Technology compass for education

Kennisnet Trend Report 2016-2017

How smart ICT prepares our students for the future

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Please note:

This report is written with the Dutch education system and its structure in mind. Similarly Dutch law is the starting point in the sections about Privacy and Ethics. Please take this into account when reading this report. More informatie on the Education in the Netherlands: wikipedia.org/wiki/Education_in_the_Netherlands

Contents

Chapter 3   **Chapter 2**   **Chapter 1**

This report follows the structure of the Gartner Hype Cycle. We start with the proven technology of the ICT essentials and then follow the Hype Cycle from back to front.
We describe technologies that are balancing between hype and disappointment and conclude by examining the latest technology and forthcoming hypes in the education of the future. The introduction explains the concept of the Hype Cycle and the structure of the report in more detail.

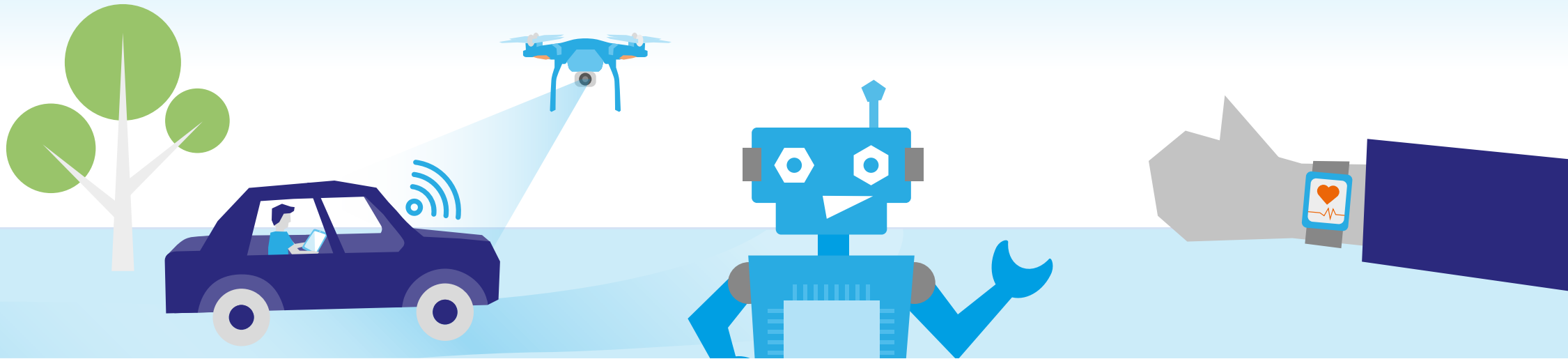*This is an interactive publication. You can use the tabs at the bottom to navigate directly to the chapters of this report.*

Introduction

The rapid pace of technological development is affecting every aspect of our society, and that naturally includes education. To build an independent existence in the future, children have to be prepared for the emergence of new technologies and taught how to use them. And that is the task of schools, which have to help children to learn how to survive in a world in which more and more of our private and working lives are spent online and in which the volume of data available about our lives, learning processes and work is consequently growing exponentially. Data which in turn feeds learning software in intelligent machines such as robots, self-driving cars and miniature devices on and inside our bodies and all around us. This ecosystem demands an infrastructure that allows us to communicate (network), store data and software (cloud) and interact with machines and with each other (devices). Schools have to respond to these trends by enabling students to develop their talents, differentiating in teaching practices and offering personalised education. And there are various technologies available to help them achieve that.

Technological trends

This report discusses those technologies. It highlights the technological trends that will play a major role in education over the next five years, from cloud computing and learning analytics to learning machines and the Internet of Things. The purpose of the report is not to give instructions to schools or administrators, but to inform them of the technologies that are available to help them in pursuing their vision of education. This report contains analyses, recommendations and instruments that will help schools in drafting a long-term ICT plan, including an investment agenda and a programme of projects, with which they can achieve their ambitions in education.

Making ICT choices

This report uses the 'hype cycle', a methodology developed by the information technology consultancy firm Gartner, to show how far the technologies relevant for education have developed. As a technology approaches the phase of 'maturity,' the opportunities it offers and its weaknesses become clearer, and hence its impact on education becomes clearer. The hype cycle, an instrument that administrators and directors of schools can use to analyse a technology's

risk profile, make strategic choices and establish priorities in their plans for the use of ICT, is discussed in more detail in a later section. Another helpful instrument is the SWOT analysis. In this report we provide a summary of the Strengths, Weaknesses, Opportunities and Threats of each of the relevant technological trends discussed in it.
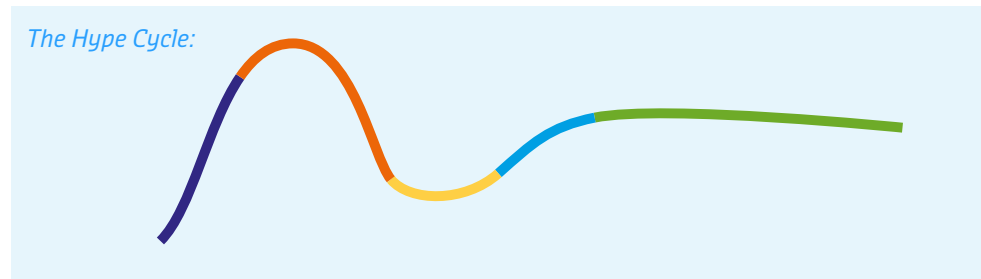
The Hype Cycle:

Visual tool

Whereas the hype cycle helps in making conscious choices from the available technologies, the Strategic Technology Map (STM) is a tool designed to ensure that decisions are made jointly and with a broad consensus.
Organisations seldom use a single ICT technology, but rather an ecosystem of complementary tools. The STM helps to visualise the mutual dependencies of these ICT building blocks, so that the stakeholders can together determine which combination of technologies and applications is needed to achieve the school's educational goals.

CORPORATE GREEN LIGHT
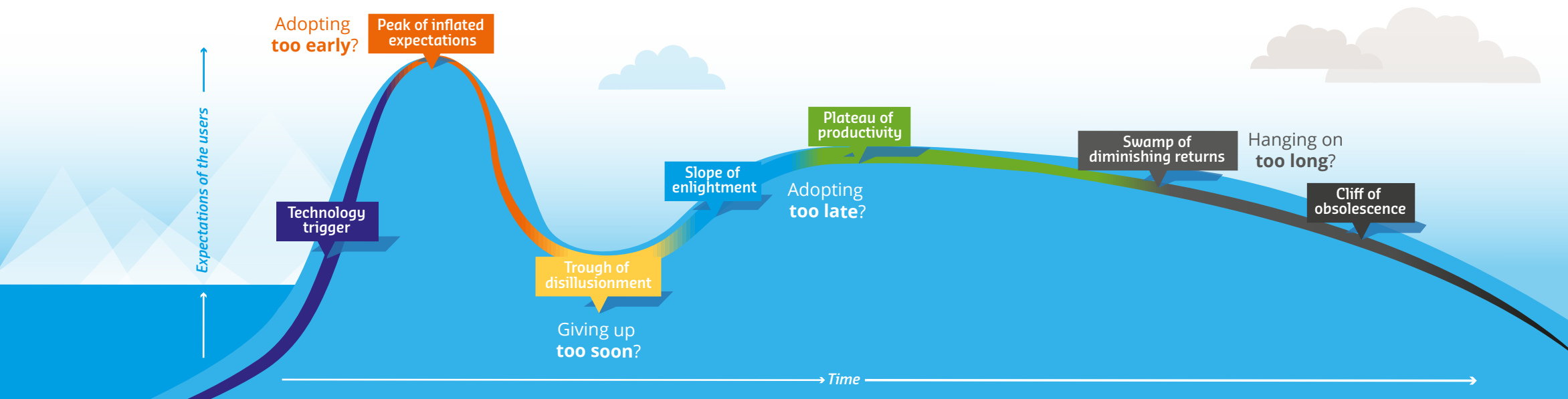
HOT SPOT

COLD CASE / ENABLER

PEOPLE'S CHOICE

Smart investment in ICT

The view of technology presented in this report is based on instruments developed by Gartner, such as the Hype Cycle and the Strategic Technology Map (STM). Since school administrators can use these instruments themselves to set their own priorities and adopt an appropriate investment agenda, we will examine the method and function of these instruments in more detail.

To establish the risk profile of a technology, Gartner Research uses the Hype Cycle to analyse and establish the profiles of technology trends. The Hype Cycle is an instrument that effectively maps the development of a new technology from promising concept to accepted product. It provides a snapshot of the relative maturity of a technology and its future potential, which helps organisations to make decisions about when the time is right to adopt a technology. The risk analysis of a technology is based on market adoption, (initial) experiences, the available knowledge and research into its effectiveness.

Since 1995, Gartner has been producing Hype Cycles for 5,000 trends in 90 areas every year. Using toolkits and research from Jan-Martin Lowendahl, Distinguished Analyst at Gartner and a Research VP, we have compiled a Hype Cycle for each technology chapter in this report specifically tailored to initial and vocational education in the Netherlands. On the vertical axis are the users' expectations for a technology in relation to the time on the horizontal axis. The Hype Cycle distinguishes five phases of development that every technology goes through, although not necessarily in a linear manner and not always at the same pace. For each trend, the period until broad adoption is shown.

Expectations of the users

Adopting **too early**?

Peak of inflated expectations

Technology trigger

Trough of disillusionment

Giving up **too soon**?

Slope of enlightment

Adopting **too late**?

Plateau of productivity

Swamp of diminishing returns

Hanging on **too long**?

Cliff of obsolescence

Time

The five phases of a technology's life cycle are:

Phase 1: Technology trigger
A potentially ground-breaking technological innovation receives media publicity following an initial demonstration or reports about experiments with it. The technology is usually not ready for immediate use or commercially viable. An example would be the virtual teaching assistant in chapter 3 of this report.

Phase 2: Peak of inflated expectations
Publicity about initial successes inspires a wave of enthusiasm. Expectations exceed the actual potential. It becomes a hype. Examples of this are Big Data and learning analytics, which are discussed in chapter 2.

Phase 3: Trough of disillusionment
Enthusiasm inevitably gives way to disappointment because of problems, delays, failures, high costs or low returns. Expectations for the technology plummet. Nevertheless, this is a particularly fertile period, offering the promise of new applications that build on the knowledge and experience gained from earlier experiments. This is the case with augmented and virtual reality (see chapter 3).

Phase 4: Slope of enlightenment
The initial obstacles have been overcome, and the benefits, as well as the essential preconditions for successful application of the technology, have become clear. With the insights gained from predecessors, there is a clearer understanding of where and how the technology can be used effectively, but also where it has no added value. Examples are the Chromebook and the public cloud in chapter 1.

Phase 5: Plateau of productivity
The actual benefits having been proved in practice, the broad adoption of the technology commences. A growing number of organisations dare to adopt the technology. This is followed by a period of accelerated growth, which slows again as more people take it up. Examples are Wi-Fi and tablets (see chapter 1).

In this report we follow technologies as far as the plateau of productivity, but the complete Hype Cycle has two more phases:

Phase 6: Swamp of diminishing returns
Ageing tools and systems – so-called legacy – can frustrate, delay or even stand in the way of new initiatives. It is therefore not only important to adopt new technologies in timely fashion, but also to replace obsolete technology in time. For example, printed teaching materials can prevent differentiation and older software can only cope with groups classified by age (student monitoring systems) or fixed timetables or school hours (rostering systems).

Phase 7: Cliff of obsolescence
Higher maintenance costs and aggravations can gradually escalate to the point where the use of obsolete technology takes up too much time and/or is too expensive. This can be the case with ageing desktop computers and network equipment or cables, for example.

Spreading investments with vision and patience
The Hype Cycle helps in choosing the right time to apply technology in order to gain the maximum benefit in terms of helping schools to realise their vision of education. Naturally, this does not mean that schools should always wait until a technology has reached the phase of maturity before adopting it. Take digital testing or (adaptive) digital learning materials, for example. These are innovative technologies with enormous potential value for education that can be adopted earlier in the development cycle – bearing in mind the increased risk – and thus allow schools to set themselves apart. In the case of technologies with less of an impact – for example the very latest Wi-Fi – the education sector can wait until they have been tested by other organisations and then profit from their knowledge and experience.

Choosing the right mix of investments in technology is similar to compiling a healthy share portfolio. Investment in high-risk technologies is interesting if it offers the prospect of higher returns in educational terms. We have to guard against buying too soon (adopting too early), but also have to avoid 'selling' when 'the market' briefly dips (giving up too soon). We can wait until there is little risk, but we then also have to accept a lower return. We must be careful not to be too late (adopting too late). Finally, we have to let go in time (hanging on too long) of a technology whose usefulness is diminishing. So how do you put together a balanced ICT portfolio with the right mix of risk and return?

Defining the ICT portfolio with the Strategic Technology Map
Individual ICT building blocks can have added value, but will only yield the maximum benefit in terms of achieving the educational goals if they fit together well and complement one another. The Strategic Technology Map (STM) is a method with which school administrators can define the ICT ecosystem – a coherent set of ICT building blocks that complement and supplement each other – that will help in achieving their educational goals. The process itself is also an important part of the ultimate result. The discussions that are conducted in weighing the risks of a technology against the contribution it will make to achieving the educational goals create a deeper understanding of the choices that are made and generate wider support for the ensuing investment agenda.
Since ICT building blocks supplement one another, the composition of the portfolio and the order of investment is not random. Most devices can only be used if there is Wi-Fi, so without Wi-Fi there is no point investing in devices, and vice versa. In other words, the investment agenda represents a critical path through the ICT landscape (the STM) to the educational goals, since the individual steps and the order in which they are taken all have implications.

The vertical axis of the Strategic Technology Map shows the organisational efficiency (the institution) in relation to the personal productivity (students and teachers) on the horizontal axis. This simple matrix illustrates the balance between the organisation and the individuals in it with respect to the chosen ICT tools and their usefulness and acceptance. The significance of the quadrants and the application of the method in creating the digital learning and working space are discussed in more detail in chapter 1.4.
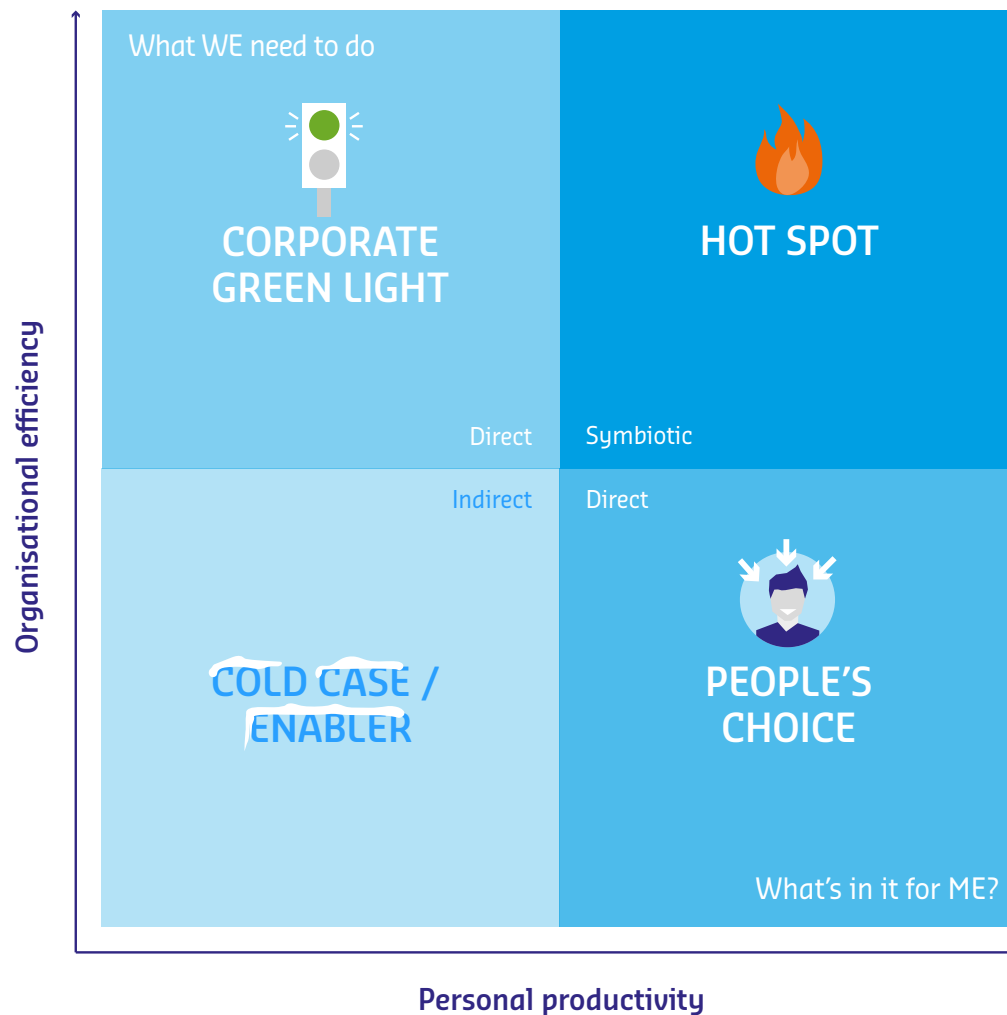

Reader's guide

This trend report comprises three chapters with clusters of related, mutually reinforcing technologies. Each cluster is at a different phase of development in the Hype Cycle and is described in a separate chapter. The relevance of each chapter depends on the degree to which you as a school or administrator have already adopted ICT.

1. **ICT essentials.** This section covers the components of the ICT infrastructure that lay the foundations for all other applications of ICT in the school. These basic facilities have already reached an advance stage in the Hype Cycle: they are mature technologies that have already proved themselves in practice and can be used by schools without any risk. This section is particularly relevant for schools that want to increase the professionalism of their ICT facilities, for example by adopting cloud computing, creating a stable network or through the choice of (personal) devices.

2. **Digital learning process.** This section describes developments in (adaptive) digital learning materials and learning environments that support personalisation through the use of data and analytics. This technology is currently in the turbulent phase between the peak and the valley of the Hype Cycle, when difficult choices have to be made. Schools that use these technologies are taking risks, but the initial obstacles have been overcome and the technologies provide a fertile climate for schools that wish to be among the frontrunners in reaping the benefits of the new applications. This section is particularly relevant for schools that want to use ICT to adopt a more tailored and personalised approach and wish to use data and analytics to achieve constants improvements in the quality of education.

3. **Education in the future.** In this section we look ahead to a world full of learning software, data and smart machines; the world in which the children we are educating will live and work. These are the genuine technology triggers at the start of the Hype Cycle, potentially ground-breaking technologies with a major impact, but not immediately ready for use in education. This section is mainly relevant for schools that want to explore what life and what profession they are preparing their students for so that they can tailor their curriculum and teaching methods accordingly.

Chapter 3 | Chapter 2 | Chapter 1
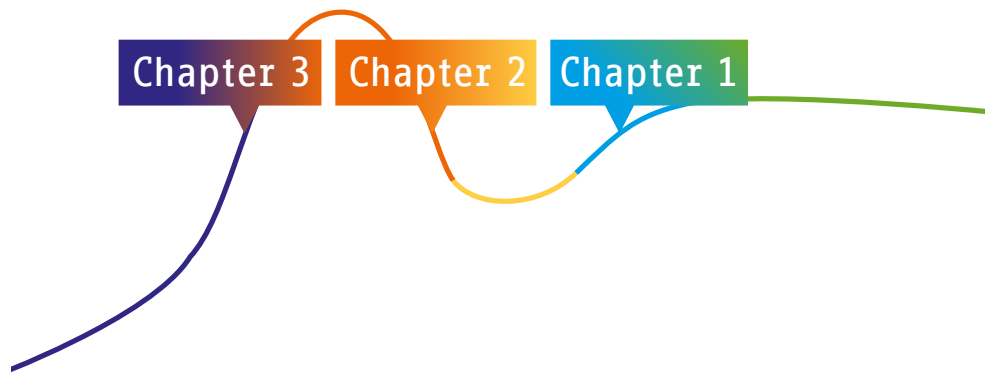
Schools will generally have a mix of the subjects discussed in the different chapters on their ICT agenda. Assembling the proper mix of technologies to support the education mission is a difficult task. Chapter 1.4 is therefore relevant for every school because, in addition to summarising the information in the first chapter, it also provides an illustration of how the Strategic Technology Map can be applied. The STM also demonstrates the relationships and mutual dependencies between technological building blocks in the other chapters.

In the introduction to each chapter, the Hype Cycle for the trends discussed in that chapter is shown. Each trend is described, concluding with a SWOT analysis and ensuing recommendations for schools and administrators. Each chapter contains a summary of the application of the STM to the building blocks discussed in that chapter. In conclusion, each chapter contains some reflections on issues such as cooperation with suppliers, questions of privacy and the development of innovative strength in schools. The report contains two appendices with a complete Hype Cycle (a combination of the three chapters) and a checklist for comparing the features of different types of devices.

This report is available in print, as an interactive PDF – with simple navigation between chapters and individual sections – and as an ePub and iBook for e-readers.
See **kn.nu/trendreport** for the different versions and additional information.

Chapter 1

ICT essentials

Introduction

First and foremost, ambitious and innovative applications of ICT in education require a stable foundation. Teachers and students must be able to rely on the ICT facilities being safe and reliable. At the same time, they increasingly need their own space to use the numerous applications available online as they see fit, with their own devices or otherwise. A solid basis is essential, but even that basic infrastructure is evolving rapidly. Every day new applications that can be used via Internet are being introduced. This type of 'cloud computing' is available for a range of mobile devices, including smartphones, tablets, Chromebooks and laptops. The ICT infrastructure must be prepared for and capable of adapting to this dynamic environment.

Introduction

The following are the building blocks of an ICT infrastructure that lays the foundation for easy-to-use, reliable ICT applications.

Cloud computing

Cloud computing is the collective name for ICT building blocks that are available online. Almost all software applications and digital learning materials are now accessible via Internet, and sometimes even exclusively so. Thanks to cloud computing, the applications and the learning materials needed in the educational process can be safely accessed anywhere, at any time and with any type of device.

Devices

Reliable, affordable and often personal devices for teachers and students that provide access to Internet and cloud applications. These devices possess the necessary attributes (for example, mobility) for every learning or work situation, in any environment and at any time.

Network infrastructure & Internet connectivity

Reliable, fast, flexible and easily accessible connections to Internet that allow cloud applications to be used on the most suitable device, anywhere and at any time. By this we mean not only an Internet connection, but also the fixed-network and wireless (Wi-Fi) connections at school, at home or elsewhere. At school, it would also include access to local devices, such as printers or interactive whiteboards.

Devoting attention to these ICT essentials pays for itself in terms of the stability and reliability of all the applications that rely on it. New applications can be implemented more quickly. Cloud computing lays the basis for the daily introduction of new, sometimes ground-breaking, applications and services that the world's entire population can use the very same day via Internet.

With personal devices that closely match the learning or work situation and a reliable Internet connection, every student and teacher can try out those new applications at home or at school.

Cloudcomputing

Devices

Network infrastructure & Internet connectivity
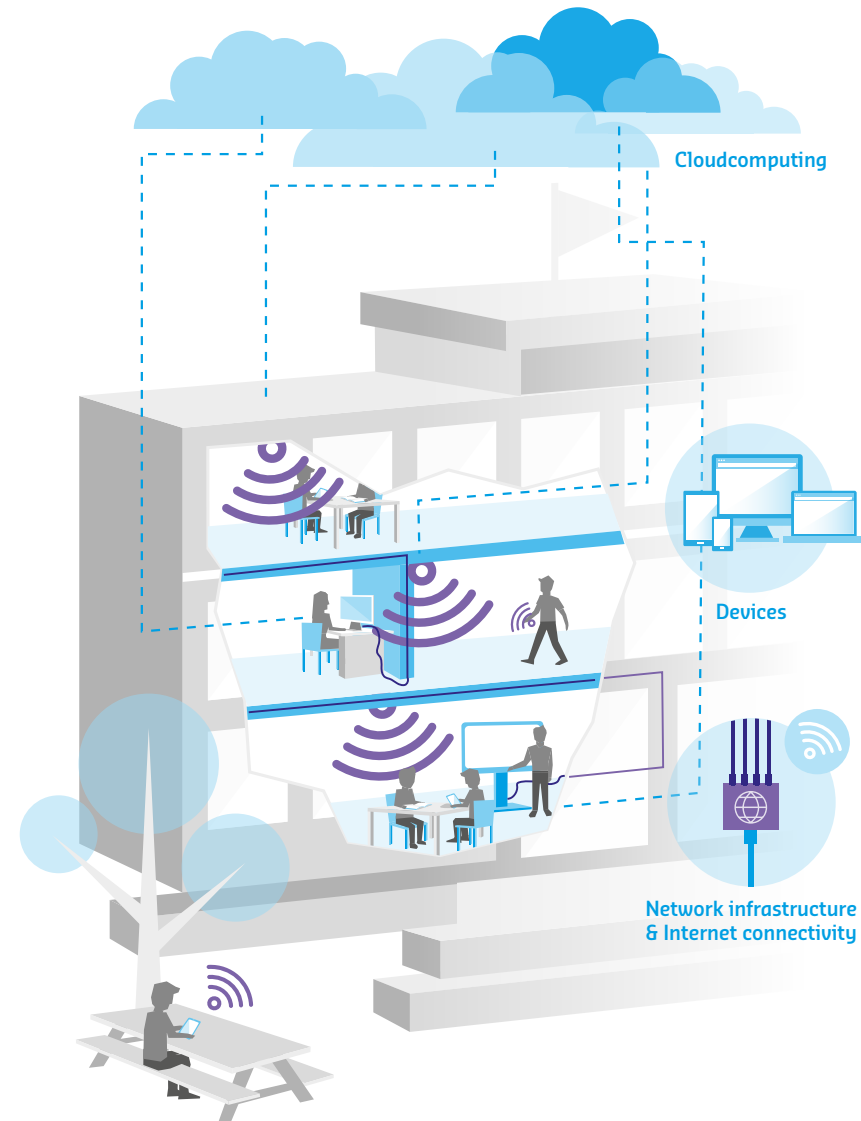
Hype Cycle for the ICT essentials

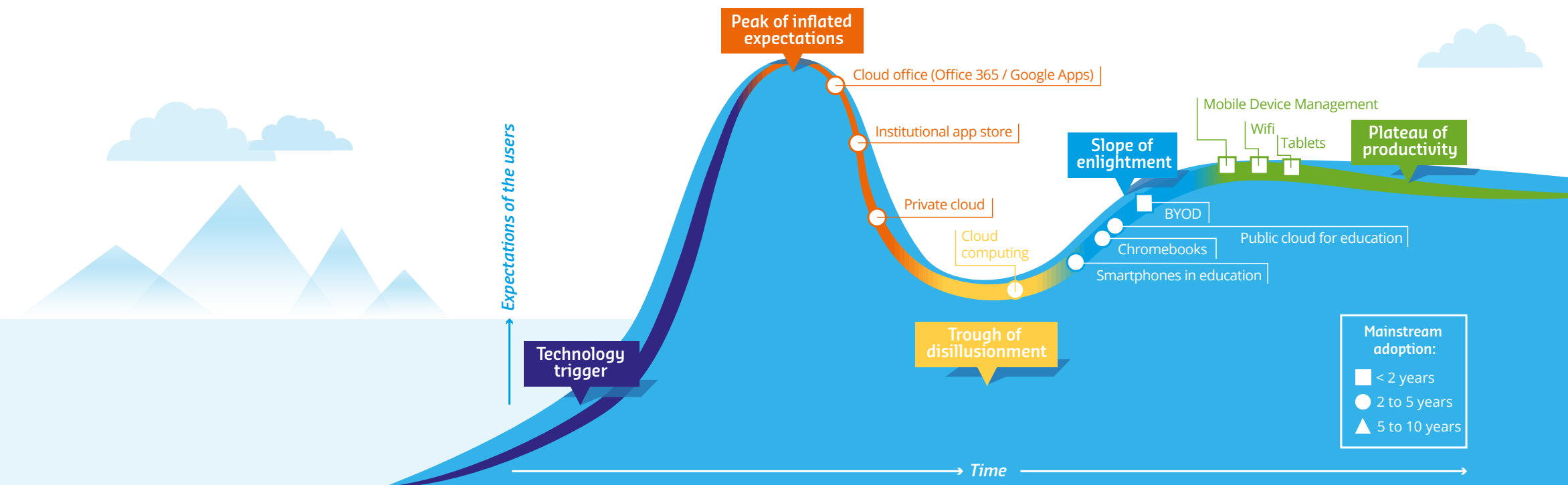The most important technologies discussed in this chapter are shown in the accompanying Hype Cycle, a concept developed by market research firm Gartner Research. The Hype Cycle maps the entire life cycle of a new technology from promising concept to accepted product. It gives a snapshot of the relative maturity of a technology and its future potential. The position of a trend – the risk profile – is determined by analysing the maturity, market adoption and available knowledge and research relating to that technology. Much of the essential ICT technology is mature or will reach that stage within the foreseeable future. Innovations in this type of technology, for example a newer, faster Wi-Fi standard, can produce a 'leap backwards' in the Hype Cycle, until that new standard has itself become commonplace. This phenomenon is particularly noticeable with cloud computing, where cloud-based office

applications still have to evolve further. Does this mean that Office 365 and Google Apps are still experimental platforms? No. E-mail, file sharing and office applications are fully mature components of these cloud platforms, but new functions are constantly being added and the hype surrounding these platforms is still growing. The criteria that can help in making a choice from amongst these cloud platforms is discussed later in this chapter. Some terms are missing in this chapter – laptops, cable networks, Internet connections and app stores, for example, are 'mature' and therefore no longer fall within the scope of the Hype Cycle – and other subjects are omitted in the interest of clarity, but the most relevant developments for education are of course covered.

Hype Cycle diagram. Peak of inflated expectations; Technology trigger; Trough of disillusionment; Slope of enlightenment; Plateau of productivity. Labels: Cloud office (Office 365 / Google Apps); Institutional app store; Private cloud; Cloud computing; BYOD; Chromebooks; Smartphones in education; Public cloud for education; Mobile Device Management; Wifi; Tablets. Mainstream adoption: ■ < 2 years; ● 2 to 5 years; ▲ 5 to 10 years. Time.

1.1 Cloudcomputing

The term 'cloud computing' entered into common usage fifteen years ago, since when the use of applications and the storage of the associated data or products on the Internet has really taken off. With the relocation of the technical facilities for ICT applications from living rooms, offices and schools to dedicated online facilities, a major change has occurred in how we deal with ICT. Hardware configuration, expansions and repairs. Software installation, updates and backups. They are all largely a thing of the past. With cloud computing, ICT can be used flexibly, with payment according to the volume of use and without any prior investment. Because of the time and effort saved in managing the technical aspects of ICT, organisations can devote more attention to the actual use of ICT in their primary process; in our case the learning process.

The application of cloud principles in the services that are provided can vary greatly, which is reflected in the degree of outsourcing of technical tasks and responsibilities. What should you leave to the supplier and what is so important that you should retain control and do it yourself? The buzz term among techies is 'Anything-as-a-Service' (XaaS): supplying technical facilities as a service. Dropbox, for example, offers data storage on a subscription basis. If you need more space, simply order more and continue working. A common classification of the degree of outsourcing distinguishes between Saas, PaaS and IaaS.

Software as a Service (SaaS)

Software provided online that is accessible via any Internet browser and can be used directly. Examples are online banking and your provider's e-mail service. To use a transport analogy, this is a taxi service – everything is provided, we only have to say where we want to go.

Platform as a Service (PaaS)

Secured and managed servers with operating systems on which customers can develop and manage their own applications, which are connected to Internet and can be used directly. These platforms allow for customisation of software, the rest is arranged. The analogy is with a rental car: no worries about insurance, depreciation and maintenance, but you have to fuel and drive it yourself.

Infrastructure as a Service (IaaS)

Building blocks such as computer capacity (virtual servers), storage space (virtual disks) and Internet connections with which customers can assemble ICT applications as they see fit. The hardware is provided, but how much of it we need and how it is put together is up to ourselves. To continue the transport analogy, this is our own vehicle that we have to buy, insure, maintain, write off and drive ourselves.

Servers in schools or private data centres for schools will rapidly be replaced by XaaS building blocks, thus relieving schools of the burden of dealing with the technical issues. They can shift their attention from designing and managing their own systems to contract management. This will yield badly needed cost savings, but calls for carefully-considered choices, and sometime tough choices if they have consequences for staffing. SaaS solutions such as Parnas-Sys or Magister handle all of the technical aspects and fall under Dutch legislation, including privacy laws. If international SaaS applications do not comply with Dutch legislation or do not meet functional requirements, combinations of PaaS and IaaS building blocks can deliver specific solutions, for instance in relation to data storage (an IaaS building block) in order to comply with legislation in European territory. We envisage three common cloud scenarios for organisations in terms of possible combinations of XaaS building blocks. The differences between them and their significance for education are discussed here.

1.1 Cloud computing

Table: the different models in the cloud and their features

Model	Description	Target group	Control	Examples	Application in education
Public cloud	Broad cloud product range accessible to everyone	Every Internet user	None, supplier determines functionality, roadmap and conditions	Productivity suites such as Google Apps, Office 365 and iCloud, but also online banking and various government services	Plenty of ELOs, business-critical administrative systems such as ParnasSys, Magister, AFAS or Exact
Private cloud	Private cloud products for your own organisation	Your own organisa-tion	Complete, functionality, roadmap and conditions according to your own specifications	Mainly larger business organisations with a need for total control	Various boards are considering this as an alternative to data centers or to replace them
Commu-nity cloud	Private cloud products for a group of organisations	Group of organisa-tions with the same require-ments	Shared within the group	Public sector organisations in addition to education; for competitive reasons this model is not popular in the business sector	Kennisnet cloud for the Dutch educati-on sector with, among other things, *Vensters voor Verant-woording, Wikiwijs, Acadin* and *Teleblik*

Explanatory note:

- By 'control' is meant the extent to which it is possible to influence the functionality that is offered and its future development (roadmap) and the terms and conditions for use of the service.
- 'Application in education' refers to examples of the range of products available for schools, many of which are not always aware of the cloud factor.

Private cloud   **Community cloud**   **Public cloud**

1.1 Cloud computing

1 ICT essentials
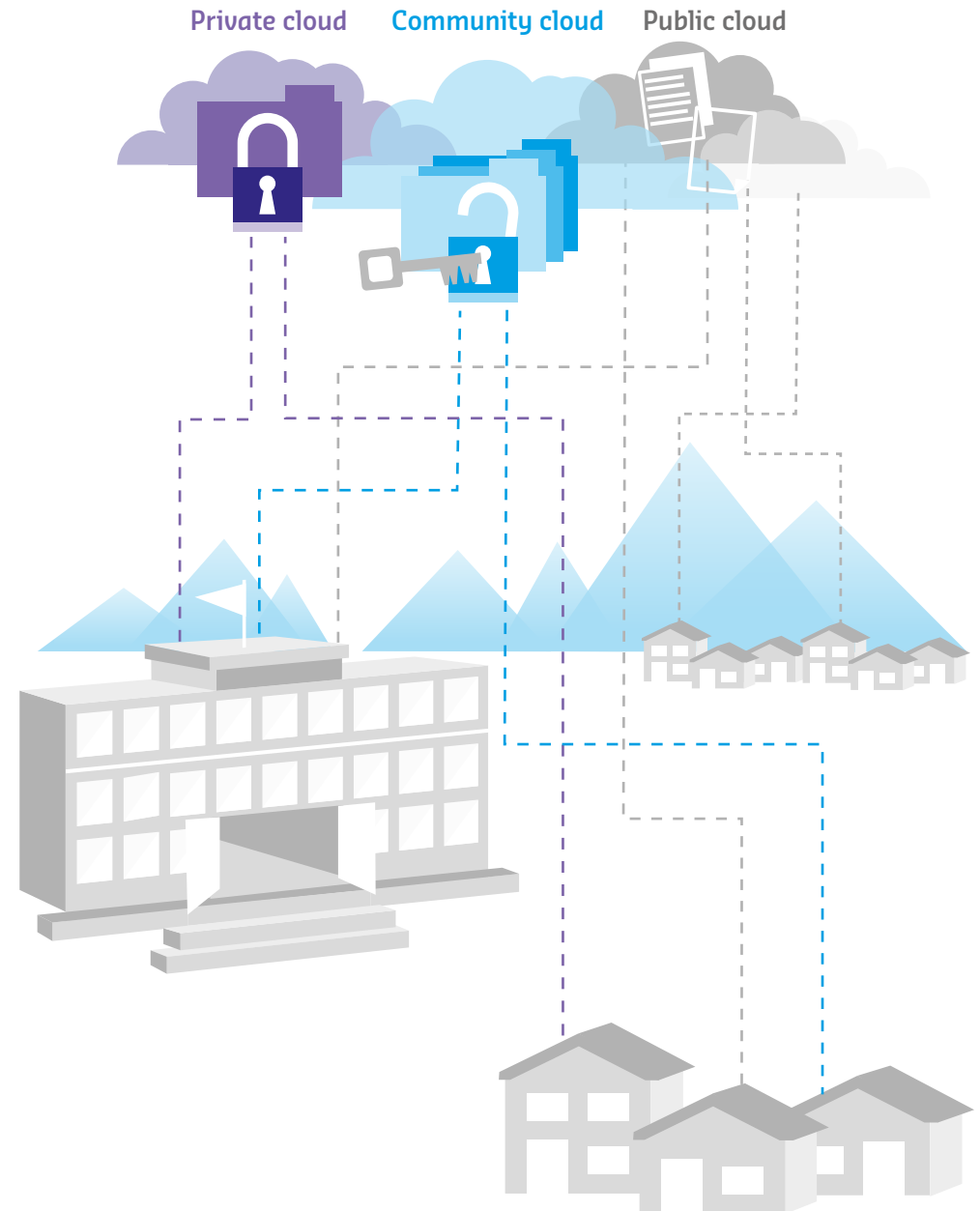
In practice, a mix of different cloud models will evolve in the coming years: the Hybrid Cloud. We will use public cloud services where they suffice, and where necessary supplement them with self-designed facilities in a community or private cloud.

Public cloud or private cloud

The public cloud services offer a lot of functionality specially designed for a wide target group at low cost. Examples are Google Apps for Education, Office 365 Education and Dropbox. If the public cloud services lack crucial functionality or the terms of use raise serious objections, an organisation can opt to use a private cloud. A private cloud is designed according to cloud principles (including access anywhere and at any time), but adopts its own specifications regarding data storage (particularly in terms of location), ownership of data, the privacy of users and the available functionality. This is similar to the former data centres of organisations, but the private cloud is composed of existing building blocks from suppliers (the aforementioned IaaS). Because of the difference in scale and the investment of its own expertise, time and attention that an organisation is required to make, the private cloud is far less cost-effective than the public cloud.

Community cloud

A good compromise is the community cloud, a private cloud created by a group of organisations – such as the Dutch education sector or a school board – with common requirements. The participants have more control in the community cloud than in the public cloud, and the community cloud is more cost-effective than the private cloud. The Kennisnet cloud, for example, contains Vensters voor Verantwoording (comparing schools) and the Overstap-service Onderwijs (School Transfer Service) and is governed by Dutch privacy legislation. The terms of use, functionality and development of the Kennisnet cloud are determined by agreement between the parties in the education sector.
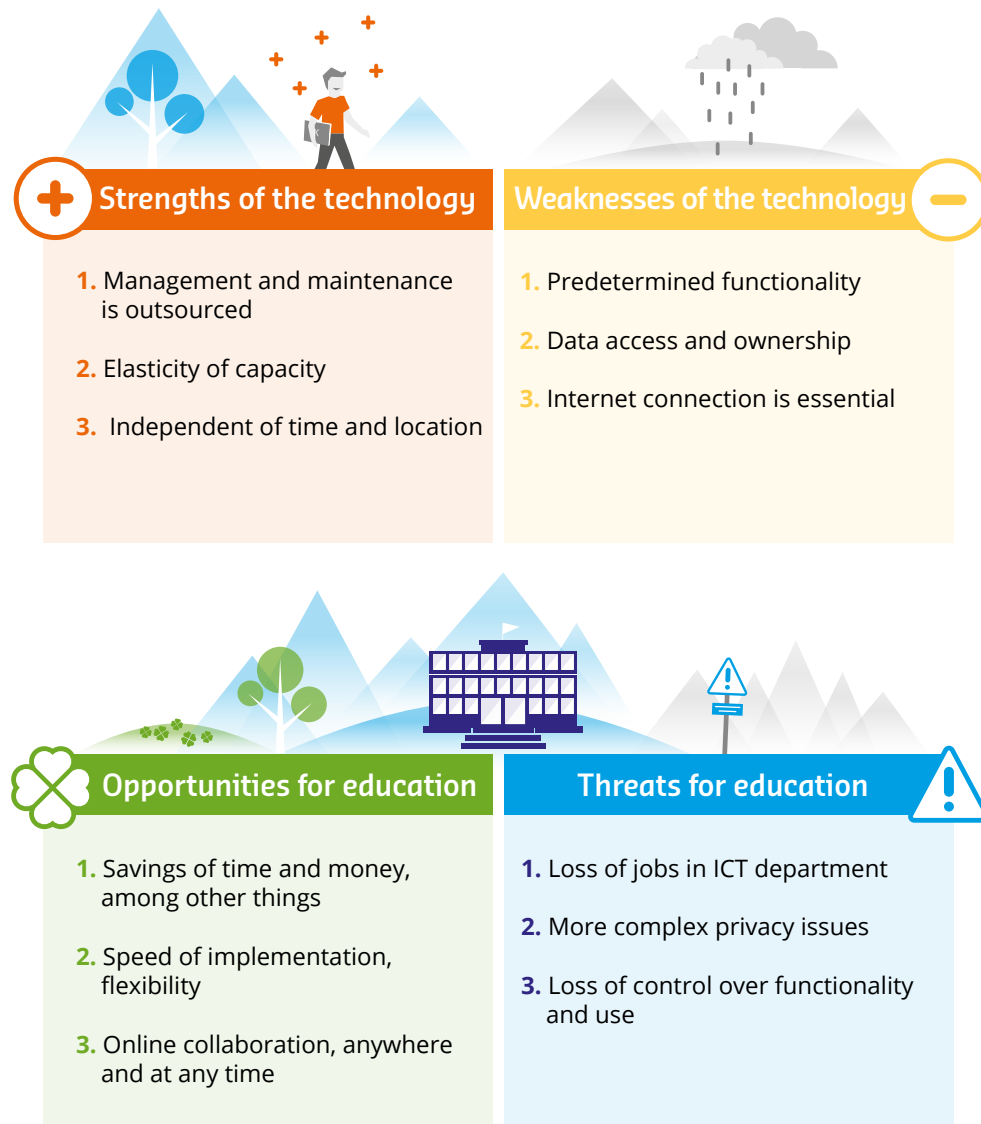
Personal cloud

Individual users of ICT store a lot of information in the cloud. E-mail, calendar, timetables and shared documents and presentations have been saved online for some time and have been joined more recently by reading lists, bookmarks for websites and e-books. Then there are apps on smartphones, step counters and other 'wearables' which add even more personal data. These personal data are stored at various locations in the public cloud and are accessible from anywhere, at any time and with any device. In practice, students and teachers will use a combination of different types of cloud in school. A school's future-proof ICT infrastructure will have to reflect that practice.

Google or Microsoft ?

An important decision in designing a modern ICT infrastructure is the choice of a public cloud platform for cooperation. For the education sector, the choice is often between Google or Microsoft. Both companies provide a robust platform and address privacy issues – such as developments in European legislation – quickly and seriously. Google Apps was literally 'born in the cloud,' having been designed from the outset for online use and cooperation, with a user-friendly structure and straightforward management. One issue with Google is the compatibility of document formats, particularly when there is constant interaction with other platforms. The Microsoft Office 365 platform contains a more complete range of functionalities – which were 'uploaded' after the cloud was created – and makes its implementation more complex and imposes greater demands in terms of management. However, the connection with the existing local Office environment is better. The choice of cloudprovider also depends on the choice of devices, which are discussed in more detail later in this chapter. The timing of the transition to the cloud depends on the depreciation of the existing ICT facilities. A timely start with the cloud allows for a phased migration because the cloud infrastructure can be constructed parallel to the existing ICT infrastructure.

