



Technology-enhanced Personalised Learning Untangling the Evidence

Wayne Holmes, Stamatina Anastopoulou, Heike Schaumburg
and Manolis Mavrikis

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Preface

Diversity has long been the norm in German schools. The educational system, however, has not yet succeeded in providing all students with equal educational opportunities: In Germany, more than in almost any other country, learning success is dependent on a student's social background.

Consequently, the call for personalisation of the learning experience, i.e. providing individual support to students, is frequently heard. In real life, however, this approach entails major challenges, both for students who will have to learn self-guided learning, and teachers who will need to support them. It still remains unclear whether technology can help in these efforts, for instance by diagnosing a student's level of knowledge, selecting learning content or adapting it to the respective student. Technology-enhanced personalised learning is not yet common in Germany, which is why we have tasked scientists with summarising the current status of international research on the matter.

This study demonstrates the great potential of technology in implementing effective personalised learning. Nevertheless, it has not been assessed yet whether the practical implementation actually works: Even in countries such as the U.S., which lead the way in using technology in classroom settings, hardly any evaluation studies have been done to prove the effectiveness of technology-enhanced personalised learning.

In the light of the above, the authors make recommendations for actions to be taken in Germany to make best use of the potential of technology in providing individual support and guidance to students. We hope this study can make a valuable contribution to improving the quality of teaching at German schools, and we are convinced that, in a digital world in particular, high-quality teaching will remain crucial – to give all learners equal opportunities to succeed in this new world.

Uta-Micaela Dürig

Vice Chair of the Board of Management
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“It seems likely that the educational system will need to adapt to the increasing individualism in societies. On the one hand, societies believe in the uniqueness of each person and promote the notion that individuals should be able to control more of their own lives. On the other hand, education systems still tend to have fixed content and timing.”¹

¹ OECD (2006).

1. Introduction

Over recent years, technology-enhanced personalised learning has been proposed as a likely candidate for addressing the issues identified by the OECD. In fact, in a wide variety of recent reports², technology-enhanced personalised learning has been identified as one of the emerging fields likely soon to have a major impact on teaching and learning in schools. So, given that the outcomes of these reports are mostly uniform (that technology-enhanced personalised learning is generally a *good and effective thing*), why have we written yet another report?

The reality is that whether or not technology can help deliver personalised learning in the classroom remains an open but important question. There is much promising evidence. However, if we are to enable educators and policymakers to make good informed decisions about how best to personalise learning with technology in schools, we need to go beyond the face-value of that evidence (which all too often can be uncritically positive). In addition, the earlier reports do not address the particular circumstances of the German educational and political context. In this report, on the other hand, we describe German national strategies to strengthen personalised learning support in schools and to equip German schools with digital technologies. We also discuss the relatively high resistance of German teachers to technology-enhanced personalised learning, especially when compared with their counterparts in other countries (which is one reason why this report presents the international scientific knowledge in the context of German conditions and findings).

And finally, we aim to provide guidance to teachers (examples of technology-enhanced personalised learning, a framework of analysis and evidence-based principles), to enable them to evaluate any examples of technology-enhanced personalised learning that they encounter – to determine which, if any, might be useful in their classrooms and for their students, and how they might best be implemented.

² E.g. Johnson et al., (2014) NMC Horizon Report Europe 2014 Schools Edition; Sharples, et al. (2016). Technology Enhanced personalised Learning summit, 2014; DOCEBO (2016); UNESCO (2017), World Economic Forum; King et al (2016); Mead et al (2014).

2. Executive summary

Everyday practice in schools almost always involves a degree of personalisation. In fact, **teachers usually personalise their teaching** by giving extra support to students who are struggling, while challenging further students who are making good progress.

In addition, given that current German education policy calls for schools to be more inclusive and to make better use of digital technologies, the many issues raised by personalised learning are especially relevant for the German context.

However, **what is meant by personalised learning is complex**. For example, personalised learning can mean different things (such as independent learning or individual competencies) in different contexts, while it particularly depends on who makes the decisions (policymakers, teachers or students).

One way through this complexity is to consider personalised learning in terms of its **multiple dimensions**:

- the personalisation of **why** something is to be learned (the learning aims, which are typically the decisions of policymakers);
- the personalisation of **how** it is to be learned (the learning approach);
- the personalisation of **what** is to be learned (the learning content and pathways);
- the personalisation of **when** it is to be learned (the learning pace);
- the personalisation of **who** is involved in the learning (the learning group); and
- the personalisation of **where** the learning takes place (the learning context).

The pedagogical debate in Germany has long focused on these dimensions in the context of internal differentiation in teaching, that is, how individual students can be supported within heterogeneous groups instead of forming homogeneous groups. In any case, it is also important to recognise that **implementing personalised learning in classrooms can be challenging**. For example, there is the need for professional training, time for teachers to adjust their practice, and opportunities for students to experience the social aspects of learning.

Increasingly, **advocates of personalised learning are turning to technologically-mediated approaches**, which involve varying degrees of customisation of learning experiences. For example, students might be immersed in a technology-enhanced rich learning environment or use technologies to meet their own personal learning needs, while other technologies might provide students with choice over what they study (perhaps to support 21st century skills or self-regulation). Some technologies might also reduce classroom tasks such as summative assessment, freeing teachers to focus on the social and creative aspects of teaching and learning. Specific technologies (covering domains as different as mathematics, languages and writing), which are described in this report, include:

- **intelligent tutoring systems,**
- **exploratory learning environments,**
- **smart learning management systems,** and
- **learning network orchestrators.**

Inevitably, **implementing technology-enhanced personalised learning in schools also can be challenging**. For example, schools often lack the infrastructure for technology-enhanced learning in every classroom, while successful implementation can require curriculum reform.

In Germany, schools often struggle with twin challenges when introducing technology-enhanced personalised learning. They lack comprehensive experience of personalised and inclusive learning and at the same time do not have appropriate concepts for using technology. Another challenge is that personalised learning may be considered contradictory to inclusive teaching in the context of collaborative learning. Further obstacles include the comparably high development and acquisition costs, as well as the unresolved issues of privacy and data protection. The latter concerns applications which store large quantities of personal data, such as individual user choices and achievements, in order to derive personalised learning paths, diagnoses and feedback. Moreover, very few personalised digital learning tools are currently available in German, which means schools have limited choice when implementing personal learning.

Technology-enhanced personalised learning can also be at the expense of social learning opportunities for students, while algorithms can all too easily reinforce stereotypes.

Most importantly, almost all technology-enhanced personalised learning tools have been evaluated only in experimental or small-scale studies. In other words, **there is little robust efficacy evidence** such that it simply is not possible to say which technology will work best in schools.

Instead, in this report, we aim to support decision making by providing an illustrated **framework of analysis** for individual technology-enhanced personalised learning tools and a set of **evidenced-based principles** for implementing such tools. These have been designed **to enable you to draw your own conclusions**, appropriate for your practice and your students' needs, about any technology-enhanced personalised learning tools that you encounter.

We conclude that **the promise of technology-enhanced personalised learning is worth pursuing** and that some extraordinary technology-enhanced personalised learning tools have been built. However, the evidence also clearly shows that **technology-enhanced personalised learning is not a silver bullet**. Indeed, it is important not to be seduced by exciting technologies and to **always start with the learning**.

To ensure the successful implementation in schools of technology-enhanced personalised learning, we propose the following guidelines:

- Start with the learning, and the students, not the technology.
- Introduce technology-enhanced personalised learning as part of a blended learning approach. Digital tools cannot replace face-to-face support and feedback from teachers, or interaction and discussions with other students.
- Establish a favourable environment for technology-enhanced personalised learning. Technology-enhanced personalised learning requires actions such as equipping schools with the necessary technical infrastructure (including support for sustainability), appropriate professional training, collaboration among teachers, the support of head teachers and administrators, teachers willing to try out innovations, and, perhaps most importantly, sufficient time. In summary, technology-enhanced personalised learning can only be implemented successfully if the school embodies a willingness to introduce change.
- Ensure the necessary flexibility that technology-enhanced personalised learning requires, including a flexible approach to curriculum, assessment, and standards.
- Guarantee privacy and data security.
- Question the software, and its underlying algorithms.

Policy, administration and philanthropy can make important contributions to ensure the successful implementation in schools of technology-enhanced personalised learning.

- An education policy framework should combine the strategic targets of personalisation, inclusion, and adopting technology in education.
- Länder, municipalities and schools should develop new equipment strategies and support concepts. Schools should be provided with affordable tools that can be personalised and learning platforms that also meet all privacy and data security requirements.
- The development of German tools should be funded and take place in close cooperation with educational practitioners to ensure the applicability of the developed software.
- Projects should be funded that build on existing technologies. This would ensure innovation is an iterative and sustainable process.
- Tools should be evaluated in real world settings before they are distributed widely. Evaluations should include both ongoing formative and summative evaluations at scale.

3. Personalised Learning



A Year 5 science teacher started the lesson with a quiz presented in such a way that making mistakes is not a punishing experience. This does not require buildings, high levels of staffing or resources. It does require changing attitudes such that the pupils' prior knowledge and experience is accepted as an essential starting point from which to progress, in order to ensure that learning, even when taking place in a group, is 'personal'.³

Everyday interactions in schools almost always involve a degree of personalisation as teachers and students respond to each other's constantly shifting needs, aims and desires. For example, when walking around the classroom, teachers usually personalise their teaching by giving extra support to those who are struggling, while challenging further those who are making good progress. In this sense, personalisation in classrooms is a long-established tenet of good teaching⁴, which is dependent on an in-depth awareness of an individual student's learning needs, in order to bridge the gap between the student's understanding and the expectations of the teacher and the curriculum⁵. Personalised learning also challenges the idea of the *average* student⁶. Instead, all students are considered individuals (each with their own individual needs, strengths, prior experiences and interests), all of whom would benefit from some measure of differentiated teaching in order to best succeed. Personalised learning also offers opportunities to challenge what counts as success. It can offer insights for becoming independent learners, achieving the aims of the given curriculum or achieving an academic qualification.

