis on measurable results. Naturally, there are various important aspects in a student's development, some of which are impossible or more difficult to measure and therefore cannot be expressed in hard results. There is a danger that we will also want to endlessly capture social-emotional skills in numbers and dashboards, and will try to use these to create a socially engineered world where everyone has to measure up to the same yardstick. While it is in fact the diversity of people that leads to synergy in teams and communities.

Consideration: with your team, discuss what your educational objectives are and the role that AI can play in reaching them

If you ask any teacher why they chose to work in education, the chances are they will answer along the lines of "to help children grow into fully fledged citizens", not "to make sure students know how to do long division". Enter into discussions with your team about how you define your educational remit and the areas where you do and do not want technology to take over. Are you not paying any explicit attention to this issue? Then you run the risk of your educational offering ending up programmed and predictable, with no room for surprises or adjustments. Or of allowing the less measurable results to be overlooked in favour of the cold, hard, measurable facts and figures.

Afterword

Dear reader,

As a budding system developer at the faculty of business administration in Rotterdam in the nineties, I tried to convince professors and students that the world wide web could be quite something. At that time, I myself had no idea that the internet would turn every sector on its head.

When it comes to innovation, we have a tendency to get ahead of ourselves, trying to see where we will be in twenty or thirty years. But, although distant vistas are interesting and inspiring, we need concrete insights, so we can make long-term plans that allow us to set a good course for the years to come. This technology compass aims to help with this.

Although distant vistas are inspiring, concrete insights are what allow us to set a good course for the years to come

The future is hard to predict. But it doesn't matter too much whether we agree on our predictions for the future. Nor is it relevant when or to what extent they will actually come true. What matters is the central threads in those predictions, which are going to be decisive. Such as the impact that intelligent machines will have on how we live, learn and work, as we describe in this technology compass. The path to the future is, first and foremost, a voyage of discovery. This compass can serve as a guide along the way: to help set the course, to adjust it when necessary, and hopefully to avoid some dead-end paths and ravines en route.

A sincere word of thanks to the many directors who made the time to go over our first drafts. We have gratefully incorporated their tips. We also questioned various experts and researchers in their fields to provide input for our analysis. Many thanks also to colleagues who cast a critical eye over the draft texts. We've tried to do justice to all the tips on clarifications. With this report, we intend to provide concrete support to directors, programme directors, school leadership teams and ICT managers. At the same time, we've attempted to keep it concise.

Last but not least, thank you to my teammates Els and Wietse. It was much more fun, sometimes more difficult and therefore much better to make this report together. Thank you ;-)

With kind regards,

Michael van Wetering
Strategic Advisor Innovation
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Colophon

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About Kennisnet
A good education lays the foundation for living, learning and working, and challenges students to bring out the best in themselves. This requires an education that responds to social, economic and technological developments. Kennisnet supports management boards in primary education, secondary education and vocational education in professionally implementing ICT and is the guide and builder of ICT foundations for schools.

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