1.1 Cloud computing

SWOT analysis of cloud computing

➕ Strengths of the technology

1. Management and maintenance is outsourced
2. Elasticity of capacity
3. Independent of time and location

➖ Weaknesses of the technology

1. Predetermined functionality
2. Data access and ownership
3. Internet connection is essential

🍀 Opportunities for education

1. Savings of time and money, among other things
2. Speed of implementation, flexibility
3. Online collaboration, anywhere and at any time

⚠️ Threats for education

1. Loss of jobs in ICT department
2. More complex privacy issues
3. Loss of control over functionality and use

SWOT analysis

➕ **Strengths** With the cloud model, there is no longer any need for equipment (servers) on the school's premises and all the equipment is managed and maintained by the supplier, including repairing faults, handling incidents with viruses or breaches of security and supplying updates. Investments required to increase or reduce capacity are the responsibility of the supplier of the services. The cloud can be used from any location with an Internet connection at any time.

➖ **Weaknesses** Outsourcing also means the loss of control over functional choices and raises new questions about access to and ownership of data. The virtual nature of the Internet presents new challenges, for example in relation to privacy legislation.

🍀 **Opportunities** The time and money saved can be devoted to providing support for the use of ICT in the education process. Applications can be selected, implemented and discarded again more quickly. Cloud platforms create possibilities for cooperation within and between schools and with other organisations, and we are less bound to the physical location of the school.

⚠️ **Threats** The nature and scale of ICT work in schools will change enormously, which has consequences for jobs. Schools lose control over the available functionality and the use of applications by students and teachers. The cloud menu is freely available via Internet. Privacy issues demand special attention.

1.1 Cloud computing

Recommendations to school boards on the use of cloud computing

1. **Choose a supra-institutional structure for cloud platforms if cooperation is important.**

An important management decision in the design of the ICT infrastructure in schools is which components should be installed centrally and which locally. With the cloud platforms of Microsoft, Google and Apple, for example, both centralised and local structures are possible. The following factors should be considered in making the decision.

Central supra-institutional structure:
- schools have more control and greater possibilities for cooperation and sharing information with other schools in the group;
- school directors do not require expertise or have to create the system environment in the school;
- the central management yields cost efficiency.

With a local structure:
- there is room for personal choices in platforms and structure that reflect the school's specific (educational) identity;
- there is expertise and supervision available in the school, which allows for more tailored solutions and local support.

Another objective criterion in making this decision is whether the specific design of an ICT component genuinely contributes to the school's identity. This will not often be the case with generic cloud platforms, but often will be with learning resources.

2. **Create awareness about interests, ensure decisions are made independently.**
- The cost benefits of cloud computing for schools lie in savings in working hours and restrictions on the freedom of action of network administrators. These are the very people who are often engaged as experts in discussions about the use of cloud computing. It can be the school's own ICT manager, but also an external cloud-computing service provider. Ensure that decisions regarding ICT and cloud computing are made independently.
- The standardisation inherent in cloud applications means compromising on functionality is inevitable. The 80/20 rule states that the final 20% of functionality accounts for 80% of the total costs. In practice, this means that insisting that all of the functional requirements are met could negate any savings that can be made with cloud computing. Organise an objective discussion about the functionality required and be willing to make compromises and look at the total costs across all jobs and departments.

3. **Enforce the 'adopt or explain' principle.**

The 'adopt or explain' principle gives people within the organisation the leeway to act autonomously and effectively subject to the rule that 'in our institution we use the standard cloud platforms'. Exceptions to the rule can be made, but have to be requested in advance and supported by valid arguments. The principle provides a framework for making conscious decisions about additional investments based on objective arguments. Those decisions can then be reconsidered after a time. For example, it may become necessary for an organisation to design or preserve its own services or customise the cloud-computing applications in order to add a missing functionality that provides essential support for the education process or to comply with privacy laws.

4. **Seek cooperation with other school boards in the community cloud.**
    It might be necessary to create your own services in order to respond to specific requirements or basic preconditions. If complex systems and substantial investment are required, it is worth exploring the possibility of cooperating with other school boards or with the rest of the education sector in a community cloud solution. An initiative like this can produce benefits of scale and cost advantages for like-minded organisations that share common objectives, requirements and principles.

5. **Adopt clear rules and guidelines.**
    Staff members and students no longer need a budget or assistance to use new cloud services. They can decide to do so whenever they like. This reality calls for clear rules and guidelines to ensure that the institution complies with its duty to treat data about students and their results with care and other requirements of the Dutch Data Protection Act.
    - Conclude contracts with the suppliers of cloud-computing services that are used by students and staff members. In association with SURF, Kennisnet is currently making agreements with suppliers of cloud services such as Google Apps and Microsoft Office 365 for the entire education sector.
    - Stipulate basic rules for the use by staff members of applications they have chosen themselves, such as a limit on the amount they can spend. Forbid them to use information relating to colleagues or students – it is, after all, prohibited by law. Clear rules like this limit the organisation's liability, while still leaving the initiative to employees.
    - Prescribe requirements for the data that should be included (or produced) in cloud applications in the teaching-learning process. Where possible, use direct transfers, but at least require data import or export. Make agreements on which format should be used to enter data into the school's existing administrative systems. For example, specify the

format to be used for the administrative feedback a teacher is required to provide about the performance of students in a particular subject or lesson and stipulate how the performance records are to be documented, transferred and filed.

1.2 Personal devices

Applications assist the organisation of teaching, administration and increasingly also the learning process with digital learning materials and learning environments. With cloud computing, applications and data can be accessed anywhere and at any time. The computer industry is responding to this trend with devices that offer the best experience for users in different situations, such as the smartphone, tablet or laptop. Our view on the use of these devices is that students and teachers should be able to use a device of their choice, which is exclusively available to them. How soon that situation will arrive is not yet clear, but it will vary from one sector, board or school to another.

A mobile device?

Mobility, flexibility and manageability are key concepts in discussions about the choice of the 'best' device. Which device is most suitable depends on the context in which the student or teacher will be working. Students working in groups at agreed times can use applications on desktop PCs for shared use. Mobile devices, such as a tablet or laptop, are more appropriate for individual assignments that are completed at different times. The same applies for teachers, who can work perfectly well on a desktop PC in their own classroom. Working at different locations in the school or elsewhere calls for more mobile solutions, with or without a fixed workplace. While we are out and about we usually use a smartphone or tablet to send short messages, for e-mail and to record appointments.

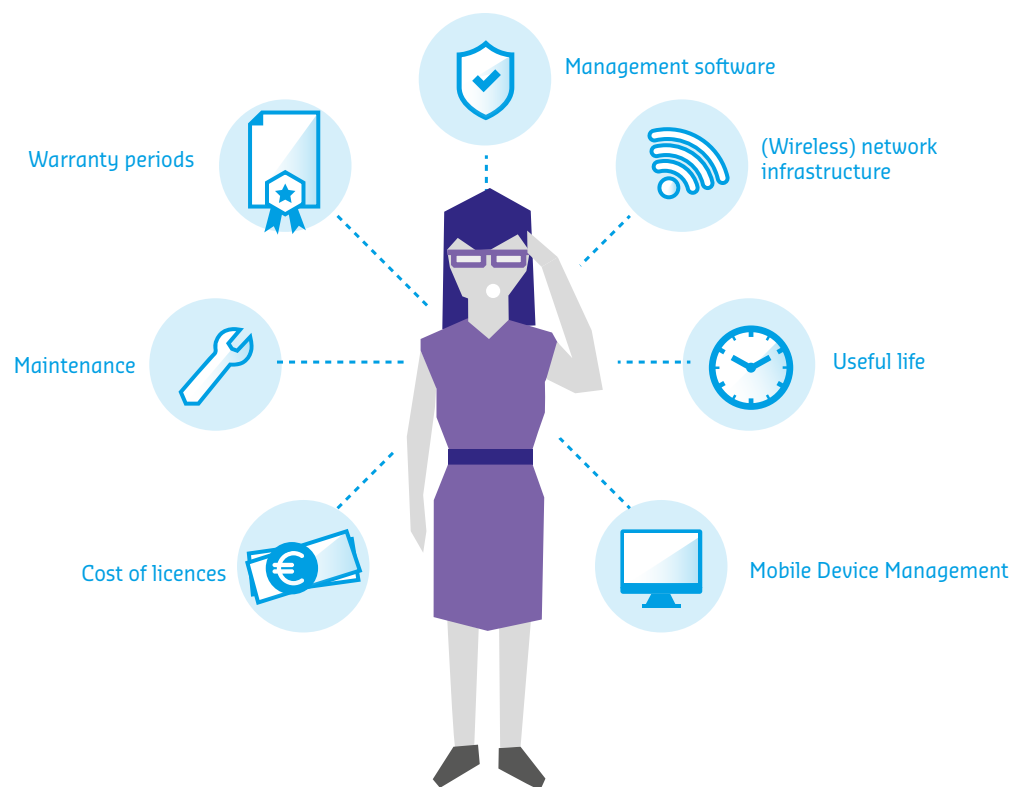1.2 Personal devices

1 ICT essentials

Tablet or laptop?

The choice between a fixed and mobile workplace is usually an easy one. The choice between a tablet or a laptop is more complicated, especially since there are numerous products that fall between the two, such as tablets with removable keyboards that can be used as laptops and Chromebooks, which resemble laptops but can almost only be used for cloud computing. These are very different devices, each with its own capabilities and limitations. A proper comparison has to be based on an objective rating in terms of the most relevant aspects for users in an educational context. Appendix 2 contains a number of tables in which different types of devices are compared in terms of a set of aspects that will to some extent be familiar to schools from their own teaching experience. The two guiding criteria for selecting a device are:

1. the device is useful: it has to deliver the necessary functionality, not the maximum possible, because
2. the device is manageable: it must be possible to use the device at any time without disrupting the teaching process.

Stories about practical experiences at schools and discussions between teachers about cloud services and the products of the major suppliers can be found in the Google Educator Group (GEG) Nederland and in the Microsoft in Education and Apple in Education portals.

Warranty periods

Management software

(Wireless) network infrastructure

Maintenance

Useful life

Cost of licences

Mobile Device Management

So how do I choose?

The comparison of the features of the various devices in appendix 2 still leaves us with an interesting dilemma: which is the most suitable device for the situation in *my* school? Is it the functionally accessible tablet, the low-maintenance Chromebook or the more powerful but complex laptop? There is no absolute best choice, but there is a device that best matches the decisions that have been made earlier with regard to ICT and the school's long-term perspective. Which cloud platform has the school chosen? What do the long-term plan for the development of education and the policy on learning resources, particularly the planned path to digital learning materials and environments, have to say? The pace at which publishers are producing flexible learning materials that can be used on every device is accelerating all the time. Suppliers of

teaching support systems and learning environments are exploring or already taking steps in the direction of packages to support tailored education. By adopting a clear position on these aspects, with the help of the descriptions of the individual properties in the aforementioned tables, schools can make a carefully considered decision about the most appropriate device.

Is it my choice (alone)?

Devices are becoming cheaper and more powerful every year. The smartphone in the pocket of every student and teacher in the Netherlands is more powerful than the room-sized supercomputers of 25 years ago. And naturally has access to Internet and all the platforms in the cloud, whether or not the school has Wi-Fi. It is this combination of the widespread availability of powerful private devices and the easy access they offer to applications and information that has given rise to the Bring Your Own Device (BYOD) concept. What do schools hope to achieve by making devices available to their students and teachers? Computers for shared use, in computer rooms or the classroom, have identical settings in order to keep system administration affordable. Students and teachers are forbidden from installing applications or saving their own work on them. This contrasts sharply with their personal devices, on which students and teachers can install whatever applications they feel are useful, whenever they need them and according to their personal preferences and wishes. Their data are stored on various cloud platforms and can be accessed from anywhere and at any time. BYOD is also derisively referred to as 'Bring Your Own Disaster'. The huge diversity of devices and of applications used on them can indeed make it difficult to support them all. The desire to control this diversity, as with the standard workstations, undermines the accessibility of information provided by BYOD. Teachers and students need to be able to create their own learning and work space with a range of apps and cloud-computing services on their own devices. This will not only reduce costs, but also promote creativity and encourage personal initiative within the school. But giving them this

1.2 Personal devices

leeway does not mean that schools should no longer adopt any rules. Cooperation and communication on a shared platform are more effective when there are agreements concerning the minimum requirements for devices and the preferred platforms (the so-called network effect). The challenge is to find the right balance: 'doing more with less' is within reach if we are restrained in what we prohibit and liberal in what we allow.

Class management with Mobile Device Management

As already mentioned, mobile devices call for a more flexible form of management. In that context, Apple and Google have developed Mobile Device Management platforms, which are geared mainly to the teachers and the school rather than system administrators. Microsoft has made a start with Office 365 and with Intune, but the functionality and level of support of Windows devices is not yet equal to those of its competitors. This refers to aspects such as the easy distribution of any app, application (including the license) or website regardless of the supplier or the temporary imposition of restrictions, such as only permitting users to work in particular apps, applications or websites ('locking'). In this way, specific work forms or temporary test situations can be established quickly and easily. Teachers can do this themselves for groups of students, which represents a totally different form of 'system administration', one that is more at the service of teaching (and its organisation). These easy-to-use, affordable MDM solutions will cause a shift in the tasks and associated management services of ICT suppliers, as cloud computing is already doing, aimed less at control and more at enabling teachers and schools to take charge themselves.

1.2 Personal devices

The total cost of using (personal) devices

The costs are obviously an important factor in the choice of a device, both the purchase price and total operating costs. A cheap device that is difficult to manage, requires a lot of maintenance and breaks down more frequently ultimately costs the school more, also expressed in time and educational effectiveness. The expected useful life of equipment, warranty periods and the costs of management are all important factors in the total costs. The costs of licences for educational applications, learning materials and the available cloud platforms are other factors that have to be considered in the choice of a device. Other factors are any additional computer facilities that might be required in addition to the (personal) devices. For example, a small number of permanent workstations with larger screens for specific applications will often be needed, or investments will have to be made in (wireless) network infrastructure and Internet connectivity to enable devices to be used effectively. The network is discussed in more detail later in the chapter.

SWOT analysis of personal devices

+ Strengths of the technology

1. Can be configured according to individual needs
2. Can be used by students anywhere and at any time
3. Individual space for user

– Weaknesses of the technology

1. Diversity complicates collaboration
2. Unpredictable peak use
3. More diffuse responsibilities

Opportunities for education

1. Individual learning path and pace
2. Integration of out-of-school learning
3. Savings with BYOD

Threats for education

1. New rules and facilities needed
2. Retaining an overview of the (group) learning process
3. Uncertainty about rights and duties

SWOT analysis

+ **Strengths** Personal devices that closely match the individual needs of students can be used. The device, and hence the applications, learning materials and sources are available anywhere and at any time. Students can organise their learning and cooperation as they see fit within the boundaries prescribed by the teacher and the school.

– **Weaknesses** Because the devices are matched to the personal needs of students there will be enormous diversity in the applications used and the learning materials consulted. With personal devices, the costs and responsibilities in relation to management and liability, for example, are less clearly defined, especially if schools apply the BYOD concept. The demands made on the school's network and Internet connections increase explosively.

Opportunities Students with a personal device can follow their own learning path at their own pace and in accordance with their own needs. This makes it possible for teachers to adopt a very personal approach, with precisely the same applications and learning materials being available to the student both during school hours and at home (with the involvement of parents). The teacher can keep track of and supervise the student's digital work remotely and has greater flexibility in the use of physical lessons with students. By applying BYOD schools can make savings on the cost of devices and use the money to invest in improvements to the network infrastructure.

⚠ **Threats** The transition to individual devices imposes new demands on the capacity of the school's facilities and requires it to formulate new rules and guidelines for their use. The agreements made have to offer a clear division of responsibilities between students/parents and the school in the event that a device is stolen, damaged or malfunctions, particularly where the BYOD concept is being applied. Special attention has to be devoted to monitoring the progress of students and the group process, since the learning process will increasingly take place outside the classroom and the school.

1.2 Personal devices

Recommendations to the board on the use of devices

1. **Guard against excessive procurement and standardisation of devices for multiple schools.**

An important decision for management in designing a schools' ICT infrastructure is the question of which components will be centralised and which will be arranged locally. An objective criterion in making this decision is the extent to which the specific design of an ICT component actually contributes to the school's identity. If it does, as in the case of devices, schools should have discretion. The choice of a particular type of device is largely determined by the school's choices in its approach to education. There are major, significant differences between schools in their approach to differentiated and tailored education and the pace at which they are implemented, while these are the usual reasons for the wider deployment of devices for students. Cloud-computing platforms are device-independent, as is the network infrastructure (as discussed later). This gives schools the freedom to operate independently in accordance with their educational identity. At management level, scale and purchasing power are regularly used to demand discounts and favourable terms from suppliers. Joint procurement of large volumes of specific devices is only useful if the schools' requirements have been identified.

2. **Effective use of personal devices calls for differentiated education.**

With personal devices students are able to work in the order and at the pace of their own choosing, but they are no more than a facilitator. Effective use of personal devices depends on two things:

- The organisation and the vision of education and the teaching methods must be geared to tailored instruction and an individual approach to the students. Allowing each student to use a personal device is not effective with joint learning activities.
- The long-term policy on learning materials has to ensure the timely availability of a differentiated range of digital learning materials that match the varying needs of the students. New teaching methods and differentiated learning materials should be in place when personal devices are introduced.

3. **Widespread deployment of personal devices calls for a different organisation and function of ICT services.**

- The policy towards applications (what will we use for what?), support for users and the capacity of the (wireless) network infrastructure will change dramatically if every teacher and student has their own personal device. The function of ICT services will shift from controlling the proper use of the facilities to providing support for the users.
- The most important questions for the school in reshaping the organisation and function of ICT services are:
  » what is the institution responsible for organising, providing and/or financing itself?
  and
  » what agreements/frameworks should be put in place to govern the use by teachers and students of their own applications?

1.2 Personal devices

4. Professional Wi-Fi and a good Internet connection are essential.

A crucial issue with the rapid growth in the use of personal mobile devices in education is the availability of rapid and reliable access to Internet. Outside school, students use mobile data networks that are becoming faster and cheaper. At school, a professional wireless network is absolutely essential for the wide deployment of personal devices, a subject that is discussed at length in the next section.
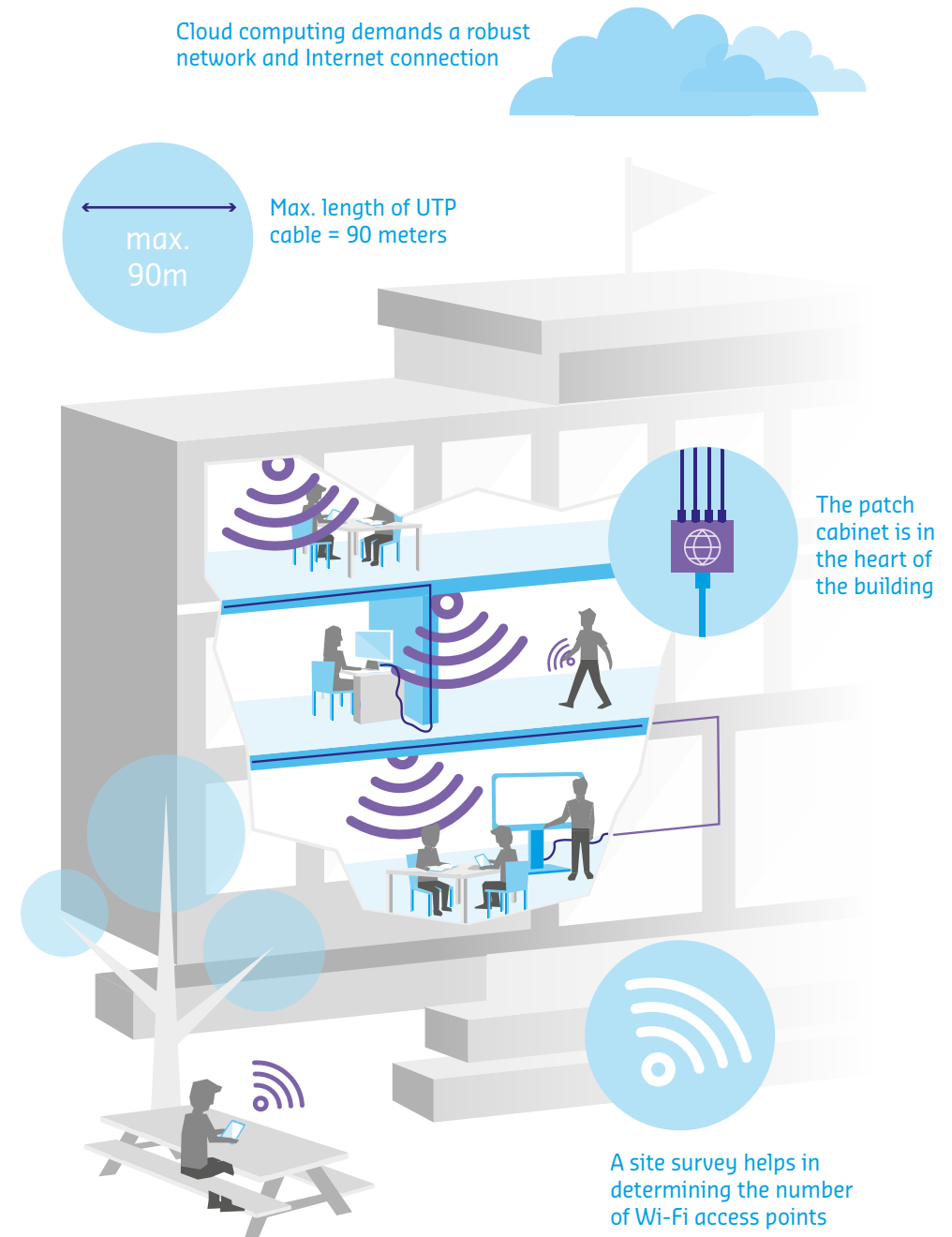
5. Set limits to safeguard the organisation and support of joint learning activities.
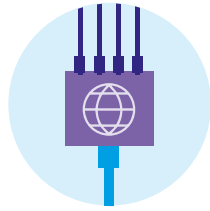
Providers of cloud-computing services leave the choice of applications largely to the individual user. Personal devices do the same thing by means of App stores, which contain enormous collections of easy-to-install applications with various functionalities – many of them free of charge. How will we address this? After all, too much diversity will stand in the way of organising and supporting joint learning activities. Broad access to web applications can be guaranteed by adopting open standards, such as HTML5, which can run on every brand and every device. Platforms such as Evernote, Office 365, Dropbox, Google Apps and Twitter also offer client applications for every common device. Agreements on the standards and platforms to be used create uniformity regardless of the variety of personal devices that are used.

1.3 Network infrastructure and Internet connectivity

Our applications, data and learning materials are in the cloud and we have a device that suits the situation in which we learn or work. What more could a student or teacher want? The answer is Wi-Fi! A wireless connection to Internet so that they are actually able to work in the cloud. The network infrastructure that establishes that connection consists of three inter-dependent components:

1. A local cabled network on the school's premises, which is installed professionally to ensure uninterrupted service and with sufficient connections at every location where learning and work take place within the school.
2. A professionally installed wireless network with a reliable signal regardless of where one is in the building and which is able to cope with the number of users and devices used in the school.
3. An Internet connection with sufficient capacity to provide reliable access to Internet from the internal network infrastructure (comprising the first and second components).

Cloud computing demands a robust network and Internet connection

Max. length of UTP cable = 90 meters

max. 90m

The patch cabinet is in the heart of the building

A site survey helps in determining the number of Wi-Fi access points

1.3 Network infrastructure and Internet connectivity

1 ICT essentials

Local cabled network

The cabled network in the school, also known as a Local Area Network (LAN), has two elements: cables and network components.

- Cables run from the workstations or shared equipment (such as prin-ters) to a central location in a so-called 'patch cabinet'. The regular UTP cable between the outlet and the patch cabinet must not be longer than 90 metres, so more than one patch cabinet may be needed in larger building.
- Components are needed to transform the large bundle of cables into a network. These network components are sockets that are also installed in the patch cabinet and into which the cables to the outlets are cluste-red. These network switches can typically support speeds of 100 Mbit/s or 1 Gbit/s at the moment.

Cables can last for 15 to 20 years. Given the relative expense of installing cable ducts and outlets, it is therefore advisable to choose a cable that will support higher speeds in the future, even if that is not an option from the outset. The supplier should deliver a network that is certified as guaranteeing the higher speeds when the time comes. Network components are a different story. They are centrally installed in the patch cabinet and can be easily replaced. The net-work can therefore provide sufficient speed in the short term and then be up-graded with new network equipment to accommodate higher speeds to sup-port new, faster personal devices after five or more years. Investing in quality always make sense – professional network equipment is easier to manage and configure remotely, since the manager can see faults in network components and repair them immediately and can switch outlets 'on' or 'off' remotely.

Wireless network

There is a lot of grumbling about Wi-Fi in schools. It doesn't work properly or is too expensive, and for some unfortunate victims both. The good news is that a reliable wireless net-work is not only entirely feasible, it is actually easy to install. On a slightly less positive note, a high-quality network re-quires investment. In the home the provider's cabinet or an extra access point works fine, but in a larger building with multiple users a professional system is essential if Wi-Fi is to work properly.

The process of installing the system starts with a site survey to assess where the access points to the wireless network should be located to ensure a strong enough signal throughout the building. The required number of access points depends on the size of the building, but also on the building materials and fur-nishings. Reinforced concrete and metal filing cabinets effectively block the Wi-Fi signal. Another requirement is to make a realistic estimate of the number of devices that will be using the wireless network simultaneously at peak times. In practice, schools quickly scale up from using tablets for specific classes to using them for various classes and throughout the building. This is usually followed quite quickly by support of BYOD, which is something to bear in mind in the design of the network.

The network connections for the wireless access points depend on the relati-onship between the cabled and the wireless network. In principle, the access points can have a wireless connection to the fixed network, but a cable connec-tion always provides more capacity and greater reliability. However, the access points can also be powered with appropriate network components via the net-work cable, which can save on the cost of installation.

Control and diversity

A modern wireless network has a central control unit that supplies the best signal strengths to the right locations for the available access points and the current use of the network. The coordination of the channels and signal strengths used between access points improves the user experience and prevents faults. This is an attribute where investment in a professional network pays for itself. This equipment can also provide parallel (virtual) wireless networks which can be programmed to provide different levels of quality and access, which means that the system can be used separately for teaching, administration and access for students with the same network equipment.

### School network as a springboard (to the internet)

Nowadays the network infrastructure in the school building is nothing more nor less than the means of access to Internet in general, and to applications, data and learning resources in the cloud in particular. Everything is located 'outside' the school, with the sole exception of shared printers perhaps. The network can perform this springboard function effectively if it accommodates a range of devices, regardless of brand or supplier. Security can be confined to preventing faults and registering (for a limited period) the use of the network so that irregularities can be investigated. Students can make unlimited use of their devices in the library, at home or in McDonald's, so they expect the same in school. Safe access to applications, data or learning materials no longer has to be arranged via the network, but agreed with the providers of the cloud-computing services that supply them. In view of the steadily increasing volume of functionality, data and sources of information available online, the network itself is absolutely crucial for learning and working. A robust network and Internet connection is a prerequisite for cloud computing.

Internet connection

Although the Netherlands has one of the best network infrastructures in the world, there are still significant regional differences. Inhabitants of larger cities often have a choice of suppliers offering plenty of bandwidth, while in less densely populated areas there is less choice and the speeds are significantly lower. But even the 'better-off' regions are facing a growing challenge. Digital learning materials increasingly contain media elements and a growing number of schools that use cloud computing are no longer able to make do with the standard products for small businesses supplied by providers. These products are usually not designed for use by hundreds of users simultaneously, who in addition to using the online agendas, documents, presentations and communication tools, also regularly hold video conferences and consult media-rich learning materials in groups. 'Stronger' Internet connections are often prohibitively expensive and intended for larger companies. How to address this market-related problem falls outside the scope of this report.
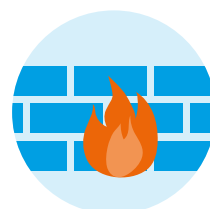
Firewall

Technically speaking, we can anticipate developments in the Internet market by building flexibility into the gateway between the internal school network and the external Internet connections. The link is made with a firewall, which can be used to provide security, ensure that capacity is used in accordance with the school's objectives and safeguard the quality of service, while

1.3 Network infrastructure and Internet connectivity

1 ICT essentials

preserving the school's independence of the supplier of Internet access. By concluding short-term contracts which can be revised if new solutions with a better price/quality ratio appear on the market, schools can consistently buy in services on sharp terms and respond quickly to new developments.

Network infrastructure at home and elsewhere

With applications and devices that run independently of the school network, in principle it is possible to work and learn anywhere. Students and teachers often have excellent Internet connections at home. Accordingly, the design principles of the school's ICT infrastructure can also produce benefits in terms of flexibility for students and teachers outside the school. The new challenges this will pose for designing, monitoring and safeguarding a good learning process is largely unexplored territory, but a well-designed network infrastructure will in any case no longer stand in the way.

SWOT analysis of network infrastructure and Internet connectivity

Strengths of the technology

1. Reliable and low-maintenance

2. Very highly standardised

3. Excellent national basic infrastructure

Weaknesses of the technology

1. Inflexibility in building due to cabling

2. Wide diversity in the quality of products

3. Capacity depends on geographic location

Opportunities for education

1. Great flexibility in location and time

2. Device-independent

3. Access to infinite online resources

Threats for education

1. Anticipating requirements is difficult

2. Striking a balance in the rules on use is difficult

3. Access to infinite sources of distraction

SWOT analysis

Strengths A professionally installed network infrastructure requires scarcely any attention and works with every device on the market. The Netherlands' basic infrastructure, including international Internet connectivity, is also world-class.

Weaknesses Cabling is expensive to adapt. At a time when education is changing so rapidly, it is necessary to anticipate scenarios for the use of the infrastructure. Comparisons of the price/quality ratios of the products are difficult to make and require technical expertise. More thinly populated areas of the Netherlands have only a limited choice among suppliers of Internet connectivity.

Opportunities A reliable (wireless) network infrastructure creates considerable freedom to learn and work with any device at any time and at any location and provides access to a potentially infinite volume of materials and applications.

Threats Anticipating the future use of ICT in education is a real challenge, as is striking the right balance between allowing freedom in the use of the ICT infrastructure and formulating rules in order to avoid problems. The school's Internet connection could also become overloaded if it is used for fun, for example to watch (live) television stations.

1.3 Network infrastructure and Internet connectivity

1 ICT essentials

Recommendations to the board on the design of a network infrastructure & Internet connectivity

1.   Standardise the (wireless) network infrastructure used by different schools.
An important management decision in the design of an ICT infrastructure in schools is which components will be centralised and which will be organised locally. An objective criterion for making this decision is the extent to which the specific design of an ICT component will actually contribute to the school's identity. That is easy to answer for the network infrastructure: the network is a neutral facility, for example running on 220V, in which the equipment used, quality standards and protocols are all fully standardised. The only variation between schools arises from differences in the timing of the roll-out (see next point) and the capacity required (the size of the school, the intensity of use, etc.). This has no impact at all in technical terms and the (cost) benefits of central standardisation and roll-out are reflected in convenience and joint procurement, and hence a lightening of the burden for schools. Schools can have a centrally adopted design installed by a supplier selected by the board, adapted to their situation and according to their timetable.

2.   Allow each individual school to introduce it in stages, so that the timing and pace coincide with the adoption of mobile devices.
There are often major differences between schools falling under the same board, which are reflected, among other things, in the education philosofy and hence also the adoption of technology. In particular the timing and pace at which schools apply ICT vary greatly. To profit from standardised network infrastructures on the one hand, and to meet the needs of individual schools on the other, it must be possible to vary the timing of the roll-out of 'the network' and the pace at which it occurs, for example by getting suppliers to offer a phased roll-out of the network facilities in schools. Schools should be able to order the next phase when they need it. At the same time, at each stage they must be able to build on previous investments, which will have been chosen smartly with the later phases in mind. This aspect can be included in the bidding process and is an important criterion for the selection of a supplier.

3.   Offer wireless network where necessary, opt for cable where possible.
There is a myth about network infrastructures that everything will be wireless in the future. Let's hope not! There has of course been explosive growth in the range of devices that can in practice only be used with wireless connections, but a cabled connection is preferable for peripherals such as printers and access points for the wireless network. Cable is always faster and more reliable than the more complex and less reliable wireless connections. The reason we are willing to accept the modest quality of mobile telephony, for example, is because we trade stability for flexibility. However, an effective network infrastructure will always have cables: the reliable foundation for all wireless applications that require flexibility. This is an important point to consider in the design of networks.

4. Demand eduroam support for wireless network, share Wi-Fi in education.

A substantial investment is needed to provide a good Wi-Fi service in every building. Investments in wireless network facilities can safely be shared within school boards, but also with other educational institutions. Eduroam is a professional community solution with which education institutions in various countries make their Wi-Fi networks available to one another. Teachers and students can use their own school's Wi-Fi account to gain direct online access to every eduroam partner (including other schools, school boards, libraries, museums, public transport stations and universities), without extra settings or measures. Firm contracts have been drawn up on the basis of international standards to regulate security and liability; a guest user is always the responsibility of his or own institution. The standards stipulated by eduroam also guarantee the security and safe use of the institution's own Wi-Fi network. Eduroam support is an optional service in the package of almost every network installer.

1.3 Network infrastructure and Internet connectivity
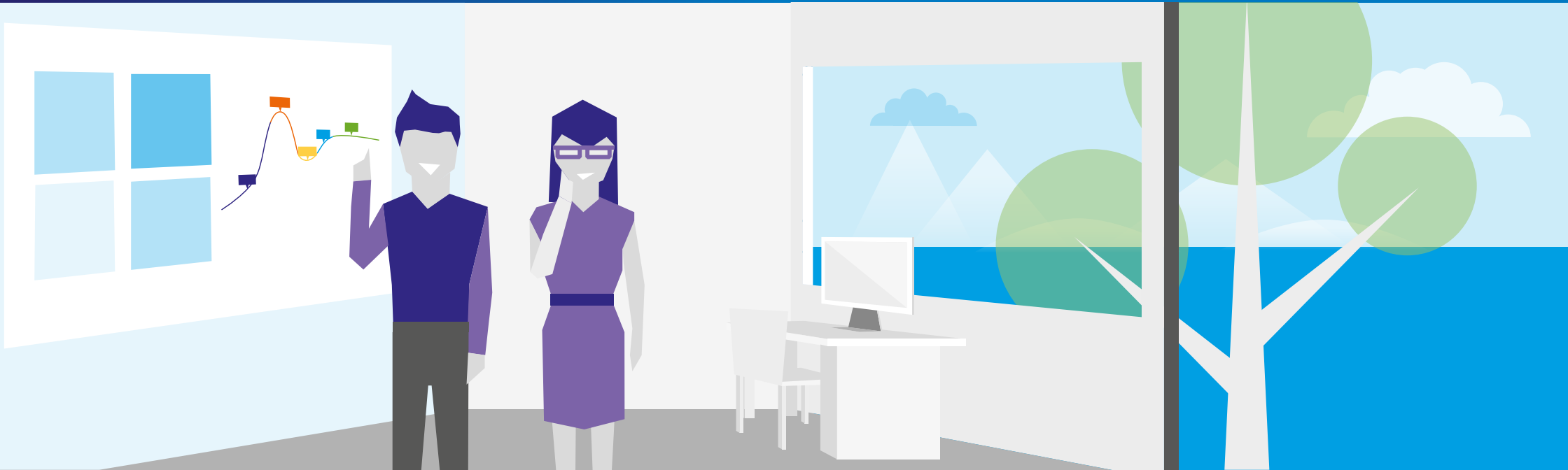
## 1.4 Coherence and consensus:
a vision of the ICT essentials

The success of investments depends not only on making the right decisions at the right time, but also on securing support for those decisions within the organisation. The Hype Cycle helps organisations to make conscious choices from the range of available technologies, bearing in mind their risk profile.
The Strategic Technology Map (STM) – or Benefit Map – is a tool that helps organisations to make decisions that are arrived at jointly and enjoy broad support. The STM is based on the following principles:

- An ICT infrastructure seldom comprises a single technology, but is rather an ecosystem made up of complementary tools that should reinforce one another. The STM helps in identifying the complex relationships and mutual dependencies between the individual components.

- To implement ICT tools successfully, a balance has to be struck between the benefits for the organisation (what 'we' need to do) and convenience for the users (what's in it for 'me'). The STM identifies who will benefit most from a technology: the organisation or the users. Preferably both will benefit.
- Decisions about substantial investments in complex technologies must be made carefully and transparently. The STM is a method by which stakeholders can jointly visualise the combination of related technologies and applications required to realise the institution's educational goals, while in the process ensuring that expectations remain realistic and providing insight into the narrative for a series of mutually dependent investments.

The STM is a simple matrix with two axes:
- The vertical axis represents organisational effectiveness (institutional productivity).
- The horizontal axis represents personal productivity (of students, teachers, other staff members).
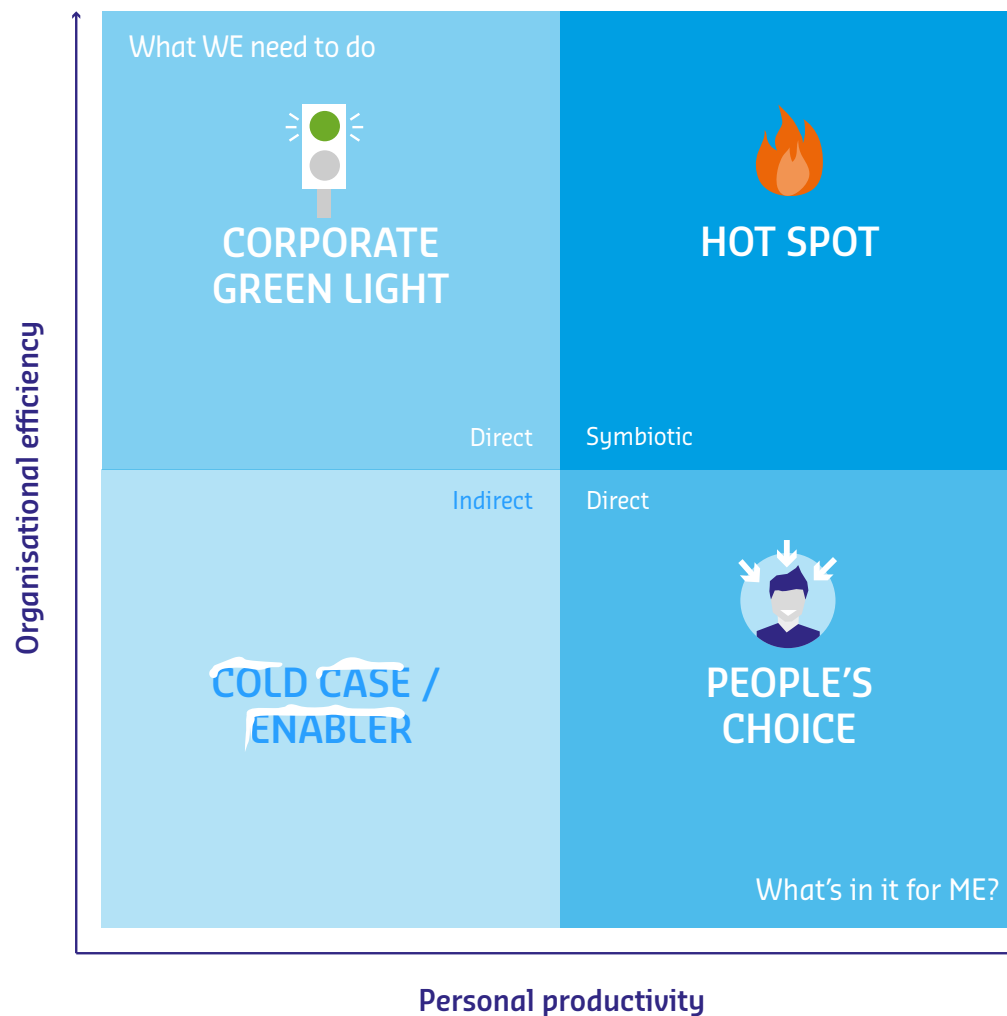
The end result is four quadrants with the following profiles for the technologies in each one:

- **Bottom left: 'Cold case' or 'Enabler'**
Technologies in this quadrant rate poorly on both axes, These are components of the supporting infrastructure, such as data centres, information architecture or identity management.

- **Top left: 'Corporate green light'**
These technologies rate highly in terms of organisational effectiveness and encompass standardised administrative systems (CRM, LAS/SIS or ERP). They are essential to the organisation, but are often regarded as a nuisance by students and teachers.

- **Bottom right: 'People's choice'**
These consumer technologies rate highly in terms of personal productivity. They include smartphones and tablets, social media, Whatsapp and cloud services like Dropbox and Google Apps. The organisation does not benefit much from these devices and applications unless it puts in place safeguards in relation to their use. They can even increase costs because of the additional support required due to the fragmentation of information and knowledge.

- **Top right: 'Hot spot'**
Technologies in this quadrant rate highly on both axes, for example where consumer technologies are combined with organisational processes, as in the use of smartphone apps for student administration or tablet apps for learning platforms.


Organisational efficiency

What WE need to do

CORPORATE GREEN LIGHT

HOT SPOT

Direct   Symbiotic

Indirect   Direct

COLD CASE / ENABLER

PEOPLE'S CHOICE

What's in it for ME?

Personal productivity

The STM is a tool that a school board or a school can use to arrive at a shared vision of and strategy for the use of ICT in education. The dialogue starts with the formulation of a widely-shared educational goal that technology can help to achieve. We will now explain precisely what we mean with an example derived from the technologies discussed in this chapter.

The narrative of the digital learning and working space

The narrative begins with the expanding possibilities of digital tools and schools' growing dependency on them. The tools that are available have to be arranged and organised into a coherent system. For example, a school can create a digital learning and working environment – based in part on their own choices – where students and teachers can learn and work together with communication tools such as chat and video conferencing facilities and options for performing assignments, exercises and sharing work. The STM below shows the combination of technologies required for this.

- The first requirement is a solid foundation for the digital learning and working space. This is the cloud office, where building blocks such as e-mail, agenda, address book, a chat program, shared folders and an application for video conferencing are directly available to every student and teacher.
- We then add the public cloud for education, with which our environment can be expanded with functionality designed more specifically for education, such as applications for student administration, financial and personnel administration and timetables, all essential components for managing the education process.
- The next component to be added is the institutional app store, from where students and teachers can download apps and install them on their personal devices.
- To ensure that the digital learning environment can be used effectively in any context, we then add Chromebooks, tablets and smartphones in
- education.