² Sebba et al. (2007).

³ National Research Council, 2000

⁴ Bulger, 2016

⁵ Lockett, 2017

What is personalised learning?

What exactly is meant by *personalised learning* is not always clear. In any case, as has been confirmed by our review of the academic research, what personalised learning refers to varies markedly over time and from context to context⁷, and between those who advocate for it (including policymakers, researchers and tech entrepreneurs) and those charged with implementing it (mostly, teachers).

What we are calling personalised learning is known elsewhere by multiple names (including learner-centred instruction, differentiated learning, individualised learning, competency-based learning...). It has also involved a long history of approaches (from teacher-developed individualised learning plans to project-based learning and adaptive technologies). At a higher level, it has been defined as a range of “*learning experiences, instructional approaches, and academic support strategies intended to address the specific learning needs, interests, aspirations, or cultural backgrounds of individual students*”⁸. It has also been used beyond mainstream education, in disciplines that are sometimes applied to learning such as psychology, computer science and artificial intelligence.

So, personalised learning is complicated. And this complexity, plus the fact that there is no universally-agreed definition, begs a key question: How can we consider the impact of personalised learning or evaluate its usefulness in schools? Our approach is first to survey the complexity, out of which a working definition will emerge, before considering how personalised learning has been the object of various technologies.

Towards a definition of personalised learning.

Step 1.

Some have argued⁹ that the numerous descriptions of personalised learning, although overlapping and sometimes contradictory, do share many common features. These include its objectives (to improve student engagement and achievement), its differentiation (its focus on meeting individual student’s learning needs), its flexibility (its ability to shift to meet changing needs), and its variable pacing (its recognition that individuals progress at different rates).

⁶ <http://bit.ly/2keGMdL>

⁷ Docebo, 2014

⁸ Hanover Research, 2014

This suggests that personalisation may occur, may be implemented, or may be considered, in multiple ways (each of varying importance and under the control of various decision makers):

- Personalisation of **why** something is to be learned (the learning aims).
- Personalisation of **how** it is to be learned (the learning approach).
- Personalisation of **what** is to be learned (the learning content and learning pathway).
- Personalisation of **when** it is to be learned (the learning pace).
- Personalisation of **who** is involved in the learning (the learner or learning group).
- Personalisation of **where** the learning takes place (the learning context).

Stanford University's Professor Emeritus of Education, Larry Cuban, on the other hand, proposes that personalised learning might best be considered as a *continuum* of approaches (while emphasising that "the continuum does not suggest the effectiveness of 'personalised learning' or achievement of specific student outcomes"¹⁰). At one end of this continuum are teacher-led classrooms, which use various approaches tailored to the achievements of individual students to teach pre-determined content and skills. At the other end are student-centred classrooms that, again with tailored approaches, frequently using new technologies, aim to "cultivate student agency" by encouraging learning to emerge from the student's own interests.

Another way to present Cuban's approach is in terms of *who* makes the decisions¹¹. At the highest level, it is policy makers who make the decisions, by determining the curriculum (the learning content) or the broad aims of the schooling experience. On another level, it is the teacher. The teacher might decide (possibly with some technological support) how to differentiate the subject matter in order to tailor it to their understanding of the individual student's learning needs. On a third level, it is the student. The student is enabled, by means of the learning experiences in which they engage and the academic support that they receive, to pursue their own learning interests and to develop strengths that they value.

Personalised learning also can mean different things in different geo-political contexts. In the USA, for example, what is meant by personalised learning emerges from the focus on individualism that permeates American society, politics and culture and that has played a major role in shaping the character of the country. In Europe, on the other hand, personalised learning tends to focus more on the empowerment of the individual student and the development of that student's personality, social and emotional skills.

⁹ <https://larrycuban.wordpress.com/2017/03/22/a-continuum-on-personalised-learning-first-draft>

¹¹ Abbott, 2014

Personalised learning and competencies

In both Europe and the US, personalised learning has involved an emphasis on students achieving specific *competencies*. However, while personalised learning and competency-based learning are often used interchangeably, what is understood by competencies varies markedly between the two contexts.

In general terms, the competency-based model of education sets out to challenge the approach common in many educational systems worldwide, in which students are sorted by age (into grade levels or year groups) and schools are accountable for one-grade level's worth of academic growth per school year¹². In a sense, in these traditional systems, credit is awarded based on what has been called 'seat-time'¹³, the amount of time the student is in their classroom seat while they learn, regardless of what is learned. The key criticism of this approach is that it is not designed to enable each individual student to reach their full potential (instead, as we have seen earlier, it focuses on the progress of the *average* student).

In competency-based learning, on the other hand, students are assessed against clearly-defined expectations and goals, and each student advances once they demonstrate mastery (once they have shown that they have achieved the intended learning goals)¹⁴. For this to work, and in order for students to be able to progress, they need to understand the learning objectives and what they have to do in order to demonstrate that they know what they need to know. It is when a student does not demonstrate mastery that they can be provided with additional individualised intervention, to help them fill in the gaps in their knowledge and skills.

In the US, competency-based learning in secondary schools centres on ensuring individual competencies in pre-determined content (specified in the Common Core State Standards¹⁵ which describe country-wide content for mathematics and English language). These standards dictate what students need to be able to know and do at the end of each school grade, and include clear descriptors of success and failure. One thing that distinguishes competencies of this type is that they can usually be straightforwardly measured (you have either achieved a competency or not) and thus they feed easily into the computerised multiple-choice testing systems (does the student know this predetermined content or not?) that are widely used across the US for some high-stakes assessments.

¹² Patrick et al., 2013

¹³ Mendenhall, 2012

¹⁴ Mead et al., 2014

¹⁵ <http://www.corestandards.org/>

In Europe, on the other hand, competences are more often defined as a combination of knowledge, skills and attitudes appropriate to the context. Key competencies are those that all individuals need for personal fulfilment and development, active citizenship, social inclusion and employment¹⁶. These competencies, sometimes known confusingly as 21st century skills¹⁷ (suggesting incorrectly that these skills have only recently become relevant), can often best be developed through project-based or other forms of collaborative work, while they are rarely amenable to multiple-choice assessments.

In summary, and returning to our core discussion, while personalised learning in the US tends to involve an approach designed to help individual students achieve competencies centred on a collective body of knowledge, in Europe personalised learning tends to involve competencies centred on personal development.

Personalised learning is also, as mentioned earlier, often conflated with individualised learning and differentiated learning, and is sometimes confused with problem- or inquiry- or project-based learning. **Individualised learning** has been used¹⁸ to mean giving students control over the speed at which they progress through the learning materials. The aim is to ensure that those learners who find the current learning objectives especially difficult are not left struggling as new material is introduced, while those who have made rapid progress are not left feeling bored.

Differentiated learning, on the other hand, has been used¹⁹ to mean tailoring the content and methods and sometimes the pace of instruction according to the students' readiness, interest, learning profile and goals. For whole classes, differentiated learning typically means dividing the students into small groups (usually according to the teacher's perception of the students' abilities, which might be considered the back-door imposition of ability streaming, an approach that has been frequently challenged²⁰).

Problem- and inquiry- and project-based learning each have their own histories (too long to cover here) and advocates but they broadly overlap. In short, they involve the learning being driven by challenging and open-ended questions or problems that have no one *right* answer, and the students work as active investigators. The questions or problems can be relevant to individual or group interests (i.e. they can be but are not always *personalised*), and can be related to a local or societal theme. Whatever way in which these approaches are organised, teachers usually adopt the role of facilitator, guiding the learning process while promoting an environment of inquiry (which again can be challenging to achieve – at the very least, it requires excellent planning and the ability to respond to unforeseen situations)²¹.

Since the 1970s, the German debate on personalised learning has been characterised by the distinction between external and internal differentiation. External differentiation means students being assigned to permanently, spatially and temporally separate learning groups. In practice, this means the assignment of students to different school types at the secondary level based on their academic performance (as is characteristic of the German 'track' system). Internal differentiation, on the other hand, means the temporally limited separation of a learning groups into variable smaller groups, in order to give students access to learning in a way that is tailored to their individual needs. Since the 1970s, internal differentiation has provided a critical alternative to the external differentiation of the track system and the "chalk and talk" teaching style. Bonsch (2006) categorises the numerous reasons debated in German-speaking countries for internal differentiation in learning in four patterns:

- In pedagogical terms, internal differentiation recognizes and supports classroom heterogeneity.
- In terms of learning theory, especially constructivist learning theories, internal differentiation improves support for students, leading to a deeper and more meaningful learning experience in schools.
- In terms of lesson theory, the concept constitutes a rejection of teacher-centred teaching approaches that are seen as undemocratic.
- In terms of education theory, internal differentiation offers the promise of ensuring the participation of all students.

¹⁶ European Commission, 2006

¹⁷ World Economic Forum and The Boston Consulting Group (2016) *New Vision for Education: Fostering Social and Emotional Learning through Technology*, Geneva, Switzerland.