Organisational efficiency

Personal productivity

The Hype Cycle's colour code:
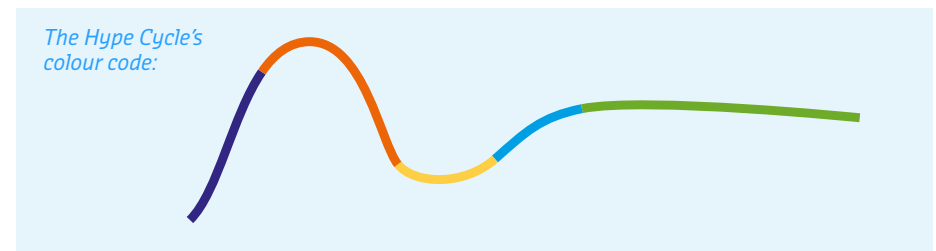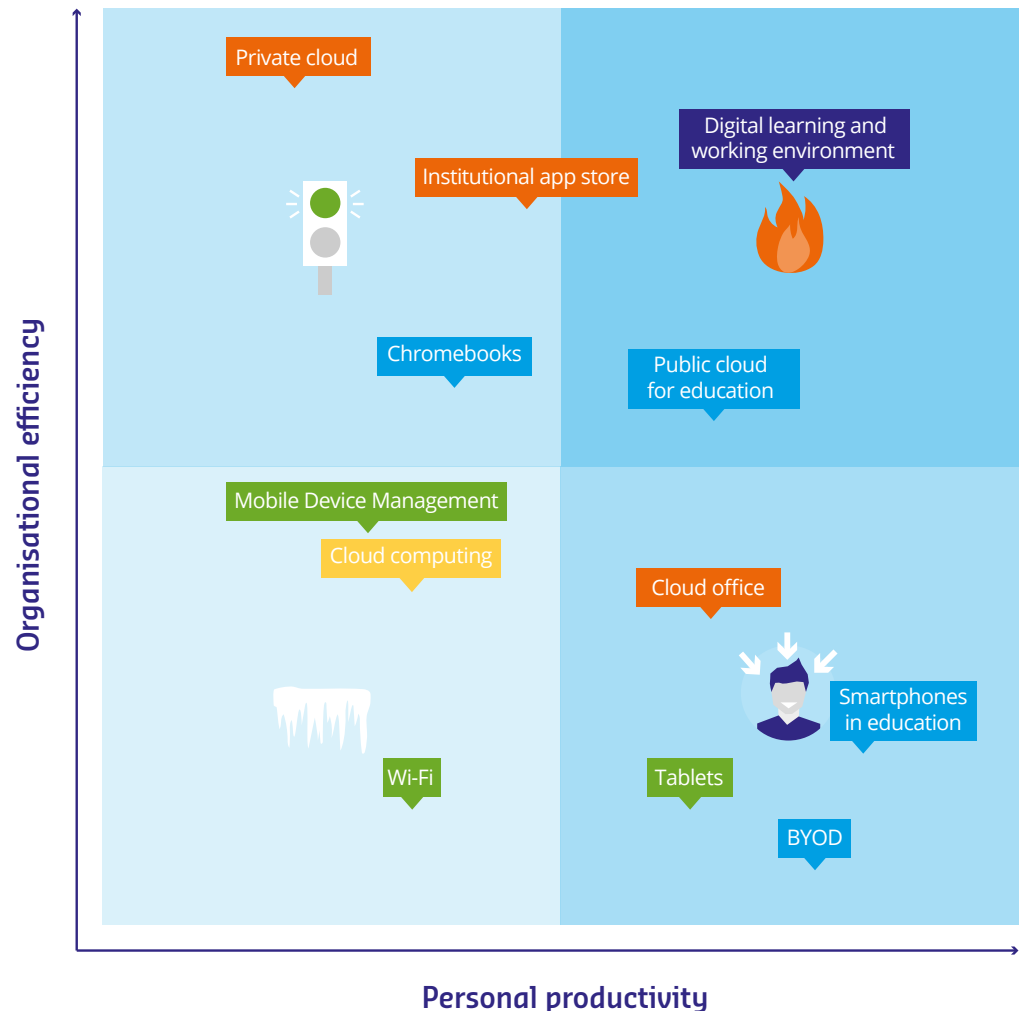
1.4 Coherence and consensus

- One question that needs to be addressed is which personal devices students will be allowed to use and what they can use them for. This has to be laid down in a BYOD policy.
- Since there can be no access to the digital learning and working space in the cloud without an Internet connection, we also need Wi-Fi.
- An educational institution also needs MDM to effectively manage the operation of the mobile devices once the system has been installed and configured by the supplier.
- School boards and educational institutions can then add any essential functionality that is still missing with the private cloud, although only with restraint in view of the high costs involved.
  The result is that we have created the digital learning and working environment, built on a robust foundation of technologies and services, which provides effective support for students and teachers in their day-to-day learning and work.

This description is only intended as a guide to help a school board in formulating a far more specific vision of how it can carry out its own education mission. It illustrates how different building blocks can be combined to achieve a specific functional goal. It also shows how the dependencies between the various components form a critical path for investments in technology. The digital learning and working environment is not feasible without the 'cold cases' Wi-fi and MDM and without the 'corporate green light' of the institutional app store it will be difficult to deploy the 'people's choices' of smartphones in education, tablets and BYOD. Naturally, there are numerous alternative paths. This example or even a self-assembled STM is merely the starting point for a continuous dialogue between stakeholders. Plans will change and budgets will be revised in response to new functional requirements, new possibilities and new priorities, but they will then have the commitment and insight of the entire board and its schools.
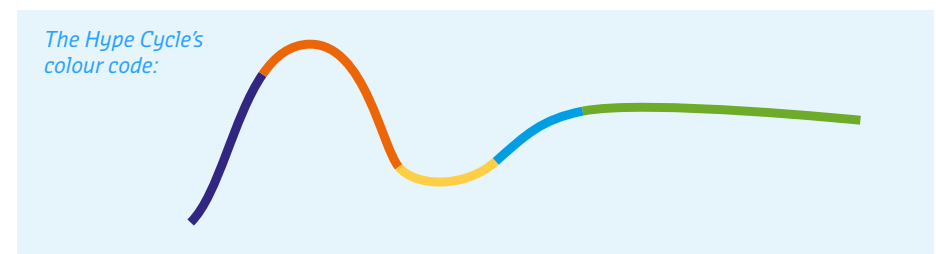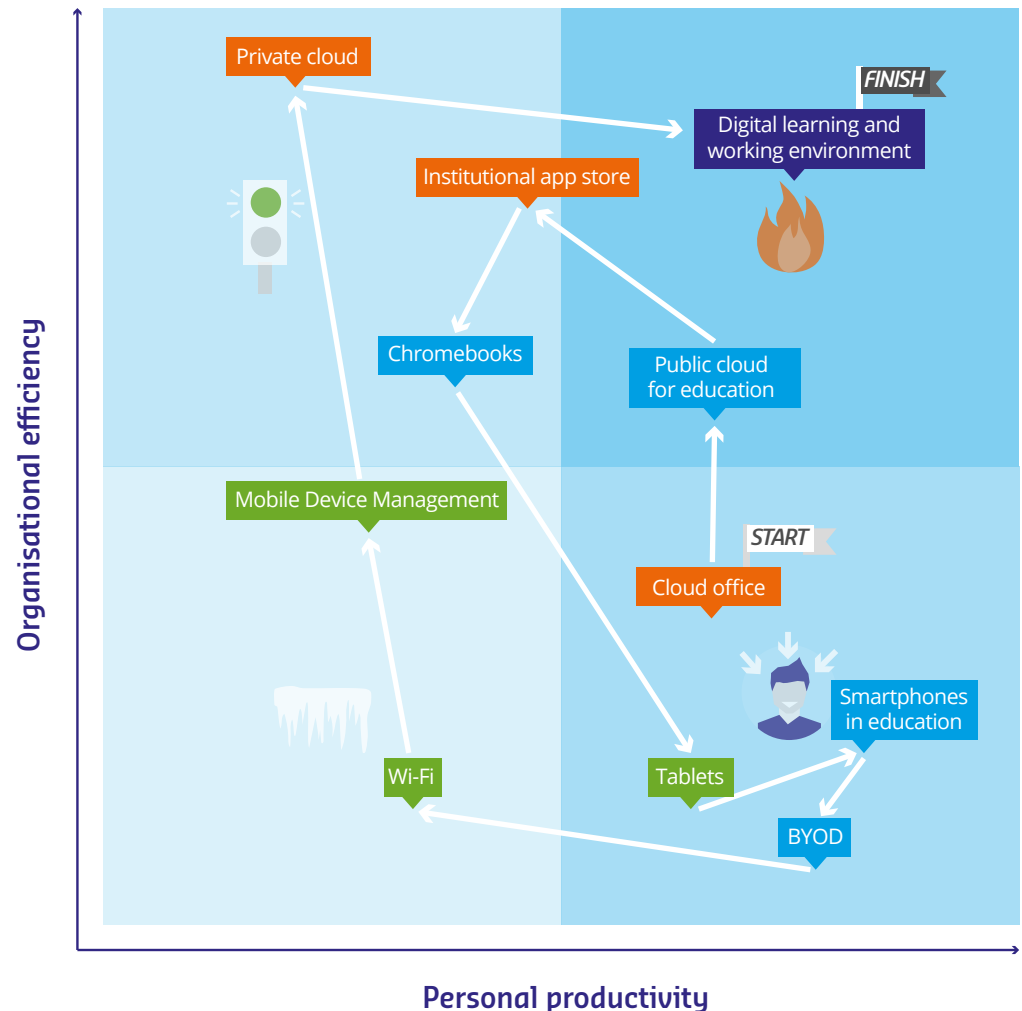
1.4 Coherence and consensus

1.5 Cooperation with suppliers

The essential ICT components lay the foundations for the productive use of ICT in education. The knowledge and experience required to create an effective system from the various components – cloud, devices and network – are available, but it is not a core task of the vast majority of organisations and educational institutions also prefer to outsource the design and management of ICT systems to qualified suppliers. The introductions, SWOTs and recommendations earlier in this chapter were primarily concerned with the issue of determining and describing 'what' is needed. In this section we explore the question of 'how' to implement the system, with particular attention to the factors that need to be considered in establishing a close and constructive partnership with the suppliers to whom schools outsource (the management of) their ICT services.
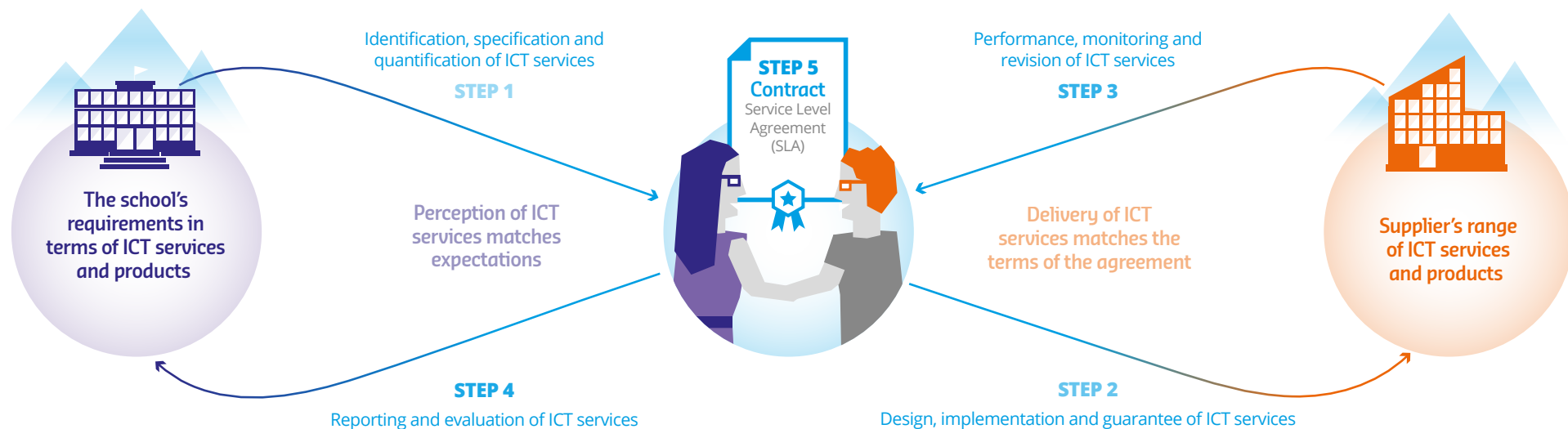
Service lemniscate

A handy model for describing the dialogue between a school and its supplier is the so-called 'service lemniscate' (devised by Theo Thiadens, Leo Ruijs and Harm Pul). The model has three parts:

1. The left-hand loop relates to the school, which determines what ICT services are needed and monitors whether the services provided meet its expectations.
2. The right-hand loop relates to the supplier, which is responsible for designing and delivering the ICT services and ensuring that the services are provided in accordance with the agreements that have been made.
3. In the centre is the contract with 'service levels' setting out the outcome of the dialogue between the school and the supplier. The contract lays down the quantity and quality of the ICT services to be provided and forms the basis for verifying that the service have been provided correctly. It can be revised by agreement during the term of the contract.

The process of requesting services, submitting a quotation, delivering the services and reporting on the services described in the lemniscate is followed every time. In practice, a great many school boards and schools are dissatisfied with

Identification, specification and quantification of ICT services
STEP 1

Performance, monitoring and revision of ICT services
STEP 3

STEP 5
Contract
Service Level Agreement (SLA)

The school's requirements in terms of ICT services and products

Perception of ICT services matches expectations

Delivery of ICT services matches the terms of the agreement

Supplier's range of ICT services and products

STEP 4
Reporting and evaluation of ICT services

STEP 2
Design, implementation and guarantee of ICT services

their ICT supplier or with the service it provides. The GAP model of service quality (developed by Zeithaml, Parasuraman and Berry) describes the five potential 'gaps' between a school's expectations and its perception of the service it actually receives. These 'gaps' provide a starting point for investigating where the cooperation has gone wrong and what can be done to rectify the situation.
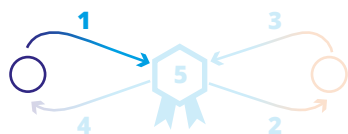
Step 1: identification, specification and quantification of ICT services
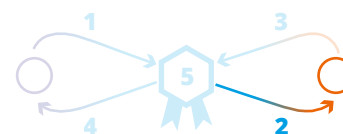
Pitfall

The expectations of users/the school differ from the supplier's perception of what it is required to deliver.

Educational goals are difficult to translate into the requirements of an ICT system. Teachers simply want the system's various components to work. Nevertheless, it is essential to formulate the wishes and requirements explicitly, because if it is not clear what precisely is being ordered there is little chance that the services provided will properly match the school's actual needs. Suppliers will then quickly be inclined to fall back on their 'standard package'. Successful deployment of ICT starts with a clearly formulated request that is properly understood and enjoys broad support within the school.

Recommendations
Create a consensus among teachers on the formulation of the requirements for the ICT system. Take the time to draft a carefully prepared description of the ICT services you need. Ask teachers to write scenarios describing precisely how they intend to work with students and colleagues in future, both in school and outside. Make provision in the contract for addressing new wishes and requirements, which often only emerge when the ICT system is actually being used. With objectives such as differentiated and tailored teaching and the dynamic in today's ICT

market, it is neither desirable nor realistic to conclude a long-term service agreement. The agreements with the supplier should include provisions on modification and expansion of the ICT services.

Step 2: design, implementation and guarantee of ICT services
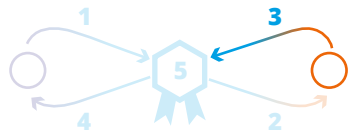
Pitfall

The supplier's organisation and procedures do not match the products and services to be supplied and/or the agreed service level.

Suppliers like to use standard products, services and procedures, since that allows them to run their operations efficiently and so make a profit. Any divergence from the supplier's standard services has to be clearly agreed between the school and its supplier. Suppliers should also clearly inform the school about the solutions they have chosen and any compromises that have been made in relation to the school's original demands, since only then can schools make an informed decision regarding the proposals made by the suppliers.

Recommendations
Secure the necessary expertise (technical, legal, financial) to properly evaluate the proposals from suppliers in relation to the original request. If necessary, hire an expert to provide advice on the offers in order to choose a suitable offer with the best price/quality ratio. Insist that suppliers specify which aspects of the specifications they regard as 'standard' and which will require additional time and effort. If necessary, together with the supplier explore alternatives to 'expensive' demands that are almost equally good and are easier to implement and support. Communicate the decisions that are made internally so that future users are aware of and subscribe to the choices that have been made.

1.5 Cooperation with suppliers

**Step 3**: performance, monitoring and revision of ICT service delivery

Pitfall

The ICT services actually provided differ from the specifications and the agreements that were made.

The people involved in arranging the contract, from both the school and the supplier, are often not the same people who deal with the delivery of the services on a day-to-day basis. The agreements that have been made, the issues that require attention and the identity of the contact persons on both sides must therefore be carefully documented and disseminated. Once the contract has been concluded, the formerly intensive contact between the parties often diminishes, which can quickly lead to uncertainty about how the services should be provided in a way that complies with both the agreements and expectations. Particularly in the event of unanticipated situations during the performance / delivery of ICT services, the parties will have to consult to ensure that the steps taken remain as close to the spirit of the agreement as possible.

Recommendations

Arrange a permanent dialogue between schools and suppliers regarding the performance and everyday delivery of the ICT services. Make specific agreements about who the contact persons are and when they will communicate. Their knowledge and understanding of the working arrangements will foster sympathy for pragmatic decisions, which can then be made in consultation. Arrange for feedback from the users in the school about the services being provided. Good internal communication on both sides during the provision of the services is very important for securing commitment to the agreements within the supplier's organisation and ensuring that the expectations of the users in the schools are realistic.
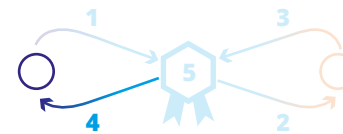
Step 4: reporting and evaluationof ICT services

Pitfall

Reports and communication about the ICT services provided differ from the perceived quality.

Formal reports often seem to portray the quality of the service that has been provided as being better than it is perceived in practice. Suppliers have the tendency to somewhat exaggerate what they have delivered or to focus on the most positive scenarios in terms of the use of the services. That tends to heighten expectations, which are then not actually met in the perception of the users.

Recommendations

Keep accessible, accurate and well-documented records of problems with the ICT services within schools. Quickly translate 'rumours' into detailed descriptions of specific cases, which can then be discussed at a meeting to explore solutions based on concrete improvements. Even with the best of intentions, problems and misunderstandings will inevitably emerge in the course of the contract. Make agreements for regular meetings to discuss the reports on service levels, which should also be attended by actual users from the schools and employees who actually provide the services for the supplier. Discuss the reports in the context of everyday practice (using the cases that have been collected), specify improvements that are needed and make firm agreements on how they will be carried out.

1.5 Cooperation with suppliers

1 ICT essentials

Step 5: documentation of agreements in a contract (SLA)

Pitfall
The service actually provided fails to meet expectations.

The agreements made during the process of defining specifications, submitting quotes, delivering the services and reporting are set out in a contract, which includes a Service Level Agreement (SLA) specifying the conditions the service performance has to meet. Differences in the interpretation of these agreements are a frequent source of conflict between schools and suppliers.

Recommendation
The source of the gap between expectations and the services provided often lies in the 'best efforts' provisions in agreements. The formally agreed response time (from the time an enquiry is received) to a telephone call or e-mail is often expressed in days or parts of a day, while teachers often feel a delay of even a few hours in fixing a problem is too long. The formal language used in SLAs provides little insight into the consequences in everyday practice. The agreement should therefore focus on the desired result. For example, include a stipulation that any problems teachers have with the interactive whiteboard or a computer must be resolved by the next school day at the latest. If there is a dispute about 'the contract,' try to identify the loop or arrow in the lemniscate that the source of the conflict falls under. By discovering where things have gone wrong, the problem can be addressed at its source. If, for example, the specifications for the desired operation of the Wi-Fi do not provide for use by students and staff members of their own personal devices, the terms of that service should be revised.

1.5 Cooperation with suppliers

1 ICT essentials

Chapter 2

Digital learning process

Introduction

The pace of digitisation in the education sector is accelerating. Publishers and distributors of digital learning materials anticipate that almost their entire range of materials will be digital within a few years. Personal devices, permanently connected to Internet via Wi-Fi, will be widely available in schools. And that's just the start. Existing materials will be replaced by digital versions and the use of ICT will optimise current processes. This upgrading – improvements to existing activities and processes – commonly occurs in the initial phase after the introduction of a new technology. The real impact of innovations only really becomes apparent in the subsequent transformation phase, when more radical changes take place.

Introduction

Gordon Moore
Co-founder of Intel
Declining digital costs

Nicholas Negroponte
Founder/director of MIT media lab
Bits have totally different properties than atoms

App Store
Apple's online software store
Small developers can serve the global market

iTunes
Apple's digital media store
Product modularisation. Buy a single song rather than an entire album.

FREE!

Chris Anderson
(Wired Magazine)
Information as currency

What does the knowledge-based economy imply for education?

| 1965 | 1995 | 2003 | 2008 | 2009 | now |

As Moore's Law states, since the 1960s the storage, processing, copying and transfer of bits (digital information) has become twice as efficient almost every year, while the costs have remained stable. This has made 'free' cloud services possible, as well as steadily faster smartphones, tablets, laptops, Wi-Fi and Internet connections. On the other hand, physical objects, and their distribution and storage, are becoming increasingly expensive because of the scarcity of raw materials, asphalt and fuel. As Nicholas Negroponte explains in his book 'Being Digital', the fundamentally different properties of bits (particularly in terms of logistics) are causing a revolution in business models that are based on physical scarcity, for example in industries such as music (music carriers), newspapers (printed news) and now also books, television and film. At the beginning of the century, iTunes cut out the middleman while also offering modularisation in smaller units (a single song rather than an entire album). Similarly, app stores are making it easier for small developers of apps to reach a global market with a niche product, quickly and without major investments. What does this much-discussed transition from an industrial to a knowledge-based economy imply for education? In his book 'Free', Chris Anderson says that the digital tracks of our habits and interests that we leave behind have become a form of currency for online services. Is that desirable in education?

From optimisation to transformation

As already mentioned, the optimisation of existing processes and tools is advancing rapidly in the world of education.

- We will soon no longer be printing countless copies of schoolbooks. (Adaptive) digital materials can be supplied easily, just-in-time and in customised form, and can be quickly updated with a new version that is immediately available to everyone. Some publishers already sell a teaching method at the start of a school year before it is even completed.
- It will soon be possible to distribute only those parts of digital materials that are necessary (modularisation), because of the rapid elimination of the complex logistics processes associated with physical materials.
- Students and teachers use various displays, from digital whiteboards in the classroom to tablets (now often with 'books behind glass') and smartphones, which provide access to an increasingly personalised online learning environment at school, in the home and on the move.

Is this optimisation of existing learning resources (books), existing processes (annual cohorts) and current forms of organisation (classes) really all that the digital era has to offer education? The transformation in education will come with the discovery of new methods of working in which digital whiteboards and personal devices are used to increase the flexibility of the organisation and support of the learning process. What is the ideal class size from the perspective of students, for example? Learning materials will use the dynamic, flexibility and Internet connectivity of digital whiteboards and devices to create a rich and diverse learning experience with the help of augmented and virtual reality. What is the best environment for different learning activities? How will we make effective use of our time, together and alone?

Introduction

The key to the transformation

The key to the (digital) transformation, however, lies in the possibility of using these digital materials and digital learning environments to differentiate in the learning paths of individual students. In this digitally supported teaching-learning community, a wealth of data about students and the context in which they learn can be measured, collected, analysed and reported on, all for the purpose of understanding and improving the learning process and the learning environment in far more detail than can be provided with just three reports a year and where all the students in a class follow the same learning path. It is not that our current education is bad or that schools are not performing well, but to train the creative workers that our knowledge-based economy requires, we need alternatives to standardised curricula and tests. What those alternatives are and how teachers and schools can use digitisation to improve education are in fact interesting and largely unanswered questions to which this trend report can also not provide the answers.

What we can do, however, is outline the aims of digitising the learning process:

- To respond to differences between individual students and so provide even more help in their development into independent, socially adept, responsible, cooperative members of society who are capable of critical thinking.
- To provide support for teachers in guiding the personal development of their students (using insights gained from data), particularly by giving them more time and space to apply their creativity and didactic skills in that
  process, for example by 'automating' language and arithmetic exercises.
- To reinvent 'the school' as an organisational concept and as a safe environment – with synergy between physical and online learning activities – in which students can learn without fear of making mistakes.

Scalable education

Another problem is the limited scalability (the student/teacher ratio) of the current education system and the growing demand for higher education in particular. In view of the high labour costs in education, it is essential to explore ways of increasing productivity, not by 'eliminating teachers through automation' but, above all, by enabling them to devote their capacities and their passion to those aspects where they are better able to make a unique contribution to the learning process than technology. We are happy to leave the boring, routine work and the administration to machines. But we must not shut our eyes to the many obstacles that have to be overcome, since the new dynamic of flexibility through digitisation also creates new concerns. This outline of the consequences of the digitisation of education looks ahead to a point on the horizon. It is intended to foster discussion about future scenarios and illuminate ideas about the choices that will have to be made. The digitisation train has left the station and will not be stopping, but there will still be many points along the way when choices have to be made about the direction to be taken.

Increasing the return

An important side-effect of learning in a digital environment is the ease with which formal records can be kept of the progress being made by individual students. With proper programming – using properly interconnected and compatible information systems – this can greatly reduce the administrative burden on teachers and schools. The information generated can also be used to improve the quality of education and achieve higher pass rates. Data about different classes and years can provide insight into aspects such as the effectiveness of teaching in materials and methods, their suitability for different students, the most effective use of staff and trends in the performance of students, teachers and the school in general over a longer period.

Hype Cycle for the digital learning process

The most important technologies discussed in this chapter are shown in the accompanying Hype Cycle, a concept developed by market research firm Gartner Research. The Hype Cycle maps the entire life cycle of a new technology from promising concept to accepted product. It gives a snapshot of the relative maturity of a technology and its future potential. The position of a trend – the risk profile – is determined by analysing the maturity, market adoption and available knowledge and research relating to that technology. Most of the technology used in the digital learning process is either still in the experimental phase or passing through the frustrating – but highly informative and therefore valuable – 'trough of disillusionment'. From practical experience, we learn the hard way (with the occasional poor investments or privacy-related incidents) how technology can be used, and more importantly what it cannot be used for, and the preconditions that have to be met for its effective use. Technologies such as digital testing and adaptive
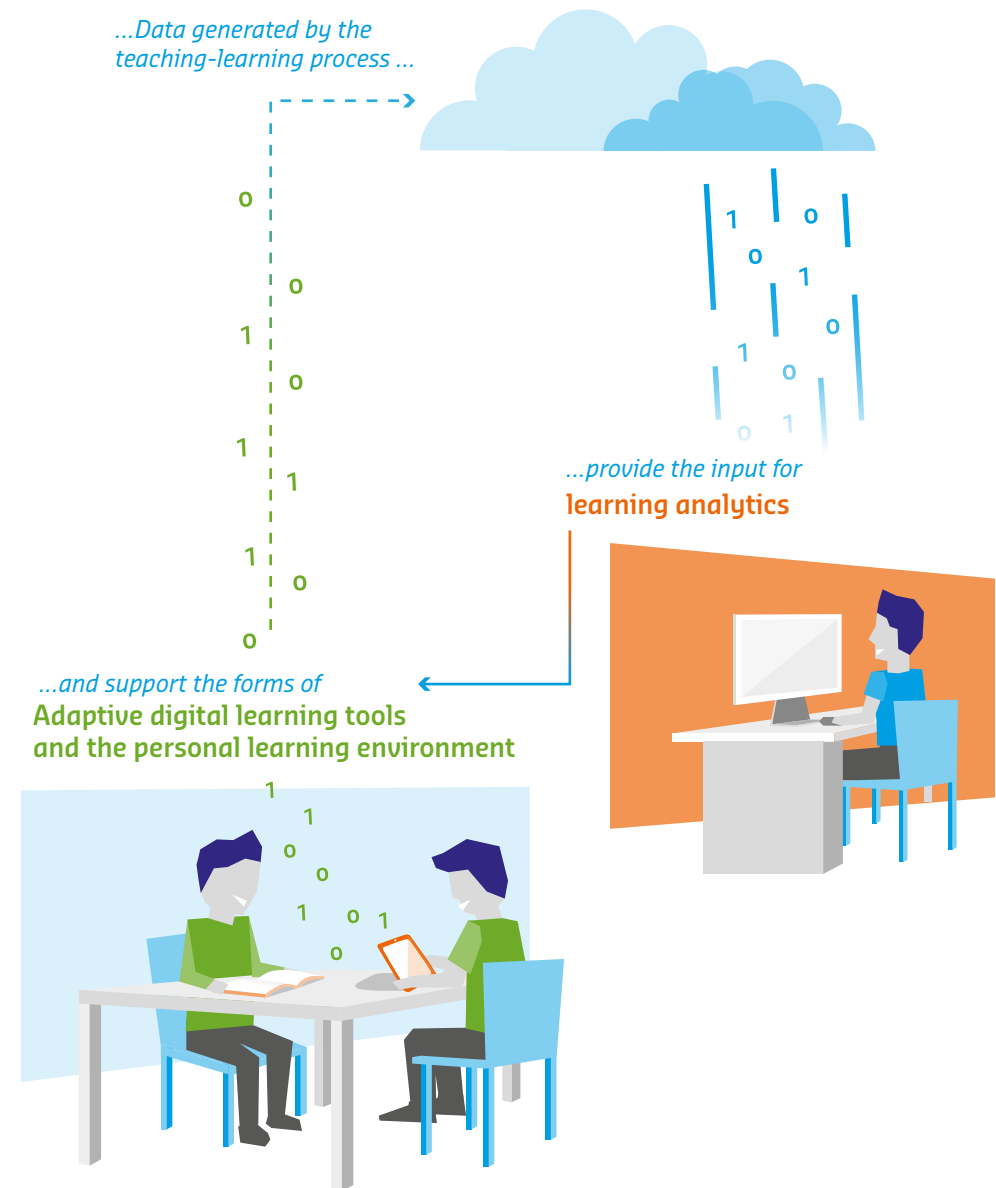
digital learning materials, which are still far from fully developed, are still disturbingly far removed from the safe stage of maturity. In short, they are not yet ready for large-scale application in mainstream education. Their experimental nature calls for consciously designed pilot projects with adequate safety nets to deal with problems. For the mandatory final exam in primary school, for example, Dutch schools can already opt for a digital, adaptive final exam – in addition to a written exam – even though the underlying technology is still in its infancy. There are risks, but the benefits – a more suitable advice on the stream a student should follow in secondary education – might justify the risks taken in pursuit of the ambition of clearly identifying the capacities of each individual student. However, an issue that needs to be borne in mind concerns the validity and comparability of test results between schools that make different choices in testing methods.
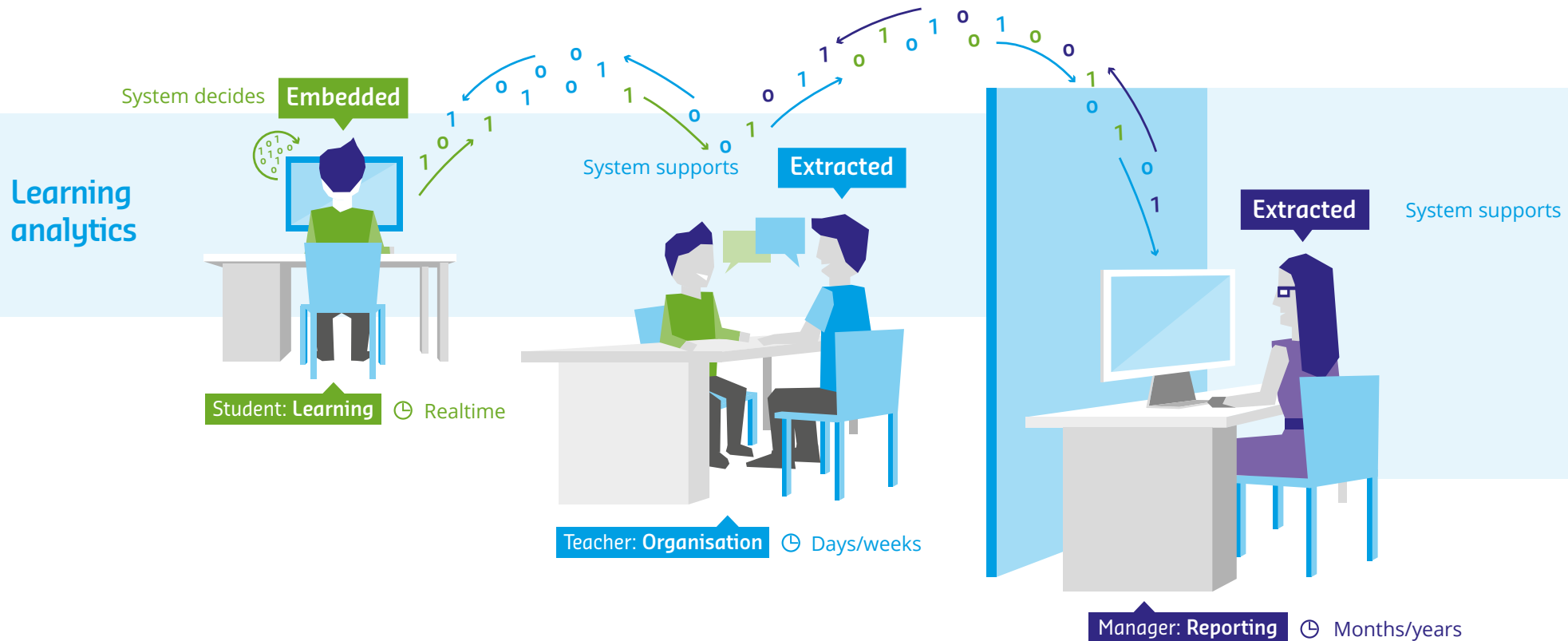

Introduction
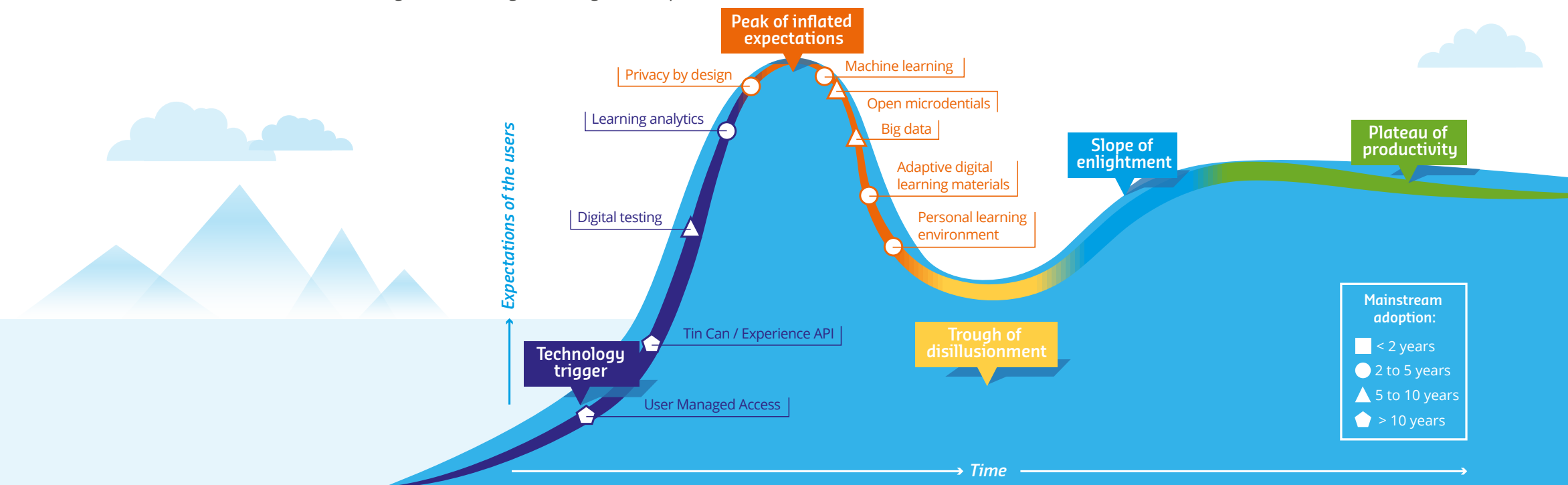
The risks associated with digital learning materials and the use of data and analytics are worth taking in view of benefits promised by differentiation and tailored learning. In this chapter we look at both the likely benefits and the threats. Terms used in this chapter that are more specifically related to education do not appear in instruments designed to analyse a technology such as the Hype Cycle. However, developments such as blended learning, digital portfolios, taxonomies, rubrics, peer-assessment and self-assessment are crucial building blocks for an effective digital learning process and are therefore certainly addressed here.

The fuel, engine and vehicles of digital education

In the following sections we describe the four closely related components that together make digital learning possible. We start with learning analytics (the analytic engine), which is fed by Big Data (the fuel). The following sections then cover adaptive digital learning materials and personal learning environments, which are the vehicles that use this engine in support of more differentiated education. We then investigate how a coherent set of components can help with the implementation of a vision of education, and the ensuing risks and mutual dependencies. The concluding section discusses the technology trends in relation to privacy and what guidance they provide for addressing the negative effects of digitisation. We also consider developments in regulation and how to address them.

...Data generated by the teaching-learning process ...

...provide the input for **learning analytics**

...and support the forms of **Adaptive digital learning tools and the personal learning environment**

Learning analytics

System decides — **Embedded** — System supports — **Extracted** — **Extracted** — System supports

Student: **Learning** — Realtime

Teacher: **Organisation** — Days/weeks

Manager: **Reporting** — Months/years

2.1 Big Data and learning analytics: the pathway to data-driven education

Although the term 'data-driven education' sounds impersonal and therefore raises objections, the concept has already been adopted on a large scale. Test scores are decisive for a student's transition from one year to the next, dictate his or her choice of secondary education and constitute the most important criterion in deciding whether or not to intervene in the learning process. However, tests are administered only infrequently, and at times when the students are highly stressed, which muddies the results. Moreover, the data they produce are often confined to straightforward, quantifiable aspects of learning.

However, the rapid digitisation of the organisation and support of the teaching-learning process potentially gives us access to an abundance of high-frequency data on a student's learning process and output. The use of digital learning materials, containing digital exercises and tests and offered in a digital learning and working environment, creates many opportunities for monitoring a student's progress. In an effective digital environment, information is easy to collect, categorise, analyse and share, resulting in a more complete picture of a student's progress and the background to any problems he or she may be experiencing. This development is known as learning analytics, or the use of Big Data (the large, rapidly expanding collections of varied data generated in the course of the digital learning process).

2.1 Data and learning analytics

Is measurement the key to knowledge with learning analytics?

The purpose of learning analytics is not merely to measure and describe what has happened, but more importantly to interpret and understand why it happened. By understanding that, it is ultimately possible to take positive action, for example to prevent students from dropping out of school or having to repeat a year. Teachers and parents have a more complete picture of the student's performance. The information enables the school and parents to conduct a dialogue in which the student's progress is seen in context. The purpose of technology is certainly not to marginalise the professional role of teachers, but it will certainly have a major impact on their role in the learning process. While technology supports the organisation and monitoring of the education process, for example by ensuring the planning, logistics, communication and information management proceed smoothly, the teacher can focus on the essentials of good education (preparing engaging classes, making connections, asking questions and encouraging and guiding individual learning processes). Technology helps teachers to perform their tasks and organise their work and supplies them with information about a student's progress from a variety of sources, just as a GP speaks to patients with an understanding of their medical history, the medicine they take and any recent health problems they have had. Technology helps every teacher to achieve their goal of respecting the differences between students by adopting a varied and differentiated approach in their teaching. At the same time, the use of data and analyses and recommendations based on them is unexplored territory. Research by the 'data teams' of the University of Twente has already identified some benefits, but has also shown that far more can be accomplished if teachers learn to use the technology more effectively.

Big Data, the fuel for improving quality

People who learn and work in a digital environment leave a data trail. There is nothing new about data in information systems. We already have enormous databases. So what is different about Big Data? It is a question of the volume (a lot of details about many different activities), the turnover rate (the information is very up-to-date) and the variety (the structure is less planned) of the data, as well as the amount of noise in the data and questions about their reliability. Every click in every digital learning tool and every action by any student in the digital learning environment leaves behind data about when they were online, for how long, where they were and the device they were using, the results of their actions, and much more.

Big Data therefore presents a very different challenge than the standard reports from mature information systems, where the context and significance of the data are, by definition, often clear and the data are of immediate practical use. With Big Data, the first challenge is to distill relevant information from the raw data. We have to take account of the context in which they were collected and filter out the noise. Which data are significant for the purpose of forming an impression of the learning process?

A number of steps are taken to increase the value of the data.

1. **Descriptive:** *what happened?*
   The emphasis here is on collecting and verifying the quality of the data that describe what has happened in the existing process. In other words, these are relatively traditional information management tasks.
2. **Diagnostic**: *why did it happen?*
   To interpret data and place them in the right scope and context, knowledge and understanding of the education process is required. Data help us to assess whether we are meeting out targets, for example by providing an explanation for the drop-out rate among a group of students. Are changes needed in the process, and if so, what changes?

3. Predictive: *what is going to happen?*

No one knows what indicators predict that students will fall behind in their studies or drop out of school. In this phase, new skills are needed that combine knowledge of the education process and the use of large collections of data. With these new possibilities we can predict the effects that different measures will have and use the findings to decide what we are going to do.
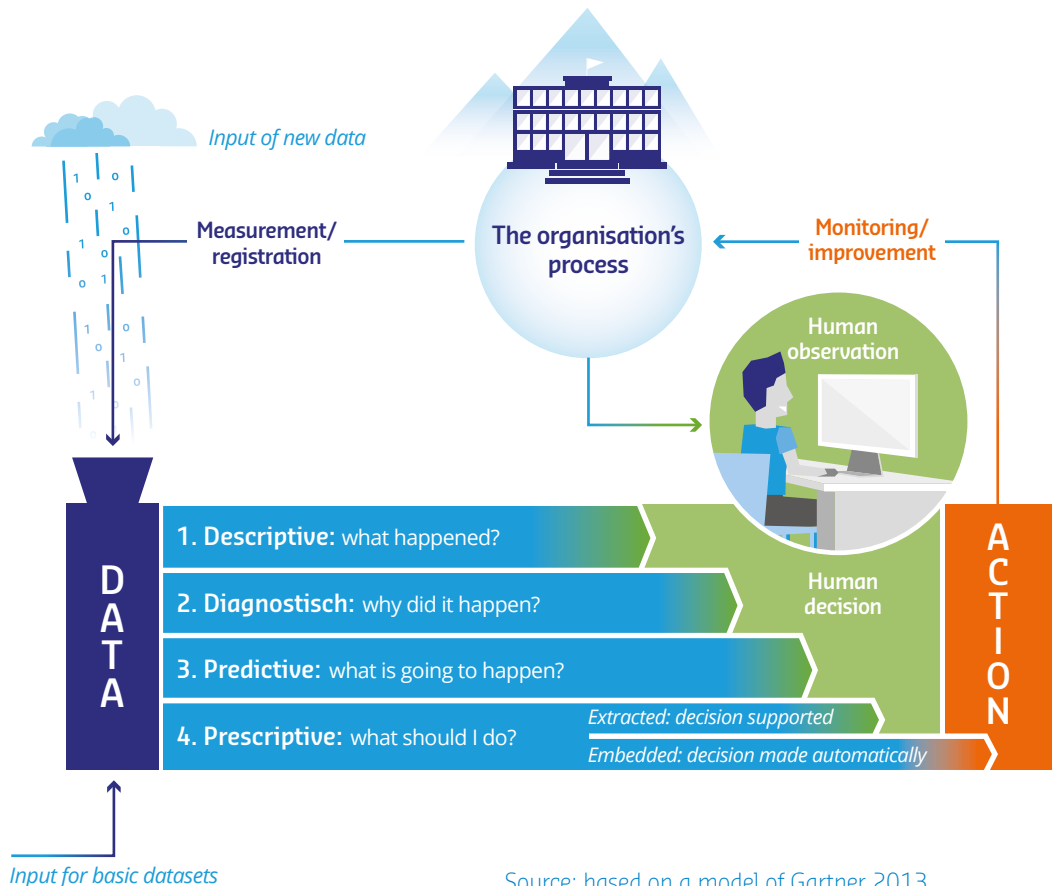
4. Prescriptive: *what should I do?*

In this step, we arrive at the best decision, which is underpinned by relevant data. This could be a recommendation that supports a particular decision or an automatic process that directly implements the 'calculated' decision. We will explain this distinction later with the terms 'embedded' and 'extracted' analytics.

The cycle concludes by consciously collecting specific information in step 1 that informs us about the effectiveness of the measure taken in step 4. Each successive step of the process involves more 'machine work' and less human intervention in analysis and decision-making. From the collection of data about the current situation, via diagnosis and prediction, to the support or even automatic making of decisions on the basis of predetermined rules. We will illustrate this latter aspect on the basis of adaptive digital learning materials in which this process is often used.

Smart followers in the application of technology

There are already developments occurring in sectors such as business and health care that the education sector could adopt as a 'smart follower'. For example, in those sectors data collection and quality assurance is organised centrally and efficiently, something that could be done at administrative level in the education sector. At the same time, this would leave more scope for schools to make their own analyses of specific issues, such as the match to local preparatory and secondary programmes. Market leaders like IBM,

Input of new data

Measurement/ registration

The organisation's process

Monitoring/ improvement

Human observation

D A T A

1. **Descriptive:** what happened?

2. **Diagnostisch:** why did it happen?

3. **Predictive:** what is going to happen?

4. **Prescriptive:** what should I do?

Human decision

A C T I O N

Extracted: decision supported

Embedded: decision made automatically

Input for basic datasets

Source: based on a model of Gartner 2013

Watson Analytics and Tableau offer cloud platforms that can be filled with data and operated without any technical expertise. These self-service platforms lower the threshold for using data and can be used on a trial basis free of charge. Naturally, knowledge of the education process and expertise in statistical analysis are still needed, and privacy and security aspects will need to be considered. But with these advanced tools, it is easy to experiment without having to make prior investments in technology or difficult choices (of products) about which an organisation does not yet know enough. In short, the barriers to using data are already significantly lower for the smart follower.

2.1 Data and learning analytics

Ascertaining the significance of data in the PDCA cycle

The first step in ascertaining the significance of the crude data is to ask the right questions. What information do students, teachers, school directors and administrators need to improve the quality of the individual learning process and the collective teaching-learning process? What do you need to assess whether the 'plan' is working, at micro level (student/parents), meso level (teacher/school director) and macro level (school board/the ministry)? Precisely because there is no predefined structure to Big Data, a carefully-formulated objective is required in order to determine which combinations of data are relevant. Once an initial answer has been distilled from the data, we can try to use the new insights to devise an intervention that will improve the process. The cycle then starts again by analysing the data collected from the revised process to determine whether the changes have had the desired effect. This type of process can relate to the supervision of a student's learning path or choice of profile for the later years of secondary education, for example. What performances in the initial years of secondary education are good indicators of success in a particular profile? What relationships between individual subjects stand out and how can students use them to make better choices in their learning path or profile?

A programme of quality improvement often takes the form of a so-called Plan-Do-Check-Act (PDCA) cycle, which is also widely used in education. Big Data can provide information for this process and facilitate repeated cycles of planning, implementation, reflection, intervention, etc.

Input big data

PLAN

DO

CHECK

ACT (pro-act/ re-act)

1. Make agreements (about standards), set objectives (say what you will do)

2. Implement, generate/collect information (do what you say you will)

3. Monitor, measure, feedback/ accountability (prove it)

4. Evaluate, adjust, intervene (improve it)

A PDCA cycle specifically tailored to education might involve the following.

- **Plan**
Together with the student and his/her parents, the teacher plots a learning path (the plan) with specific learning goals (the standards). The relevant question in the context of data and analytics might then be: is this still the best learning path for this student?

- **Do**
The student sets out on the chosen learning path. We observe and measure the student's progress during the learning process by actively collecting the data generated by the digital learning materials, exercises, tests and the learning environment and combining them with our own observations. The end result is an impression of the student's learning process.

- **Check**
The teacher evaluates the student's progress partly on the basis of the interpretation and analysis of the available data from the learning process, including test results. In the process, the teacher can provide the student with feedback that is backed up by the data.

- **Act**
The teacher (and student) carry out interventions on the basis of the conclusions from the analysis. This could, for example, involve revising the learning path to improve the match to the individual learning route and/or a new selection from the available learning materials.
'The system' can also do this automatically, as we will discuss later.

Data-supported education using learning analytics

Learning analytics is the process of measuring, collecting, analysing and reporting about data relating to the various day-to-day activities of students and teachers with the aim of improving the student's learning process and enhancing the quality of education provided by the institution on the basis of good 'data-driven' insights. There are two distinct forms of learning analytics that support differentiation in the learning process in different ways and at different levels:
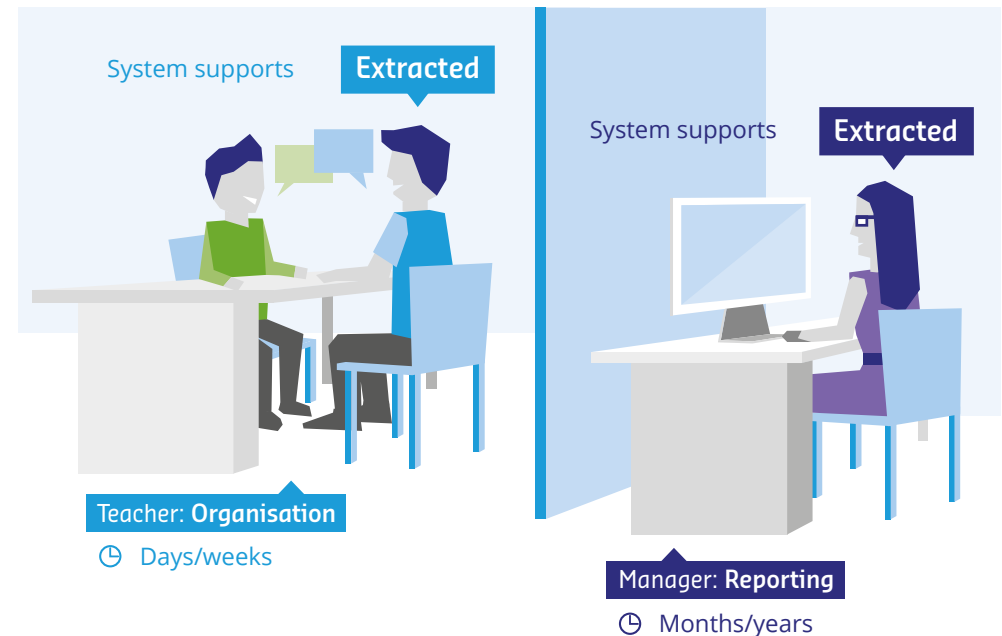
1. Embedded analytics

Embedded analytics are used in real time, as the student is actually learning. This form of analytics allows data from a learning activity to be used immediately to adapt exercises to the student's current proficiency in a particular subject. The technology controls the adaptive teaching material without any intervention by the teacher. For example, if a student is able to complete an assignment correctly and more quickly in an adaptive program, he or she will be given more difficult problems to solve. If a student makes repeated mistakes, remedial action will be taken and the student will receive further explanation of the subject matter, be given easier assignments or advised to ask the teacher for help. This form of independent learning by practice has been shown to work just as well or even better than classical methods and creates room for other, supplementary group activities.

System decides — Embedded

Student: **Learning**

Realtime
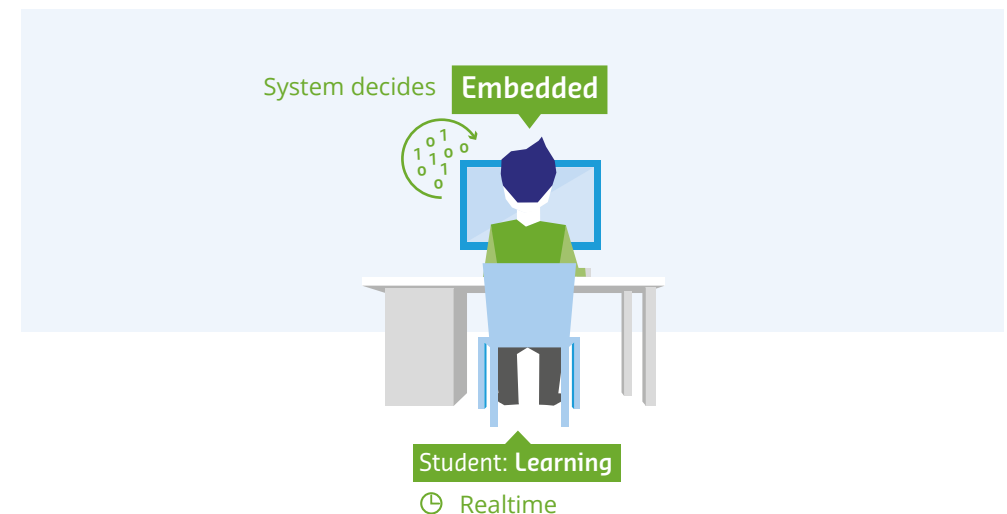
2. Extracted analytics

This comes into play after the learning activity has been completed. It is a more reflective tool, which helps teachers to monitor how a student or a class are progressing in a particular subject with a particular teaching method. Extracted analytics are not intended to influence the learning process directly. There is time to reflect and consider additional factors, whereupon the teacher can choose an appropriate intervention. At a higher level of abstraction, this approach also helps school directors and school boards to assess the performance of the educational institution as a whole (and any changes in the level of performance). This form of analytics is particularly helpful for evaluating processes and making recommendations for improvements. When it comes to real-time adjustment of the learning process of each individual student, teachers cannot compete with embedded analytics, moreover any incorrect decisions by the learning tool can be quickly identified and corrected. With extracted analytics, which focus on periodic decisions (decisions made every week or month), teachers are often able to devote the necessary attention to the individual. Periodic changes in the learning process have a greater impact, and hence also the importance of decisions and of involving additional, human observation in making them. Learning analytics is promising because it can make differentiation in education possible. By monitoring the learning process continuously, instead of testing progress at intervals as is customary at the moment, it is easier to spot problems in time and to predict how well a student will do or whether he or she might drop out of school. In addition, feedback on how learning materials are used and how effective they are will also help developers to improve the quality of their products. Accordingly, learning analytics can make an important contribution to improving the output of education in various respects, while also lightening the administrative burden.

System supports **Extracted**

Teacher: **Organisation**

🕐 Days/weeks

System supports **Extracted**

Manager: **Reporting**

🕐 Months/years

Information as a form of currency

There is nothing new about the collection and analysis of the digital tracks we leave. Every time we surf the Internet, communicate on social media or use free e-mail, agenda or other functions in the cloud, we leave a digital footprint with details of where we are, our movements and what we are doing via our smartphone. These raw data assume value from the recommendations that can be distilled from the record of our behaviour: 'You bought A and liked B, so maybe you would be interested in C?' Bol.com, wehkamp.nl and many other companies employ this model every day. Our profile represents valuable marketing information for them. The greater the volume of data that such organisations have collected and analysed about our behaviour, the more relevant the recommendations they make to us are. Google and Facebook also use our profiles to personalise their services. For example, Google 'predicts' what you will be searching for even as you type, simply on the basis of your previous

interests. We swap information about ourselves in return for the use of free platforms – information about our behaviour has become a form of currency. We will leave aside the interesting discussion about the stickier aspects of this situation for the moment, since they are discussed at length in the concluding section of this chapter on the subject of privacy. The question to be addressed now is: what can this trend teach us about the opportunities the digitisation of education will bring? There is a close relationship between the desire to offer a customer what he or she wants on the basis of an accurate profile and the ambition of providing tailored education for every student. That means we need to know more about him or her. The more accurate the profile, the more relevant the education we can offer and the closer it will match the needs of the individual. Obviously, it is essential to find the right balance. Students must still be allowed to assume their own responsibility. Excessive personalisation will also be at the expense of serendipity; after all, we learn most from what we don't expect and perhaps had not consciously chosen.

SWOT analysis big data and learning analytics

Strengths of the technology

1. Very frequent registration of the learning process
2. Supply of detailed management information
3. Facilitates interventions for individual students

Weaknesses of the technology

1. It is impossible to measure everything of value
2. Limited possibilities for data collection
3. Fragmentation of data storage

Opportunities for education

1. Lightens the administrative burden
2. Detailed insight into (learning) processes
3. Constant quality management

Threats for education

1. Privacy of students and teachers
2. Requires new knowledge and tasks for teachers
3. Technology is immature

SWOT analysis

Strengths Big Data in education facilitates the documentation and improvement of the individual's learning process. Learning analytics generates a wealth of management information and advice that enables schools to make interventions at different levels of abstraction (lesson, subject, course).

Weaknesses It is impossible to measure or capture all of the significant aspects of the quality and progress of the learning process in quantitative analyses. Some digital learning tools do not yet meet the demand for data on progress within the learning process. Furthermore, data are scattered among different locations and are not all of the same type, while information is not properly combined to create a better picture of the learning process.

Opportunities Big Data as a by-product of digitisation provide students, teachers, school directors and school boards insight into learning processes at an unprecedented level of detail. The simultaneous easing of the administrative burden and workload leaves teachers the time to use the management information to provide (individual) supervision and differentiation and to identify students who have problems or are at risk of dropping out of school at an early stage. School directors and school boards can take proactive measures to improve quality within their own organisation and elsewhere.

Threats Prudence is called for in view of the concerns about infringements of privacy arising from inappropriate use of data, while teachers lack the training and experience to interpret and use information on this scale in the day-to-day learning process. The market is still immature, which means it is difficult for schools or schools boards to make choices from the range of technically complex products. There is a lot of 'hype' surrounding this technology. The market is very aware of the value of data from the education process and schools must therefore be cautious in their dealings with market actors.

2.1 Data and learning analytics

Recommendations to the school board on the use of Big Data and learning analytics

1. Determine which data is helpful for guiding policy and strategy in education.

To be able to register, save and collect precisely the right data (data that are relevant), a school needs to be clear about the aspects of the learning process and its own organisation for which information is needed. What indicators provide insights that can support the implementation of its policy and strategy? The result achieved in other subjects? The nature of the preparatory education? Is it relevant how long a student takes to complete assignments? What data can we use to improve the student's learning process, the teacher's performance and the output of the educational institution? The market can only guess at the data that schools need; the education sector has to take the initiative and provide that information.

2. Create a complete picture of the relevant data at every level of administration.

The goal is to create a complete picture from all of the various sources of information. A dashboard for the student, teacher, school director, school board and minister, which clearly shows the situation as it is so that everyone can make considered decisions about the next steps to take, whether it concerns the next section of the mathematics textbook or a new education policy. The challenge is to compile a comprehensive picture from different subjects (and publishers/suppliers) and different aspects of the teaching-learning process. This imposes demands on the interoperability between systems and calls for standardised links, guided by a clear demand from the education sector. This insight must dictate how the education sector performs its role on the demand side of the market and in the selection and implementation of new or replacement digital tools and platforms.

3. Determine what (additional) data has to be collected.

Big Data and learning analytics call for conscious choices in whether or not to document or save data that is already (potentially) available as a by-product of digital works. What information should ideally be available to enable continuous improvements in education? To this end, explore what data is already available in existing systems and what additional information is available in the digital learning materials and systems of (cloud) suppliers. Then decide what data need to be actively collected and saved in order to identify the indicators that can guide the school and school board in pursuit of the goals they have set. This process will also clearly demonstrate the paradigm shift caused by the digitisation of education. By clearly ascertaining what data they require, schools become a critical, well-informed partner in the dialogue with the market about digital learning tools, teaching platforms and information systems.

4. Choose complementary information systems that can be easily linked.

To actually reduce the administrative burden and lay the foundations for maintaining oversight of learning processes with ICT, it must be clear what has to be registered, in which information system and for what reason (see recommendation 1). These information systems should be disjunct (each piece of data is recorded once) and interconnected (each piece of data is saved once), so that data are available in the context they are needed and for the individuals who need them (multiple use of data). Examples would be data about group structures, students' choice of profile and other data that are needed at different times and in different contexts. Repeated registration creates extra work and increases the chance of mistakes. Relevant data from the systems of suppliers (results from digital learning materials, for example) should be standardised and capable of being imported automatically into schools' systems. A genuine lightening of the administrative burden demands that functionality is properly compartmentalised (a single system for each task) and that interoperability of systems used within school boards and with other parties 'is standard practice.'

5.   Guarantee control over and access to (online) education data.
Data about the progress of students and how they use learning platforms, as well as administrative records, are all stored online in the suppliers' cloud platforms. These suppliers are very aware of the enormous commercial value of these data. The education sector must therefore impose demands on the availability of (being able to share) and access to (being able to transfer) these data. That is a precondition for the use and analysis of data about experiences with the learning process to provide adequate support for differentiation in education, which will also help to enhance the performance of students and so increase the completion rates in primary schools. In short, who controls the data from the systems used to monitor the teaching-learning process and the support needed in terms of learning analytics are important issues that will have to be discussed with suppliers in the coming years. In 2015, a covenant on privacy, including a model agreement on the processing of data, was concluded between the councils of the various education sectors and the trade associations of suppliers to regulate the effective documentation of agreements. This subject is discussed at greater length in section 2.5 on the subject of privacy.

2.1 Data en learning analytics

2.2 Adaptive digital learning materials

The first generation of digital learning materials often comprised 'books behind glass' or a book projected onto an electronic whiteboard. The objective with these learning materials is to make the learning process more appealing by using interactivity to reflect the world of the students. But the transformative qualities of digital learning materials – flexibility in their form, content and method – only really come into their own with the more recent development of adaptive digital learning materials. These tools provide a dynamic learning environment for students by applying insights about the learning process, derived from analyses of data relating to that process (embedded analytics) directly – in real time – as they learn. Consequently, the learning process is more efficient (time is saved) and more effective (results are better). Good adaptive learning materials keep students motivated and allow them to learn at their own level. They save teachers time in checking work and produce detailed analyses for each student. They have the additional benefit of producing large data sets very frequently, which is very useful for researchers. That was the original reason for starting Rekentuin, a well-known example of an adaptive exercise programme. Other examples of adaptive materials are Taalzee, Snappet, Bettermarks, JUMP and Got it?!

Adaptive digital learning materials consist of three elements:

1. Digital learning content

The content is broken down into small pieces of information devoted to a single learning activity and describing it in detail. The descriptions facilitate the link with a network of detailed learning objectives, so that within a particular learning pathway they can be adapted to the level and pace of learning, the interests and any other features of individual students, who can then learn and work independently according to their own specific needs.

2. Data about the learning process

This is a detailed data set – collected as the student is using the digital learning material – that provides a complete picture of how each individual student learns. The data set contains a record of the student's learning process, the results of exercises carried out while using the material (formative testing) and of tests of the student's command of a subject (summative testing). Insights gained from data about other students can also be used to determine the most effective follow-up steps for each individual student.

3. Processes and algorithms

This refers to the procedures and rules that should be followed in analysing the data about the learning process. The analysis identifies the individual student's learning needs so that the learning process can be adjusted dynamically. In other words, adaptivity is created. The system itself can also learn about the effectiveness and correctness of the rules that are followed and recommend or implement modifications.

Adaptive digital learning materials call for integration of the content of lessons, learning objectives, data collection, data analysis and well-designed software into a complete teaching-learning process. The question is how can schools and suppliers accomplish that?

Some examples of digital learning materials can be found – clearly arranged – in the GEU publication 'Onderwijs vernieuwen, Samen aan de slag'. A number of organisations also offer interesting (adaptive) digital learning solutions, such as Oefenweb, Snappet, Dedact and Muiswerk.

2.2.1 PDCA cycle applied to digital learning materials

The process of implementing adaptive digital learning materials follows the Plan-Do-Check-Act cycle, which is familiar in the education sector.

- **Plan: determine the learning path**

An immediate start can be made on the basis of the known characteristics of the students. It is not necessary to produce a detailed profile in advance because the learning environment quickly adapts to the actual learning process, so the 'plan' is constantly being adjusted according to the findings from the learning process.

- **Do: learning through practice**

The data (the fuel) for the 'embedded' learning analytics (the engine) is derived from the students' interaction with the adaptive learning materials. A good example is the length of time it takes a student to complete an assignment. What strategy did he use to find the solution? Is the answer correct or incorrect? Did he find the assignment easy or difficult? The system can determine the last point objectively by analysing the results of other students who performed the same assignment and data about their level of ability. All of the data from the teaching-learning process is collected and saved, at present usually in the supplier's environment.

- **Check: testing with assignments**

In regular teaching materials, testing is usually a separate process that takes place after a subject has been covered in full. With adaptive materials, students are constantly practising and their mastery of a subject is being continuously tested. Every exercise, arranged by subject and degree of difficulty, is considered in determining the student's current level, which is therefore apparent to the student and the teacher at any time.

- **Act: data-analysis**

After every action by the student the system can make an analysis on the basis of the available data and determine the appropriate intervention. Adaptive learning materials. make this analysis in real time and automatically carry out the appropriate intervention by making the assignment harder or easier, giving the student a different type of assignment or providing remedial instruction, perhaps by advising him to seek advice from someone with a deeper knowledge of the subject. When the student resumes working with the material, the cycle is repeated.
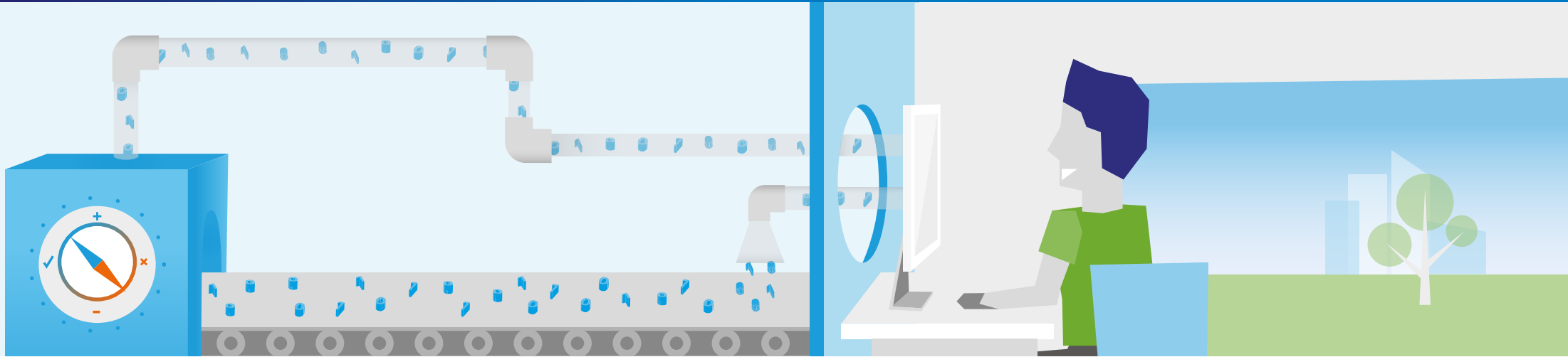
2.2.2 Who programmes the 'machine'?

The rules followed by the system in performing the analyses are further developed by researchers in fields such as psychological methodology and by the developers of digital systems, who analyse the large volume of data in the system about the learning experiences of former students at a higher level of abstraction than the individual student in order to learn more about the most effective learning strategies. The next step in this process, which is still in the research phase, will be 'machine learning', where the system itself revises the rules on the basis of its own analysis of the data. The American adaptive learning platform Knewton already uses this method. It is always important to bear in mind that self-learning machines operate on the basis of frameworks and rules conceived by humans. It is our responsibility to ensure that decisions made 'automatically' are 'fair' and are made on the basis of data that do not discriminate. In short, the machine should have a moral compass and use it in making decisions about students and their future. However abstract and remote this might appear, particularly in relation to education it is important to formulate such frameworks. This novel issue of 'digital ethics' is discussed in more detail later in this report in the context of developments relating to robotics.

Critical reflection on the correctness and effectiveness of the rules and principles that are adopted has already had an impact on 'traditional' learning materials. Big Data and learning analytics can help in determining the effectiveness of a particular method for different groups of students. It will then be possible to make specific changes to the structure and content of a method and the criteria for classification of students by level for different target groups, which is now done 'manually', all on the basis of data from actual learning situations. It is certainly not the purpose of adaptivity to offer individual students only what they would prefer to do or what suits them best. Education innovator Gert Biesta expressed it as follows: 'The question is what this specific individual needs in order to develop in the desired way for the purpose of finding good work and being a good member of society.' We may perhaps never be able to instil this wisdom in a machine, which means it is an important task and responsibility of the developers and users (students and teachers) of 'the machine'.

2.2.3 Is testing still necessary?

If adaptive digital learning tools continuously provide information about a student's performances and mastery of a subject, what is the point of testing? To answer this question properly, it is useful to distinguish between two types of testing:

1. **Formative** testing is specifically designed to support the learning process. This type of testing provides the feedback that informs the student and the teacher of the knowledge or understanding the student is lacking.
2. **Summative** testing is used to assess the progress being made by students and includes tests given on completion of a particular subject and tests or exams to measure a student's proficiency or to determine whether he has passed or failed in a subject.
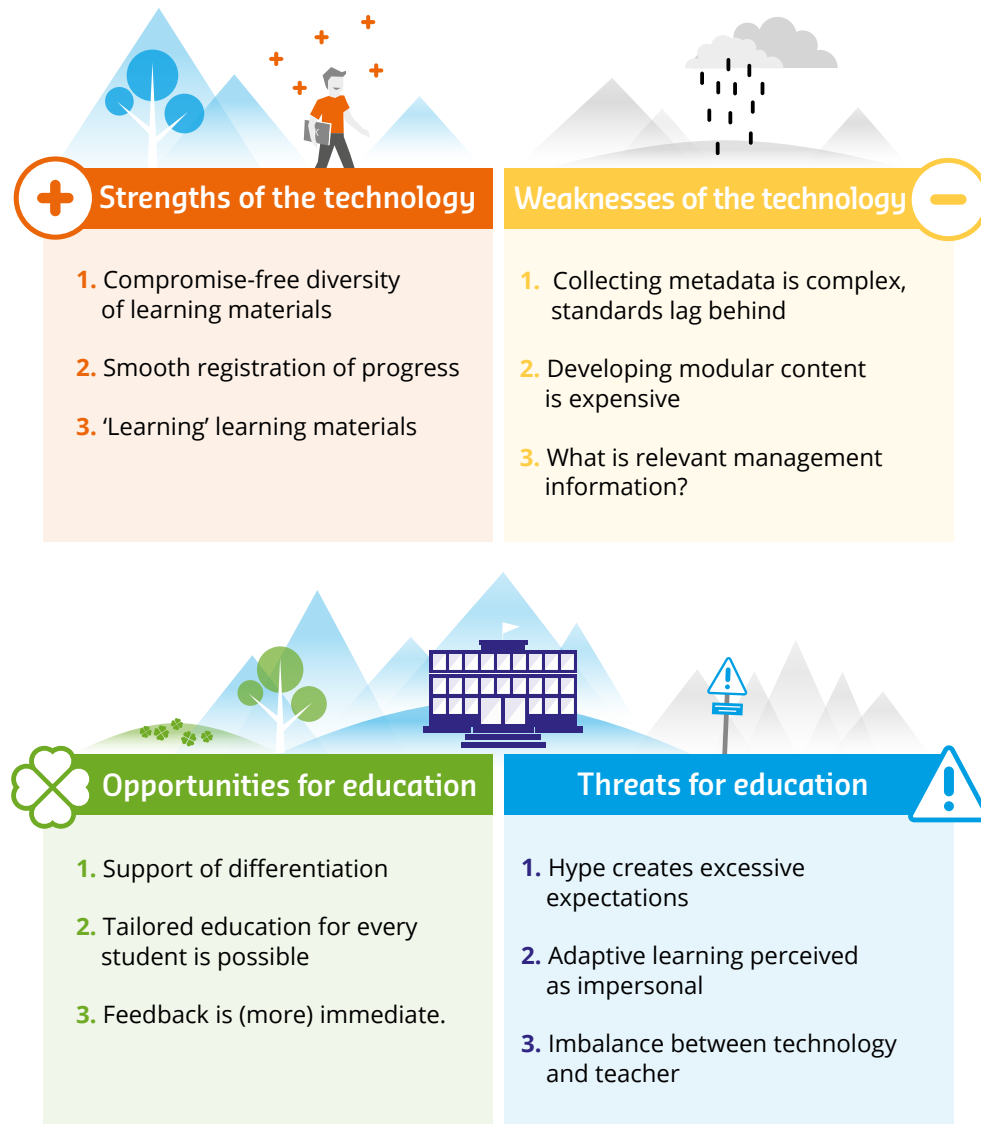
It is immediately apparent from this distinction that adaptive digital learning materials are constantly applying formative testing based on the nature of the learning material. Adaptivity is impossible without formative testing, which tends to blur the boundaries between learning and testing. Formative testing does not automatically replace summative testing, partly because there are national and international standards that have to be met, but we must keep on asking ourselves what summative testing adds to the picture we have of a student's development. After all, we will soon be able to follow the student's development over the years from his or her personal dashboard in the adaptive learning tool. This is an important aspect of the discussion in the teaching profession about the consequences of digitisation for testing and the effective organisation of teaching-learning processes.
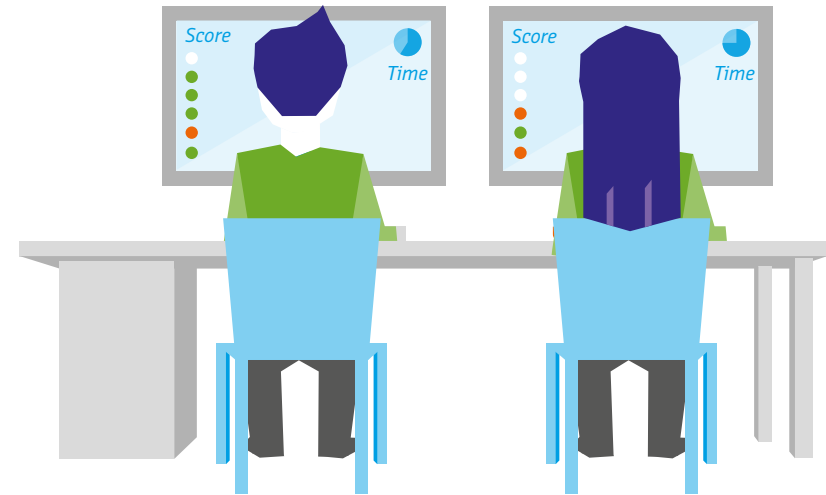
Digital (adaptive) testing

Digital testing is also on the increase outside the domain of (adaptive) digital learning materials, principally in the form of formative testing in existing methods such as Ambrasoft, Muiswerk, JUMP or Got it?!. An important trend is the move from 'testing of learning' to 'testing for learning,' where digital testing software is increasingly used as a method of activating students with the help of programs such as Kahoot or Socrative (although these programs are still oriented towards the classroom). The benefits of this form of testing match those offered by adaptive learning materials: students receive immediate and specific feedback, which motivates them to focus on areas that require improvement and reduces the amount of checking the teacher has to do. Digital testing has also paved the way for another development in the use of embedded analytics: adaptive testing. In an adaptive test, whether an answer is correct or incorrect determines what item will appear next. Here too the benefits match those of adaptive learning materials: the pace of learning and the difficulty of the assignments are geared to the individual student and the test scores and reports are available immediately.

SWOT analysis adaptive digital learning materials

Strengths of the technology

1. Compromise-free diversity of learning materials
2. Smooth registration of progress
3. 'Learning' learning materials

Weaknesses of the technology

1. Collecting metadata is complex, standards lag behind
2. Developing modular content is expensive
3. What is relevant management information?

Opportunities for education

1. Support of differentiation
2. Tailored education for every student is possible
3. Feedback is (more) immediate.

Threats for education

1. Hype creates excessive expectations
2. Adaptive learning perceived as impersonal
3. Imbalance between technology and teacher

SWOT analysis

Strengths Differentiation within digital learning materials can be developed without compromising on its suitability for the majority of the group. The student's progress in the learning process is registered as a function of the system's adaptivity, thus reducing the administrative burden. The materials 'learn' about the level of difficulty and effectiveness of the content from the experiences of students and can calibrate themselves more closely to each student's needs.

Weaknesses Generating metadata for (adaptive) digital learning materials, which are themselves still evolving, is a complex and labour-intensive process. It is difficult for the developers of standards to keep up with the rapid pace of innovation and so ensure that materials can be used on different platforms. It is still not clear what datasets give a good impression of the progress a student is making in his or her learning process. Consequently, work is still proceeding on the development of the building blocks of adaptivity.

Opportunities Adaptive learning materials can offer every student a learning experience that matches his or her level of knowledge, pace of learning and interests, which increases their motivation and enhances the effectiveness of the learning process. With digital materials, students can also work independently outside school and teachers can keep track of the progress of the group and differences within the group. They then have more time to provide specific support and plan specific interventions for students who need them. The student and his or her parents can be kept informed of the student's progress and results. This direct and regular feedback enhances the quality of the learning process and the student's performance (as well as the dialogue about these subjects).

2.2 Adaptive digital learning materials

⚠ **Threats** The initially inflated expectations for adaptive technology are beyond what the current products can deliver and the technology is rapidly approaching 'the trough of disillusionment' in the Hype Cycle. The potential opportunities need to be carefully explored. The idea of working alone with adaptive learning materials evokes the image of an impersonal learning situation, which could distract attention from the added value and the perspective in which these tools should actually be seen. The threat to the current role and job definition of the teacher often renders any discussion mute, even though the appropriate use of digital materials and its consequences in the classroom and the school should actually be the subject of a lively debate.

Recommendations to the school board on the use of adaptive digital learning materials

1. **Determine the positioning of the materials in the day-to-day teaching-learning process with the teaching team.**
Working independently with adaptive digital learning materials will have a major impact on the everyday learning environment. The correct use and role of these materials and the weight to be assigned the data derived from them in the learning process must be determined in consultation with the teaching team. The effective use of digital learning materials saves time that can be used to provide individual guidance and to profit fully from the insights that detailed records of the learning process can offer. The aim of the discussion should be to strike the right balance between the use of data and analysis, on the one hand, and human observation and didactic skills, on the other.

2. **Conduct limited, small-scale experiments in a market that is still rapidly evolving.**
A feature of the current market for digital learning materials is the wide diversity of views and strategies in relation to adaptivity and the use of data in the learning process. The products range from specific solutions for a single school subject, topic or target group to generic platforms designed to offer adaptivity for every school subject. The first step in this regard should be to consciously experiment on a small scale, since the market is still too unsettled to embark responsibly on broad implementation. Because the impact on the learning process has also not yet become clear enough to fully gauge the consequences for the organisation, experiments will give teachers the opportunity to gain the necessary knowledge and experience.

3. **Specify requirements for the selection of (adaptive) digital learning materials.**
The school and its students must have easy access to records of the learning process, compiled at the right level of abstraction (not too detailed, but providing sufficient insight), without having to perform any additional (manual) work. Only then will the school benefit from the possibilities afforded by (adaptive) digital learning materials. It should be possible to link the tools to existing administrative systems, in order to register past results for example, and the new learning materials must use data that are already available elsewhere, such as the class a student is in and his or her choice of subjects and profile. These are essential criteria for lightening the administrative burden and facilitating a differentiated approach when selecting new digital learning materials.
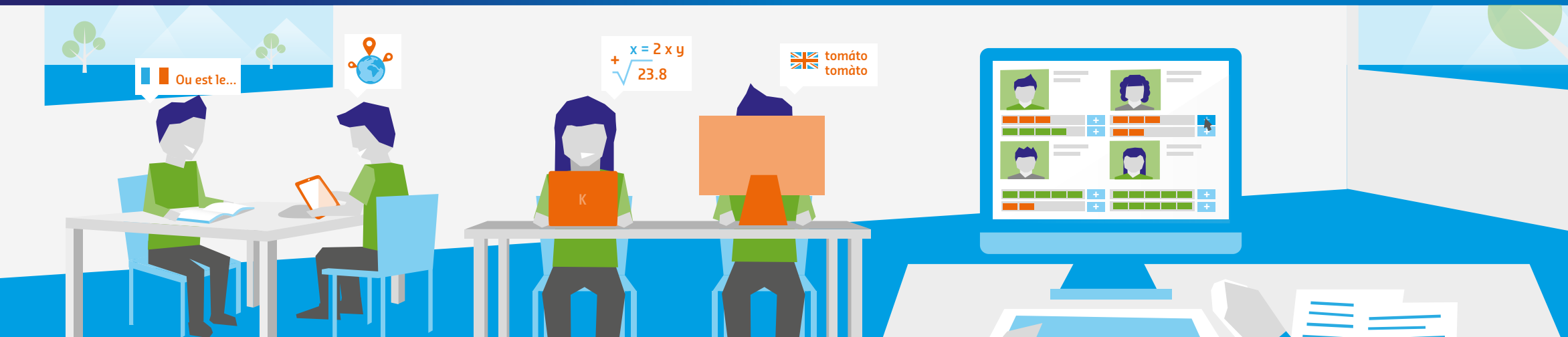
2.3 The personal learning environment

Learning does not start or end at the school gate. With the digitisation of learning tools and the learning environment, learning is becoming less dependent on a particular time and place. The physical and virtual learning environments therefore have to be brought together to form a coherent whole (blended learning). In the context of the digital learning process, this raises the question of what is the appropriate digital learning environment?

Clearly, the teaching itself, with the ambition of offering students a more personalised approach, guides the measures to be taken in pursuit of the flexibility that digitisation offers. The students themselves, naturally depending on their age and degree of self-reliance, should also assume greater responsibility for their own learning process and, with guidance, become capable of self-study. This implies that a diverse range of tools will be needed, but also that students should have a choice in the tools they use, especially in view of the range of convenient digital tools that are available for communicating and collaborating with each other and the wealth of useful, but unstructured, information

available online.

In 2012, the NMC Horizon Project introduced the concept of the 'personal learning environment' (PLE), which describes how learning comes together in a virtual environment that is personal to every student. The PLE is not a single product that can be purchased off the shelf, but a collection of digital tools that a student (or teacher) assembles on his own to optimise his path through instruction or work. The collection consists of formal (organised by the school) and informal (self-selected) components. This trend is already evident in schools. What are the distinctive characteristics of a personal learning environment and what are its components?

From schoolbag to personal learning environment

You could think of the personal learning environment as the digital equivalent of the old-fashioned schoolbag, but whose contents can be used regardless of time or place. The 'traditional' schoolbag contains learning materials provided by the school, but also diaries, exercise books and writing materials bought by the student. The new schoolbag (the personalised learning environment), which can also be accessed by the teachers, contains a digital version of those

items, but goes a good deal further by also connecting students and teachers during their daily activities. The precise contents will vary depending on the school's educational concept.

Mix of formal and informal components

To learn and perform to the best of their abilities students need a mix of tools, some provided by the school and others self-chosen. Many existing digital systems that support the learning process try to be all-in-one systems, offering a combination of administrative and portfolio functions, links to learning tools, etc. But in light of the divergence in the learning paths of individual students that is likely to ensue from a tailored approach, such a total solution seems needlessly restrictive. Students need greater freedom of choice from the variety of products available than a closed total solution can offer to meet their individual needs. Innovative schools, for example within Pleion (Platform Eigentijds Onderwijs), want to be able to use a flexible collection of digital tools that work well together and share information. The collection certainly still includes formal systems with which the school safeguards its processes and handles the necessary administration, but in addition teachers and students will use a constantly upgraded selection of informal apps and web platforms (which are not fully controlled by the school) in the learning process.

Apart from the question of efficiency (how do we design the ICT system?) raised by the cloud model (see the chapter on ICT essentials), the main question here is which functional components of the personal learning environment the school has to guarantee (what will we provide?). Given their purpose, function and importance, for which components do we need to apply safeguards and hence restrict freedom of choice? And where can students and teachers be given freedom of choice? With a deliberately assembled combination of formal and informal tools and platforms, a school can leave that discretion and therefore increase flexibility. In addition to cost savings, the freedom of choice also promotes creativity, initiative and innovation within institutions. Introducing new functionality in existing formal environments (integration of all functions) and innovation in the informal domain (introduction of new functions) will force institutions to consciously consider the decisions they make regarding changes in the mix of supported systems.

Freedom of choice within limits

Total control is an illusion in the concept of the personal learning environment. Students and teachers will engage in 'app snacking' to meet their functional needs. However, allowing freedom of choice is not the same as not adopting any rules at all. How can a school meet its responsibilities? The following preconditions will contribute to the creation of an effective personal learning environment:

- Enable easy access to (preferred) cloud platforms with the institution's familiar log-in account. Cooperation and communication are more effective on a jointly used platform (the network effect).
- Ensure that stored data and products from 'informal' components (self-made learning materials, for example) are also migrated if you change supplier. Help teachers to do this.
- Make agreements on the documentation of proof of results and products in the various platforms. Blogs, online videos and other results will in future constitute a distributed portfolio for students, but the results and assessments must also be formally documented in the administrative records. Make explicit agreements with the teaching team about the channels to be used for formal communication, taking into account where it will attract the attention of students.

2.3 Personal learning environment

2.3.1 The digital learning and working environment (DLWE)

The first important building block of the personal learning environment is the digital learning and working environment (DLWE). Cloud office, an example of a public cloud platform, forms the basis of the DLWE. Office 365 and Google Apps are varied environments in which diaries and documents can be shared, but which also provide options for audio communication or video conferencing. Students and teachers will supplement their DLWE with informal components such as:

- communication tools, such as messaging (WhatsApp, Snapchat or Skype) and social media (Twitter, Facebook) or platforms designed to facilitate group processes (Socrative or Classdojo);
- tools to increase productivity, such as digital notebooks (Onenote or Evernote) or to-do lists and reminders (Remember the Milk, Google Keep, Clear or Any.Do);
- collaborative tools that support the organisation of a team (Trello or Slack) and with which teachers can informally monitor the progress of their teams.

Based in the cloud, these functional building blocks can be used on every device independently of time and location, while all of the information can be shared quickly and easily with other students or teachers. As we write, students are in fact probably already switching to newer platforms and apps.

This dynamic is the primary characteristic of the informal part of the DLWE, and in the other components of the personal learning environment. The personal learning environment also includes formal applications established by the educational institution – such as ParnasSys (primary schools) or Magister (secondary and vocational schools) – as important components of the administrative system. By properly integrating these components with the informal components in the personal learning environment, the communication (using messaging and social media) is more effective, the organisation is more flexible (the use of information about groups and profile choices) and mutual use of available information about the progress being made by students is enabled.

Use of data in the digital learning and working environment

The term 'personal' relates not only to the possibility of making one's own choices. The personal learning environment is all about trying to help the student as well as possible, for example with relevant information about the learning process or up-to-date learning materials or sources of information. The data collected, mainly from the informal components of the personal learning environment, for the purposes of communication and collaboration, can also provide an interesting impression of the dynamic within groups, the functioning and productivity of teams, thus providing clues for interventions that would improve a team's performance. The platforms in the personal learning environment use these data to provide tips to students, but teachers can also use the insights gained to assess the progress being made by students in terms of communication, collaboration and the skills needed in the 21st century. There is also an obvious contradiction: how do you collect that information from informal platforms unless the school manages them? What is in any case not the solution is for the institution to offer an alternative formal platform and expect students to use it and so allow themselves to be observed more closely.

2.3.2 Planning system, dashboard and portfolio

To monitor the progress of individual students, their learning paths need to be documented in a planning system. In the classical education model the number of different learning paths was overseeable. To be able to offer students appropriate individual paths, a system is needed in which teachers or coaches can keep a record of the learning path that has been chosen with the student. The National Institute for Curriculum Development (SLO) is currently engaged in formulating national standard learning objectives, on the basis of which continuous learning paths can be planned regardless of the specific methods or teaching materials that are used. An administrative or portfolio function will then be needed to register the student's results. These two components will give both students and teachers an overview of where they stand (How far have I got? What I will do next?) and the progress they are making (Am I on course? Are interventions needed? Should changes be made in my learning path?).

The need for something like a dashboard has emerged from the insight that a tailored approach for each student inevitably leads to great diversity in the pace and sequence of the individual learning paths. The variety of new learning tools is also expanding with the use of apps and open teaching materials, as well as some aspects of teaching methods. As a result, the sources of information about a student's progress are fragmented. How do you, as the supervisor of the learning process, collect all the relevant information to respond to a student's needs or to make timely interventions? The purpose of the dashboard is to ensure you can maintain an overview of an increasingly divergent group of students, each of whom is following his or her own learning path with an increasingly diverse collection of learning tools.