¹⁸ e.g., Michell, 2016

¹⁹ e.g., Tomlinson and Imbeau, 2010

²⁰ e.g., Hallam and Parsons, 2013; Hattie, 2008; Johnston and Wildy, 2016

²¹ Anastopoulou et al., 2012

Similar to the Anglo-American literature presented above, German countries also have a wealth of methodical concepts, methods and procedures that describe in greater detail how to apply internal differentiation to learning in actual lessons. These concepts are rooted, firstly, in progressive educational approaches such as student-led “open learning” (in contrast to frontal instruction), independent work and project-based learning. In addition, American concepts of teaching and learning research such as adaptive teaching and its prioritisation of the diagnostic skills of teachers, are also adopted in German countries. Manfred Bönsch’s topic map (shown in Figure 1) illustrates the complex German discourse on internal differentiation in learning. The map systematises and structures also the far-reaching overlaps and relationships among related teaching concepts, such as self-organised learning, skills-focused teaching and learning paths, which are discussed in the German literature.

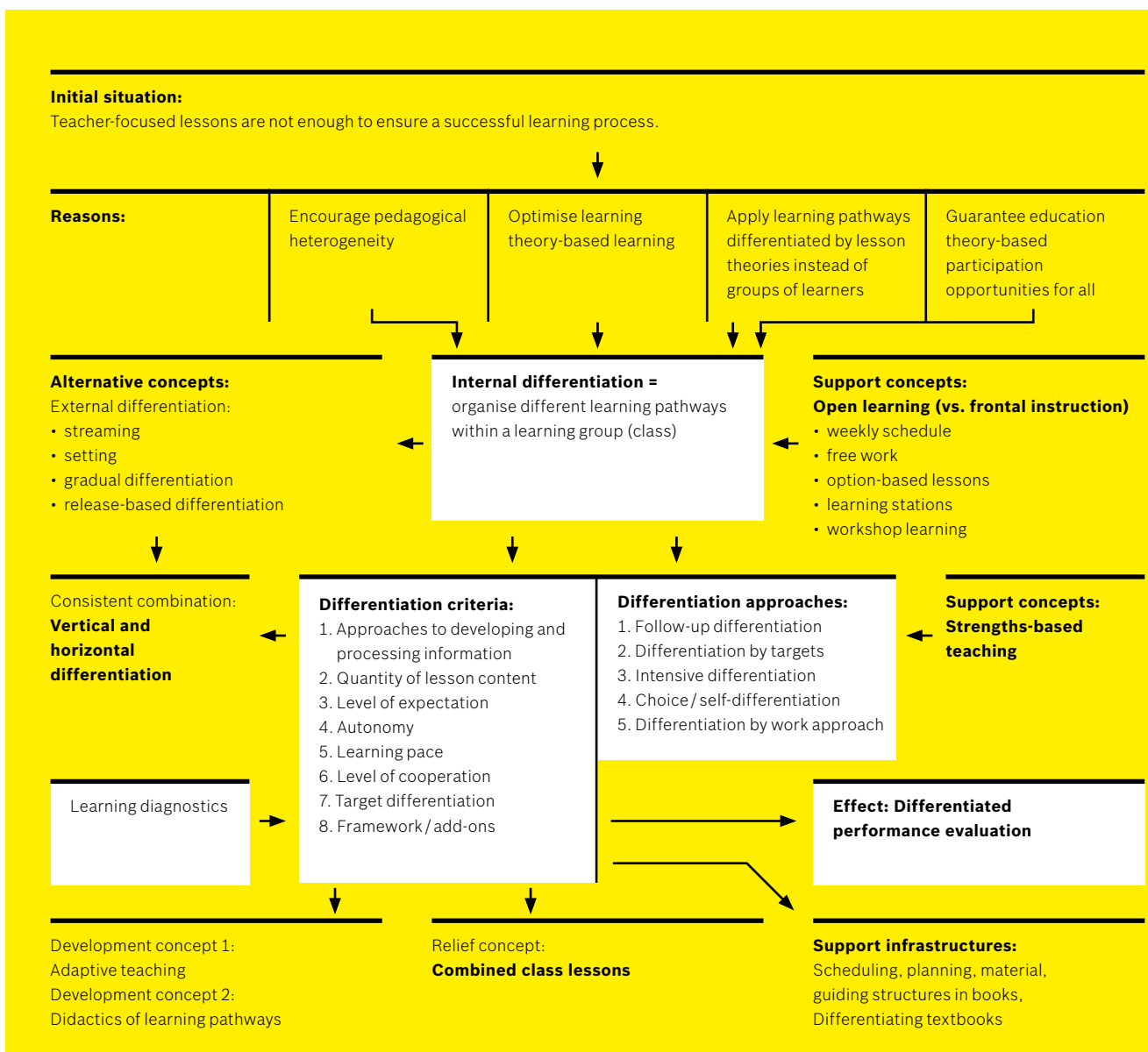


Figure 1 Topic map “Internal differentiation” (Bönsch, 2016; p. 14)

In fact, internal differentiation and individualisation are often used interchangeably in the German literature.²² Some authors define the terms more tightly, applying it only to actions that tailor lessons to the specific demands of individual students.²³ The present study mostly uses the wider, interchangeable interpretation of the terms.

The term “personalised learning” is much less commonly used as a technical term in Germany than the terms differentiation and individualisation. If the term is used in the German discourse at all, it is mostly in reference to Anglo-American concepts of personalised learning. In doing so, to draw a distinction from the constructs of differentiation and individualisation, some authors underscore the role of participation and autonomy of students in designing suitable learning opportunities. Differentiation and individualisation, on the other hand, are understood as methodical actions determined by the teacher.²⁴ However, such an understanding of the terms personalisation, differentiation and individualisation entails a narrowing of concepts that are generally meant in a broader sense. This is why it is not surprising that many authors use personalised learning and the terms differentiation and individualisation synonymously.²⁵ Furthermore, the term is frequently used in Germany in connection with the use of digital technologies as tools for differentiation in the classroom. In this context, the literature talks about “personalised learning environments” (PLE), especially in ICT lessons.²⁶

This study mostly uses the term personalised learning interchangeably with the wider understanding of inner differentiation as illustrated by Bönsch’s topic map. In fact, the dimensions listed in Section 3 – the learning aims, the learning approach, the learning content, the learning pace and learning pathway, the learner or learning group and the learning context – tie in perfectly with the German discourse on internal differentiation.

²² E.g. Bräu, 2007; Klieme & Warwas, 2011; Schratz & Westfall-Greiter, 2010, Trautmann & Wischer, 2008

²³ Trautmann & Wischer, 2008

²⁴ Schratz & Westfall-Greiter, 2010; Stebler, Pauli & Reusser, 2017

²⁵ Engeli, Smit & Keller, 2014; Zylka, 2017

²⁶ Förster, 2004; Ebner, Taraghi & Altmann, 2011; Petko et al., 2017; Zylka, 2017

Towards a definition of personalised learning. Step 2.

Now we are in a position to draw three elements raised earlier together, towards a helpful definition of personalised learning: (i) Cuban's *continuum* approach to personalised learning, (ii) the *why, how, what...* questions, and (iii) the various levels of inquiry (policy-makers, teachers, students). In doing so, it becomes clear that personalised learning actually involves *multiple* continuums²⁷.

At the policy-maker (or state) level, we need to address the *why* of personalisation (the aims of the curriculum, the approach to learning) and, broadly, the *what* of personalisation (the learning content). These decisions tend to constrain decisions that can be made by the teacher and students.

At the teacher level, we need to consider other macro-strategies, the *how* of personalisation (whether to use, for example, instructionist or problem-based approaches to learning), as well as various micro-strategies, the *what* of personalisation (the learning content), the *when* of personalisation (the pace of learning), the *who* of personalisation (the learning group), and *where* the learning takes place. These decisions tend to constrain decisions that can be made by students.

At the student level, we need to consider the *who* of personalisation (prior experiences, individual interests, cognitive, behavioural and affective states, as well as the groups in which the learning takes place).

To begin with, in Figure 2, we consider the macro-level personalisation strategies *learning aims, learning approach* and *learning content* continuums. In this figure, the left of the continuum represents less personalisation, while the right of the continuum represents *more* personalisation. This is not to suggest that one end of the continuum is better than the other but only to reinforce that personalised learning is both difficult in concept and in practice.

²⁷ We note that for many the plural of continuum is continua. Here, for simplicity, we will use continuums.

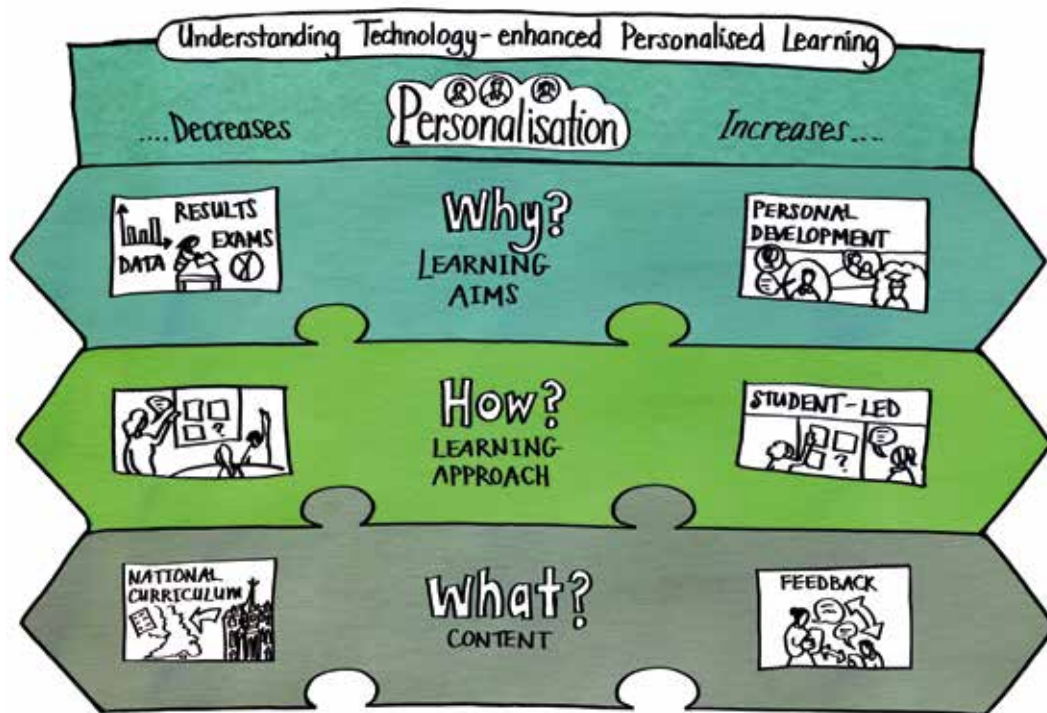


Figure 2: Continuums of personalised learning: macro-level

As illustrated in Figure 2, top continuum, decisions around personalisation might focus on the *aim* of learning (the *why*), with the continuum ranging between focusing on passing exams or focusing on personal development.