The records of results will be formal in nature, because they must of course be reliable and fraud-proof. In this new context, a portfolio function would ideally facilitate feedback to students on each other's results, which is a very valuable and effective aspect of the learning process. Peerscholar is an example of a platform that helps teachers in allocating assignments and organising peer- and self-assessment among students.

Insight in the portfolio with (open) micro credentials

Blogs, YouTube video channels and other online publication platforms in the cloud will assume an increasingly important role in the student's portfolio. How can teachers validate their performance and keep track of the work that is submitted on different platforms? One option is to follow the example of open

2.3 Personal learning environment

online learning environments like the Khan Academy, which use 'micro credentials', or digital certificates or 'badges'. The badge infrastructure itself keeps a record of the results attained by each student and where the relevant product can be found. In the Netherlands, the SLO is developing Rubrics, an analytical scale with which teachers will be able to assess the level of a student's skills in areas such as communicating, acquiring, processing and presenting information, cooperation, planning and organisation and to use the findings to provide more specific feedback. The Mozilla Open Badge Infrastructure is an environment that can be used independently and has been adopted by numerous established and innovative parties in the education sector. These recent developments form a fantastic bridge between informal learning environments and formal registration of results.

Dashboard: the notification centre for teachers and students?

Our smartphone contains a large collection of apps that contain information about various aspects of our private and working lives. The notification centre on the phone collects and displays all the relevant (personally selected) and up-to-date information from the various apps. It sends an 'alarm' when prompt action is required, and displays lists of appointments and traffic warnings, for example, without the need to open each separate app. Every notification allows you to drill down to the specific app for more detailed information. Similarly, a dashboard can provide an overview of warnings being sent from the fragmented landscape of digital tools that support the learning process. It can alert students and teachers to developments that demand immediate attention.

Use of data in the planning system, dashboard and portfolio

The planning and dashboard components of the personal learning environment collect a growing volume of records of earlier successful choices and appropriate alternatives to them. These findings from the experiences in previous years and

cohorts help to make the right choices for new students. They also create a valuable foundation of objective (statistical) information about the return on the choices that have been made, at both individual and institutional level. One aspect that requires special attention in this context is continuity in collecting the data, especially when the mix of components in the personal learning environment is changing. We will see later that new standards could provide solutions for this. With the help of data, the dashboard itself will also assume a dynamic character, acquiring the ability to learn what information is relevant, which signals will receive attention and what action will be undertaken. In other words, the dashboard will not just be a smarter adviser, but if necessary will also be able to act autonomously in response to specific signals and evaluate what interventions have proved most effective, using machine learning (the software learns from the data).

2.3.3 Digital (online) learning materials and resources

To acquire knowledge and skills as they proceed along the learning path laid out for them, students use learning tools and sources of information. The planning component of the personal learning environment will make suggestions, based on the agreed learning path (and the national standard learning objectives), for tools that have been shown to be effective for students with the same profile. In addition to the formal methods chosen by the school, students will also use additional informal resources that they find on Internet, such as Wikipedia, blogs and online video platforms such as YouTube. These Open Educational Resources (OER) come from their own teacher or from teachers outside the school. The material will be sometimes be structured, such as the Massive Online Open Courses (MOOCs) given by the Khan Academy, but more often they will be individual sources that supplement the formal learning materials.

Use of data in the choice of learning materials and resources

We discussed (adaptive) digital learning materials and digital testing at length earlier in this chapter. In the context of the personal learning environment, we can therefore skim over the role of data in learning tools. Apart from adaptivity and detailed information about the progress being made by students, the planning and dashboard components of the personal learning environment also show how the various learning tools are actually used in practice. Provided the various components of the personal learning environment are compatible, we also know how often the different tools are used, their effectiveness in general and the profile of the students who learn most effectively with each tool.

Consequently, the components of the personal learning environment can steadily improve the match between learning tools and forms of work and the needs of an individual student on the basis of that student's profile, planned learning path and earlier results. This is a version of the model of 'You bought A, other clients that enjoyed A also bought and enjoyed B' that we mentioned earlier. The personal learning environment will become a sort of app store with reviews of learning tools from a diverse population of students. An adaptive learning environment, in other words, but at a higher level of abstraction. Naturally, the crux lies in the capacity of the components of the personal learning environment to exchange data and so facilitate these insights. Is this actually feasible in a personal learning environment composed of a variety of tools, and if so how?

Sharing learning experiences between components of the personal learning environment

This is the Achilles' heel of the personal learning environment. Schools therefore often opt for closed, fully integrated platforms, but they lack the necessary flexibility in terms of freedom of choice of learning resources. Is it possible to create a system of mixed, self-selected and properly integrated solutions? The Experience API (xAPI) is an e-learning software standard that enables learning tools and learning platforms to share information about learning experiences. Information is stored in Learning Record Stores (LRS), standardised but highly flexible records of learning experiences that provide more insight than results alone. The records can be saved in traditional learning platforms, but also in separate registration systems, controlled by school boards for example, which can be accessed with the platforms used by the board. This localisation of the storage of data about students is also an effective means of implementing and monitoring compliance with privacy guidelines. A recent initiative with similar ambitions is the IMS Global Learning Consortium's Caliper Analytics. The UWLR standard (for exchanging data about students and their results) was recently

adopted in the Netherlands and the major market parties have promised to implement it. The outlook is bright, therefore, but these developments are at an early stage and there are still many obstacles to overcome.

PDCA cycle applied to the personal learning environment

The process of (automatically) adapting the individual learning path of students follows the same steps in the Plan-Do-Check-Act (PDCA) cycle as the process outlined earlier for adaptive digital learning tools.

- **Plan: determine the personal learning path**

In consultation with the students, the teacher or coach determines a personal learning path for each student. The students can then follow their personal plan independently. Their activities and the results of tests in the digital environment are registered, so the teacher and the student have a clear picture of the situation at any given time and can use the information to adjust the learning path.

- **Do: learning with (adaptive) learning materials**

In the personal learning environment the students have a set of learning resources tailored to their learning path, the progress they have made and their profile. The progress they make provides input for the learning environment: does the student need alternative or additional tools? Does the student need help or advice from a teacher (on a particular subject) or a coach (planning of studying in general)?

- **Check: registration of (test) data and portfolio (results)**

The results attained by students are classified and documented using taxonomies, rubrics and micro-credentials. Products are incorporated in the (distributed) portfolio. A wealth of data about the teaching-learning process can be collected within the personal learning environment, making it easier to assess the results of individual students in a proper context.
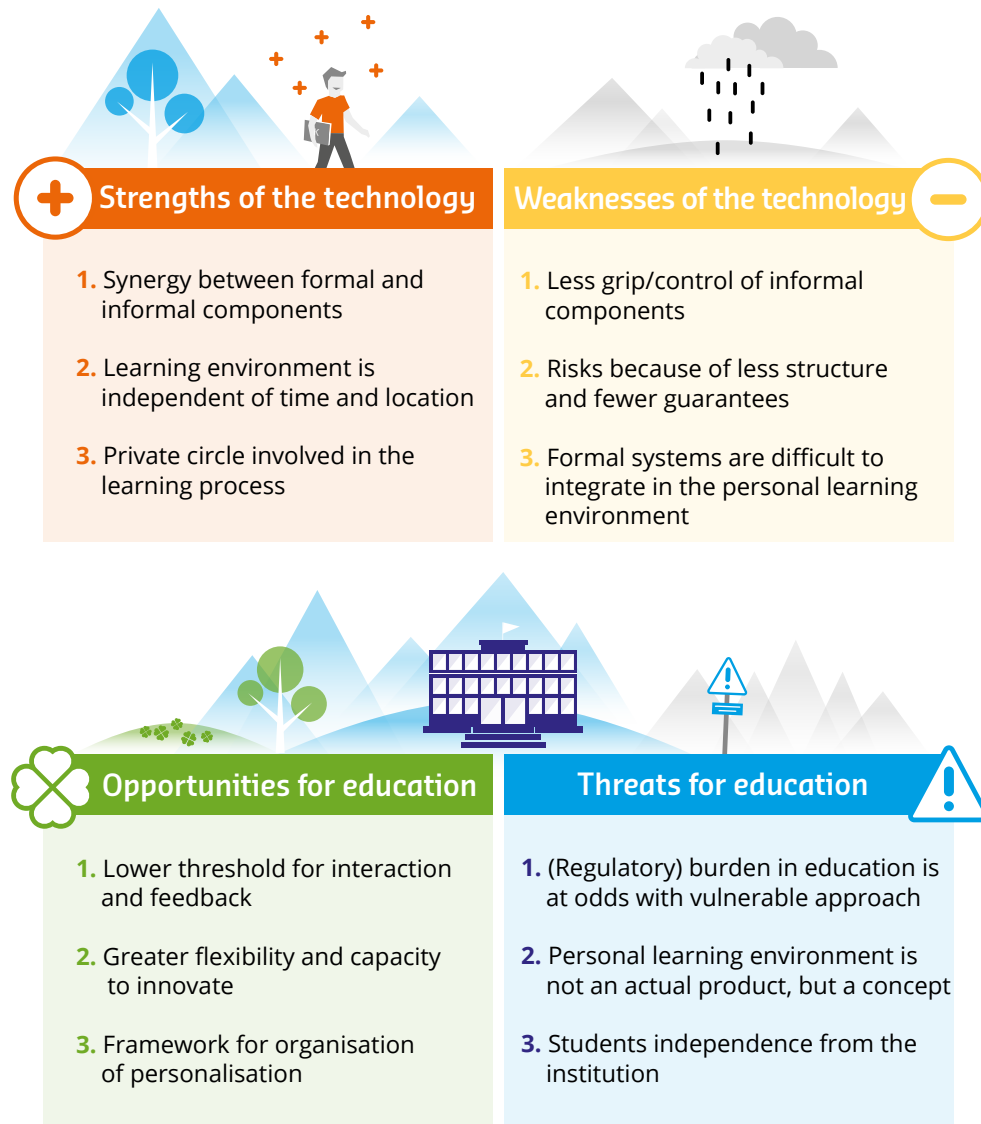
- **Act: determination of interventions, if required**

The teacher monitors the progress of the students under his or her supervision by means of the dashboard. The personal learning environment generates information on the basis of the criteria or basic variables selected by the teacher or student. The student and teacher can discuss changes in the learning path or the pace and method of learning on the basis of objective information in its proper context. The evaluation can be carried out every month or more frequently, since the information required can be accessed quickly and any agreements made can be incorporated easily. As a result, a tailored approach can be organised and implemented for each student.
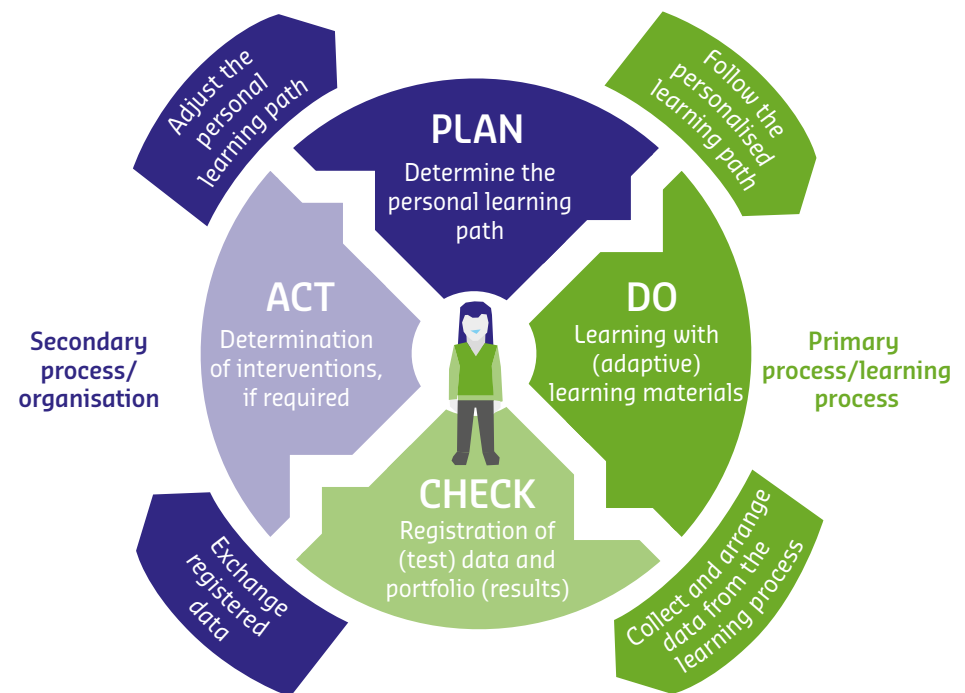
2.3 Personal learning environment

SWOT analysis personal learning environment

Strengths of the technology

1. Synergy between formal and informal components

2. Learning environment is independent of time and location

3. Private circle involved in the learning process

Weaknesses of the technology

1. Less grip/control of informal components

2. Risks because of less structure and fewer guarantees

3. Formal systems are difficult to integrate in the personal learning environment

Opportunities for education

1. Lower threshold for interaction and feedback

2. Greater flexibility and capacity to innovate

3. Framework for organisation of personalisation

Threats for education

1. (Regulatory) burden in education is at odds with vulnerable approach

2. Personal learning environment is not an actual product, but a concept

3. Students independence from the institution

SWOT analysis

Strengths The combination of formal and informal components clustered in the personal learning environment is diverse and flexible and therefore better suited to the needs of students and teachers. For some learning activities, the learning process no longer depends on time and place. There is plenty of opportunity to share resources and to collaborate.

Weaknesses Because the institution has less control over the informal components of the personal learning environment, there is always the possibility of faults and incidents relating to privacy. The (closed) market for formal educational support systems fears competition from informal systems, many of which are free. It is therefore difficult to connect systems to each other.

Opportunities The more informal parts of the personal learning environment make it easier for students to interact and give each other feedback, which is a valuable aspect of the learning process. The flexibility and dynamic of a personal learning environment also makes it possible to respond quickly to innovations and changing demands. The personal learning environment provides a framework to support a more personalised approach to learning.

Threats The pressure to perform in education (regulatory and otherwise) is at odds with the open, vulnerable approach required by a personal learning environment. Moreover, the personal learning environment is a concept of an ICT system rather than a specific product that can be bought off the shelf. Established suppliers of formal ICT systems have nothing to gain from supporting a more open system with interchangeable components. For the educational institution, its role and added value will be called into question as the informal part of the personal learning environment expands and students become more independent.

2.3 Personal learning environment

Recommendations to the school board for creating a personal learning environment

1. Adopt a long term ICT policy setting out the choices for a central/ local structure and formal/informal systems.

Formulating a long-term ICT policy is a difficult task. For administrators and institutions in the education sector it is particularly crucial to make clear choices about what will be organised centrally (at board level) and which functionality should be arranged locally (at institutional level). The decisions should be guided by the needs and requirements of the (learning) process:

- Administrative systems that are primarily intended to provide management information for the purposes of accountability to funding bodies and inspectorates should be set up centrally and standardised. This information is primarily of importance for central management and should therefore be controlled by it.
- Applications that directly support the primary teaching-learning process need to be flexible enough to adapt to a specific type of curriculum, to local circumstances or to the methods used by the teaching team. The primary purpose of these applications calls for flexibility at the local level.

A mix of such systems will work perfectly well in practice as long as the educational institution's ICT policy is clear about the need for data-sharing between them. The personal learning environment adds a further dimension to this discussion: which systems should the educational institution set up itself and which one can it allow teachers and students to choose themselves? Here too, the school's ICT policy should provide a framework for making consistent choices about which ICT services it can and should organise itself and which it can leave to teachers and students. If the educational institution can focus on the added value of an ICT service in supporting the learning process, it will be able to make conscious functional choices and ultimately achieve cost savings in and with ICT.

2. Insist on coherence and compatibility between ICT components in the school.

The actual effectiveness of ICT applications is subject to careful scrutiny, and rightly so. A common complaint is that ICT does not live up to its promise of lightening the administrative burden or generating cost savings. This is often due to the fact that ICT systems are not compatible. If users are left to solve the problems themselves, for example by entering information twice, they grow frustrated. This is why it is important to consider how the formal components connect and – in the context of the personal learning environment – how compatible they are with the most common informal components, such as the platforms of Google, Apple and Microsoft and the various social media platforms. An important criterion in the selection, implementation and delivery of new ICT building blocks is that they have to mesh with the surrounding systems. When they do, it eliminates functional overlap between systems (multiple systems performing the same task) and the need to restore broken links manually (when systems do not share data). This aspect must receive close attention because it is not always in the supplier's interest. It is a crucial condition for setting up an ICT system that makes a genuine contribution to better education by reducing the administrative burden, saving time and facilitating a learning process that invites cooperation and mutual feedback.

2.3 Personal learning environment

3.   Consider the need for a change of culture in relation to ICT support.

ICT support staff often resist the transition from centralised control to freedom of choice for end users in selecting, designing and using ICT systems. They fear that this will give rise to problems and questions that they will not be able to cope with given the available staffing and resources. Firm agreements and clear policies will remove some of these concerns, but a change of culture is also needed among ICT staff, who are used to being in total control of all the services and the equipment that is used, but will now be exercising far less control. Nevertheless, they will still have an important role in providing badly needed expert advice and guidance for users. After all, the greater leeway teachers and students have in selecting and using ICT services leads to a better match with local processes and individual needs. This transition will impose heavy demands on the ICT expertise of teachers, while the ICT skills of students should also not be overestimated.

4.   Critically assess the available range of learning resources and the incorporation of informal resources.

In addition to weighing up the formal versus informal ICT applications and whether systems should be centralised or organised locally, similar conside-rations apply for the school's policy on digital learning tools. Once again, the point is to choose which tools the school will provide itself, which ones they will recommend that students use and how to deal with tools that the students bring with them and use in the learning process. Quality assurance is important, but so is practical usefulness. For example, students are still often required to buy a dictionary even though they never use it because it is easier to use Google. What conclusions can we draw from that?

2.3 Personal learning environment

2.4 Coherence and consensus: a vision of the digital learning process

Building on a robust ICT infrastructure, it is possible to experiment with new technology designed to support the realisation of educational goals without taking too many risks. However, consensus within the organisation is essential for this. The Hype Cycle helps in making decisions about which technologies are worth experimenting with. The Strategic Technology Map (STM) – also known as a Benefit Map – is used to ensure that the decisions made are coherent (the chosen technologies are compatible with technology that is already used, and in some cases vital) and enjoy broad support within the organisation.

The chapter on the ICT essentials described the STM in some detail and here we briefly repeat the underlying insights:

- Identify the relationships and dependencies between the various technologies.
- Find a balance – and preferably synergy – between the benefits for the educational institution (we) and the convenience for the users (me).
- Ensure that the decision-making process on necessary combinations of investments is transparent and enjoys broad support through visualisation and storytelling.

The STM is a simple matrix in which the vertical axis represents organisational efficiency (institutional effectiveness) and the horizontal axis represents personal productivity (of students, teachers and other staff members). The four resulting quadrants were also explained earlier: in the bottom left are the 'cold case' or 'enabler' technologies (supporting); the top left quadrant contains the 'corporate green light' technologies (effective for the organisation); in the

bottom right are the 'people's choice' technologies (personal productivity) and in the top right are the 'hot spot' technologies (synergy).

The narrative of the personal learning environment

This narrative explores the mutual dependencies of digital technologies that can assist in organising and supporting the learning process, and particularly a differentiated and personalised learning process. In the digital learning and working space created by the ICT essentials teachers and students have to be able to record agreements about learning paths, have access to suitable, flexible learning tools, monitor progress and results and revise plans. The combination of technologies required for this is shown in the accompanying STM.

- The narrative begins with the foundation of the personals learning environment: adaptive digital learning materials. Because students work every day with tools that offer them the appropriate learning experience at that moment, relevant data about the progress of the student is collected very frequently.
- We then add digital testing, both formative testing as an integral component, but also summative testing to supplement it. Apart from saving a lot of time and allowing for greater flexibility in the timing and location of tests, we can also collect even more information about the performance and the progress of the students.
- By adding open micro credentials, students are also able to see the assessments of their skills and the work they have submitted from various platforms both within the school and elsewhere, while the teachers and the school administration retain an overall view of the assessment of the students' work and the progress they are making.
- In order to save the information about the learning process in such a way that it can (only) be shared with specific parties and individuals, we add the Experience API standard, with which we can save the information in Learning Record Stores (LRS), irrespective of the supplier's source

system and under the school's own control.

- With Big Data we add technology to arrange all the data that has been collected so that it can be used to make carefully-considered decisions about changes in the learning paths.

- In order to analyse and interpret these data and use them to help in making decisions, we add learning analytics. This typical 'cold case' technology also helps drive adaptive learning materials and adaptive testing and 'calculates' the automatic decisions that have to be made in relation to them.

- We now add the closely related machine learning, which is hidden even deeper beneath abstract technical jargon. Nevertheless, we would be well-advised to study the framework we wish to adopt for learning software, if only to retain control of the didactic aspects of decisions.

- It is now time to add privacy by design to our STM. Explicitly considering how to deal with data, including personal data, during the process of selecting educational systems provides a solid basis for complying with the increasingly strict national and European rules on privacy. There is a section later devoted entirely to the issue of privacy.

- The addition of User Managed Access (UMA) gives us the technology that allows the student and teacher to retain control of the data (right to inspect them, make changes and to remove them) in practice. In the personal learning environment, students and teachers decide what information they want to reveal about themselves for the purposes of facilitating a more personalised learning process.

- These are the building blocks of the personal learning environment that support and guide the process of realising the ambition of providing tailored education with the help of information technology.

Personal productivity

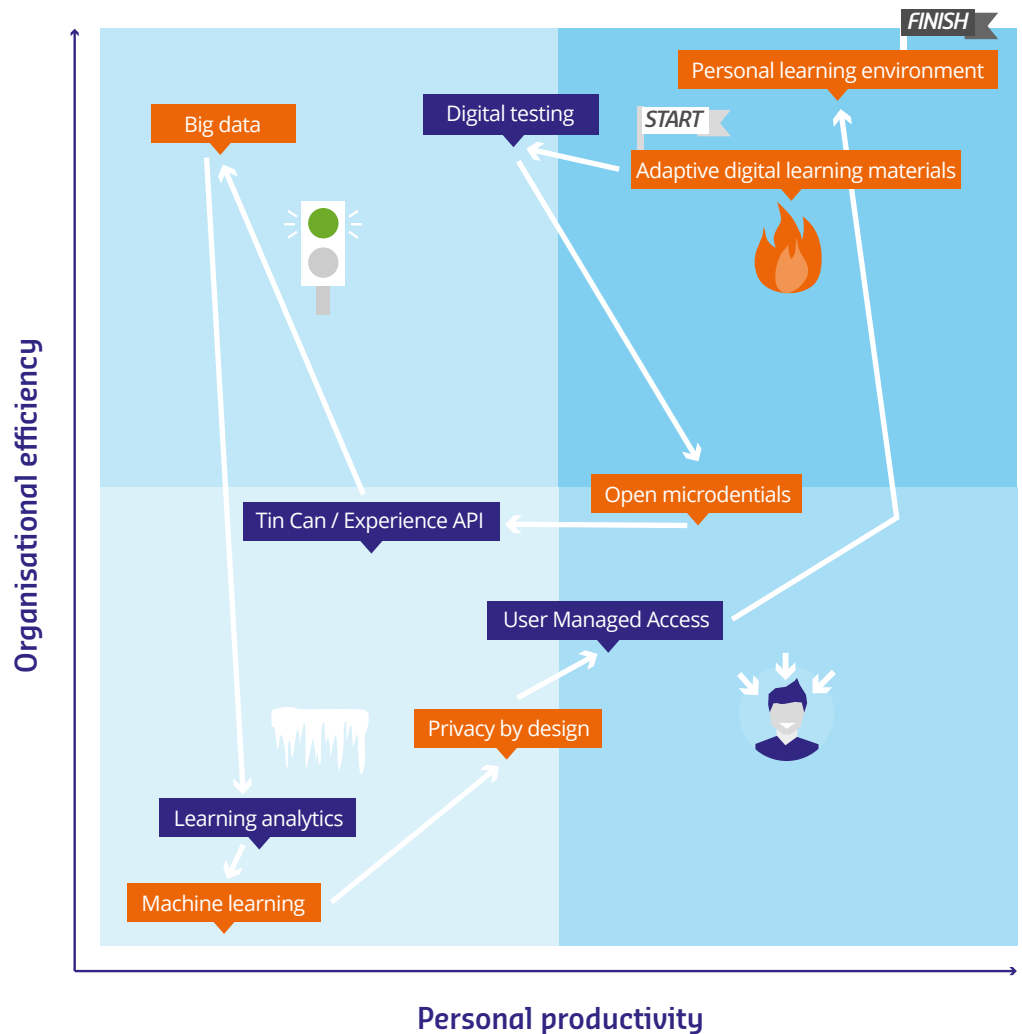*The Hype Cycle's colour code:*
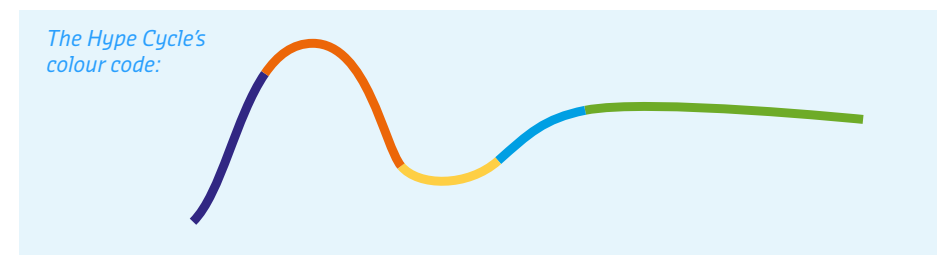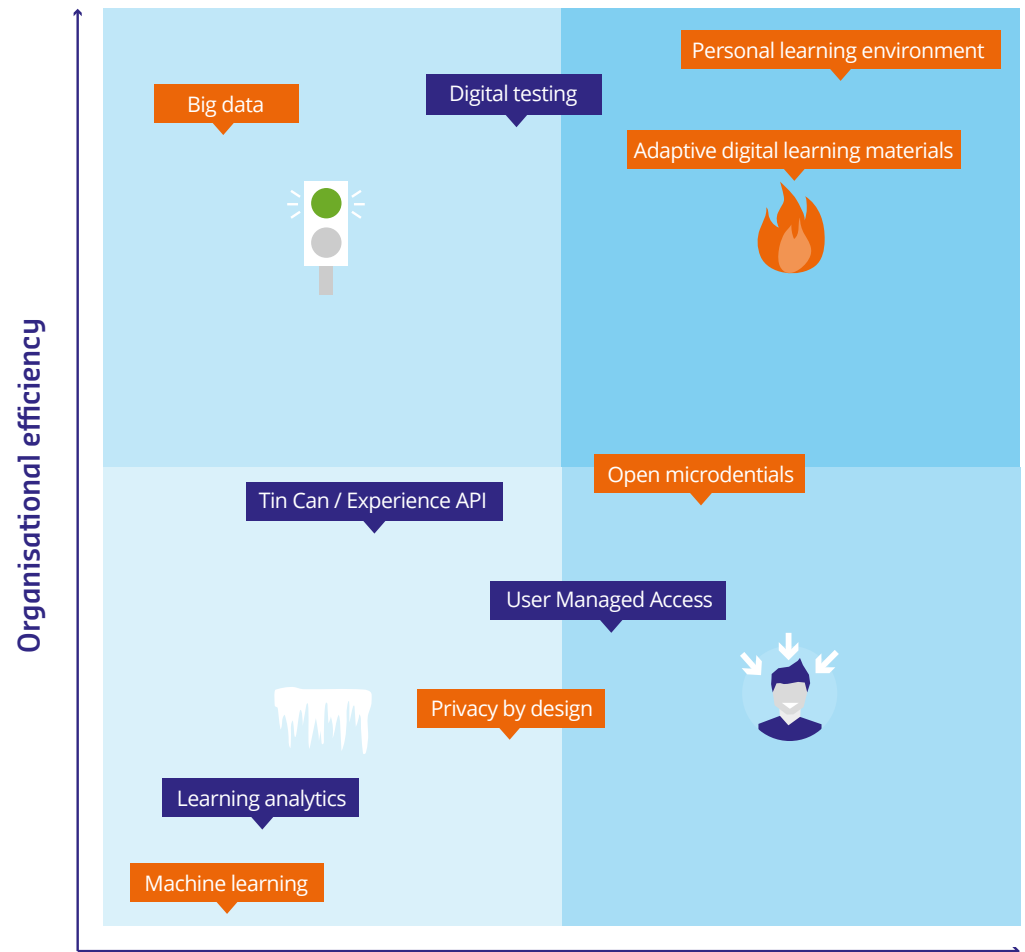
2.4 Coherence and consensus

If we look at the Hype Cycle position of the trends discussed in this chapter and the corresponding colours of trends in the STM, what we see is that the technologies are all at an early stage of development. This calls for selective experimentation. The risks still seem too great for the technologies to be rolled out on a large scale.
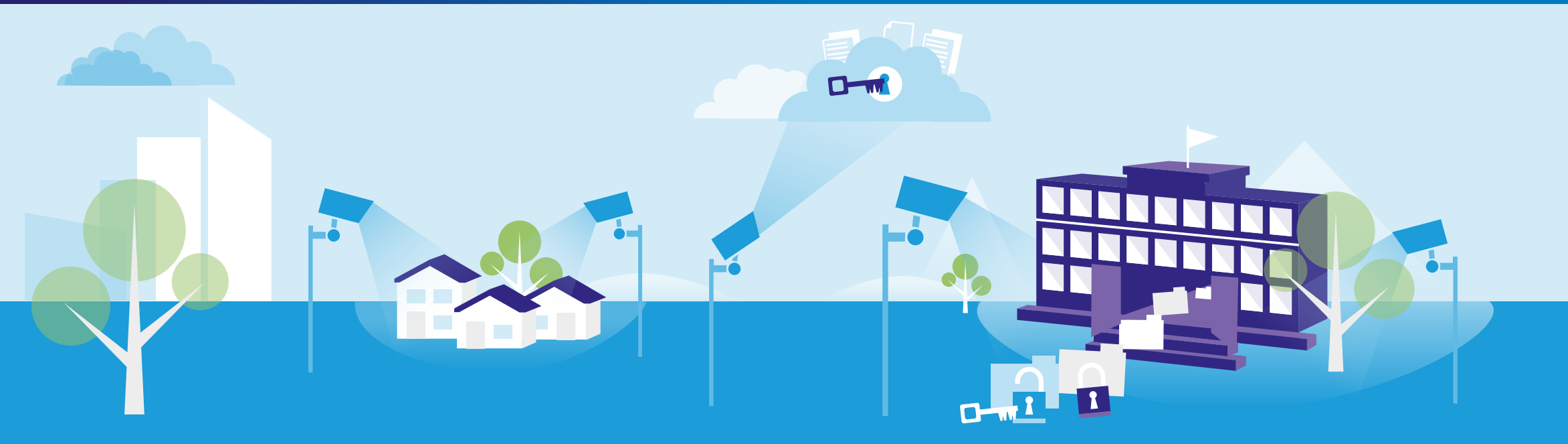
This narrative of the personal learning environment is merely intended to prompt a far deeper, more specific discussion of a school board's mission and vision of education. Other choices and risks, and hence other (combinations of) ICT building blocks, might be a better match for the profile of a school board and schools. The STM is an instrument that identifies the components needed to provide the necessary functionality, the mutual dependencies between them and the ensuing critical path of investments in ICT.

Without the cold cases learning analytics and the Experience API, no useful data can be derived from the teaching-learning process. And without the corporate green light Big Data in combination with the people's choice User Managed Access (UMA), either the data are not available for the personal learning environment or there is no permission from students and their parents to use the data. Adding new technologies, changing the objectives and developing new insights and priorities can produce many alternative STMs, which can form the basis for a continuous dialogue between stakeholders that leads to adjustments of the plans and budgets that have the commitment and support of the entire school board and its schools.

Organisational efficiency

FINISH

Personal learning environment

Big data

Digital testing

START

Adaptive digital learning materials

Open microdentials

Tin Can / Experience API

User Managed Access

Privacy by design

Learning analytics

Machine learning

Personal productivity

The Hype Cycle's colour code:

2.4 Coherence and consensus

2.5 Privacy: the sacrifice for tailored education?

Privacy is difficult to define, hence the many different definitions and interpretations of the concept. It is concerned with personal freedom of choice, for example between seclusion (being left alone, not being disturbed, no intrusion from the outside world) and companionship (with a partner or friends), but also the desire to live without being watched or kept under surveillance. In the digital context, we refer to the right to communicate confidentially and to decide who can have access to what information about us. As we mentioned earlier, there is a conflict between that desire and the way in which the digital society is evolving.

Views and myths concerning privacy

Facebook's founder, Mark Zuckerberg, argues that social norms regarding the sharing of information have changed and asserts that the importance we attach to privacy is diminishing. That seems to be wishful thinking. In his novel

'The Circle', Dave Eggers highlighted the argument with statements such as "Secrets are lies," "Sharing is caring," and "Privacy is theft." Those remarks sound uncomfortably logical, the implication being that if you have nothing to hide, you have nothing to fear. Another controversial figure, Edward Snowden, has clearly espoused ideas about privacy: "Arguing that you don't care about the right to privacy because you have nothing to hide is no different than saying you don't care about free speech because you have nothing to say." It is an interesting analogy, which at the very least gives food for thought. Privacy is more than hiding something you are ashamed of or not being caught in a lie. It is a fundamental right, closely related to autonomy and free will. The younger generations who have grown up with social networks are said to be less concerned about privacy. However, research has shown that their behaviour is attributable mainly to their youth rather than a lack of concern about the long-term impact of their behaviour. Most teenagers are genuinely concerned about their privacy and do want to know how to protect their personal information more effectively.
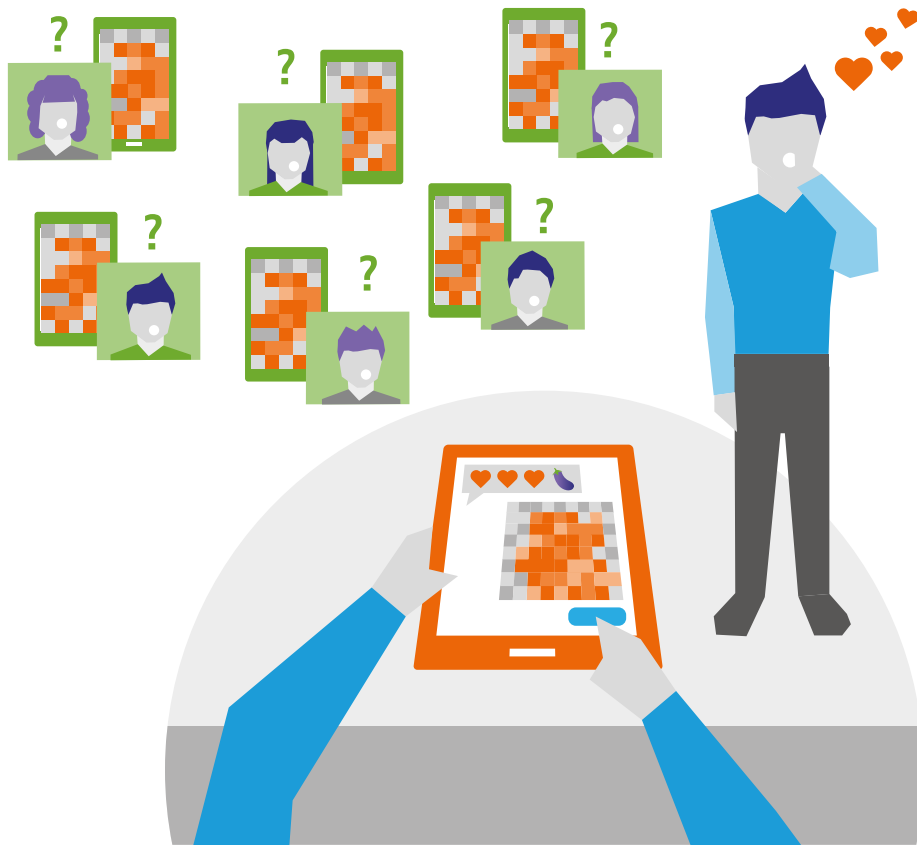
Privacy has to be seen in context

The philosopher and Professor of Media, Culture and Communication Helen Nissenbaum argues that defining privacy solely in terms of control over access to personal information is too crude. In her view, privacy has to be seen in context (privacy as contextual integrity). According to Nissenbaum, this explains why individuals regard some specific contexts as very threatening to their privacy and others as not at all threatening. For example, we only regard searches of our luggage and body searches acceptable at airports. The (social) context in which we share our personal information is decisive for our own perception of privacy, and the perceptions of others in our environment.

Nissenbaum argues that the (generally accepted) purpose for which information can be used is socially determined, so we regard failure to observe the relevant standards as a violation of privacy. We share intimate information during consultations with our family doctor on the assumption that he or she will treat the information in confidence. The information can be shared with a specialist if necessary, but using it for marketing purposes is considered to be a gross violation of privacy. These socially-defined objectives and standards for 'the appropriate flow of information' apply in a variety of contexts, including the learning and working environment. It depends on the context whether we decide that flows of information are acceptable or not. This is an important factor to bear in mind in the context of education.

The further integration of ICT into our daily lives will continue, which could create a conflict with our perception of contextual integrity. After all, in the digital world we are endeavouring to achieve independence of time and place, and hence of context. Comments, photos and text messages sent in a private context can be totally out of place in an educational context, as teachers have experienced to their embarrassment (sexting to classroom groups by mistake). The fluidity of the context in the digital world complicates the issue of digital privacy, for both teachers and students.

Tailored education requires customised handling of data

The focus of schools is shifting from arranging the technical prerequisites for ICT services to managing 'subscriptions' to platforms and learning materials. Growing attention is devoted to ensuring that data on those platforms (such as Office 365 or Magister) are used with proper care.
ICT can help enormously in achieving the ambition of tailoring education to the individual student, but in order to understand each student's personal needs schools have to record more information about each student and his or her learning process. In addition, the administrative records relating to students

2.5 Privacy

and the results of their assignments and tests are no longer kept in the school, but in the cloud. Finally, the school's environment – the government, society and parents – is demanding to know more about the performance of schools and the return on education. This combination of forces – remote storage of data, a larger volume of data and greater demand for that data – makes it essential to carefully manage how data is handled. Schools must also be able to persuade students (and their parents) that the registration and use of data about their day-to-day activities are both useful and necessary.
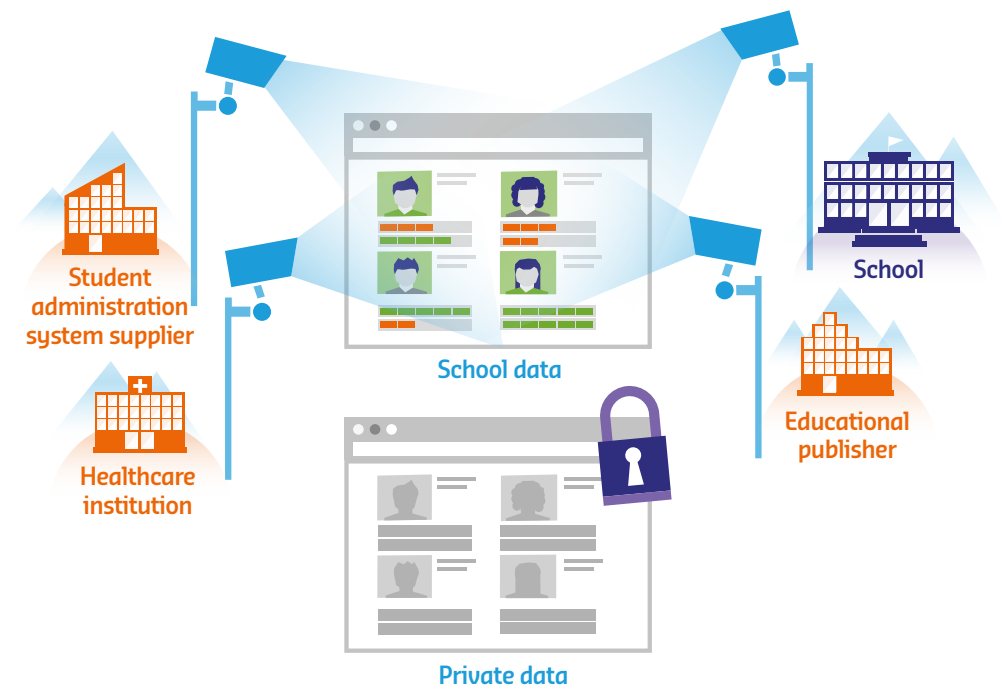
Privacy by design: the principles

Privacy by design is an essential building block that has already been discussed in the context of the Strategic Technology Map (STM) for the personal learning environment. The basic principle behind this proactive and preventative approach to privacy is that prevention is better than cure. With this approach, privacy is not treated as a separate issue, but it is integrated into the process of selecting, designing and implementing an ICT system. Respect for the privacy of data subjects is the standard. The system protects the privacy of students and teachers even without any action on their part, while at the same time helping the school to meet its legitimate educational objectives. The digital learning process allows for no compromises on privacy, but the use of technology and the teaching methods must be transparent. The system is based on trust, but always with the possibility of control. These are sound principles, but could they perhaps be defined in slightly more specific terms?

The metaphor of a transaction

Providing personal information and allowing it to be circulated is essentially a transaction. Providing information in exchange for a service or product is a transaction that satisfies both parties. For example, even as an adult I have to be able to provide identification when buying alcohol. This transaction serves a socially-defined purpose, which is to prevent harm to children from the con-

sumption of alcohol. Sometimes, I will have a range of choices in a transaction. If I order a printed book from Amazon, I can give my address so that the order can be delivered to my home. However, if I don't want to give my address, I can choose to collect the book from a pick-up point. In the latter case, I have to make a greater effort to collect the book, but I don't have to provide as much information. If we apply this principle to differentiation and a tailored approach in education, the envisaged benefit is a learning process that is more relevant and effective for the individual student, but in return the students (and their parents or guardians) must be willing to provide personal data. If the data are used more widely than is necessary for the agreed purpose, students and parents will no longer regard the transaction as reasonable and that will prompt a discussion about privacy. How do we explain to students and parents who will have access to their information, and which specific information, as well as for what purpose and for how long?

Student administration system supplier

Healthcare institution

School data

Private data
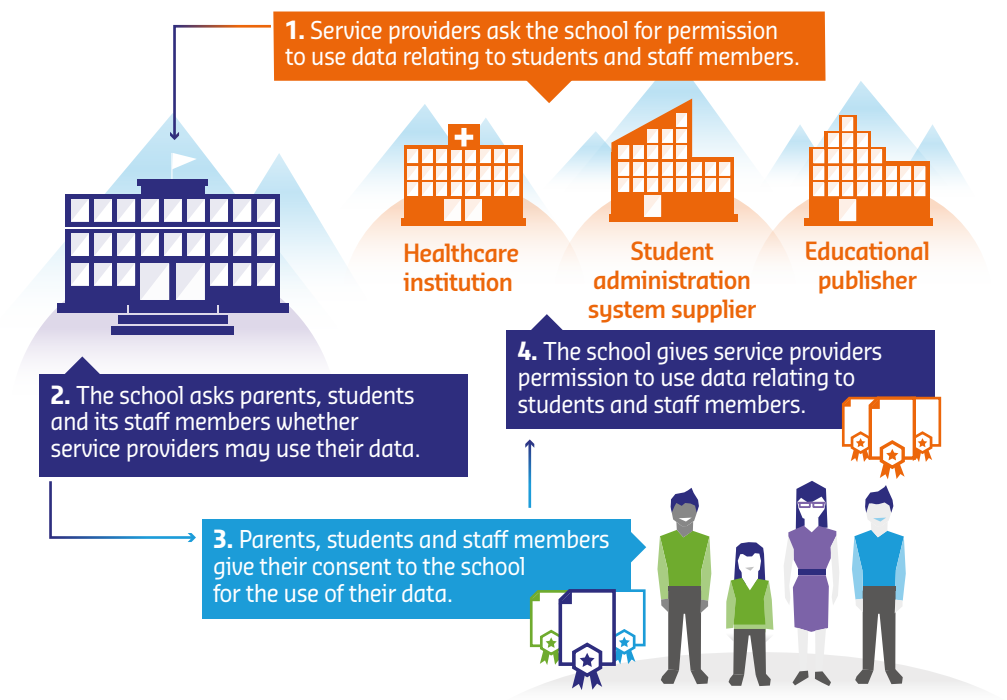
School

Educational publisher

Two options for securing permission to use personal data

In view of the growing volume of data available and the variety of purposes for which we want to use the data, the system devised for securing consent for the use of personal data must be efficient. However, consent is only required for the use of data that are not strictly essential for the teaching-learning process or the supervision of students (i.e. within Dutch law). Schools can always use, and if necessary share, data that are essential for those purposes. For example, permission is needed to supply data to external institutions that provide help with homework or cramming in a specific subject, but not if they will be used with regular digital learning materials, used for all students. However, as we found earlier, providing education tailored to the individual student leads to divergence not only on the supply side of the teaching-learning process, but also in the demand for learning materials and support. Schools are capable of doing far more than merely teaching the 'basic curriculum', either themselves or by hiring third parties. It will therefore soon become necessary for schools to request permission to use data throughout the course of the school year.