On the other hand, as illustrated in Figure 2, middle continuum, decisions might also focus on the *learning approach* (the *how* of learning), which ranges from entirely teacher-led (i.e. not personalised at all) to entirely student-led.

Finally, as illustrated in Figure 2, bottom continuum, decisions around personalisation might also focus on the content to be learned (the *what* of learning) which, depending on the level of detail, could be specified by the state or the school, the teacher or the student.

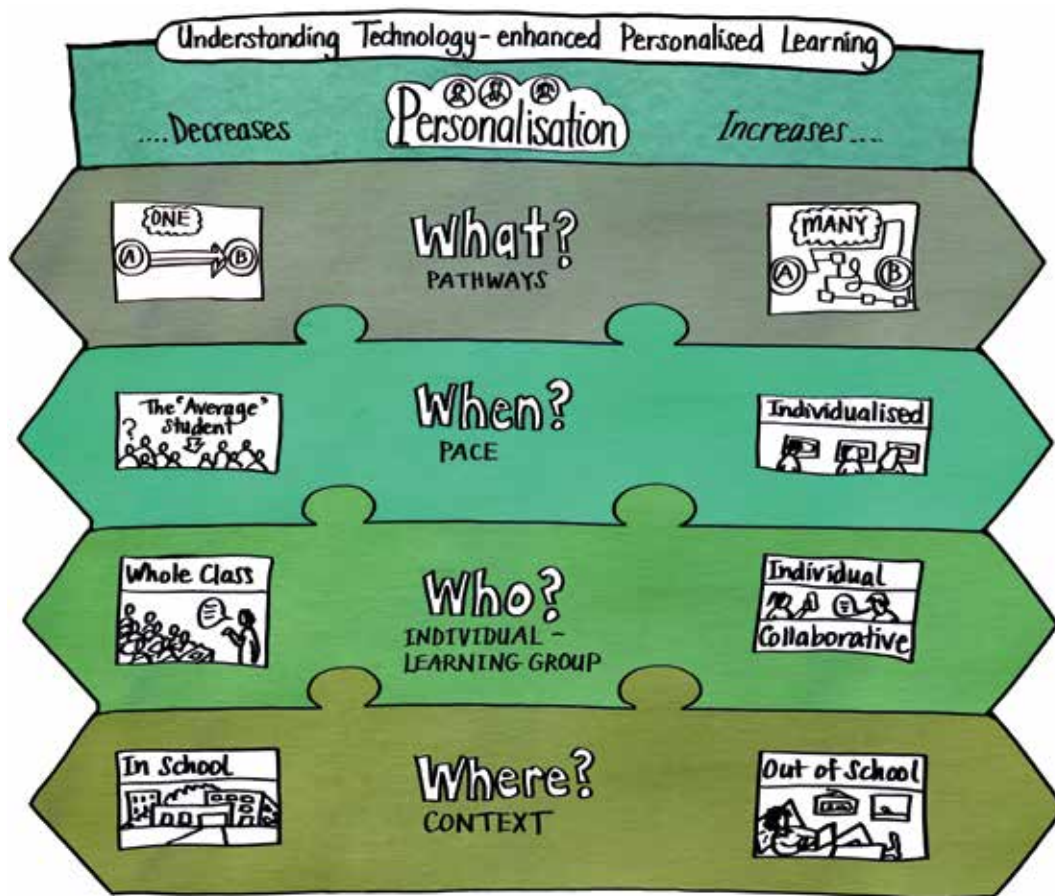


Figure 3: Continuums of personalised learning: micro-level

As illustrated in Figure 3, top continuum, decisions around personalisation might also focus on learning pathways to accommodate (or ignore) student differences or the learner profile (relating to prior experiences, personal interests, and their cognitive, affective and behavioural states).

As illustrated in Figure 3, second continuum, decisions around personalisation might also focus on the pace of learning, ranging from class-based (one pace for all students in the class) to individual-based (an individual pace for each student in the class).

As illustrated in Figure 2, third continuum, decisions around personalisation might also focus on *how* the students are grouped for learning, ranging from whole-class, through smaller groups to students working individually.

As illustrated in Figure 3, bottom continuum, decisions around personalisation might also focus on *where* the learning take place, ranging from in-school activities (either within or outside the classroom) to out-of-school activities (including homework).

Considering personalised learning across a set of continuums helps us understand the complexity of the term, and offers a way to understand how personalised learning might be implemented. In summary, and as we've seen, personalised learning can refer to macro decisions (such as the aim and approach to teaching and learning) or to micro decisions (like the context, the pace, the grouping and the learning pathways). Indeed, this complex continuum-based description will here function as our working definition of personalised learning – because if a school is to consider implementing personalised learning in (or around) their classrooms, each of these dimensions or continuums must be considered (even if some cannot be controlled at the school level and although not every continuum is equal in importance).

Examples of Personalised learning

Relating topic to an individual student's life

In an area where earthquakes are common (such as Sicily or California), a hands-on lesson on earthquakes could facilitate students understanding of the phenomenon by relating it to their prior knowledge and experiences. The lesson might start with a discussion of a recent earthquake, where students discuss their own experiences, and express their own feelings, in class. In small groups, students might then carry out a review of major recent earthquakes. Towards the end, students might discuss the reasons behind the safety advice that they receive from the authorities.

Allow students to express their ideas in multiple ways

Having read the story *The Three Little Wolves and The Big Bad Pig* the teacher might ask children to tell her how the story is different from the *Three Little Pigs*. Then she might ask students to work in pairs to discuss their own understanding of the *Three Little Pigs*, and to create a puppet show, or a poster or a comic strip to illustrate. Students could then be given twenty minutes to prepare and five minutes to present their ideas.

Differentiated instruction

A teacher might take students on a field trip to investigate the local flora (which might happen to include many herbs). At the end of the field trip, the teacher might suggest that each student picks a herb and relates it to their favourite dish. For example, they might have to answer specific questions that relate to the way the dish is cooked, where the ingredients can be found, and the dish's history, all of which might be illustrated in a poster to be hung in the classroom.

The political imperative for personalised learning

As noted earlier, while it is teachers who are frequently tasked with implementing personalised learning in the classroom (and in some senses already do so as a matter of normal practice), over many years, in many countries, there has been a pressure for schools to adopt personalised learning approaches from policy makers. Here, to illustrate the variety, we will briefly summarise what has taken place in three European countries: the UK, Finland and Germany.

The UK

We begin with the UK only because personalised learning has been part of the UK political discourse for many years. Initiated by developments in technology during the 1990s²⁸, the potential of personalised learning became foregrounded with the publication of the government's *A National Conversation about Personalised Learning*²⁹ in 2004. The political imperative was driven by concerns that too many children were not achieving their potential, which meant that the workforce was insufficiently skilled for future global requirements. The government argued that personalised learning depended both on effective teacher differentiation of a set curriculum (thus adopting a similar approach to that used in the US, discussed earlier), and on the development of independent learner capacities. The exact roles and practices expected of teachers and learners were not specified. However, it was made clear that it did not involve students developing their own curricula independent of teacher guidance, and teachers should not abdicate their roles as teachers, while it did involve shaping learning around student interests and prior experiences (whether in one-to-one provision, in small group settings or in whole classes)³⁰.

²⁸ Brown, 1997

²⁹ <http://dera.ioe.ac.uk/5932/1/personalisedlearning.pdf>

³⁰ Waldrup, 2014; Johnson, 2004

Finland

Personalisation is also part of the political discourse in the Finnish education system³¹, where it involves individualisation at both whole-school and classroom level. For many years, the entire system has been non-selective, allowing flexible (rather than age-based) student groupings, and where it is the school's responsibility to ensure that every child achieves their full potential³². Accordingly, the overarching Finnish curriculum has four broad emphases. First, it uses inquiry-led approaches, focusing on helping students learn *how to learn* rather than *what to learn*, in other words helping them develop 21st century skills for an uncertain future. Second, it emphasises the development of broad-based personal competencies, skills that traverse multiple subjects, such as cultural competence, multi-literacies, competence for the world of work, and competencies for individual development as a human being and citizen. Third, it prioritises assessment as learning (rather than of, or for, learning), in which assessment is formative and ongoing. Rather than to differentiate between students, assessment in Finnish schools is used to identify areas in which individual students lack understanding or competence so that personalised early intervention can be provided. Fourth, the Finnish system prioritises the physical spaces (the where) in which learning takes place. This has involved the refurbishment of hundreds of schools and the building of many new dedicated learning environments, all specifically designed to support the Finnish personalised yet collaborative approach to learning.