Securing that consent can be arranged in two ways.

1. Organisation-centric

With an organisation-centric approach, a hierarchical model is developed in which decisions have to be made regarding access to personal and other data for various purposes for a large number of individuals, often for a lengthy period of time. The school draws up a contract in which all the data subjects (students, parents, staff members) in a group or class are asked to give their consent for the use of their data for at least an entire school year. This model gives the school a sort of 'blank cheque', since the data subjects, when they give their consent, don't know precisely when the data will be used or for what purpose. With this approach, the school acts as a filter in processing requests for data from service providers and consent to the use of the data from data subjects.

1. Service providers ask the school for permission to use data relating to students and staff members.

Healthcare institution

Student administration system supplier

Educational publisher

2. The school asks parents, students and its staff members whether service providers may use their data.

4. The school gives service providers permission to use data relating to students and staff members.

3. Parents, students and staff members give their consent to the school for the use of their data.

2. User-centric

In the user-centric approach, there is no mediation by the school. The decision on whether to grant access to data lies with the individuals (or their (legal) representatives) and is made whenever access is required to specific information for a particular purpose. It is what you might call just-in-time access to data. Service providers (contracted by the school or otherwise) ask the data subjects directly for permission to use their data for a specific service and period at such time as that consent is required. The value of that consent or the consideration for it are then also known at that moment.

1. Service providers request permission from parents, students or staff members to use their data for each individual service.

Healthcare institution

Student administration system supplier

Educational publisher

2. Parents, students or staff members decide for themselves – after each request by the service provider – whether they will consent to the use of their data.

What stands out in a comparison of the two approaches is that although the organisation-centric approach is efficient, it is also based on the assumption that the parties that will need information are known at least a year in advance, as well as precisely what information they will need and when they will need it. The user-centric approach forms a far better match with the ambition of providing students with tailored or appropriate education, an ambition that leads, by definition, to less standardised demand in education and hence to wider diversity in the necessary learning tools, professional supervision and other elements of teaching. At present, the requirements in terms of learning materials, expertise and supervision are still estimated, procured and planned in advance. That will have to change with a tailored approach, and with the digitisation of learning tools it can. Agreements can be made on access to information for suppliers and supervisors as the guidance that students require and the most appropriate materials for them become apparent in the course of the school year.

The user-centric approach also reflects the guidelines and legislation on the careful treatment of information. Access to information is requested and permitted for a limited, predetermined period and in accordance with the principle that the information is stored at a single location (no copies of files), for multiple use and subject to increasingly strict privacy rules, including the principle of purpose limitation (for what purpose is it needed) and data minimisation (no more information than is necessary is stored and not for any longer than is necessary). In addition, the method provides a sound basis for providing the transparency demanded by students, parents and teachers.

The user in control with User Managed Access (UMA)

But how do we ensure that data can be used in everyday practice? Does the user-centric approach mean that students (or their parents) and teachers will be constantly having to approve requests for information? Once again, the

prospect of a tailored teaching-learning process implies that this may not be desirable in every situation. In the user-centric approach, permission to access information can be given for a lengthy period, if that is necessary and advisable. Suppliers already participate in work on standards such as User Managed Access (UMA), which prescribe how data subjects can manage access to their (personal) data and provide third parties with easy access to protected information. Although this standard is still under development, experiments show that it is entirely possible to create a workable system with UMA. Among other things, such a system provides:

- **Transparency**: data subjects can see who has access to what data and for what purpose at any moment and can also see when exactly data have been accessed and by whom.
- **Privacy settings**: data subjects can specify the data and applications for which they are granting permission for direct (automatic) access (low level of privacy) and for which requests and data they have to give their explicit consent (high level of privacy). They can also later review their automatic consent and revoke it if they wish.
- **Customised consent**: data subjects decide for themselves whether they will grant access to their data and for how long. The consequence of a refusal to give their consent is that the product or service cannot be supplied.

By using UMA to create a user-centric system of granting consent for the use of data, students/parents assume some of the responsibility for the use of data. The transparency and oversight also increase the engagement of parents, whose support is important during the transition to a digital learning process in which a growing volume of information is registered and used. This approach also creates opportunities for suppliers of applications and learning materials. New products with specific requirements in terms of access to information can be quickly supplied to selected target groups. Permission is always up-to-

Bas van der Hoef   PO VO Next step

Request privacy setting

Zandvliet College

What level of privacy do you wish to attach to Bas van der Hoef's data?

Privacy level High — • •• •••   **Greater control, but securing approval involves more work**

Privacy level Medium — • •• •••

Privacy level Low — • •• •••   **Securing approval involves less work, but less control**

Transmit consent

date and properly registered, so it is easy to demonstrate to regulators that the rules are being followed. There is one challenge: what to do if permission is denied? Where basic information for the teaching-learning process is concerned, by (Dutch) law the school does not need permission. But what is 'basic information' in the context of a tailored approach and differentiation in regular education? Increasingly, schools will provide additional services that differ from one student to another in response to the specific needs of individual students as they become apparent in the course of the school year. If the added value of the service does not visibly outweigh the objections to supplying the information required to provide that service, the discussion ends there. Parents have to make that decision themselves. Often, however, the students and parents will already have been consulted about the additional support and the request for information will clearly be reasonable. In other cases, a supplier will have to explain more clearly why particular information is needed to provide the service and demonstrate that the request does comply with the Dutch Personal Data Protection Act.

What can and should we already be doing?

The concepts, standards and technologies described here are still at an early stage in the Hype Cycle. A specific measure that educational institutions can already take is to apply 'privacy by design' in their processes and in how they handle information. New models for interaction with information flows – created by adaptive learning materials and dashboards – should be prepared as far as possible on the basis of the user-centric approach. What information can students and parents already find in the new learning environments? What agreements can be made with suppliers about the process of securing permission to use data from students who want to use new products? By being flexible in how the personal data of students and teachers are handled, and for how long, school boards can respond quickly and adequately to innovations in applications and learning resources, as well as changes in rules and

regulations. The scrutiny of compliance with the Personal Data Protection Act is becoming more intense every year, for both schools and suppliers of learning materials.

Because the issue of protecting the privacy of students can no longer be left solely to individual school boards and suppliers, the sector councils and trade associations of suppliers concluded a covenant on privacy in 2015. They agreed a set of minimum conditions designed to bring about uniform improvements in the field of privacy. Model agreements have been drafted in which suppliers can specify the data they need about students for a particular product. With that information, schools can be more transparent towards parents about how the data are used. The covenant on privacy anticipates a further tightening up of legislation and stricter enforcement of the rules.

In December 2015, agreement was reached in the European Parliament on the new General Data Protection Regulation (GDPR). An EU regulation has the same 'direct effect' in the Netherlands as national legislation. Privacy by design and a user-centric approach are central features of this new, more stringent privacy regulation, which will enter into force in 2018. It is therefore time to start building on the existing foundations for the sound and effective use of ICT in our schools!

2.5 Privacy

Chapter 3

Education in the future

Introduction

Education needs to prepare students for life outside the classroom. But how do we do that? This chapter looks ahead to trends that are not necessarily apparent yet, but which are likely to have a major impact on our world. A distinction is made in this report between education about these advanced technologies ('the what') and education that uses these technologies as a tool ('the how'). In the two previous chapters, we looked in detail at the 'how'.

Many developments in the ICT essentials and digital learning process are sufficiently advanced to discuss their possible applications. Looking further ahead, however, it is difficult to envisage the practical use of emerging technologies in education, which is why we can only explore their potential significance ('the what'). Many novel trends are building on earlier developments like Big Data and machine learning, hinting at their impact.

Introduction

This chapter discusses the trends that are likely to have an impact on society and education in the years ahead. It is divided into two parts:

- The continuing development of technology, with examples such as the Internet of Things, drones, robotics and self-driving cars, fitted with sensors that observe and analyse and which, thanks to machine learning, are increasingly able to operate independently.
- How the education sector is responding to these developments and the digital or information society that is emerging from them. Examples include digital literacy and technical self-confidence – also known as the Maker Movement.

Changing expectations and demands on education

Trends in society are causing a shift in people's expectations of education. Students and parents have different expectations when children start school

and businesses expect their future employees to have different skill sets. Children are used to using tablets at home to do all sorts of things on the Internet, such as learning to read, write or do sums, using educational apps. Schools, however, often tend to remain stuck in their former ways: children look up information in books and write their schoolwork in exercise books that are marked by hand. Admittedly, it is not easy to weave these accelerating social, economic and technological trends into education without affecting quality standards. It is equally clear, however, it has to be done more rapidly than has been the case so far. We cannot afford to allow the gap between home and school and work and education to grow too wide.
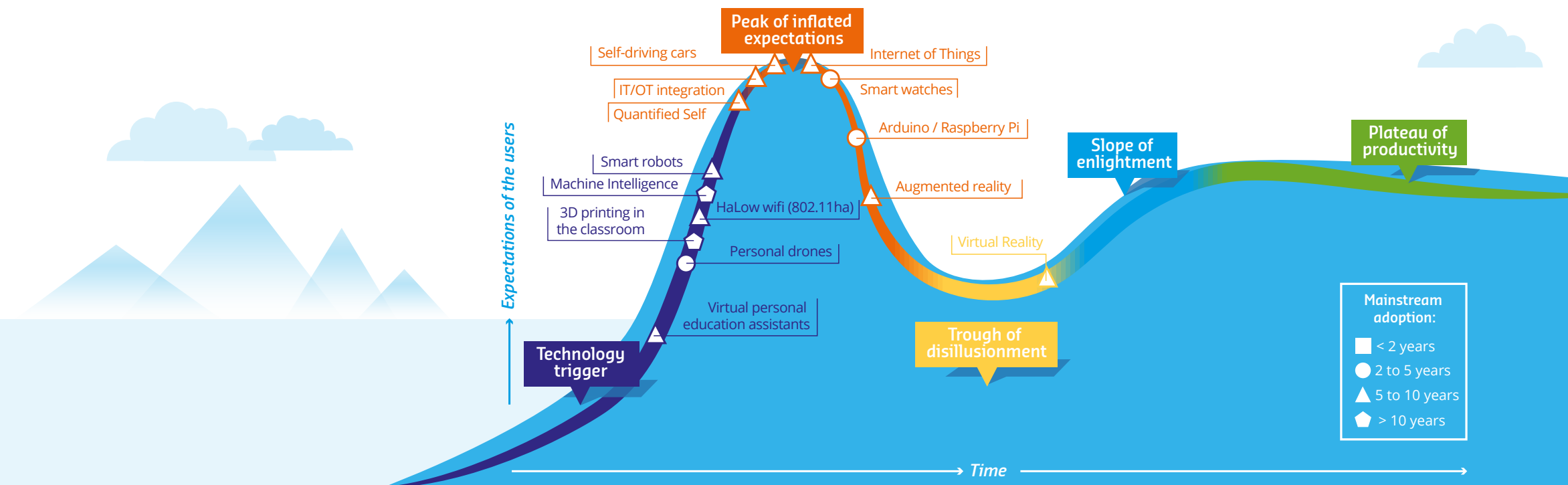
How to deal with the accelerating adoption of technology

Technologies are being adopted ever more quickly. It took the telephone a hundred years to become ubiquitous, while the Internet took twenty years, social media seven and the smartphone just three. How can education deal

Introduction

effectively with this dynamic? It seems neither practical nor responsible to undertake a complete overhaul every few years in order to accommodate new technology. The good news is that there is no need to do so. Innovation is not about trying out every new technical option as quickly as possible. True innovation combines exploring new opportunities and ideas, learning from them, and timing the across-the-board implementation of valuable technologies correctly so that they help schools achieve their educational mission. Change is the only constant in our lives today. Our only option therefore is to learn how to deal with change on a long-term basis, using the school's vision of education and its mission as a guiding beacon.

Hype Cycle for education in the future

The key technologies discussed in this chapter are plotted in a Hype Cycle, a concept developed by Gartner Research. The Hype Cycle shows how a new technology follows a cycle from promising concept to accepted product. It is a snapshot of the relative maturity of a technology and its future potential. The position – or risk profile – of a trend is determined by analysing the technology's maturity and market adoption and the extent to which it is known. Nearly all the building blocks of education in the future are 'technology triggers' – exciting concepts that still need to mature into practical applications in different sectors. Some are being hyped (the Internet of Things), while the hype around others has already ebbed away (augmented or virtual reality).

Expectations of the users

Peak of inflated expectations

Self-driving cars
Internet of Things
IT/OT integration
Smart watches
Quantified Self
Arduino / Raspberry Pi
Smart robots
Machine Intelligence
Augmented reality
3D printing in the classroom
HaLow wifi (802.11ha)
Slope of enlightment
Plateau of productivity
Personal drones
Virtual Reality
Virtual personal education assistants
Trough of disillusionment
Technology trigger

Time

Mainstream adoption:
□ < 2 years
○ 2 to 5 years
△ 5 to 10 years
⬠ > 10 years

Introduction

Keeping an open, inquisitive mind and using small-scale pilot projects, the education sector can form its own opinion of the opportunities and constraints of particular technologies. Technologies such as smart robots with machine intelligence are still in their infancy and are still a long way (in Hype Cycle terms: 5 to 10 years) from the safe and practical stage of maturity. And yet there is every reason to start immediately exploring these novelties. Practical applications of robotics and machine intelligence are already emerging in the health care sector, home construction and industries that make household appliances and cars. There is every reason to believe that these emerging technologies will impact on how we live, learn and work. As the author William Gibson, who coined the term 'cyberspace', puts it: "The future is already here – it's just not very evenly distributed." If we know where to look, we can see the initial contours of that future emerging and use that knowledge to our benefit when drawing up long-range plans for (investment in) staffing and resources. Because many of the technologies discussed in this chapter are 'technology triggers', little is known about their practical potential in education. That is why we are taking a broader perspective and exploring where the future is already becoming manifest and whether we can draw any lessons from what we find.

This chapter also addresses key educational themes that are not captured by a technology-based analytical tool like the Hype Cycle. Examples include digital literacy, learning to program, the Maker Movement, and FabLabs or smart school buildings, subjects that are equally vital to shaping a forward-looking educational sector and certainly feature in the descriptions, analyses and recommendations.

Introduction

3.1 The (further) development of technology

Although information technology appears to be evolving rapidly, the basic concepts have remained remarkably stable. Computers were and still are processing units that receive instructions (a program) for analysing input and producing output. That said, Moore's Law and the ensuing miniaturisation have led to computers becoming ever smaller, more powerful and less recognisable (by being integrated into utensils, clothing, jewellery, and other accessories). They are, in fact, often invisible to us, hidden on or in objects around us and increasingly also on or inside our bodies. Communication networks benefit from these rapidly advancing technologies in much the same way, providing faster speeds with smaller and less expensive devices, making it almost self-evident that we can connect to the rest of the world wherever we are, also with the many unrecognisable computers all around us.

Interacting with the computer: input from people and sensors

Technology also enables us to provide computers with improved input using 'natural' interfaces such as touch, speech and imagery (including gestures) rather than typed instructions. Computers also receive input from sensors, without any human interference. Temperature, air pressure, the composition of atmospheric gases, the weather, traffic and noise and light levels are all effortlessly measured, logged, and shared. Our own movements, sleep patterns, heart rate, blood pressure, stress levels and blood sugar levels can also be measured increasingly accurately with smartwatches or trackers. The (wireless) connection between these sensors and our smartphones allows data to be stored immediately and provides processing power and communication options for these sensors.

Interacting with the computer: output displayed on screens

Similarly, computer output has expanded from print and paper to audio,

3.1 (Further) development of technology

displays on watches, glasses, telephones, tables, car windows and across entire rooms, to light signals and haptic feedback (information through vibrations). These forms of output are increasingly blurring the boundaries between digital and physical. Augmented reality adds to our experience of our surroundings, for example by adding background information on our screen. Virtual reality tricks the user into believing that they are somewhere different, using simulations and experiences in a virtual environment, sometimes mixed with elements from the real-life environment. It allows to envisage buildings that have not yet been constructed or to experience a computer-generated environment that is unreachable, like the ocean or universe. Google's Expeditions Pioneer Program offers a designated educational environment in which teachers can introduce students to a low-threshold application of virtual reality using Google Cardboard (and using apps on their own smartphones).

Instructions for the machine: programming

With each new generation of development and programming environments, software allows us to forget more about the mechanics beneath the 'car bonnet'. Approximating our own natural language, programming languages offer constantly improving assistance in writing structured and error-free code, allowing the computer to interpret what we want to achieve with the computer program. Just go and ask a question on the WolframAlpha knowledge platform! With the increasingly powerful hardware, extra layers of abstraction and interpretation can be added. Programming is becoming available to a wider public, as any visit to the Apple, Google, and Microsoft app stores will show you.

Between hope and fear?

New combinations and applications of hardware and software are driving innovations that have far-reaching implications. Social robots in the healthcare sector, self-driving cars on the streets and drones delivering parcels are the first examples of machines that process sensor-fed input using smart
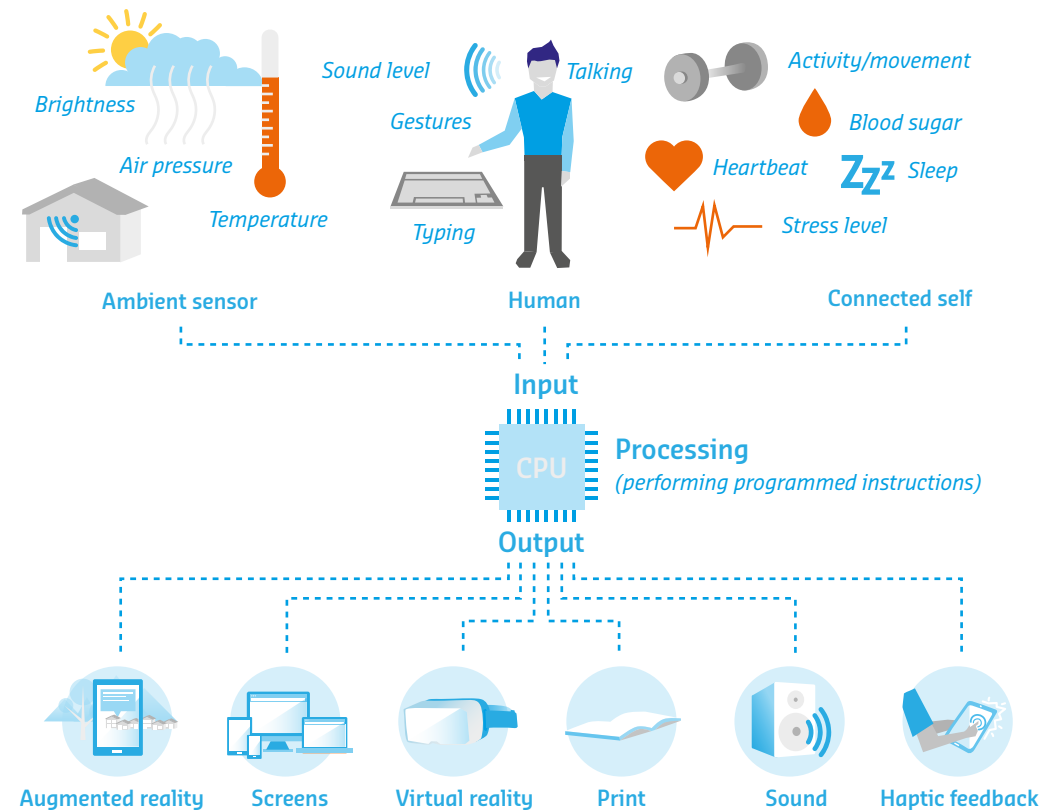
self-learning software that enables them to operate independently, increasingly dealing well with unexpected situations. The opportunities and implications for mankind range from hopeful expectation to concerns and fear. Will learning, intelligent machines replace humans? Take over their jobs? Of their own free will? As early as 2000, Billy Joy wrote an article entitled 'Why the future doesn't need us' in Wired magazine. This report makes a conscious effort to take an unbiased look at the opportunities without ignoring the threats. Naturally, the technology discussed here is positioned on the far left-hand side of the Hype Cycle and is unlikely to be adopted on a massive scale in the near future. At present, it raises more questions than it answers.
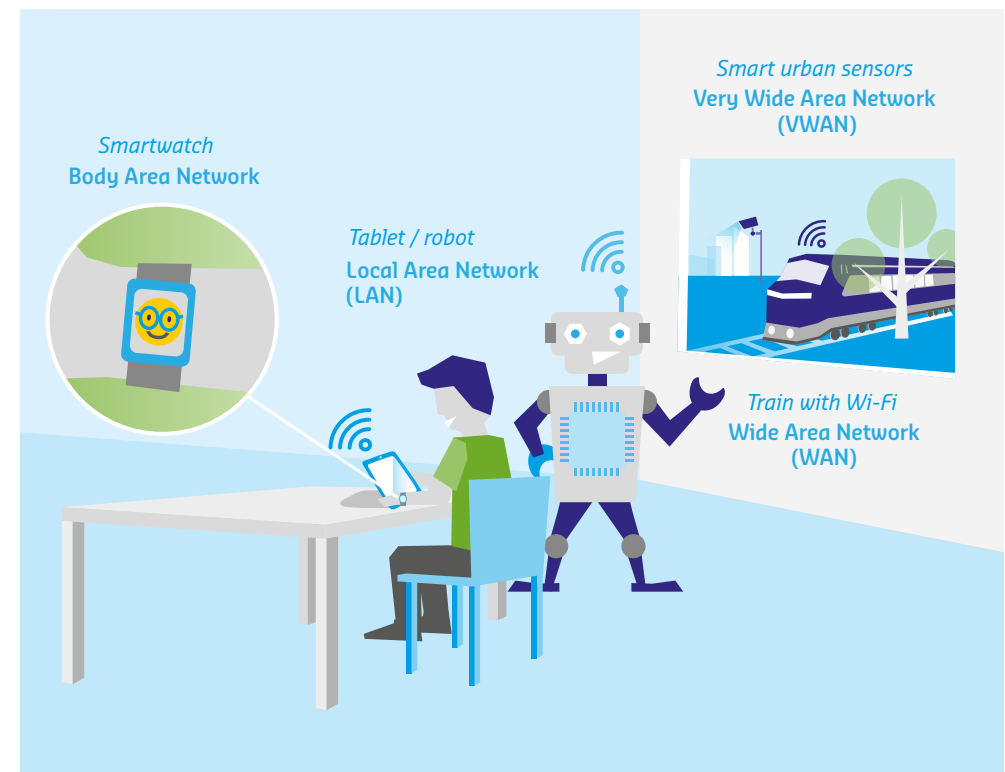
3.1 (Further) development of technology

3.1.1 The Internet of Things: the fourth industrial revolution?
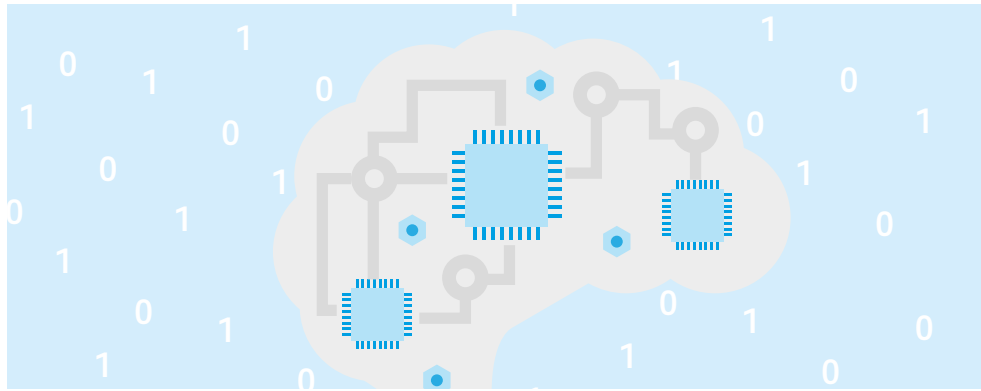
The connection of (intelligent) devices – computers that are often no longer identifiable as such – to the Internet and to each other is often referred to as the Internet of Things (IoT). These 'things' share their (sensor-based) observations and analysis and perform actions as instructed or on the basis of data-based insights (self-learning). We are already getting used to 'watches' encouraging us to get up when we have been sitting for too long at our desks, or alerting us when our blood pressure is too high, our blood sugar level too low, our stress levels too high or our sleep patterns too irregular. What will be next? Devices that automatically contact a physician if certain critical levels are exceeded or provide advice on medicines as well as our diet and exercise? And what about a living and learning environment that alerts you to poor learning conditions, such as an overheated classroom, poor air quality or insufficient lighting? When will that environment become self-adjusting and immediately track the adjustments to analyse their effectiveness? The Internet of Things has been dubbed by some as the fourth industrial revolution. After mechanical production, mass production using conveyor belts and digital computerisation, we are witnessing the birth of cyber-physical, intelligent network systems that radically integrate the physical and virtual worlds in every aspect of our society. The impact on education will be enormous, although it is difficult to pinpoint the precise effect at this time. In our analysis, we look at this relatively new, but rapidly advancing technological wave from different perspectives.

Perspectives on the Internet of Things

Quantified Self refers to the trend of people using sensors to collect data about their behaviour and bodily functions in order to receive health advice based on quantitative insights. Mobile (care) robots and self-driving cars are designed to assist us in our daily lives. Similarly, sensors in buildings and public spaces collect data in order to warn of any problems (threats) at an early stage, ranging from defective lifts to traffic congestion and extreme weather conditions. Take these technologies further and we will be able to create smart buildings and cities that use the benefits of an interconnected digital world to strengthen and expand the existing properties of buildings and cities. In order to examine these different manifestations of 'things' more effectively, we focus first of all on the common denominator of these devices, their 'brain'.

Smartwatch
Body Area Network

Tablet / robot
Local Area Network (LAN)

Smart urban sensors
Very Wide Area Network (VWAN)

Train with Wi-Fi
Wide Area Network (WAN)

3.1.2 The computer is the 'brain' of self-learning machines

Sixty years ago, John McCarthy was the first to explore Artificial Intelligence (AI), developing smart software that imitates (aspects of) human skills such as analysis, decision-making and problem-solving. A few years earlier, Alan Turing had designed his famous test to see whether a machine's ability to exhibit intelligent behaviour was indistinguishable from that of a human. AI protagonists have been promising major breakthroughs for decades, but in the last few years authoritative scientists, engineers and successful entrepreneurs (including Bill Gates, Elon Musk, Steve Wozniak, and Stephen Hawking) have been warning that AI finally is on the brink of a breakthrough. They fear the dominance of technology because we will no longer be able to control the consequences of what we are creating. There are two reasons for the imminent breakthrough, a combination of two effects discussed earlier in this report:

1. In the chapter on the ICT essentials, we noted the exponential improvements in hardware. Computers that in the old days filled entire rooms now easily fit inside a pizza box, and soon a smartphone.

2. The chapter on the digital learning process discussed the exponential growth in the volume of data being fed into self-learning systems.

Hardware and data will continue to develop and grow exponentially unceasingly. We can compare this to the legend of the chess board and the grains of rice, in which the number of grains of rice doubled on each successive square. Added up, the rice in the squares on the chess board exceeded global production many times over. By analogy, the transistor (the smallest digital building block) positions us on the second half of the chessboard where the exponential curve is becoming much steeper. This enables us to have increasingly faster and cheaper 'computers' that learn from unprecedented quantities of data, with AI teaching them to deal with probabilities rather than a simple yes or no. In other words, we are teaching computers to learn, for instance to be able to deal with unforeseen circumstances. In the chapter on ICT essentials, we already noted that virtual computer facilities (servers, storage, computing power) are available to anyone with access to the Internet. Google, Facebook, Microsoft, Apple, and Amazon very recently added self-learning machines to the toolbox. It will, of course, be very interesting to see what creative applications this will generate. The self-learning 'computer brain' is becoming more and more advanced in cognitive terms, but who will take responsibility for 'the behaviour' of these intelligent machines? Who will exercise control over their many possible uses?

Open access to AI as an extension of humans

The aforementioned engineers and entrepreneurs are translating their fears into action, with Elon Musk, Sam Altman (CEO of the successful start-up Y-combinator) and others investing in Open AI. This independent research institute has been given a billion dollars to investigate how AI can be developed further whilst remaining in a healthy relationship with us humans. The findings of the research will be published and there are no commercial interests involved. The idea is that AI should be an extension of and for humans, rather than an independent central, and hence threatening, intelligence. It is time to be more specific: to what uses is AI already being put?

3.1 (Further) development of technology
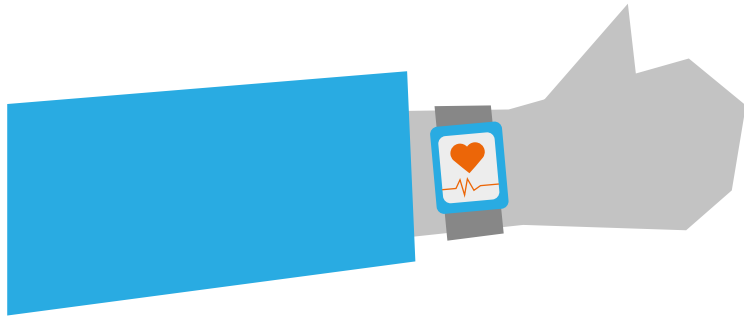
3.1.3 Improving our Quantified Self

Activity trackers have become all the rage in recent years. Accessories such as wristbands and watches, and soon clothing, monitor and record our daily activities, performance and bodily functions without our noticing or even being aware of it. This is definitely an interesting development because measuring and charting your performance can be highly motivating, whether it is a bike tour recorded on Strava, a virtual sports community of cyclists or runners, or a high score in a game. Measuring your performance requires no additional effort and the results are provided on the spot. With instant feedback of information, we can understand the impact of our behaviour and it strengthens our will to stick to the resolutions we make. Graphics shown on apps or dashboards on our smartphones or tablets show our behavioural patterns, physical activity and sleep patterns over a longer period of time, h elping us to set realistic goals. This is why adaptive learning platforms are based on the educational premise that quick feedback contributes substantially to learning and motivation.

Eat, exercise, and sleep to become cleverer

Activity trackers add another dimension to optimising the learning environment in the sense that they allow students (or teachers) to deal consciously with the surrounding physiological conditions and respond better to the varying levels of concentration throughout the day. They receive alerts to exercise or take a break, eat the right food or take a specific dose of medicines. As part of the GOALS project, the Open University of the Netherlands is conducting a large-scale study into activity (exercise and sleep) in relation to school performance. The initial findings have shown that taking physical exercise before going to class leads to significantly better grades, especially among girls. Other studies are looking into the link between food and school performance. There seem to be many unexpected ways to improve school performance figures. A futuristic vision? Not at all. In 2015 Oklahoma's Oral Roberts University made it compulsory for Health Fitness students to buy and wear a Fitbit (including a heart-rate meter) and to walk a minimum of 10,000 steps every day. This activity accounts for twenty percent of the grade for the subject.

Shared improvement

Although we use Quantified Self technology to measure and record our own personal data, the apps on our smartphones can also be used very simply to share this data online with others in a (closed) community or on social media. For example, activity trackers like Fitbit, Jawbone's UP and various smart watches provide options to connect with friends and compete with them in losing weight, taking more exercise or getting more sleep. Oklahoma's Oral Roberts University uses this functionality to track their students' performance. Students can decide for themselves which data they wish to share with which group – exercise and heart rate are mandatory, GPS data (where was I at a particular time of day) are optional but encouraged. Examples like this raise all sorts of ethical questions to which we will return later.

3.1.4 From factory machinery to mobile social robots

We now move from Quantified Self to objects in our immediate environment: robots. We are accustomed to the image of factory halls and robotic arms patiently assembling endless quantities of products. While robots are becoming increasingly mobile, 'skilful' and social, we are becoming more technical; the differences between us are growing smaller. At what point will we meet? We observed earlier that there are growing concerns about people being replaced by machines and technology. Films like 'Wall-E' (robots serving a society grown idle, 2008) and 'Her' (featuring a character who has become emotionally dependent on a personal digital assistant, 2013) explore this very theme.

Manufacturing robots   **Domestic robots**   **Social robots**

Peter-Paul Verbeek, Professor of Philosophy of Man and Technology, believes this negative perception is not entirely justified. He sees technology as a means of helping us to live our lives, as an extension of ourselves. It is merely a further change in the nature of the work performed by people. In the United States and Japan, robots are already being deployed in the health care sector to carefully lift patients in and out of bed, pick up laundry and deliver medicines and meals. Robots actually perform these tasks more precisely than people. According to Professor Verbeek, robots are changing the landscape of care provision, freeing up more time for human interaction. Contracting out boring, dirty or dangerous jobs to machines creates space for service and for more creative jobs. And, of course, robots have to be designed, manufactured and serviced. At least until they can also do that by themselves...

The impact of robots on jobs and occupations

Social robots with machine intelligence are here to stay. In its research report 'Working on the Robot Society', the Dutch Rathenau Institute of Science, Technology and Innovation concludes: "Information technology like robotics will contribute to productivity growth and continued job polarisation due to
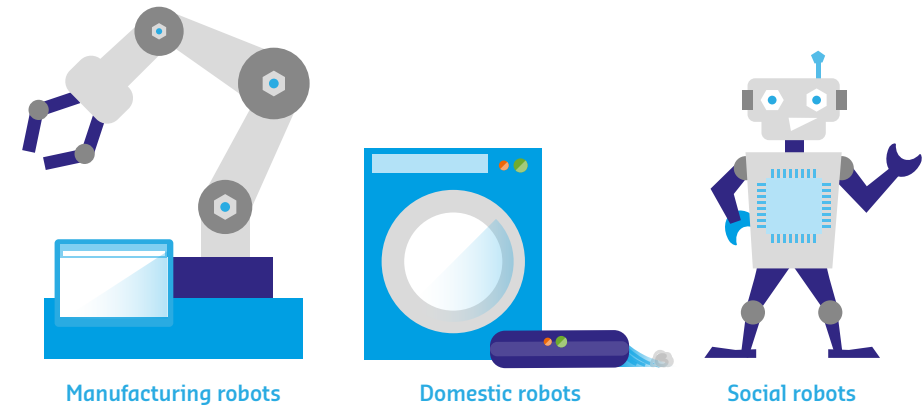
computerisation". Likewise, labour sociologist Fabian Dekker expects employment at secondary vocational level to be eroded by advances in technology. As a result, inherently human skills such as creativity, empathy, social skills and the ability to observe are rapidly growing in importance, which begs the more practical question of what jobs will actually be threatened by this latest industrial revolution. In a study entitled 'The Future of Employment: How Susceptible are Jobs to Computerisation?', researchers at Oxford University calculated the probability of jobs being threatened on the basis of a variety of job characteristics. High-risk occupations included Office and Administrative Support, Sales, Production, Transportation and Service. In the Netherlands, secondary vocational schools are already exploring the likely impact on the courses for these types of jobs and the range of programmes they offer. The researchers note that the best way of coping with these developments as a society is to encourage a public debate about the impact of technology on the job market and to invest in training and education.

Understandably, the reaction of some people – as a form of self-protection – is that it will probably not come to this at all. But although robots still have a lot to 'learn', the number of examples is growing rapidly:

- Care robot Zora is being used successfully in the Netherlands to combat loneliness and boredom among elderly people. She also teaches maths to 12-year-olds as part of an experiment conducted by researchers at the Free University in Amsterdam.
- In Japan, a theme park hotel uses robots as doormen, cleaners, receptionists, to carry suitcases and to escort guests to their rooms.
- Vanessa Evers, Professor of Social Robotics at the University of Twente, designs robots that can show people the way at an airport or take them on a tour of a museum. To do this, the robots need to be able to interpret human signals such as irritation, appreciation and attention, or whether a person is just waiting.

Robots in the driving seat?

In the opening chapter of her book 'Smart Technologies and the End(s) of Law', Mireille Hildebrandt portrays a day in the 'onlife' life of Diana. Hildebrandt offers a credible account of a potential future with self-learning intelligent Virtual Personal Assistants (VPAs) that are omnipresent digitally (software) and physically (robots) to support people who are juggling home and work and caring for children, parents, elderly people, etc. The – undoubtedly very expensive – robots are paid for by employers and care institutions, each with their own agenda. Chatbots – which have no physical shape – have already become established on Facebook and for a growing number of businesses through WhatsApp. How this trend will be taken up in education is anyone's guess. On the basis of the Oxford University study referred to above, the US media group NPR has posted a Will-Your-Job-Be-Done-By-A-Machine calculator online for people to 'calculate' the risk of their jobs being replaced by robots. Spoiler alert: teachers are calculated as low risk, but the calculator does not say

whether their work will remain the same. Silicon Valley veteran Mårten Mickos believes that it is mainly a question of your own attitude to your job: "If you behave like a robot at work, it is only a matter of time before you get replaced by one".

If you behave like a robot... ...you get replaced by one.
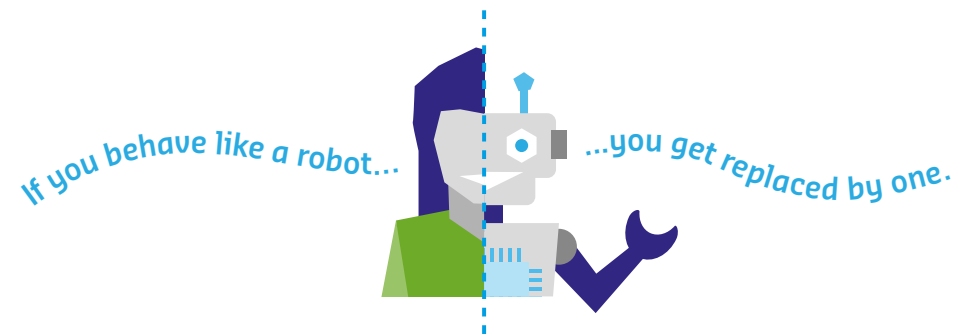
In its report 'Mastering the Robot: The Future of Work in the Second Machine Age', the Netherlands Scientific Council for Government Policy (WRR) examined the impact of robotisation on education. It warns against placing too great an emphasis on technical skills, saying that it is important to combine technical knowledge with the skills and sensitivities students acquire in the Humanities. As far as the looming dominance of robots is concerned, the WRR report takes a nuanced position saying that it ultimately comes down to what we want people to do, even if robots can do it. The WRR emphasises that it is up to us to make deliberate choices in shaping a future in which robots can support us in our work and lives, in those areas where we want them to.

3.1 (Further) development of technology

The self-driving car: a mobile intelligent machine

The self-driving car is perhaps the best example of how a machine operated by humans to get from A to B is gradually evolving into an intelligent 'robot' offering mobility services. The more expensive car marques and models are taking the lead. With a little help and guidance, these cars are increasingly capable of operating independently. First there were automatic lights and windscreen wipers, then came adaptive cruise control (with queue assist), followed by lane-keeping apps, automatic braking when approaching an object, and automatic parking. It will not be long before the Tesla drives itself to the nearest charging point and then returns to pick up its driver at a specified time. While there is a 'battle for the dashboard' going on in the automotive industry between Apple (CarPlay), Google (Android Auto) and Tesla, in the ten years since the introduction of smartphones established car makers have made little or no progress with the interfaces and functionality of their own systems. 'The Innovator's Dilemma' (authored by Clayton Christensen) came as a severe

blow to the automotive industry: dominant market players are not capable of disruptive innovation. There may come a day when the software – including sensors and screens – forms the heart of the car, while the hardware is inter-changeable and perhaps not even owned by us. These are a few examples of unpredictable changes triggered by robotisation that are difficult to fathom. Legislation will have to follow quickly to regulate self-driving vehicles. What will be the requirements for driving them safely? Who will be responsible in the event of an accident? These are questions discussed in more detail in the section on digital ethics.

Drones: flying (intelligent?) machines

They look like toys, but unmanned drones go a long way back in military history. From flying practice targets, the military applications have evolved into the use of drones for remote-controlled surveillance and as strike weapons, giving rise to all sorts of strategic and ethical issues. In our field – education – their observation and recording capabilities, using cameras that are becoming better and lighter all the time, are a welcome addition to our toolbox. There have already been a number of educational projects in which drones were used to map a particular part of the landscape (applied geography/geology), take measurements and analyse, interpret and explain the findings. The practical uses of drones are infinite, from road construction, agricultural control, building supervision, journalism, cinematography and emergency services to climate research and archaeology. The technology will also have an impact on jobs in these sectors and, by extension, in education. Drones too will need to be regulated, not only for reasons of safety and security, but also to ensure people's privacy when drones fitted with HD cameras and microphones are used to monitor situations.

3.1 (Further) development of technology

3.1.5 The intelligent school building

Accommodation as part of the learning environment takes up a considerable part of a school's budget. Internet of Things applications in or around the school can make a substantial contribution to making better use of capacity and controlling maintenance and utility costs. They can also be used to create optimal conditions for learning, for example by managing air quality, noise levels and lighting. The physical (as well as virtual) learning environment can be measured, recorded and analysed so that recommendations for improvements
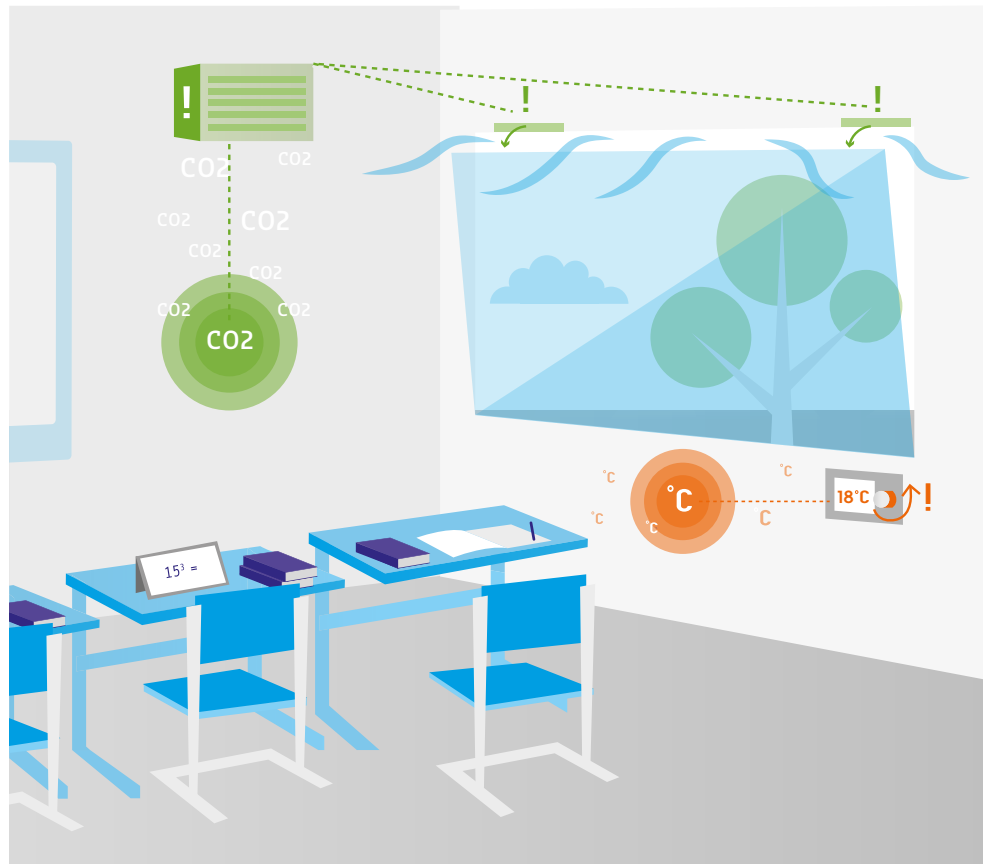
can be made, sometimes automatically according to predetermined criteria (for temperature, oxygen, light). This is rather like a 'smart home' (domotics), where heating boilers, energy management and lighting are designed smartly to improve the quality of living. Preventive maintenance can also be carried out more precisely. Aircraft engines use electronics to inform the manufacturers of any wear and tear and non-conformities after each flight. This has been standard practice for years. Similarly, IoT applications can make equipment and systems in homes and buildings more reliable and hence have an impact on a variety of jobs and course programmes.