Germany

In Germany, two events in particular have contributed to a wider education policy debate on individualised support for students: the unexpectedly poor scores of German students in the first PISA study of 2000³³ and the ratification of the UN Convention on the Rights of Persons with Disabilities (CRPD) of 2006.³⁴

The PISA study identified what it suggested were various failings of the German educational system. It showed that, compared to international standards, a large share of German students did not even master the lower levels of the basic skills in literacy and mathematics, and comparably few students could be classified as peak performers. Another finding of the PISA study was that in Germany, more so than in other countries, the parents' educational background and socio-economic status were decisive in students' educational opportunities and that students from migrant backgrounds were especially at a disadvantage. In social terms, the German school system proved to be fairly impenetrable, and the three-track structure less suitable to provide adequate support to students, both for lower and higher achievers.

In response to the "PISA shock", the Federal Conference of Education Ministers (Kultusministerkonferenz, or KMK in short) passed various resolutions: "Principles to promote students with specific deficits in literacy and mathematics"³⁵, "Promotion strategy for low-achieving students"³⁶, "Basic position of the German states on promoting students according to their abilities"³⁷, and an initiative of the federal government and the states, "Promotion of high-performing and potentially particularly high-performing students"³⁸. In summary, these resolutions specifically asked the German states to improve their offerings for individualised learning support, especially at the secondary level. The recommended measures included

³³ Baumert et al., (2001)

³⁴ KMK, 2010a

³⁵ KMK, 2007

³⁶ KMK, 2010b

³⁷ KMK, 2009

³⁸ KMK, 2016

³¹ Broussard, 2014

³² Sahlberg et al., 2012

the introduction of individualised curricula and educational offerings as well as differentiated feedback on performance and learning guidance, the strengthening of students' responsibility for the learning process and self-motivated activities, the individual adaptation of learning times, and the expansion of enrichment offerings for especially high-performing students. In institutional terms, many German states responded to the PISA findings by, among other things, introducing new school types, which combine different tracks under one roof and apply internal differentiation as the core learning principle (e.g. the comprehensive schools in Berlin, Saarland, Saxony-Anhalt, Schleswig-Holstein and Thuringia, and the middle schools in Hesse), or the introduction of all-day schools.

Policy efforts to establish individualised support in education were reinforced by the ratification of the UN Convention on the Rights of Persons with Disabilities (CRPD) in Germany. As a consequence of the CRPD, there has been a gradual transition away from teaching learners with disabilities in special-needs schools towards inclusive schooling in mainstream schools. The resolutions of the KMK laid out the goal to develop individualised guidance and support at general-education schools.³⁹ Education policy principles of inclusive teaching methods allow for the participation and self-determination of students in the learning process, and the appreciation of diversity. The measures suggested in the policy documents included removing barriers by providing personalised, supporting assistance systems, compensating for disadvantages, internal and external differentiation, feedback on personal progress, and the establishment of individual guidance and support offers through multiprofessional teams.

In these resolutions and strategy papers, the use of state-of-the-art digital technologies as a means to personalise learning is mentioned only in passing, if at all. However, the KMK strategy paper, *"Education in a Digital World"*⁴⁰, published in 2016, lists the use of digital technologies to design teaching and learning processes in schools as one of the key strategic goals. In this context, it emphasised the individualisation of the learning experience. The objective here is to enable students "to plan and design personal learning targets and paths"⁴¹, in other words "personalisation" in learning is highlighted.

To summarise the situation in Germany, the design of personalised learning opportunities has no strong tradition, due to the historically established three-track German school system and the associated assumption that external differentiation creates homogeneous groups of learners. Only in the past 15 years has the individualisation of learning become a priority in education policy. At the same time, support remains focused on mandatory educational standards, newly introduced in Germany also in response to the PISA studies. Higher objectives are, just like in the UK, the successful participation of young people in the workplace and in society.

The progress made with personalising schooling varies in the different German states, ranging from the mandatory incorporation of individualised learning opportunities in educational legislation and framework curricula, to procedures aligned across schools to individually document learning progress, the central development and provision of learning materials for individualised teaching methods, and the setup of school networks and the respective training offers for teachers.⁴² However, many of these measures are often pilot projects, in which only selected schools participate. In short, Germany has set out to personalise its learning but still has a long way to go before the concept is implemented consistently and comprehensively across all schools.

³⁹ KMK (2010b, 2011).

⁴⁰ KMK (2016).

⁴¹ Ibid., p. 12.

⁴² KMK (2017).

4. Personalised learning in classrooms: the challenges

On a first look, personalised learning appears to be an extremely worthwhile approach, with each student being enabled to achieve their personal goals and capabilities. However, in a class of around thirty learners, personalised learning (in terms of each of the various continuums discussed above) can be especially difficult for teachers to implement. For example, switching teaching practices and allowing student choices requires not only training but also time for teachers to accommodate the approach in their own teaching practices and in response to their own teaching experience. In fact, at least according to one group of researchers⁴³, it can take more than three years for a reform (such as personalised learning) to be implemented and mainstreamed, whether in a whole school or individual classes.

The process of personalising a school's approach is long and needs to be considered as a school reform. It involves not only providing resources to promote quality teaching but also restructuring of the curriculum and changing teachers' classroom practices. As most case studies indicate, introducing new technologies in the classroom requires support for teachers through either professional development seminars, ad hoc sessions to address specific challenges they might face or both. Similar findings were found in the US, England and Wales⁴⁴. Furthermore, professional training should also focus on existing misconceptions around what works in teaching and what does not (such as the ever-popular but incorrect notion of learning styles, which have been heavily criticised by leading educational researchers).

⁴³ Ryder & Banner, 2013

⁴⁴ Thomson & Gregory 2013

Another set of challenges centre on what has been called the *hidden curriculum*⁴⁵, the lessons implicit in school organisation and routines, with schools being important agents of *secondary socialisation*. One valued but sometimes forgotten outcome of schools is social cohesion, where students learn tolerance and respect for one another and shared values. The importance of social learning cannot be overestimated, but it is likely to be difficult to achieve if a school only uses personalisation which effectively separates students from one another. Shared values demand group interactions and reflection on those interactions.

Importantly, school is intrinsically a social experience, and not merely a series of relationships between individual learners and their teachers⁴⁶, and collaboration has an important role to play. This importance, of social interactions with the purpose of solving problems, has been recently acknowledged by the OECD⁴⁷, with the inclusion of collaborative problem solving skills in the PISA studies. Collaborative problem-solving (which has its own challenges⁴⁸) aims to bring together individual problem-solving and the social process of learners working together. In the social domain, it is important to establish a joint understanding of the problem and then to negotiate the route to the solution, through processes of thinking together and argumentation. Therefore, even though personalised learning stresses individual needs and competencies, social interactions also need to be facilitated, with the class learning as a cohesive unit.

In addition, there is a fundamental decision to be made by policymakers around who decides what to personalise and the amount of influence that learners and teachers are allowed. Personalised learning requires a new approach for achieving curriculum aims, which are usually specified centrally by policy makers at a state level, not at the school level. This means that teachers often have to achieve specific targets (such as examination results) regardless of the pedagogical approach that they are using (which might involve one set of criteria being used to evaluate an approach to teaching for which they are not designed or appropriate). Meanwhile, if existing practices appear to meet the required targets, teachers do not have the motivation (let alone the time or the resources) to experiment with new approaches. In short, if policymakers do not give teachers (and schools) control over decisions around curriculum, approach and assessment, it becomes incredibly difficult for teachers to implement practices that are genuinely personalised and effective.

⁴⁵ Giroux, H. Penna, A. (1983)

⁴⁶ Johnson, 2004

⁴⁷ OECD, 2017

⁴⁸ Luckin et al., 2017

In summary, when aiming to implement personalised learning in classrooms, the following challenges emerge:

1. The need for appropriate teacher training.
2. The need for time for teachers to adjust their practices.
3. The need to address critical social aspects of learning.
4. Conflicts of interest between policymakers, school leaders and teachers (raising question around who decides the curriculum aims, what to personalise, and how much influence teachers and learners are allowed).

In the remainder of this report, we consider how technology might provide effective support for personalised learning. In fact, the reader might be forgiven for assuming that technology has been proposed in order to address at least some of the challenges that we have just discussed around the implementation of personalised learning in classrooms. However, as we will discover, the reality is quite different. Rather than addressing the challenges of personalised learning, *technology-enhanced* personalised learning introduces a variety of new challenges about which policymakers and teachers also ought to be aware.

Having noted that possibly disappointing reality, we nevertheless continue this report by investigating what exactly is meant by *technology-enhanced personalised learning*.

5. Technology-enhanced Personalised Learning

Technologies to support personalisation are increasingly common and are attracting large amounts of attention and funding. For example, Amazon, YouTube and Netflix use technology to personalise the advertisements or video choices we are shown, all in an attempt to encourage us to spend more time or more money. Increasingly, advocates of *personalised learning* are also turning to technologically mediated approaches. This can involve varying degrees of customisation of a learning experience by using particular hardware or specialised software (including apps and online platforms⁴⁹). In Section 8 of this report, we describe a range of examples of technology-enhanced personalised learning. First, we explore the history of technology-enhanced personalised learning and consider the various challenges that come with it.

The use of technology to facilitate personalised learning can be traced back to the 1920s, with the invention of what became known as the first *teaching machine*, by the psychologist Sidney Pressey. Although this was originally designed as a self-scoring multiple-choice testing machine (it administered multiple-choice questions and only moved on when the student submitted the right answer), Pressey showed that testing with immediate feedback resulted in the student consolidating their learning of the materials⁵⁰.