Intelligent school buildings can help optimise the learning environment by, for example:
- providing a detailed picture of a building's energy consumption, and automatically taking action by switching lights and heating on and off according to (scheduled and actual) room use and weather conditions;
- monitoring air quality and taking action autonomously if it falls below a certain standard;
- providing long-range data on the actual use of a building's rooms in relation to the schedule and making recommendations for improved capacity utilisation. This may be data on capacity usage, the number of people present, the type of activity and necessary/available facilities.

Using Social Physics to improve cooperation and knowledge sharing

An interesting combination of Quantified Self (to observe human behaviour) and room utilisation is to use sensors to observe and measure interactions at work. The data produced can be used to position workstations differently in the room in order to improve collaboration and knowledge sharing. In his book 'Social Physics: How Good Ideas Spread – The Lessons from a New Science', Professor Alex Pentland, a data scientist at the Massachusetts Institute of

Technology (MIT), describes how he and his team, using sensors to observe, discovered patterns in how environments and (organisational) structures can be designed to ensure effective cooperation and creativity. Interestingly, they found that continuous and rapid interaction can adversely affect creativity and the quality of knowledge acquisition. 'Delayed' interactions can work very well. Pentland and his team are now using this principle to design collaborative structures and internal communication platforms within organisations. Their findings could conceivably also be applied to the design of learning settings and learning communities.

3.1.6 The Internet of Things: a marriage between information and operation?
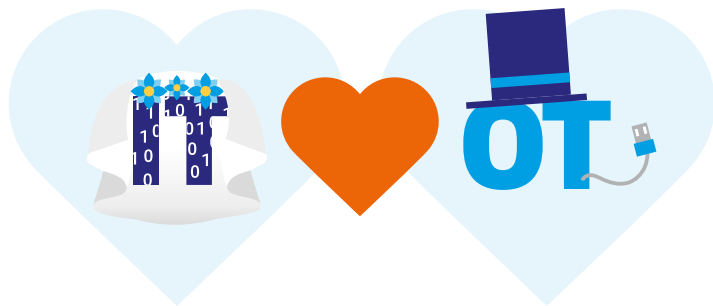
In the chapter on the ICT essentials, we referred to the component parts of the ICT infrastructure as elements of an ecosystem. Its different building blocks (network, cloud software, storage and devices) constitute a set of mutually supportive elements that depend on each other to function properly. Internet of Things applications expand this ecosystem with more devices, more (sensor) data (in the cloud), more network connections, etc. What is clear is that we are becoming increasingly dependent on this ecosystem. The fact that the system processes and stores personal information could have major implications

when intelligent machines start operating autonomously. On the plus side, all the background information about our behaviour, preferences and plans stored in this ecosystem can be transferred to other settings. My car will soon know which apps, interfaces, and software I am accustomed to using, what information about me is available in the cloud, the places I like to visit and the people I hope to meet there. Mobile 4G and 5G communication networks are providing more reliable and faster connections when we are on the move, and new WiFi standards such as HaLow (802.11ah) support low-energy (and low-speed) connections for various IoT applications in and around our homes. In other words, these are rapid developments that will have a huge impact on the ICT infrastructure as we know it.

IT/OT integration

Maybe the most important effect of the Internet of Things is that it provides a link between Information Technology (IT) and Operational Technology (OT), bringing the two together in an expanded ecosystem. All kinds of applications and products will soon have built-in sensors that allow them to be used more easily and more effectively. Still, there is a wide gap to be bridged between engineers looking at technology from a control and operational perspective and computer scientists focusing more on functionality, processes, and the market. Understanding both perspectives and possessing the ability to cooperate will prove crucial in many occupations. The successful implementation of its 'digital transformation agenda' may well hinge on an organisation's ability to integrate its operations and information provision, and this will create a new and interesting field of work that calls for new training programmes, or combinations of existing ones, that provide students with the tools to perform new jobs that may not even exist yet.

3.1.7 Digital ethics: principles and regulations for our machines

With various uses of intelligent machines in mind, we now turn to their potential impact. As computers learn to speak and understand ordinary human language, a whole new field of ICT applications is emerging. But what are the implications of self-driving cars or care robots for our safety, privacy, social interactions, free will and liberty? The aim of digital ethics is to mitigate the undesired consequences of information technology, including intelligent machines. Back in 1942, in his 'Handbook of Robotics, 56th edition, 2058 AD' science fiction author Isaac Asimov devised the 'Three Laws of Robotics':

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given to it by human beings except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

After applying these laws in various books and exploring a variety of 'unintended consequences' in his stories and discussing them with his contemporaries, Asimov introduced a 'zeroth' law that takes precedence over the earlier laws:

0. A robot may not harm humanity or, by inaction, allow humanity to come to harm.

Seventy years on the practical dilemmas arising from the use of robots make it clear that the issues facing digital ethics are far more complex and more nuanced. What is good for humanity is not necessarily good for the individual. Who weighs up these interests? And what is ethical? Ensuring minimum harm to humanity or generating maximum benefits for society? Unlike humans, computers usually have all the information needed to make a decision and they

Rules for humans

Rules for machines

possess sufficient computing power to consider all the interests involved. But this is all to no avail if there is no clear decision-making framework. Here is an example.

Who controls and is responsible for a machine's behaviour?

What happens if a self-driving car with passengers inside is suddenly confronted with a pedestrian crossing the road, oncoming traffic in the other lane and pedestrians on the pavement? The car's sensors will have a visual impression of all these factors, allowing different avoidance scenarios and braking distances to be calculated and the probable damage ensuing from each scenario to be estimated and compared. What will be the decisive criterion? Cause the least possible harm to the passengers and 'owners' of the car? Minimise the number of casualties (regardless of age?), perhaps at the expense of the passengers? Or do we hit the brakes without swerving, in view of the crossing pedestrian's rash behaviour, although we have calculated that we will not come to a stop in time?

Leading physicians have indicated they can make only limited use of all the data recorded by smartwatches and trackers. Their medical malpractice

insurance does not allow them to accept the responsibility. For if you can monitor a person's heart rate, blood pressure and other vital bodily functions around the clock, why did you not see the heart attack coming and do something to prevent it?

How not to mess up with technology

The study of (digital) ethics and morality needs to address new and interesting issues in terms of who is responsible for the 'behaviour' of intelligent machines. Frank Buytendijk, a Gartner VP & Fellow, has pioneered the development of digital ethics. Or, in his words, "How not to mess up with technology?". He notes that many occupations have ethical codes in place, but that it is not common practice in information technology. At the same time, the need for regulation is growing rapidly, as evidenced by our exploration of the use of data and analytics in the digital learning process and the potential of Machine Intelligence. The tension between teacher and system is increasing. What guardrails do we need to enable us to use cloud computing, social media, Big Data, and intelligent machines safely in our society? Interesting questions also
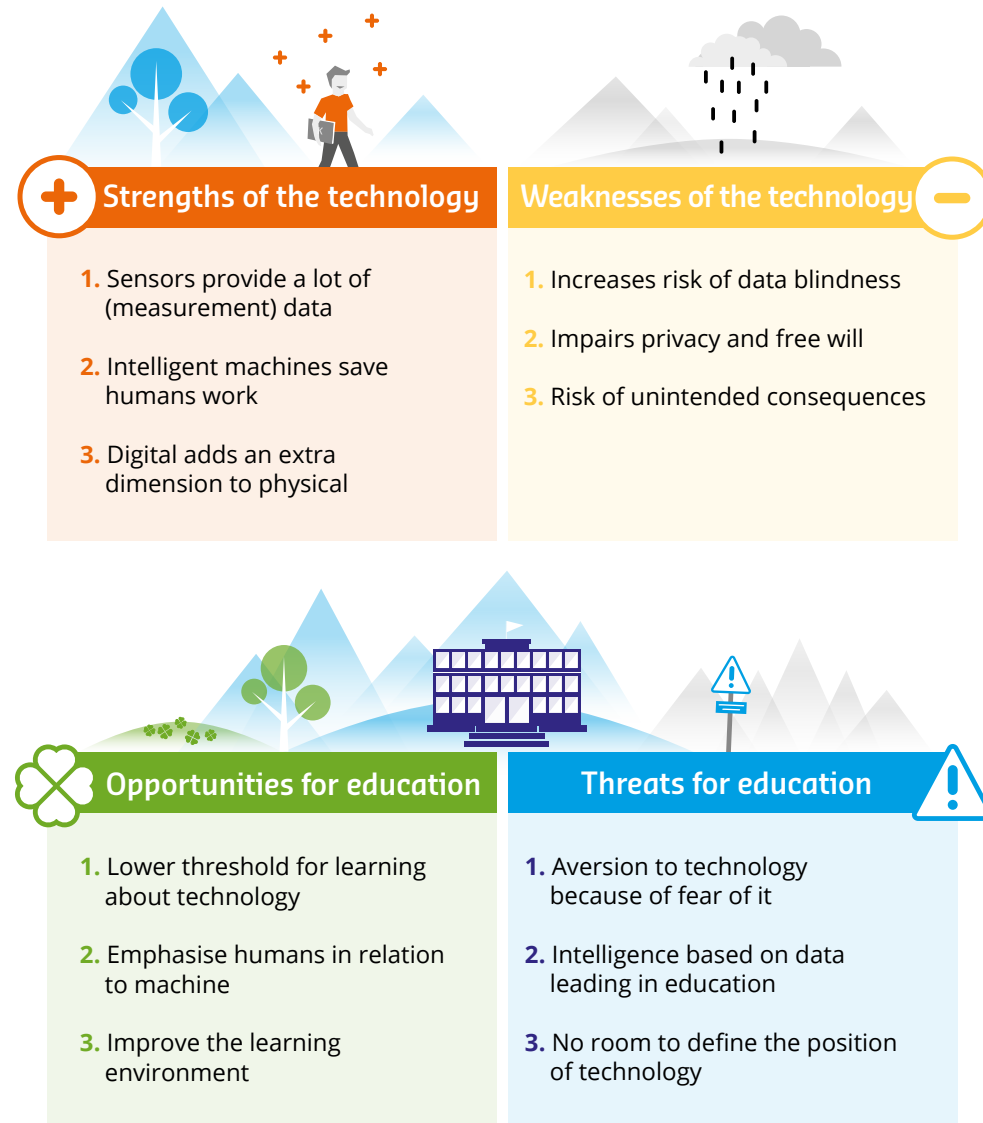
arise in education. How do we explain to an educational robot what cribbing means and that answering a question on behalf of a student is actually cheating? The original versions of Apple's and Google's smart digital assistants were surprisingly willing to aid and abet in wrongdoing.

Smart buildings in smart cities

Smart buildings and smart cities create an extra digital layer, a new structure that allows us to make better use of buildings and benefit more from the city-'s amenities. At the same time, these digital uses threaten to create a 'digital divide' in society because only the better off and better educated are likely to benefit from them. In this new environment, a common framework can ensure that data is publicly available and people's privacy is ensured, and that everyone has easy access to the smart city and everything it has to offer using low-threshold tools. A building or city is not necessarily smart in and of itself. It is the technology that lays the foundation for smart applications, which will in turn boost entrepreneurship. This digital layer opens up new opportunities, but how they are used and by whom should be the leading criteria.

Technology is evolving rapidly and society and the economy are having difficulty keeping up. Legislation or protocols are often lacking, leaving us to chart our own course using our own moral compass. As we have seen earlier, there is a practical need in the digital learning process for a regulatory framework for the use of data in personalised education. The issues raised here are only a sneak preview of the wider debate that we should be having. The role education can play in that debate is discussed in the following section on education in a digital information society.

SWOT analysis (further) development of technology

Strengths of the technology

1. Sensors provide a lot of (measurement) data
2. Intelligent machines save humans work
3. Digital adds an extra dimension to physical

Weaknesses of the technology

1. Increases risk of data blindness
2. Impairs privacy and free will
3. Risk of unintended consequences

Opportunities for education

1. Lower threshold for learning about technology
2. Emphasise humans in relation to machine
3. Improve the learning environment

Threats for education

1. Aversion to technology because of fear of it
2. Intelligence based on data leading in education
3. No room to define the position of technology

SWOT analysis

Strengths Sensors collect data about ourselves and our environment effortlessly and at a high frequency. Intelligent machines learn from this data and can help people meet their duties and responsibilities. The digital layer provides new opportunities to make better and different use of the physical capabilities of people and resources.

Weaknesses It is still difficult to interpret data for the purposes of a process. How to ensure that humans retain enough space in relation to machines is also uncharted territory. This is one of the reasons why we must remain alert to negative consequences. In education, we need to ensure that teaching and guidance do not become too mechanical or too impersonal.

Opportunities Technology is rapidly becoming more accessible and easier to use for non-specialists. Getting started and experimenting with it in schools has also become easier. Creativity, empathy and social skills (which distinguish us from machines) are at the heart of education. Teachers have every opportunity, and the obligation, to teach these skills to their students. They can use technology to free up more time and space for this.

Threats The fear of being dominated by technology could paralyse technological research. Data-fed Machine Intelligence must not be allowed to determine our approach to education, but could help to reduce the pressure of work. As technology continues to evolve, we need enough time and space to adjust the teaching-learning process to the needs of the 21st century (economy).

Recommendations for school boards on how to develop and take technology further

1. Explore the direct benefits of the Internet of Things in dedicated pilot projects.

The Internet of Things is still in its infancy and its technology and potential uses are evolving as we speak. Applications are at the experimental stage and it is far too soon for proven performance or output. This is why IoT technology cannot be deployed on a large scale for the time being. That said, its potential uses and benefits are highly diverse and significant. In education, studies are being conducted to examine the impact of physiology and students' mental well-being on effective learning. In needs-based education, in particular, this provides opportunities to track students' behaviour and mental and physical well-being in a subtle way so as to improve the teaching-learning process. This might mean that more students with needs can continue to perform well in regular education or reduce the amount of guidance they require. Dedicated small-scale pilots could be launched to explore these opportunities and gain more knowledge. An example would be to combine physical exercise with logging the amount of exercise students do on a school day. Is there a link between school performance and physical activity? Use the data with care and explain to parents why the school wants to use this technology.

2. Invest in a smart school building to provide maximum support to the educational process.

When designing a more personalised learning process, schools also often take a fresh look at their accommodation needs. IoT technology can be used inside buildings to observe, measure and analyse whether existing facilities adequately meet the requirements of the new educational set-up. For example, sensors can easily be fitted in classrooms, communal areas and corridors to measure how intensively they are used. The data generated can then be used to evaluate plans for new accommodation or renovations. Sensors can also be used to examine how newly built flexible accommodation can be designed in a way that is best suited to the teaching-learning process. As previously discussed, Social Physics can have a major impact on how students interact with one another and with their teachers and the environment. It is advisable to explore specific possibilities, for example by observing the organisation and digital interactions within small groups. The added advantage is that teachers (provided they are involved!) will gain experience in using the very technology that they themselves and their students will encounter in their jobs and other aspects of their lives.

3. Discuss the focus on and role of technology with teachers.

Reports published by Oxford University, the Netherlands Scientific Council for Government Policy (WRR) and the Rathenau Institute all point in the same direction: intelligent machines (like robots) will have a major impact on our lives and work and on society in general. Exactly how and when this impact will be felt is not yet clear and will depend in part on our own input. This responsibility is a key theme in and for education. Creativity, empathy and social skills should be a focus in education, probably more so than 'competing' with machines in terms of skills. Regularly discuss with teachers and students the significance of this debate for the school's vision of education and for the day-to-day activities in and around the classroom.

Digital literacy

| Basic ICT skills | Media savvy | Information skills | Computational thinking |
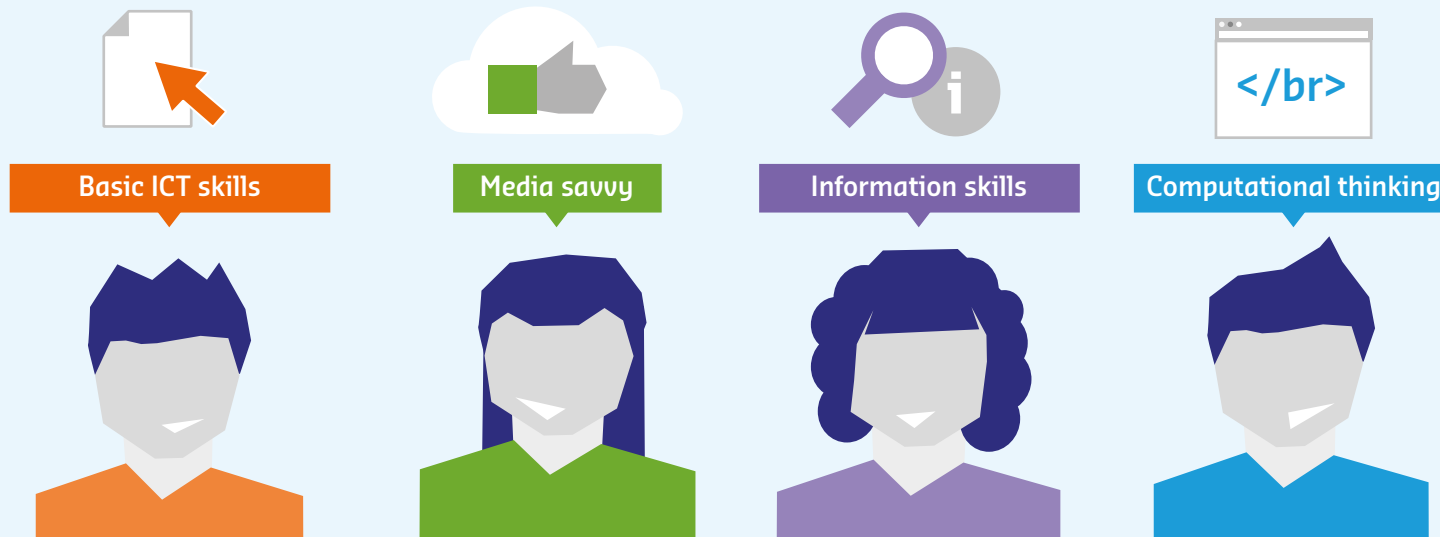
3.2 Education in the digitising society

Having formed an impression of what advancing technologies may bring us, we will now examine the implications for schools, which have to prepare students for life and work in the 21st century – in a society which requires a totally different mix of knowledge, skills and probably also attitudes than a century or even fifty years ago. Things that were taken for granted such as jobs for life and the certainty of finding a job after graduating have been replaced by a sweeping dynamic triggered by the rapidly evolving digitisation of society. To be able to keep our footing, we need to be digitally literate and confident in the use of the available technology. Augmented reality allows easy and timely access to the information that is available. Virtual reality explores uncertainties and teaches us skills by means of simulations and training.

3.2.1 Digital literacy and 21st century skills

The report published by the Royal Netherlands Academy of Arts and Science (KNAW, 2012) defines the digitally literate as people who think digitally and who are digitally capable and responsible. Kennisnet and the Netherlands Institute of Curriculum Development (SLO) have formulated a new and more detailed set of 21st century skills. The model defines eleven skills which students should acquire in school. The new model builds on the old one, the main exception being that 'digital literacy' is no longer a skill in its own right, but rather comprises four separate skills:

1. Basic ICT skills: an understanding of how new technology tools work and ability to assess the opportunities and constraints with a critical eye, knowing the impact they will have on human actions.
2. Media literacy: acquisition of the knowledge, skills and mindset needed to deal consciously, critically and actively with a complex and changing mediatised world.

3. Information skills: ability to formulate sharp questions, analyse sources, perform systematic searches, select and process large volumes of data and assess their usability and reliability.

4. Computational thinking: ability to rephrase problems and organise data so as to be able to analyse and solve problems using computer technology.

In its final advisory report to the Dutch government, the Education Platform 2032 wrote that learning and working in a digital world should be the focus and at the heart of education. The Platform also refers to the four elements of digital literacy referred to above. This entire set of digital skills is a prerequisite for understanding and controlling the implications, opportunities and threats of information and communication digitisation. In '21st Century Skills in the Curriculum', the Institute of Curriculum Development went on to define a digitally literate student as an active and responsible participant in the information society, who is aware of the ethical, social, legal and economic aspects of digitisation when making informed choices that involve considerations of privacy, ownership and freedom. In this section, we explore the various elements of digital literacy on the basis of recent trends, such as the Maker Movement and the debate about learning to program.

3.2.2 Computational thinking: learning to ride a bike?

Steve Jobs sought to describe the possibilities offered by the computer as broadly as possible when he compared it to 'a bicycle for the mind'. In terms of speed and endurance, people could not really compete with animals until they had their bikes. We are 'tool builders' and a computer does much the same thing for our brain. By learning to program, we develop 'computational thinking'. We learn to think creatively about translating a problem in order to analyse and solve it using computer technology. To stay with the metaphor, we

learn to pedal, steer, brake, choose the best gear and chart our own route. As citizens, we need similar basic and practical computer skills to be able to move freely within society. However, programming as a skill or a new subject on the curriculum has triggered a lot of debate. Surely, we are not all meant to become programmers? Is this not just the hobbyhorse of technology giants wanting to solve their shortage of programmers in the short term to prevent wages within the industry from rising too quickly?

Programming as a basic skill
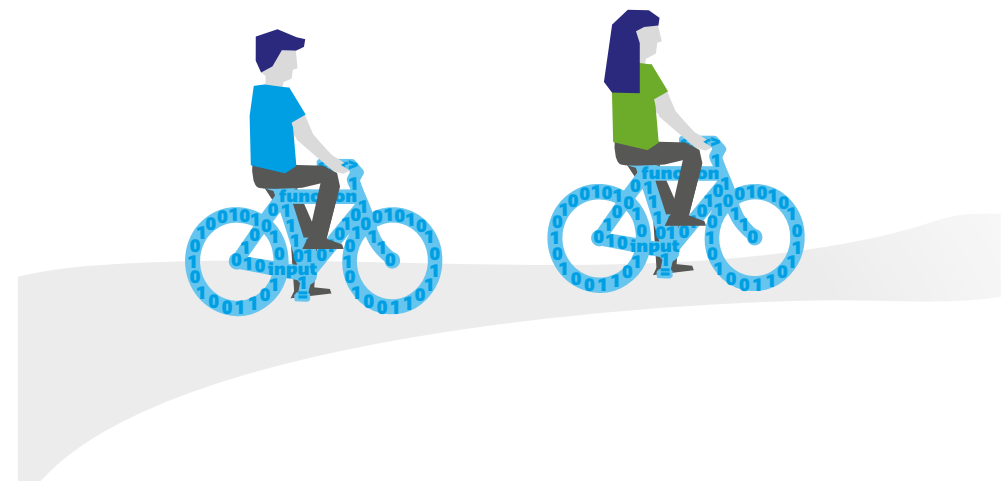
A clear distinction should be made at this point between the profession of software developer and computational thinking as a generic skill needed to function effectively in a digital world, regardless of the setting or profession. Chemistry is not intended to teach everyone in secondary education to become a chemist, but is aimed at providing them with an understanding of our periodic table of elements and the chemical behaviour of substances. Similarly, learning a programming language adds to our knowledge of the mechanisms behind

computers and their uses. With a decent basic knowledge of different computer concepts and languages, we can also quickly grasp how to use new digital tools. But can children learn to program? Yes, absolutely! The Codekinderen. nl website contains a collection of tools, resources and sample exercises designed to encourage children from the age of six to discover the basic principles of programming, with or without a computer. Many schools have already picked up on this trend. Tools also often provide combinations of physical objects (to be constructed in part by the user) and programming. This is discussed in more detail below in the Maker section.

Computer science to be introduced as a final examination subject?

Learning to program shows how computers work and how they are used, but there is more to the digital world than that. Subscribing to this view, Han van der Maas, Professor of Psychological Methods at the University of Amsterdam, is a strong advocate of making computer science a mandatory final examination subject at schools. Computer science is a multi-disciplinary discipline that brings together mathematics, electrical engineering, information and communication technology, and other subjects. The driving force behind the 'Maths Garden' online exercise tool for students, Van der Maas knows a thing or two about education. Recognising that schools do not always have the resources to teach an extra subject like programming or computer science, he believes that the government should highlight its importance by prescribing official learning outcomes. This would require re-prioritising the curriculum. In terms of relevance, computer science is on a par with Dutch language and literature and mathematics, which are also mandatory final examination subjects. The term 'digital literacy' shows how fundamentally important and broad-based the subject is for each student or student, study or training programme, job or profession.

3.2.3 Maker: learning by making

An unintended side-effect of the rapid development of electronics is that we seem to be less knowledgeable about, and perhaps also less interested in, 'how things work'. And this at a time when we should actually be engaged in regulating and controlling the position of technology in our society. For example, a smartphone or tablet is a 'black box' that we use constantly, but we haven't a clue about its component parts and how they work together. It is becoming increasingly difficult to get people interested in the technical professions that will keep our society running. Businesses are calling for more engineers and technicians and stressing the need to get young people to enrol in technical training programmes. How do we break this impasse?
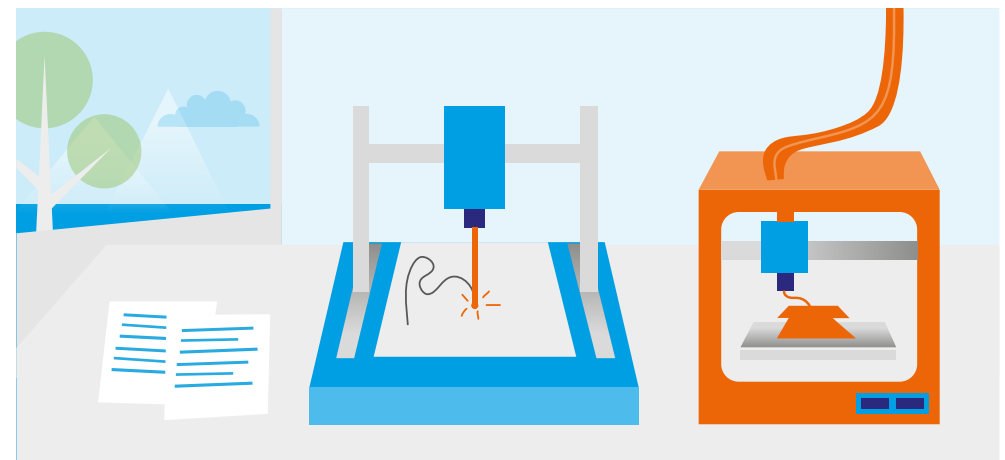
'Tinkering' involves thinking and making

Fortunately, technology itself is creating new opportunities in the shape of DIY (Do It Yourself) technology. The last few years have seen the emergence of 3D printers and laser cutters in what are known as FabLabs. Fabrication Laboratories – an idea first launched by Professor Neil Gershenfeld at MIT's Center for

Bits and Atoms – are public digital workshops where people make things. A FabLab provides low-threshold access to computer-controlled prototyping machines and electronics that students and students can use to turn their ideas into tangible products. Welcome to new-style 'tinkering'! Aside from the much-talked-about 3D printers, a large variety of affordable and often open-source hardware has come onto the market. Well-known examples include Arduino (initiated by Italian design students) and the slightly more complex and more powerful Raspberry Pi (developed for educational purposes by the University of Cambridge). Because the specifications are freely available, anyone can copy, adapt or improve the hardware. There are entire start-up toolkits available and affordable, full of electronic components that a person without a technical background can use to build a piece of hardware and write the necessary instructions for, in a simple programming environment. Why is this so interesting and relevant for the education sector?

An enquiring attitude
We already used the word 'tool makers'. DIY technology gives us the building blocks to tinker with technology that used to be incomprehensible and inaccessible, not to mention expensive or complex. DIY technology allows students to learn as they go and discover how the technology around them works. 3D printers and laser cutters can be used to design or alter an object and immediately print a tangible 3D model of it. Toymaker Mattel's 'Thingmaker' allows children to use the ThingMaker Design App to design and print their own toys in all sorts of colours. And after an afternoon's tinkering with an Arduino kit, students will look at electronics and computers in a totally different way. Taking a few wires, a breadboard, a print board, some sensors and LEDs, they can build a device that measures the number of visitors to the assembly hall. Or add a small electronic motor and build a small self-steering robot that can find its way around a maze. This method of learning – by designing and making things – encourages the inquisitive attitude that we want our students to deve-

lop. It is probably also a useful tactile counterweight to a digitising society, in which it seems everything is becoming digital and virtual. Once again, not every child has to become an engineer. But it would be better for our society if we were less in awe of the technology that is there to serve us. If we understand at a basic level how technology works and what its weaknesses are, we can develop the technical self-confidence we need to feel safe and secure in a digitising society. And we can help students who are gripped by a passion for technology become aware of their talent and interest at a much earlier age. Experiencing how much fun it is to be creative and to make things with others is the best advertisement for technical studies and training programmes.
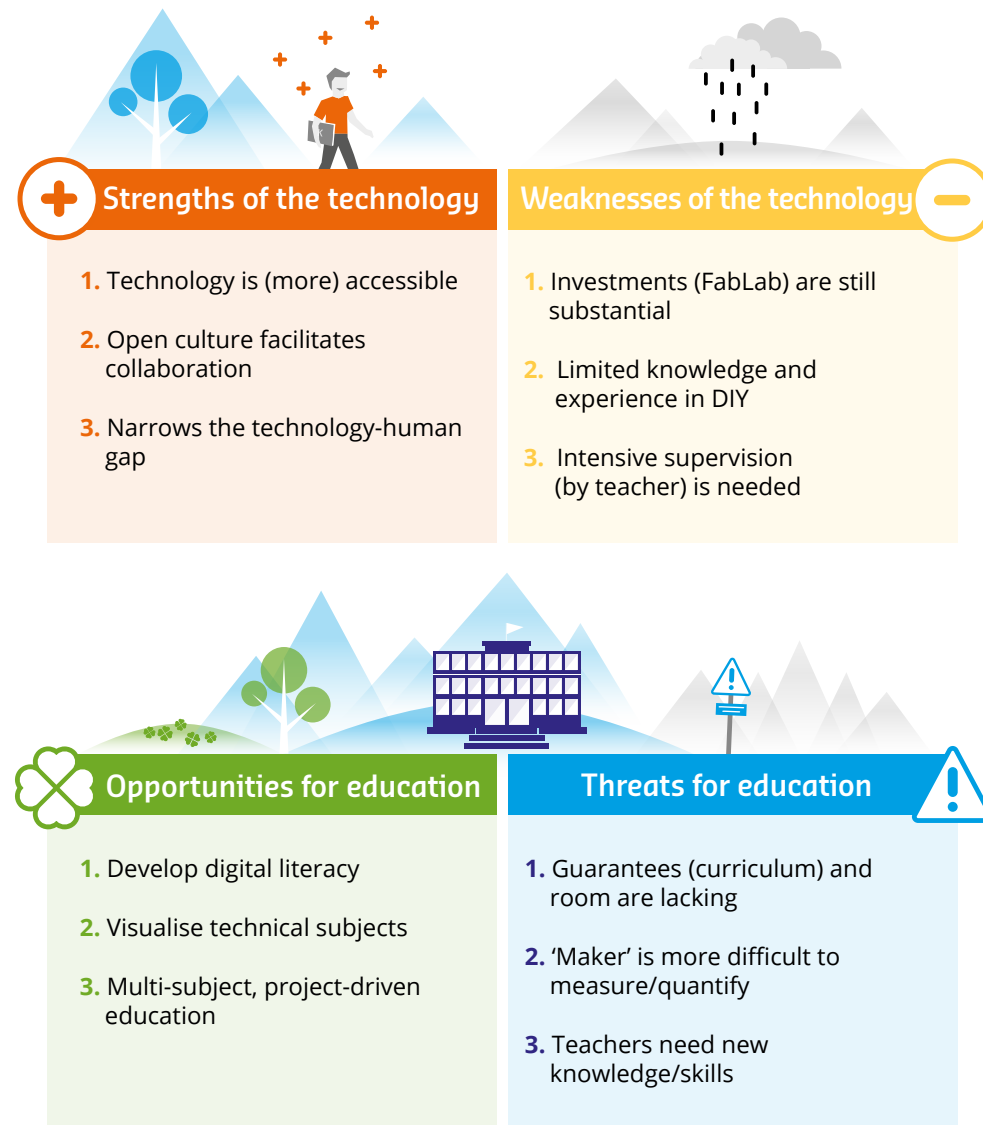
The collaborative network: the rebirth of manufacturing industry?
DIY technology has also been heralded as the rebirth of manufacturing industry. Widely available and inexpensive technological building blocks, coupled with Internet's communication firepower, enable people to develop concepts and share designs very quickly across multiple disciplines. It has also once again become possible and affordable to design innovative products on a small scale and manufacture them in limited quantities. Production of large volumes can be outsourced at a mere keystroke. Internet has democratised the publication and distribution of information. DIY technology does the same for the design and manufacture of physical products. The main drivers behind the development of much of the DIY technology are the personal needs of people and their inspiration. DIY technology considerably narrows the gap between feeling a need or being inspired by an idea, on the one hand, and developing it by trial and error into a product or service, on the other. Those who cannot afford their own 3D printer can have designs – whether their own or someone else's – printed commercially. Shapeways also allows designers to offer their designs for sale. It is early days, of course, but these developments are likely to have a huge impact on and major implications for manufacturing industry and related (vocational) training programmes.

Maker Education

The Maker Movement is also making rapid inroads into education. Arjan van der Meij, a physics teacher at a school in The Hague, is the driving force behind Maker Education in the Netherlands, working with Karien Vermeulen of the Waag Society and Jeroen de Boer of Frysklab (a mobile library FabLab). The Maker Education Platform's blog reports on the initiatives undertaken in this field in the Dutch education sector. Consistent with good Maker practice, the blog can be used to share Maker sources, materials and ideas. Maker Education provides low-threshold access because ideas for lessons, examples of projects and descriptions of the resources needed are freely available. Makers are keen to meet offline as well as online, in FabLabs and at Maker fairs and festivals where plenty of equipment and materials are available for them to use and share. Visitors are typically a mix of children and adults helping each other with projects or working out ideas together. Maker Education shows us that technology is, if nothing else, a very useful tool for explaining what science is about and familiarising students with technical subjects.

SWOT analysis education in the digitising environment

Strengths of the technology

1. Technology is (more) accessible
2. Open culture facilitates collaboration
3. Narrows the technology-human gap

Weaknesses of the technology

1. Investments (FabLab) are still substantial
2. Limited knowledge and experience in DIY
3. Intensive supervision (by teacher) is needed

Opportunities for education

1. Develop digital literacy
2. Visualise technical subjects
3. Multi-subject, project-driven education

Threats for education

1. Guarantees (curriculum) and room are lacking
2. 'Maker' is more difficult to measure/quantify
3. Teachers need new knowledge/skills

SWOT analysis

Strengths DIY technology and programming tools are low threshold and can be easily used in education. The DIY community is open and conducive to sharing knowledge and helping schools draw up and implement plans in this field. DIY technology is becoming easier to access and therefore more inviting for people to use.

Weaknesses Some FabLab tools, such as 3D printers and laser cutters, are still prohibitively expensive and shared broad-based facilities are still few and far between. The knowledge and experience required to use DIY technology are scarce and students will need intensive guidance. Schools may be put off by the amount of time they will need to invest to get started.

Opportunities DIY technology can be used to improve digital literacy in an exciting, creative, and context-rich manner. Technical subjects take on a more vivid quality and, if teachers work together across disciplines, time can be found to do educational projects, which will then automatically involve 21st century skills, such as creative thinking, collaboration, problem-solving and communication skills.

Threats Because digital literacy and technology are not yet embedded in the curriculum and linked to practical learning outcomes, it can be difficult for schools to free up the time and resources needed to fit them into the teaching-learning process. The benefits of DIY projects are not really easy to quantify. This will need to be addressed from the outset. Teachers who wish to use DIY technology must move beyond the traditional theoretical teaching methods. This may be a barrier to using DIY technology, especially in primary schools, which may not have technical teachers available.

Recommendations for school boards on how to shape their educational programmes in a digitising society

## 1. Encourage interest and initiatives in the field of digital literacy and DIY education.

Teaching digital skills and DIY technology will have no direct impact on a student's school performance as measured and valued through tests and examinations. The benefits are also harder to quantify. Yet these trends touch upon the core tasks of schools because DIY technology allows (digital) knowledge and skills – which are vitally important to 21st century citizens – to be acquired in much more practical and visual ways. Schools should create enough room in their curriculum for digital literacy and technical talent to flourish, and to encourage an inquiring attitude at an early age.

2. Use DIY and Maker Education to drive change.

In primary education, DIY and Maker provide all sorts of opportunities for new-style 'tinkering' and craft activities, which can also extend to digital literacy. In secondary education, DIY can be used for multi-disciplinary educational projects, which will automatically involve 21st century skills: working together requires discussion, coordination, problem-solving and making use of students' diverse knowledge to complete a project successfully. Secondary vocational education is already very much skill-based, with schools often partnering with local businesses. DIY technology makes this more affordable and more broad-based. In short, DIY and Maker can be used in all sectors to drive change in education.

3. Look for partners in and outside the school to shape DIY education.

Putting DIY education into practice will require multi-disciplinary and multi-site collaboration among teachers and between teachers and school boards. The aim of the National Technology Pact 2020 is to inspire and provide opportunities for nationwide and local collaborative networks. The platform's mission is to ensure that the Netherlands continues to have a well-educated and skilled workforce that includes enough engineers and technicians. Educational institutions can team up with other schools, the local Maker Community or other local partners to design and build their own FabLab to share the cost of expensive equipment (such as laser cutters) and professional training and guidance. And if local residents become involved as well, the term 'broad-based' school will acquire a whole new meaning.

3.2 Education in the digitising society
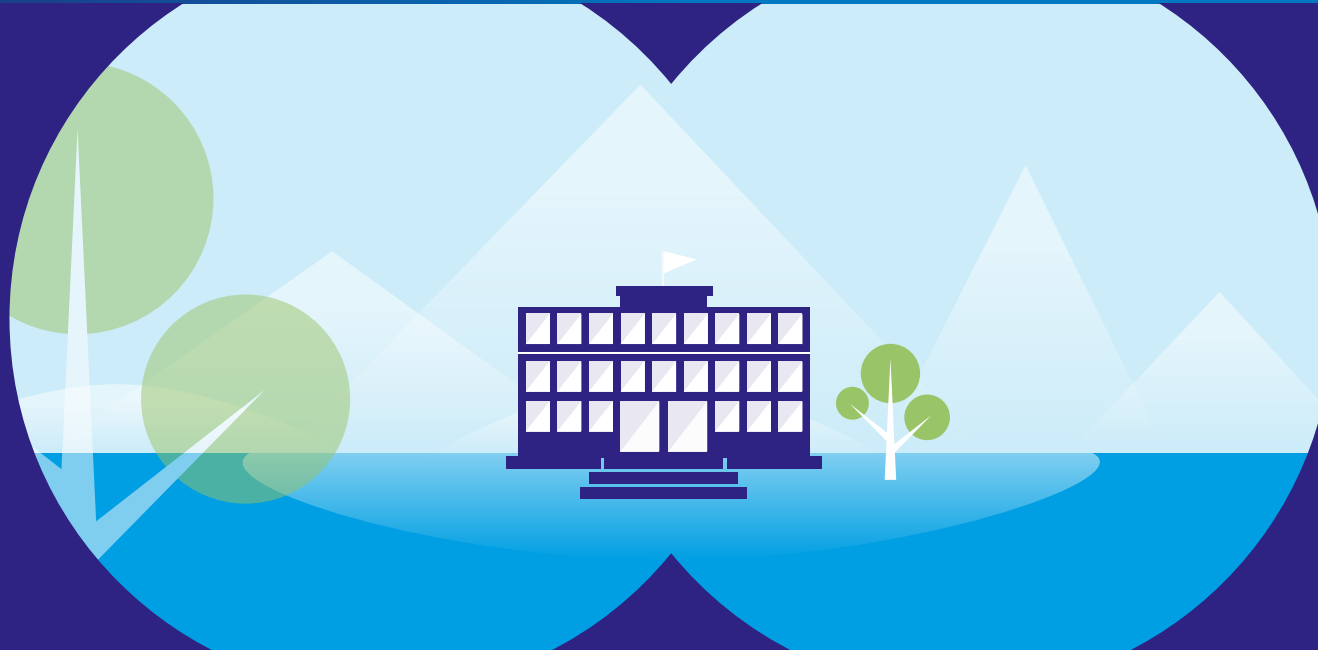
3.3 Coherence and consensus: a vision of education in the future

The ICT essentials and the digital learning process are practical enough concepts – despite all the choices and uncertainties still surrounding them – to write about in terms of goals, risks and recommendations. To decide how we want to use the technology that will determine our own future and the future of education, it is important, first of all, to determine what scenarios we consider to be interesting and valuable and then to set up pilot projects to test them. This will require support from within the organisation. The Hype Cycle can help schools choose which technologies they consider to be worth experimenting with. The Strategic Technology Map (STM) – also known as a Benefit Map – is a tool that helps in making coherent decisions (perhaps building on technology that is already in place) and securing a broad consensus. They are explained in greater detail in the chapter on the ICT essentials, so here we confine ourselves

to a brief summary of the underlying principles.
- Identify the relationships and dependencies between the various technologies.
- Find a balance – and preferably synergy – between the benefits for the educational institution (we) and convenience for the users (me).
- Ensure that the decisions made about the necessary combinations of investments are transparent and enjoy broad support through visualisation and storytelling.
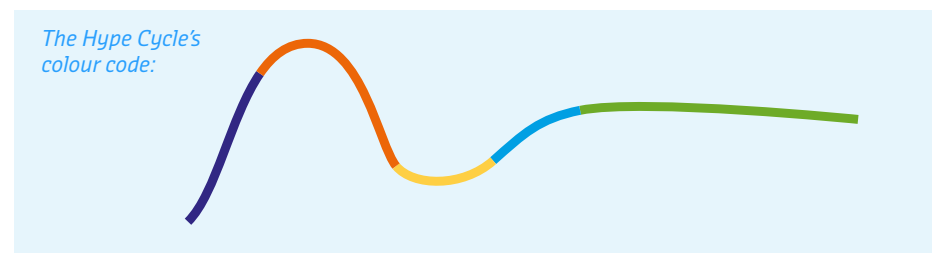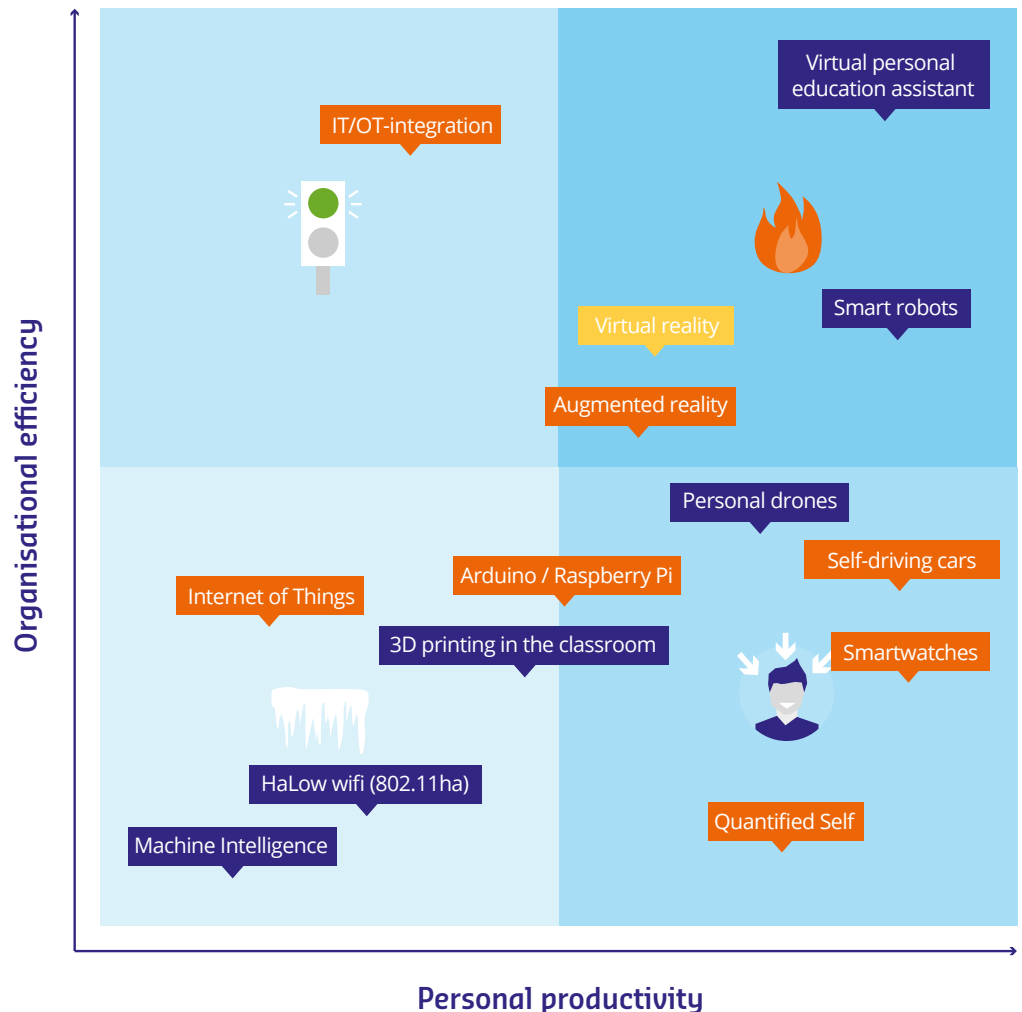
The STM is a simple matrix in which the vertical axis represents organisational efficiency (institutional effectiveness) and the horizontal axis represents personal productivity (of students, teachers and other staff members). The four resulting quadrants were also explained earlier: in the bottom left are the 'cold case' or 'enabler' technologies (supporting); the top left quadrant contains the 'corporate green light' technologies (effective for the organisation); in the bottom right are the 'people's choice' technologies (personal productivity) and in the top right are the 'hot spot' technologies (synergy).

3.3 Coherence and consensus

The narrative of a student in the school of the future

This narrative describes one of the many possible scenarios for the future of education in a world in which the technology we have just discussed has reached full maturity. In 'The Diamond Age' (1995), Neal Stephenson describes a world in which nanotechnology (intelligent machines the size of bacteria) controls every aspect of life. The book's main character Nell, a four-year-old orphaned girl, is given an interactive 'tutor' – 'A Young Lady's Illustrated Primer' – to guide her to an intellectually challenging and socially rewarding life. The tutor gets to know Nell very well, responds to her, and teaches her what she needs to know to survive as she grows up, partly by interacting with other children and in consultation with their personal tutors. Similarly, the narrative of the STM also outlines a future scenario, although its aim is to trigger people's imaginations and encourage them to think freely about scenarios of their own and the implications for education:
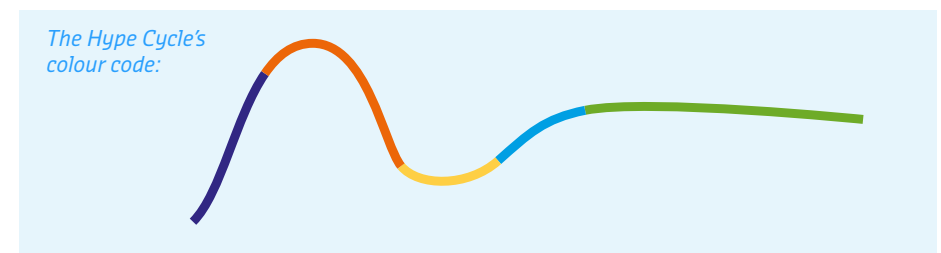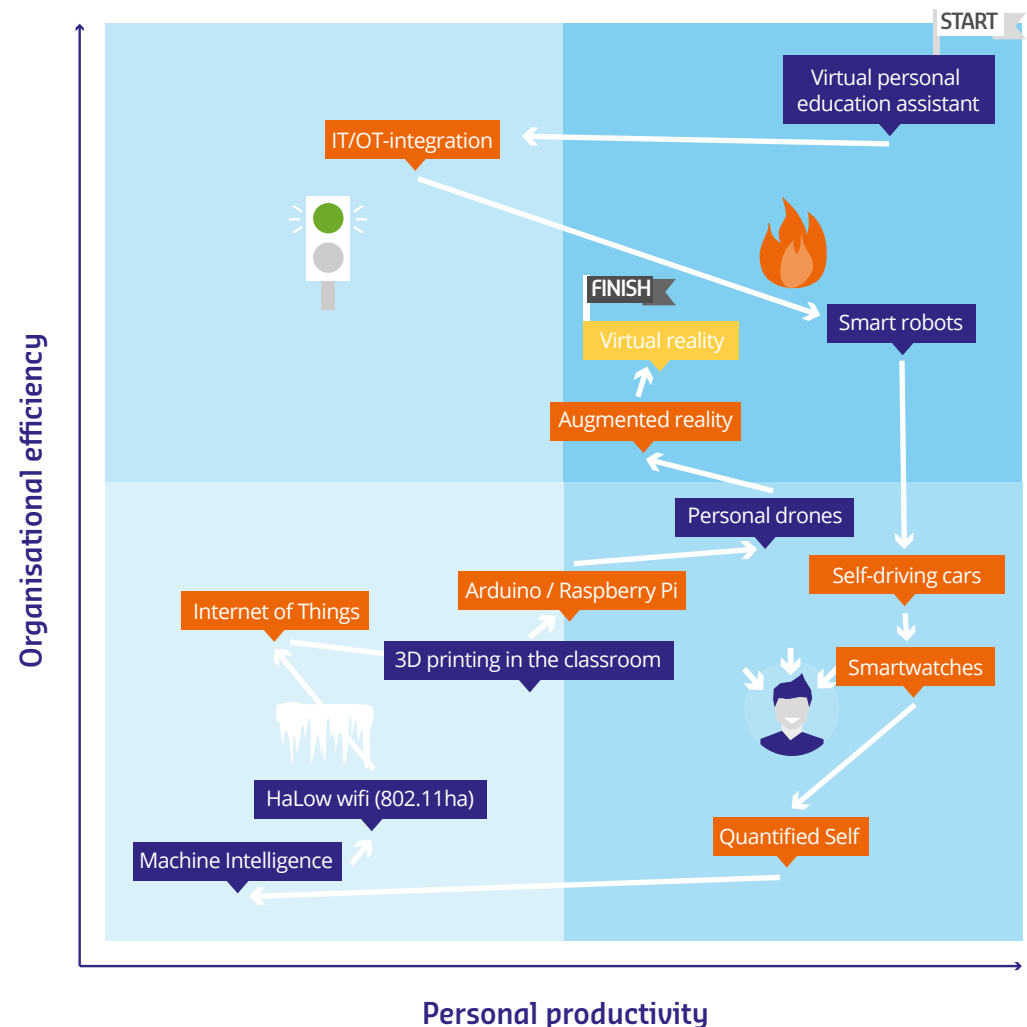
- This is the story of a school day in the life of Emma. It is 20 March 2032; spring is approaching. Noa – which is the name Emma has given to her Virtual Personal Education Assistant (VPA) – wakes her in time for breakfast, with melodies that wake her gradually from a deep sleep and slowly set her brain in motion. Noa notes that Emma is fully rested for the busy day ahead.
- The family's smart home is already comfortably warm on this cold spring morning and the family can start their day in a calm and relaxed manner. Their VPAs have already exchanged incoming messages and changes to the day's schedule and recorded them in the diaries.
- Using a smart mix of information and hardware made possible by IT/OT integration, a smart robot has already cleared up the mess from yesterday evening and prepared breakfast, reflecting the various diets and preferences of the family members.
- After breakfast, Emma starts the day with some exercises in English from

Organisational efficiency

Virtual personal education assistant

IT/OT-integration

Smart robots

Virtual reality

Augmented reality

Personal drones

Self-driving cars

Internet of Things

Arduino / Raspberry Pi

3D printing in the classroom

Smartwatches

HaLow wifi (802.11ha)

Quantified Self

Machine Intelligence

Personal productivity

The Hype Cycle's colour code:

her personal learning environment. They are particularly fun to do with the house robot, although granddad's care robot is even more helpful, helping him to get up, wash and eat.

- Emma completes her assignments in plenty of time. She says goodbye to her mother, who works at home, and goes to school in the self-driving car. Even though there are road works on her favourite route via the park, she gets to school in time for assembly because the car automatically makes a detour.

- Noa discusses the school timetable with Emma on the way and tells her what the plans are for the day. Noa contacts the VPAs of Emma's teachers to inform them what time she will be arriving and what her physical condition and state of mind are.

- Emma remains in contact with Noa during the day with her smart bracelet. Granddad recently told her that they used to call them smartwatches and that once upon a time all they could do was tell the time!

- Noa uses the Quantified Self technology in Emma's bracelet to tell Emma to take some exercise or to rest at appropriate times. Noa will not interrupt her with messages from other people when it observes that Emma is concentrating on a particular learning assignment.

- The Machine Intelligence that enables Noa to provide Emma with solicited and unsolicited coaching learns from Emma's activities and behaviour and makes its own decisions on when to help Emma and involve those around her in her experiences and in meeting her needs during the day.

- The seamless integration of high-speed connections with a shorter range and slower, energy-efficient connections with a longer range with the addition of the HaLow WiFi standard means there is always contact with the Internet of Things at home, at school and on the move. These are the numerous smart objects in the home, in the city and at school that constantly surround and support Emma and her family and friends. The family's personal data are all online, securely encrypted, in their personal

Organisational efficiency

START

Virtual personal education assistant

IT/OT-integration

FINISH

Virtual reality

Smart robots

Augmented reality

Personal drones

Self-driving cars

Internet of Things

Arduino / Raspberry Pi

3D printing in the classroom

Smartwatches

HaLow wifi (802.11ha)

Quantified Self

Machine Intelligence

Personal productivity

The Hype Cycle's colour code:

family cloud, from where the learning software of their VPAs is also available anywhere and at any time.

- To explore the potential of technology for themselves, in the afternoon Emma and her study group work together on their final project for phase 1 of primary education (the former Group 8) under the guidance of the technology teacher.

- For example, Tim, one of the students in the group, has printed extra components using the 3D printer with which their self-designed mini-weather station, which is operated by an Arduino microcontroller with various sensors, can be securely attached to their personal drone, which they will use to record and analyse the weather conditions in the park adjacent to the school in the coming weeks.

- With the augmented-reality learning materials, which Emma's group are able to use with their AR/VR lenses, they learn how to attach the sensors to the Arduino controller, and Emma is given examples for her program that will be used to collect the measurement data.

- In their joint virtual team corner, which is part of their personal learning environments, they have already viewed various exciting virtual reality simulations about weather stations in remote areas like Antarctica and the Andes in Chile. Emma regularly asks Noa to keep a record of the fragments that she found particularly interesting or useful so that she can share them with her group.

- In the latest VR simulations you can even ask questions or try things out, but sometimes the VR doesn't understand what you mean! Fortunately, Noa has already learned to understand what Emma means. But no one knows Emma as well as her best friend, with whom she will be going to the stables in the afternoon. In consultation with Emma's mother, Noa has arranged an additional private lesson for them. This evening, Noa will reflect on the events of the day and review the agreements that were made with Emma.

Looking at the Hype Cycle position of the trends in this chapter, the corresponding colour of trends in the STM and the science-fiction-like nature of the story of Emma and her Virtual Personal Education Assistant, these technologies are all clearly at a very early stage of development. Selective experiments are very useful for stimulating ideas about future scenarios and enabling teachers and students to experience for themselves the impact technology will have on their private lives, in learning and at work.

This narrative is also intended to prompt an interesting and open discussion about the significance of these trends for the school's mission. What role will technology be given in the teaching-learning process? Will it be used only as a tool to help in learning, or will it also be a subject that is taught? The STM is a tool that helps explain the practical consequences of specific scenarios by showing what functional components are needed, the relationships between them, and hence the critical path that needs to be followed in terms of investments in ICT.

Without the cold cases Machine Intelligence and HaLow WiFi, the Internet of Things will not function, and without that the combination of 'corporate green light' IT/OT integration and 'people's choices' smartwatches and Quantified Self will be unable to allow smart robots to function. Our 'hot spot' Virtual Personal (Education) Assistants also rely heavily on 'enablers' like Machine Intelligence and the availability of smart robots as a medium for providing support. The arrival of new technologies, changing objectives and new insights and priorities all mean that there are numerous alternative STMs, which form the basis for a continuous dialogue between stakeholders whereby plans and budgets can be revised with the commitment and insight of the entire board and its schools.
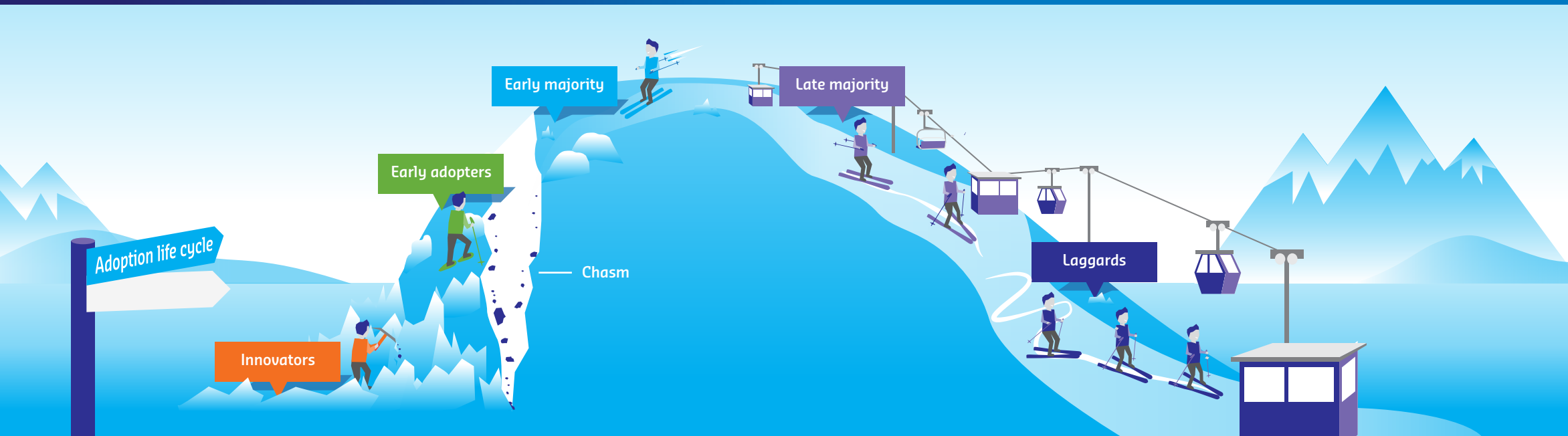
3.3 Coherence and consensus

3.4 Innovative strength and capacity for change

We started this chapter with the observation that the pace of adoption of new technology is accelerating. We certainly do not reach the conclusion that we should try as hard as possible to keep up with every hype and trend. But the continuous innovation does mean that school boards and their schools must have a robust innovation process in place in order to be able to respond constructively to the dynamism and rapid pace of technological developments. To ignore those developments would be short-sighted in view of the impact they will have on the society in which students will be living and working. However, this does not mean that we should follow every trend, and in fact sometimes should explicitly not do so, but that the course we follow should be a conscious

one. Accordingly, the innovation process calls for a structural exploration and assessment of the significance of technology for education in order to select those that are of value. Such a process is crucial for producing a constructive response to the dynamic and rapid pace of technological developments. But a process alone will not ensure that school principals and teachers innovate. They also need innovative strength! Innovative strength is the sum of the factors that enable a school to translate the opportunities created by innovations into added value for the teaching-learning process autonomously and efficiently, to put them into practice by experimenting in teams and thereby learning from each other, and to successfully expand those experiments with respect for one another's views on what constitutes good education and a fine school. Innovative strength rests on three crucial pillars: the willingness (motivation), ability (requisite knowledge) and capacity (space and support) to innovate. How do we ensure that these three pillars are in place?

Adoption life cycle

Innovators

Early adopters

Early majority

Chasm

Late majority

Laggards

3.4.1 Willingness to innovate

Everett Rogers' theory of innovation describes the spread of innovation within a group (in 'Diffusion of Innovations'). Rogers' adoption curve shows that people take action at different times. He identifies five different groups according to how they adopt a new idea or product.

- 2.5% are innovators: they are curious, want to be the first to try out something new, take greater risks and are willing to accept initial problems and wasted time.
- 13.5% are early adopters (pioneers): they like to follow closely behind innovators, as soon as there are examples of the application of an idea or product and initially cause rapid growth in adoption.
- 34% represent the early majority: this is the first large group who prefer to see evidence of the potential and benefits of a development before they feel it is safe to adopt it.
- 34% are the late majority: they step in when the development is widely

accepted and has reached the stage of maturity. The rate of adoption gradually slows during this phase.
- 16% are the laggards: they are uninterested in innovation and will only be persuaded when practically everyone has already embraced the development.

Crossing the chasm

The discussion about innovation in education (technological or otherwise) quickly becomes polarised. Innovators and early adopters accuse the majority of lacking initiative, while the early and late majority and the laggards accuse them of recklessness and wasting time and resources. In a group that is functioning properly, there is synergy and cooperation between leaders and followers, so that they profit from each other's preferred approach. Rogers calls this 'crossing the chasm'. The pioneers take risks and the followers ask the right questions ('What is the situation precisely?'). A constructive dialogue yields a great deal. In addition, the experiments by the pioneers often identify new

3.4 Innovative strength and capacity for change

possibilities – which have often initially gone unnoticed – from which followers can profit (learning by doing). The followers can then start with a clearer idea of what they are doing and lose less time and money along the way. However, the experiences of the pioneers do have to be clearly explained and shared: the prerequisites for their experiments (preparation), how success is measured (objective) and the most valuable lessons that have been learned along the way (knowledge). In every school, for example, there are teachers who were quick to start using iPads in their class or group or using cloud platforms for teaching, supervising or assessing their students. If their colleagues can learn from their experience, the time and energy devoted by the teachers who preceded them are a useful investment.

A mission that matters

To properly steer and channel the intrinsic motivation of pioneers, and hence use it effectively, the school's mission has to be clear: what does the school stand for? The school's mission gives meaning to what is happening in the school, and every experiment with new technology must contribute to it. After all, directionless innovation is ineffective. What is a meaningful mission? Google's stated mission, for example, is not to make the very best search engine but to "organise the world's information and make it universally accessible and useful." This mission leaves scope for Google to constantly revise and expand the way in which it can best be achieved, for example by producing everything from worldwide interactive satellite maps (universally accessible) to self-driving cars (useful). The mission does not have to be immediately within reach; it is a shifting point on the horizon that continues to provide inspiration. A sharply defined and widely shared mission answers the question 'Where are we going to?' rather than 'How will we get there?'. This often constitutes a pitfall in the context of the use of ICT, where the question is not 'Will we use tablets to modernise the teaching-learning process?', but 'What is the purpose of modernising education and can tablets play a useful role in that process?'

3.4.2 Ability to innovate

Following the exploration of the possibilities by the pioneers, the goal seems clear. We can start innovating because we know 'how' we should approach it! The pitfall here lies in the communication between the pioneers and the large group of followers, who have only heard the enthusiastic stories of the pioneers with details of 'how' they have learned what they have. The pioneers often forget to explain why they started experimenting in the first place. What is it they want to achieve in their teaching? If in the course of implementing an innovation we fail to consider the underlying objectives there will be opposition, since people working in education have different personal motivations and convictions. If the goals remain implicit, a proposed innovation could raise objections. Teachers might then incorrectly believe that the values they wish to convey in teaching have to change, while a change is being initiated from those same values. Consensus for a major change can only be reached if there is a willingness to listen to and learn from one another.

3.4 Innovative strength and capacity for change

The difference between the goal and the means

For example, a school principal may decide after a successful experiment to introduce the widespread use of devices (such as tablets or Chromebooks) to facilitate more personalised teaching. Some teachers might then object that they want to guide students in their learning process by inspiring them with stories, not sit behind a device, even though the intention of the measure is to enable students to work independently by practising and learning at their own pace, with the help of appropriate equipment and good adaptive learning materials. Research has shown that this substitution for regular lessons in arithmetic and reading and writing saves teachers time and leaves them more opportunity to provide specific instruction for smaller groups and for other activities that could not previously be included in the timetable. These are considerations that are worth discussing with colleagues and go beyond the simple question of whether or not to use devices in school.

In his book 'Theory U', Otto Scharmer addresses the importance of listening carefully to each other. The basis of cooperation is a knowledge and understanding of what it is that drives you and others. If we are willing and able to learn from one another in discussing and defining the objectives, the result is a deeper insight into those objectives. The 'what' becomes clearer and is easier to define in terms of 'for what purpose' or 'why'. Defining what we want to achieve with the use of devices creates a context for the discussion of the best way of achieving those objectives.

3.4.3 Capacity to innovate

If the motivation is there, the direction is clear and the team works well together, all that is lacking is the time needed to experiment and the room to fail. Thomas Edison very succinctly expressed the notion that failure is an essential
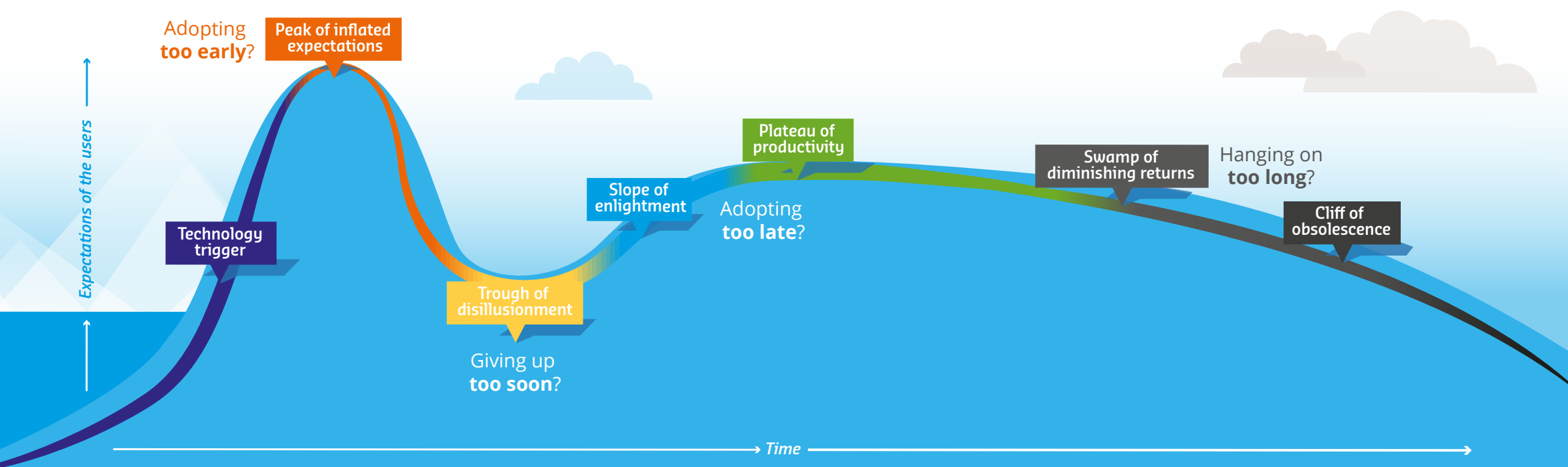

3.4 Innovative strength and capacity for change
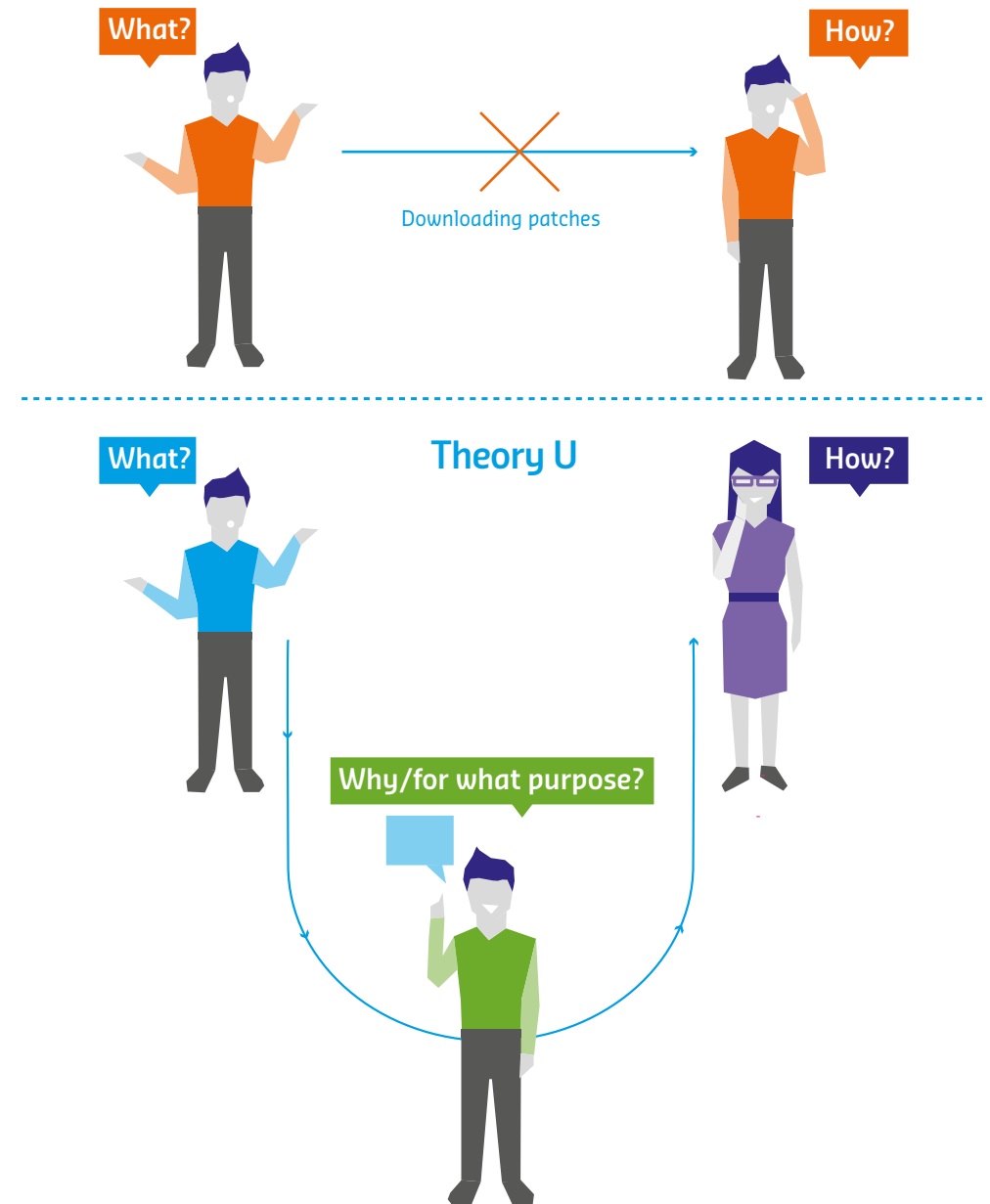
element of the innovation process: "I have not failed, I have just found 10,000 ways that don't work". The willingness to free up time and money shows how committed you are: are we willing to invest in experiments when we don't yet know what the outcome will be? Would it not be more advisable to wait until research has demonstrated the benefits of a new technology?

The Hype Cycles in the three chapters of this report show the stage reached by each of the technologies discussed. The purpose of the different stages in the Hype Cycle is not to show how long we will have to wait before a technology reaches the safe stage of the plateau of productivity, but to give us a context for making a conscious decision on the best time to test the potential use of a technology. Waiting for the further development of technology and the availability of research provides greater certainty and can save time and expen-

se when the technology is finally being implemented, but by that time there are no longer any opportunities to set ourselves apart or to profit sooner from the benefits. On the other hand, premature broad adoption of a technology can cause major problems, high costs, loss of time and damage to the school's reputation. The innovation process in the school should be aimed at supporting the educational mission with specific experiments that generate the knowledge and insight needed to decide which technologies can be widely deployed, and when.

Evidence-based prediction of the future?

Fortunately, there are enough schools in the Netherlands and other countries that realise the potential of new applications. Their experiments and the experience gained from them form the basis for research that could show

Expectations of the users

Adopting **too early**?

Peak of inflated expectations

Technology trigger

Trough of disillusionment

Giving up **too soon**?

Slope of enlightment

Plateau of productivity

Adopting **too late**?

Swamp of diminishing returns

Hanging on **too long**?

Cliff of obsolescence

Time

3.4 Innovative strength and capacity for change

3 Education in the future

what benefits are feasible. The pyramid of knowledge is built from ideas (inspiration), experiments, tangible returns and, finally, the evidence of benefits in the teaching-learning process. Every phase has value and makes a contribution. Every school board, every school, every school principal and every teacher is on a personal quest to discover the most suitable timing. The information technology specialist Alan Kay – known for the graphic user interface, among other things – outlined a strategy for an effective response to the dynamic field of computer technology: "The best way to predict the future is to invent it". We should not take 'invention' too literally, but a more proactive dialogue can be conducted with suppliers of (learning) products by helping to design products – in a process of co-creation – rather than waiting for the market to supply them. Meanwhile, insights generated by earlier research are still only used to a very limited extent.

Guidance, space and support

Research institute TNO has – in cooperation with the education sector – developed the digital tool iSELF, which schools can use to measure 21st century skills and discover the most effective way for students to learn to manage their own learning process. Against the background of rapid technological and social change, TNO also argues that a proactive approach is becoming increasingly important and that people have a personal responsibility to pursue lifelong learning. Its research shows that direction, space and support are important underlying concepts for enabling people to take control of their own personal development.

- Direction: a clear vision of the organisation's mission and vision of the future that provides direction for the 'willing' (the pioneers).
- Space: providing the time and opportunity to 'be able' to learn more in a personal way, to promote mutual cooperation and discovery and provide necessary tools.
- Support: being 'allowed' to learn autonomously, with the support of the

school, with recognition and appreciation of the effort and the progres made, not just for the results.

These three aspects of support have to be in balance. A lot of direction and little space creates the impression of a rigid school organisation where 'there are no alternative ways'. Little direction and a lot of space can create uncertainty: teachers have the feeling that they have to discover everything for themselves. Not everyone is good at that. A lot of direction and a lot of support can appear patronising. A lot of space and little support gives teachers the feeling that they are not being listened to. In 'Innovatie die werkt, duurzaam leren' [Innovation that works, permanent learning], Theunissen and Stubbé write that it is the task and responsibility of the school board (with its school principals) to build a learning organisation with a good combination of the three elements of support. Such an organisation facilitates the learning of all its members and promotes a culture of innovative behaviour, and as a result is constantly transforming itself.

To help schools move forward in the innovation process, Kennisnet has developed the innovation accelerator for teachers, which is a practical toolkit with 20 techniques that can be used in the various phases of the process of innovation.

Afterword

This trend report can be read as a plea for the benefits of technology, although I would not want my enthusiasm to create the impression that technology should be applied without reservation. It is perhaps because of my detailed knowledge of ICT that I am particularly curious about its possibilities, reassured as I am by what are – to me – its evident limitations and the conviction that we can always master technology.

What I set out to do with this report is help the education sector to take a step forward, by providing some insight into what awaits us in terms of technology, sketching some promising applications, warning of threats that demand attention and, finally, suggesting some instruments that will help schools to make their own plans. Because the decisions about which technologies should be applied, and when they should be implemented, remain a question of what is appropriate for the goals and the vision of education of school boards and schools themselves.

"The decisions about which technologies should be applied, and when they should be implemented, remain a question of what is appropriate for the goals and the vision of education of school boards and schools themselves."

At the same time, the use of technology has implications, particularly in education. It is the task of schools to prepare children for life in the society of the future and to help them find useful work. After all, the children will have to make a contribution to that society and be able to support themselves. To achieve this, the education system will have to be flexible enough to offer students an individual learning process. Properly applied, technology can make an important contribution to the personal development and school performance of students.

On a more personal note, another objective was to remove some of the mystery surrounding technology – to show that it is we who create technology and demonstrate the opportunities we humans have to play a decisive, responsible role in its further development.

It is the capacity to set meaningful goals that distinguishes us from the smart machines that we ourselves create. Another distinctive attribute of humans is their unique ability to discuss, in a creative and enduring manner, the possibilities that technology offers us in pursuing our educational goals.
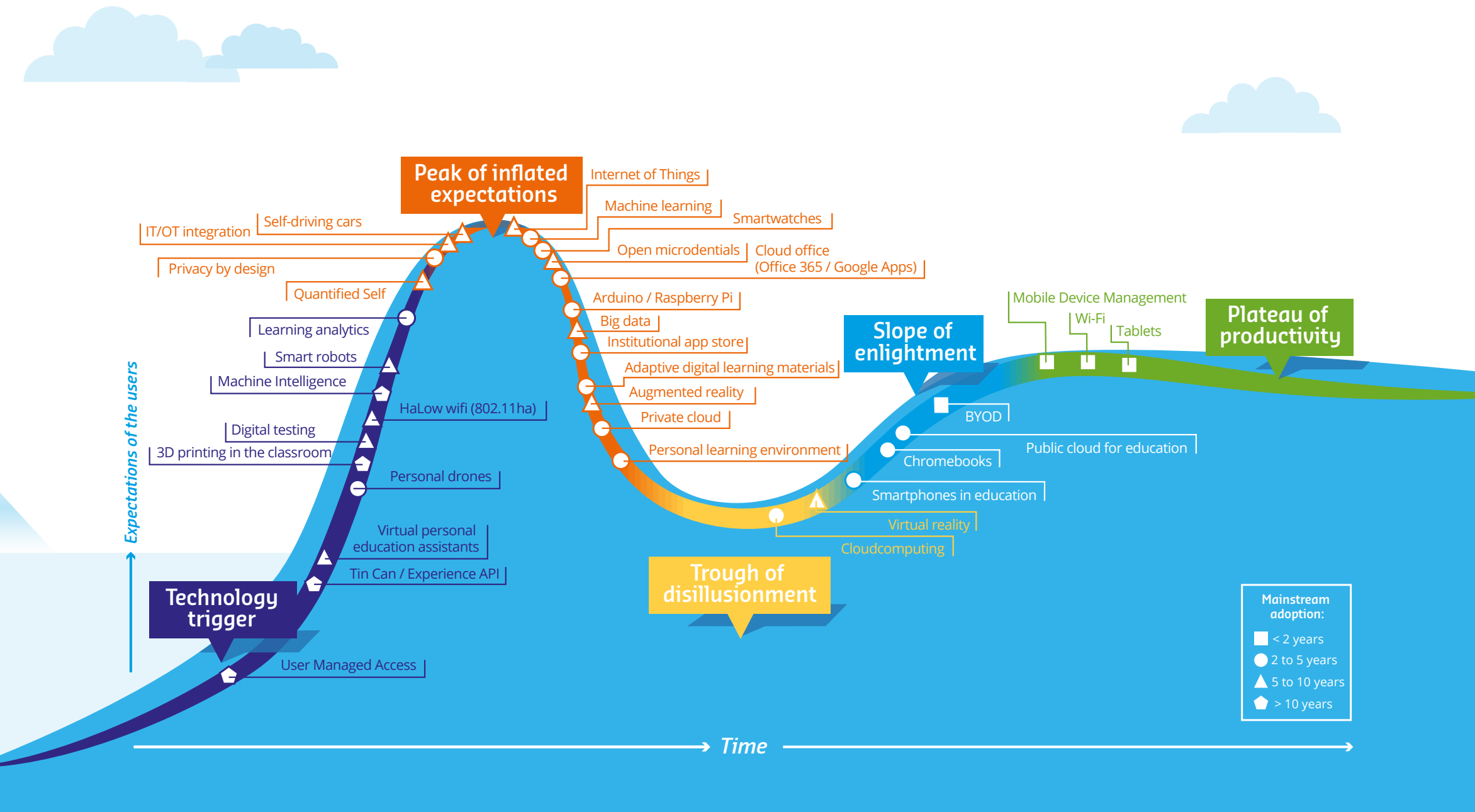
I am therefore grateful to everyone who helped in the writing of this report for their extensive feedback. You are all totally correct. Fortunately, there is always a future edition!

Michael van Wetering
Innovation Expert, Kennisnet Foundation

Appendix 1: Kennisnet Hype Cycle for Education, 2016-2017

Peak of inflated expectations

- Internet of Things
- Machine learning
- Smartwatches
- Self-driving cars
- IT/OT integration
- Privacy by design
- Open microdentials
- Cloud office (Office 365 / Google Apps)
- Quantified Self
- Arduino / Raspberry Pi
- Learning analytics
- Big data
- Institutional app store
- Smart robots
- Adaptive digital learning materials
- Machine Intelligence
- Augmented reality
- HaLow wifi (802.11ha)
- Private cloud
- Digital testing
- Personal learning environment
- 3D printing in the classroom
- Personal drones
- Virtual personal education assistants
- Tin Can / Experience API

Technology trigger

- User Managed Access

Trough of disillusionment

- Cloudcomputing
- Virtual reality

Slope of enlightment

- BYOD
- Chromebooks
- Smartphones in education
- Public cloud for education

- Mobile Device Management
- Wi-Fi
- Tablets

Plateau of productivity

Expectations of the users

Time

Mainstream adoption:

- ■ < 2 years
- ● 2 to 5 years
- ▲ 5 to 10 years
- ⬠ > 10 years

Appendix 2: Checklist for devices

Typical features of devices

Devices		
Accessible, but limited tablet	Manageable, but limited Chromebook	Complete, but complex laptop

Features of devices			
Deployability	Highly mobile and immediately on (optional lock)	Mobile, takes time to start up and log in	Mobile, takes time to start up and log in
Use in the classroom	No screen between student and teacher	'Laptop-like' barrier	'Laptop-like' barrier
Keyboard	Virtual or supplementary	Always present	Always present
Options for 'creation' (in addition to consumption/inter-action)	Touch control is sometimes restric-tive, becoming more complete	Web interface is still restrictive, becoming more complete	Full laptop functions, limited touch control.
Presentation options	Airplay, Chromecast and beamer/monitor	Chromecast and beamer/monitor	Beamer/monitor
Offline use	Excellent, dependent on the apps	To a limited extent	Excellent, dependent on applications/apps
WiFi use	Easy	Easy	Requires knowledge
Typical battery life	Entire day	Part of a day	Part of a day
Fragility	Limited with a case	Very limited	Limited with a case

Functional features			
Cloud platforms in general	Apple (iOS) or Google (Android) (required), Microsoft supplementary	Google (required), Apple and Microsoft supplementary	Microsoft (required), Google and Apple supplementary
Range of educational applications	Diverse range of apps and online applications	Only online applications (must be Chrome compatible)	Very extensive range of (traditional) apps and online applications
Cloud ELO platforms	iTunesU, Google Classroom, Sharepoint	Google Classroom, Sharepoint, iTunesU	Sharepoint, Google Classroom, iTunesU
Options for collaboration	Cloud platforms, apps	Cloud platforms	Cloud platforms, applications and apps
Sharing of files	Cloud platforms, Bluetooth, WiFi	Cloud platforms, USB stick	Cloudplatforms, USB-stick

Management features			
Installation of apps and applications	Easy to do yourself	Not necessary	Requires knowledge
First-line support	Easy	Easy	Requires knowledge
Management platform	Simple Mobile Device Management	Simple Chrome Device Management	Complex, very com-plete management platforms
Back-up/recovery	Easy	Never necessary	Requires knowledge

Explanatory note:

The devices compared in the table do not include desktops, regular Windows laptops or MacBooks. The functional differences are minor or evident. Choices here will mainly depend on the more important choice of a cloud platform and the connection to the type of tablet that is selected.

Appendix 2: Checklist for devices (contd.)

Typical differences between Android and iOS tablets

Features	Tablet	
	iOS (Apple)	Android (Google)
Diversity	Apple has several types in three formats, confined to the intermediate and higher price/quality segments	Wide diversity of suppliers, formats and price/quality ratios
OS updates	New iOS updates are typically easy to acquire for the limited number of models for up to 4 years after purchase and apps work on practically every model (including older ones).	Because of the large number of very different models, new Android updates are limited to recent top models; apps work to a limited extent on older models.
App store product range and policy	Enormous range of apps, free and paid (payment is easy); strict curation of quality and rules guarantees stability, safety and uniformity.	Enormous range of apps, largely free; scarcely any selection on the basis of quality or rules, therefore diverse and with risks.
App development	Despite the curation, developers often initially choose iOS in connection with more intensive app use and low payment threshold.	Android gives developers a lot of scope and freedom to experiment, which leads to an innovative and bold range of apps.

Typical scenarios for the use of each type of device

Features of scenario	Devices		
	Tablet (iOS/Android)	Google Chromebook	Windows (hybride) tablet/laptop
Use	The 'computer' that everyone can use due to its simplicity and touch control. Easy to use in the lesson or school and elsewhere, appropriate for a creative teaching-learning process. The high degree of mobility and built-in camera also make it highly suitable for students making reports.	The ideal, practically interference-free 'school computer'. Can easily be used simultaneously by various users in different classrooms. All applications and data are online, transforming the Chromebook into a flexible mobile workstation.	The complete Windows computer. Despite touch control, it is primarily a flexible laptop in view of the still limited range of apps. Runs on a full version of Windows with the widest range of (traditional) applications, together with the associated complexity. Requires 'heavy' management.
Didactic impact	Opens up new perspectives, but selecting suitable apps to support working methods and the distraction to be found on a tablet demand a lot of attention.	Is low-maintenance because all the applications, materials and data are stored online. Seldom requires attention during the class.	Less suitable for creative didactic use. Closely matches the traditional use of the computer and is therefore perhaps more accessible. Support is required during lessons.
Personal influence	The preeminent personal device. User can personally add and remove apps and customise their own settings.	Not a personal device because of the limited scope for personal configuration; an additional personal tablet or laptop is required.	By nature a personal device, but in practice with limited possibilities to maintain control of the complex management.
Strengths and Weaknesses	The simplicity of the tablet and the apps on it are both its strength and constraint. Everything is optimised around the touch interface; another device is more suitable if a lot of work has to be done with a keyboard.	Everything that works in the Chrome browser can be used directly on a Chromebook. The Internet connection is crucial: a web interface limits the user experience compared with the 'rich' interfaces on tablets and laptops.	Strong on continuity: all Windows-based traditional applications work. However, migration to device-independent web platforms is proceeding rapidly, so good timing of a choice based on continuity is important.

About this publication

About Kennisnet

Kennisnet is the public organisation for education and ICT which supports and inspires primary, secondary and vocational education institutions in the effective use of ICT. We provide advice for administrators, managers, teachers and the sector councils about available ICT technology and application thereof so that they can make the right choices for the use of ICT in education. Kennisnet makes ICT work for education, so that the sector can achieve its ambitions.