Pressey's approach was extended by the well-known behaviourist B. F. Skinner of Harvard University, who argued that the techniques that he had pioneered for training rats and pigeons (in operant conditioning chambers also known as Skinner boxes) might be adapted for teaching people. Skinner's teaching machine was a wooden box with a windowed lid. Questions written on paper disks appeared in one window, the student wrote a response in a second window and advanced the mechanism. This automatically covered their answer, so that it could not be changed, and revealed in the first window the correct answer.

⁴⁹ Bulger, 2016

⁵⁰ Pressey, 1950

These early teaching machines may be considered precursors of today's technology-enhanced personalised learning if only because they facilitated the learner to control the pace at which the teaching materials were presented. Bear in mind however that the content was very specific, in clearly defined domains (i.e. mathematics) with definite right and wrong answers. Later versions also adapted which specific teaching materials were presented and in effect, at least according to Skinner, acted like a personal tutor, presenting automatic, immediate and regular reinforcement without any use of punishments:



“The machine itself, of course, does not teach ... but the effect upon each student is surprisingly like that of a private tutor.... (i) There is a constant interchange between program and student.... (ii) Like a good tutor, the machine insists that a given point be thoroughly understood ... before the student moves on.... (iii) Like a good tutor, the machine presents just that material for which the student is ready.... (iv) Like a skilful tutor, the machine helps the student to come up with the right answer.... (v) Lastly, of course, the machine, like the private tutor, reinforces the student for every correct response, using this immediate feedback ... to shape his behavior most efficiently.”⁵¹

⁵¹ Skinner, 1958

The 1980s saw the introduction into US schools of so-called Integrated Learning Systems (ILS) (they arrived in the UK almost a decade later): “*ILSs operate on a neo-behaviourist model of learning which uses automatic task selection, guided practice and feedback to deliver core curriculum content and skills through individualised tutoring and practice.*”⁵² The ILS in question comprised three main component systems:

- a tutorial system (tutorial, practice and assessment modules across a range of curriculum subjects and designed for various levels of ability),
- a learning management system (that identified a pathway through the learning materials that was thought appropriate for the individual student, that delivered the materials in sequence, and that provided feedback to students and teachers), and
- a logging system (that recorded and updated the student’s achievement levels).

Research outcomes, however, were equivocal. Use of the ILS led to very variable results (some positive, some neutral and some negative), with the researchers drawing two main conclusions. First, there was inconsistent evidence that knowledge was being successfully acquired. Second, that to be effective ILS needed to be integrated with, or at least accommodated by, the teacher’s usual practices.

In short, enabling teachers to transform their teaching practices to provide personalised learning journeys for each individual student depends on the curriculum and pedagogical design as well as on the technology. Nevertheless, technology, it is often argued⁵³, does have the potential to mediate many different approaches to learning. In addition, technology can immerse students in rich learning environments, and can enable students to meet their own personal learning needs⁵⁴. All of this has important implications for the way in which schools and teachers design and support learning activities.

⁵² Wood et al., 1999

⁵³ e.g. Zhang et al., 2016

⁵⁴ Conole et al., 2007

Understanding Technology-enhanced Personalised Learning

As we have seen earlier, thinking about personalised learning as a series of continuums across a range of dimensions helps us understand how personalisation might support learning. Here, we will apply this approach to considering how technology might be used to enhance personalised learning, in order to highlight how teachers might use it effectively in their classrooms. We will also draw on a framework proposed by FitzGerald and colleagues⁵⁵ that models different aspects of personalisation in technology-enhanced learning, before going on to consider some specific examples.

Personalisation of why it is to be learned – the learning aims



As we have seen, the ultimate aim of technology-enhanced personalised learning is to enable the learner to have agency when making choices over what, when, how and where to learn. To achieve this, teachers hold a vital role in drawing out and building upon a learner's prior experiences⁵⁶. Personalisation theory pushes educators to think outside the box by emphasizing the need for learners to be involved in designing their own learning process⁵⁷. It is about cultivating agency by listening to students when they say what they need. In a technology-enhanced personalised learning environment, learners are given control over setting their own goals for learning. The technology might also enable a reflective process during the learning journey, and might be flexible enough for the students to take their learning outside the confines of the traditional classroom⁵⁸. However, it is important to note that these researchers have very different understandings of learning aims. The first group are from the UK, the second group from the US, such that their understanding of learning aims could be related to differences in their understanding of *competencies*.

⁵⁵ FitzGerald et al., 2017

⁵⁶ Robinson & Sebba, 2010

⁵⁷ Campbell & Robinson, 2007

⁵⁸ Patrick et al., 2013

Personalisation of how it is to be learned – the learning approach



Technology-enhanced personalised learning can support teaching and learning by, for example, providing opportunities for student-led project-based learning (which can offer authentic real world contexts) or teacher-led (or curriculum-led) *drill and practice* (or *structured practice*⁵⁹) exercises for students to master specific content (e.g. mathematics). It can also provide students with choice over what they study (which can support the development of competencies, like critical thinking and collaboration), and can help students to self-regulate their learning. It might also reduce classroom operational tasks, such as assessment, freeing time for teachers to focus on the social and creative aspects of teaching and learning. Technologies can therefore enable multiple opportunities for personalised learning and can help teachers manage the complexities of it – although it has been strongly argued, and we agree, that technology can never substitute for a good teacher⁶⁰.

Personalisation of what is to be learned – the learning content



As we have seen, there are different conceptions of content. On the one hand, there are subjects such as mathematics, where problems and solutions are clearly defined. Using technology-enhanced personalised learning tools, such content can be made bite-sized, so that it is easily practised and assessed. In particular, technologies such as so-called *Intelligent Tutoring Systems*⁶¹ (which are discussed in more detail later) can be used to support student pacing, continuous assessment and feedback.

⁵⁹ Rummel et al., 2016

⁶⁰ Herold, 2016; Luckin et al., 2015

⁶¹ du Boulay et al., 2018

There are other types of content, however, that relate to life-skills which are not so well defined. To support this type of content, what are known as *exploratory learning environments* can be used, that can support the process of finding out about new things (for example, through hypothesis generation or data interpretation). In addition, technology-enhanced personalised learning might be used to help students make stepwise improvements to a piece of writing (e.g. *WriteToLearn*⁶²) or can encourage them to reflect on the content of their writing (e.g. *OpenEssayist*⁶³). Both of these approaches allow for immediate feedback to students which facilitates their engagement and helps them improve their work. It also frees time for the teacher to focus on different aspects of learning (such as social aspects of learning or enhancing the main argument of the essay). In this way, technology-enhanced personalised learning can transform writing into a holistic, open-ended, project-based endeavour.

Technology can also support personalised content in other ways. For example, it can be used in blended learning which involves a mix of traditional face-to-face instruction and online learning. Sometimes, this can include so-called flipped classroom⁶⁴ or individual rotation⁶⁵. For this, technology could be used to provide online content with extra adaptive features (e.g. *Khan Academy*⁶⁶), but it could also involve a learning management system to coordinate learning across subjects or teachers, or it could involve learning network orchestration, where a network of peers is created in which participants interact and share learning experiences.

Here, we will now explore a few of these approaches, to help understand how they might be used in and around school contexts: *Intelligent Tutoring Systems*, *Exploratory Learning Environments*, *Smart Learning Management Systems*, *Learning Network Orchestrators*, and (briefly) *Digital Games-based Learning*.

⁶² <https://www.writetolearn.net/>

⁶³ Whitelock, et al. 2014

⁶⁴ The Flipped Classroom model flips the traditional relationship between class time and homework. Students learn at home via online coursework and lectures, and teachers use class time for teacher-guided practice or projects. This model enables teachers to use class time for more than delivering traditional lectures (<https://www.blendedlearning.org/models/>).

⁶⁵ The Individual Rotation model allows students to rotate through stations, but on individual schedules set by a teacher or software algorithm. Unlike other rotation models, students do not necessarily rotate to every station; they rotate only to the activities scheduled on their playlists (<https://www.blendedlearning.org/models/>).

⁶⁶ <https://www.khanacademy.org/>

Intelligent Tutoring Systems

Intelligent Tutoring Systems (ITS) are technologies that can guide students through each step of a problem solution by creating hints and feedback as needed from expert-knowledge databases⁶⁷. They are based on Artificial Intelligence and Cognitive Science theories. ITS often comprise four main components. The Domain Model is a representation of a given subject area, such as mathematics or physics, divided into tasks. The Student model, represents the student's demonstrated knowledge, including any misconceptions, and achievements. As the learner works through the various tasks, the technology informs the student model based on what the learner can reliably get right, what they seem to partially understand, and what they seem to be poor at. The Pedagogical Model, represents the knowledge of pedagogical experts around how the domain might best be taught. It could include a set of learning goals that the learner needs to achieve as they work through the tasks, and how best to present new material, how best to deal with requests for help, how best to deal with incorrect steps and answers and so on. It might also include an understanding of how to motivate the learners if they become demotivated and tactics to deal with students who try to fool the technology into providing the correct answer. Finally there is the Interface component (what the student sees and hears) that provides the channel through which the student and the technology communicate⁶⁸.

An ITS could be used at schools in addition to a human classroom assistant, by an individual student or by a group who need extra practice or who need exposure to more challenging material (see *Cognitive Tutor* in the example tools described below). It could also be used in after-school classes, revision classes or for homework (see *ASSISTments* in the Case Studies). An ITS could also be the prompt for discussions between students or between a parent and a student (see *Maths-Whizz* below).

⁶⁷ VanLehn, 2011

⁶⁸ du Boulay et al. (in press)

Exploratory learning environments

Exploratory (or open-learning) Learning Environments (ELE) are learner-centered applications that help students actively construct and use knowledge for complex problem-solving tasks. They provide direct access to a domain (or to its simulation) and offer appropriate tools to support the learning experience. To do that, they employ supportive technology, resources, and scaffolding techniques⁶⁹. With these tools, the process of scientific inquiry is valued more than acquisition of scientific truths. Accordingly, students are immersed in rich, concrete experiences, through which they encounter, shape, and revise theories in action. They get to experience an idea, rather than simply being told about it.

In Exploratory Learning Environments (such as *Crystal island*⁷⁰ and *iTalk2Learn*⁷¹), students can explore as they like, to discover what they like. In other words, these environments are designed to facilitate learning in an unstructured and open-ended way. This, however, is both a strength and a weakness⁷². There is often no clear definition of correct behaviour and some students sometimes have difficulty engaging in productive explorations, monitoring their own learning and making sense of their progress (they don't understand what they should be doing)⁷³. Research with microworlds, simulators and other Exploratory Learning Environments repeatedly report the need for student-adaptive *guidance* and *support*⁷⁴.

⁶⁹ Land et al. (2012); Quintana, et al. (2006)

⁷⁰ Sabourin et al., 2013

⁷¹ Rummel et al., 2016

⁷² Mavrikis, et al. (2013)

⁷³ Fratamico, et al. (2017)

⁷⁴ Noss & Hoyles (1996); Joolingen & Zacharia (2009)

Smart Learning Management Systems

Learning Management Systems (LMS) are software-based platforms (such as *Blackboard*⁷⁵ and *Moodle*⁷⁶) that help teachers and school administrators with the management, delivery, and measurement of learning progress in their classes. Some LMS might also be thought of as being smart as they also use data analytics, the analysis of what the student does on the platform (when they log in, what they do, where they click...), in order to recommend a personalised instructional plan or a personalised learner pathway for each student. Examples of schools using these *Smart Learning Management Systems* include *Alt Schools*⁷⁷, *Spectra Secondary school*⁷⁸, and *Florida Virtual School*⁷⁹.

Learning Network Orchestrators

Another use of technology to help personalise learning may be called *Learning Network Orchestrators* (LNO), in that they enable and support networks of peers or of students and tutors. With these technologies, participants can interact with one another, share their learning experiences, build relationships, share advice, give reviews, collaborate, co-create and more. Bearing in mind that sources of information, capabilities, and assets lie in and around every school, a Network Orchestrator can create more value by connecting and activating such sources, tapping into new sources of value, both tangible (e.g. sharing technologies and other resources) and intangible (e.g. the expertise of a school in a domain, like science education).

Learning Network Orchestrators can also match learners and teachers based on their availability, the subject domain and other features. They can possess important characteristics in terms of facilitating coordination and cooperation among different stakeholders and can act as facilitators or hubs for purposeful network building to support learning. Network orchestrators might also support the student's capacity to influence their learning by taking action and asking a tutor for help (e.g. *Smart Learning Partner*⁸⁰), individual decision making to learn a new language (e.g. *busuu*⁸¹) or to receive help from a tutor via video-conferencing (e.g. *Third Learning Space*⁸²).

⁷⁵ <https://www.blackboard.com/>

⁷⁶ <https://moodle.org/>

⁷⁷ <https://www.altschool.com/>

⁷⁸ www.spectra.edu.sg/

⁷⁹ <https://www.flvs.net/>

⁸⁰ <http://slp.bnu.edu.cn> (NB Only available to students with accounts)

⁸¹ www.busuu.com

⁸² www.thirdspacelearning.com

Digital Games-based Learning

A final approach to technology-enhanced personalised learning to be mentioned here involves digital games. However, digital games-based learning has been explored in depth elsewhere⁸³ and it introduces a range of difficult issues that take it beyond the scope of this report. Accordingly, having noted that digital-games based learning can provide a dynamic approach to technology-enhanced personalised learning, and having named some examples below, it will not be considered any further.

Personalisation of what is to be learned – pathways



Technologies that support personalisation in commerce (e.g. in Amazon, YouTube, and Netflix) refer to varying degrees of customisation of a customer's experience. As we've seen, this has also been extended to learning, where the customisation refers to decisions around multiple pathways, pace, and grouping. We now consider these continuums and dimensions from the perspective of technology-enhanced personalised learning. Based on a student's interaction data (what they do with the system), an algorithm could suggest a personal learning pathway or a specific route, to address each student's difficulties or successes. A student could also receive suggestions of where to go next to learn content and skills in ways that would be better suited for their needs. Such pathways can be specified by technology like ITS (see for example *Cognitive Tutor* or *Assistments*). Personalised pathways can also be provided by Smart LMS, if they provide suggestions for learner development (as is the case with *Spectra Secondary school*).

⁸³ Holmes (in press)

Personalisation of when it is to be learned – the learning pace



When a student progresses from one topic to the next, or when they have mastered a learning domain, they could potentially move to the next one. The speed at which this transition takes place specifies the learning pace. This pace can be specified for the whole class (or the average student) or can be specified by individual students, with the latter approach building on the individual learner profile (a set of data that includes the student's cognitive strengths and weaknesses and their learning goals). These profiles are constantly refreshed as the learner works through various tasks, while the learning goals are always visible to students and their teachers. Some ITS (such as *Math-Whizz* and *Accelerated Reader*) inform the student profile based on what the learner can reliably get right, what they seem to partially understand, and what they seem to have difficulties with.

Personalisation of who is involved in the learning – the learner or learning group



Learning activities can take place as the whole class, or in smaller groups, or with individuals. The way in which students are grouped for each activity depends on the organisation of school resources, teachers' portfolio of activities and the available technology. Classrooms as learning spaces can change according to the needs of each learning activity and the requirements of the students. Most of the technologies discussed in this report support individual learners, although there has been some early research in using technology to support collaborative learning in small groups⁸⁴.

⁸⁴ Cukurova, et al. (2018); Rummel et al (2016); Soller et al (2005)

Personalisation of where the learning takes place – the learning context



Learning activities can take place inside a class or out of class, they could also happen across multiple classes or out of school. An algebra course for example can be personalised by an ITS during a class lesson (e.g. *Cognitive Tutor*) or for homework (e.g. *ASSISTments*). Alternatively, a Smart LMS could provide students personalised information in one class based on their attainment across all of their classes. In addition, a learning network orchestrator could provide tutoring support for maths in school but out of class (e.g. *Third Space Learning*) or out of school entirely (e.g. *Smart Learning Partner*).

Technology-enhanced Personalised Learning in Germany

Over the past few years, several representative teacher and student surveys were conducted on the use of digital technologies in schools in Germany.⁸⁵ Furthermore, the use of digital technologies in Germany was also evaluated in an international comparison as part of ICILS 2013 and PISA.⁸⁶ We know from these studies that the frequency of use of digital technologies in German classrooms has stagnated at a low level for decades. According to the *International Computer- and Information Literacy Study 2013* (ICILS), for example, only one in three teachers in Germany use digital technologies in the classroom once a week or more. This proportion is considerably higher in countries such as Australia, Denmark and the Netherlands.⁸⁷ The Digital School Country Indicator 2017⁸⁸, however, shows an upward trend of at least one in two teachers using digital technologies once a week or more.⁸⁹

⁸⁵ E.g. BITKOM 2011; 2015; Bos et al. 2015; 2016; Initiative D-21 2016; Lorenz et al. 2017

⁸⁶ Eickelmann et al. 2014; Fraillon et al. 2014; OECD 2015

⁸⁷ Eickelmann et al. 2014; Fraillon et al. 2014

⁸⁸ Lorenz et al. 2017

⁸⁹ Lorenz, Endberg & Eickelmann, 2017

In Germany, technologies used by teachers in lessons primarily comprise word processing and presentation software as well as web-based information sources. No user data is available for schools in Germany about the types of approaches described in the previous section, which have been designed explicitly for personalising students' learning experience. It is known, however, that one in four teachers in Germany uses tutorial software and training programmes (in the broadest sense, these include the intelligent tutoring systems described in the previous section) at least occasionally. The international average is above 50%. Only 1.5% of teachers teaching grade 8 state that they use such programmes "in most lessons", while the international average is 15%.⁹⁰ Once again, the Digital School Country Indicator 2017 identified an uptrend. To date, some 20% of the interviewed teachers reported that they used a wider portfolio of software that included not only word processing, presentations and Internet research sites, but also data collection and processing, spreadsheets, and modelling and simulation software. Close to a third of all interviewed teachers reported that they used digital technologies at least once a week in providing individual student support.⁹¹

Other findings of the pilot projects illustrated how the potential of digital technologies for personalising the learning experience in German schools is perceived and implemented.⁹² These studies show that in Germany, a pedagogical benefit of the use of digital technologies can often be identified in support of personalised learning, connected to a broadening of teaching methods to include project work and self-directed learning.⁹³ Here, surveys of teachers demonstrate that digital technologies to provide individual learning support for students are credited with significant added benefit in inclusive education – but do not say much about the actual use of technologies in this context.⁹⁴

In Germany, little research, apart from individual field reports, has been undertaken on the use of digital technologies in inclusive education. Such reports assess positively the broad range of assistive technologies that are available to students with disabilities today, such as voice control for computers for students with communication impairments, screen readers for visually impaired students, and tablet PCs for those with motor impairments⁹⁵. The few available surveys show that computers at special-needs schools are primarily used to help students acquire basic skills in literacy and mathematics through tutorial software and games, as well as (just like in mainstream schools) for word processing and Internet research.⁹⁶ Surveys have also indicated that tablet computers are used for individual support for students with specific needs and as communication tools.⁹⁷

⁹⁰ Eickelmann et al. 2014

⁹¹ Eickelmann, Lorenz & Endberg 2017

⁹² E.g. Gerick & Eickelmann 2017; Schaumburg et al. 2007; Welling et al. 2014

⁹³ Q.v. Eickelmann 2010; Herzig 2014; Heinen & Kerres 2015; Schaumburg 2015

⁹⁴ Gerick & Eickelmann 2017; Wahl 2014

⁹⁵ Bock 2008, Fisseler 2012, Münzer 2012, Rüger et al. 2008, Wahl 2014

⁹⁶ Schwier 2009

⁹⁷ Wahl & Wiedecke 2015

Overall, the findings confirm the potential described in the previous section for the German context. On the other hand, they also show that technology-enhanced personalised teaching is so far practised only by a small minority of teachers. In this context, the quoted surveys and evaluations mostly do not assess the use of digital technologies specifically for personalised support, so that little data is currently available. In addition, these studies on technology-enhanced teaching are primarily based on survey data, while analyses based on class observations or standardised performance evaluations remain an exception in Germany. In short, there is still a need for research on the use of technology-enhanced personalised learning in Germany.

6. Technology-enhanced personalised learning in classrooms: the challenges



“Even in relation to systems designed to support individualised, automated teaching, there are sound theoretical reasons to expect that any long-term and cumulative effects on performance will be mediated and influenced by classroom practice.”⁹⁸

The challenges discussed below primarily concern aspects of media-related school development and its conditions. In Germany, barriers and success factors of media integration have been studied repeatedly in pilot projects.⁹⁹ The findings confirm those of international studies¹⁰⁰ by suggesting that the preconditions for successful integration of digital technologies in German-speaking countries include:

- technical, didactic and pedagogic knowledge of teachers¹⁰¹;
- positive mindset and attitudes of teachers regarding the use of technology in classrooms;¹⁰²
- positive self-efficacy expectations about the use of digital technologies in schools;
- a willingness to accept innovation and change in one's own teaching practice through digital technologies and to get involved in corresponding development processes at the school.

⁹⁷ Underwood et al. 1999

⁹⁹ Breiter, Stolpmann & Zeising (2015), Eickelmann (2010), Prasse (2012), Schaumburg et al. (2007).

¹⁰⁰ Becta (2004), Bingimlas (2009), Tondeur et al. (2008).

¹⁰¹ Q.v. Blömeke (2000).

¹⁰² Q.v. Petko (2012)

On a school level, the following additional conditions apply:

- the availability of a suitable technical infrastructure and the relevant IT planning;¹⁰³
- a supportive attitude of head teachers and school administrators;
- structures for cooperation among the teaching staff that promotes the sharing of knowledge;¹⁰⁴
- an intra-school network of promoters.

It is likely that these success factors also play a role in the implementation of technology-enhanced personalised learning in German schools – to which we now turn.

Equipment / technical infrastructure

As there is often an inadequate infrastructure within schools to support the use of technology-enhanced personalised learning at scale¹⁰⁵, school infrastructure needs reforming.

Technology-enhanced personalised learning in schools requires a certain level of equipment with digital devices. In principle, a 1:1 device-to-student ratio is favourable to the personalisation of learning (i.e. every student having access to their own device). If this is not the case, there should at least be a sufficiently high number of devices available to ensure their flexible use in school. At present, this does not apply to the majority of schools in Germany. On average, more than 11 students at German Secondary Level I shared a computer in 2013, a high number compared to countries such as Norway, Australia and Denmark, where three to four students on average share a computer.¹⁰⁶ Another aspect is that a school's computers are usually located in ICT rooms, which makes it difficult to employ them in a flexible and personalised ways. Portable devices for classroom use were available to less than half of all students at Secondary Level I in 2013. Meanwhile, according to ICILS 2013, only close to 20% of German eighth-graders had their own computer to bring to school.¹⁰⁷ A more current study carried out by BITKOM reports that 35% of students at Secondary Level I bring a private laptop and 19% their private tablet PC to school.¹⁰⁸

¹⁰⁵ Horizon 2017

¹⁰⁶ Gerick et al., 2014

¹⁰⁷ Ibid.

¹⁰⁸ BITKOM 2015

Another limiting factor in the use of digital technologies in German schools is the frequent lack of high-performance network infrastructure. According to the BITKOM study, fewer than half of all teachers interviewed stated that their school had wired or wireless Internet access in *all* rooms.¹⁰⁹ According to various surveys, 40 to 70% of all those surveyed consider the technical conditions at their school to be in need of improvement.¹¹⁰

The private households of children and teenagers, on the other hand, are almost all equipped with computers and/or laptops and Internet access.¹¹¹ In principle, personalised learning could, at least to a certain extent, be moved to the home environment, for which several technology-enhanced personalised learning tools may well be suited. However, only a small number of schools provide their students with an accessible learning platform, which would be required to support personalised learning at home. In any case, in the Digital School Country Indicator 2017, only 40% of teachers state that they use such a platform.¹¹² While this number has increased slightly over the past few years, learning platforms are still not part of the digital tools available in all schools.

It is certainly true that effective use of technology-enhanced personalised learning tools use in classrooms cannot be achieved simply by increasing the number of computers. Nevertheless, according to Breiter, Stolpmann & Zeising,¹¹³ a well-functioning IT infrastructure is fundamental for integrating digital technologies in schools, and even more so for technology-enhanced personalised learning.

To summarise, there is still a significant need for improvement at schools in Germany. Here, the challenge is to rethink previous concepts for equipping schools with digital technologies and, in cooperation with municipal school boards, develop and implement new models (such as a reasonable combination of permanently installed computers, school-owned mobile devices, rental / leasing solutions, and / or students' personal devices).¹¹⁴

¹⁰⁹ *ibid.*; similar results were also found by a survey of the initiative d21 from 2016.

¹¹⁰ *ibid.*; Lorenz & Endberg 2017; d21 2016.

¹¹¹ MPFS 2017

¹¹² Lorenz & Endberg 2017

¹¹³ Breiter, Stolpmann & Zeising 2015

¹¹⁴ *Ibid.*

Cost

An obvious challenge for technology-enhanced personalised learning centres on its cost and cost-effectiveness. Sometimes, these technologies cover only a small part of the curriculum but can be very time-consuming and thus expensive to make¹¹⁵. For example, they can require a large multidisciplinary team of pedagogical experts, learning designers and computer scientists to work together and understand what information is useful to whom and in what learning contexts¹¹⁶.

These high development costs may be another reason why relatively few “intelligent” or personalised learning technologies are available for German schools. While most educational book publishers offer additional digital exercises to supplement the print editions of their textbooks, they do not usually offer individual learning support in the form of adaptive tools or automated feedback. The extracurricular tutoring sector, the so-called “afternoon market,” in Germany does however draw on a wide range of simple commercial personalised learning and tutoring software.

Cost is also a challenge for German schools because of the additional infrastructure costs that have not been factored into budgets so far. In a report from 2015, Breiter et al.¹¹⁷ calculated annual costs of between close to €100 to €180 per student for equipping computer rooms and classrooms for an average of five students to share a computer, while, according to the authors, a 1:1 setup would cost between €320 and €460 per student per year. These costs include not only the technical infrastructure, but also maintenance and support costs, as well as training courses and teaching materials. As schools often make use of free offers, such as open educational resources, tool programmes and apps, as well as materials developed in-house, Breiter et al. arrive at a cost calculation for digital learning materials of €2.80 per student per year. However, open educational resources rarely offer any personalised learning. When schools use commercial offerings, costs increase significantly.

¹¹⁵ e.g. Barab 2013, and see Holmes (in press).

¹¹⁶ Du Boulay et al. (in press)

¹¹⁷ Breiter et al., 2015

School reform

As we saw earlier, implementing effective personalised learning in schools can also require difficult reforms across the whole school. This is only exacerbated when technology is involved. For example, when smart learning management systems are used, it requires the active engagement of teachers and administrators across the school, otherwise the data can be incomplete such that students are given inappropriate content or learning pathways.

Finally, focusing on individual needs also increases the pressures on the teacher, resources and the school. It can encourage support to be directed exclusively at individual students, at the expense of other students, rather than at supporting the teacher to create effective pedagogy for the whole class.

In this respect, many schools in Germany need to improve in two critical areas, as they are only at the beginning of developing concepts for personalised support through inclusive schools (as described in Section 3) and implementing technology-enhanced personalised learning. The implementation of technology-enhanced personalised learning makes it necessary to consider and handle inclusive school and technology developments not as separate requirements but instead as synergistic and interconnected. For example, it would be possible to increase the application of digital tools and learning platforms in learning support, as well as in diagnosing and documenting individual learning stages and progress made by individual students. A shared learning platform can also support cooperation within an interdisciplinary team of educators.¹¹⁸ Tapping the full potential, however, requires a strong innovative spirit on the part of the teachers, who would need to master technical, pedagogical, and school organisational challenges while fundamentally changing their working habits. It is evident that the change processes only briefly touched upon here require proper support of the teachers in the form of further training, time and organisational resources, as well as the establishment of suitable structures for cooperation.

Addressing inequalities

One reason often given for introducing technology-enhanced personalised learning in schools is to close the gap between underachievers and higher achievers. However, digital technologies can, on the contrary, often reinforce and reproduce existing inequalities in the education system (especially when the high achievers also come from higher socio-economic groups and have access to more computer technology at home)¹¹⁹. If in school the technology is going to support all individuals, it is also going to enable high achievers to move more quickly, thus extending the very gap that everyone wants to close. This is known as the Matthew Effect¹²⁰ and it needs to be considered carefully. One approach to address this issue is taken by *ASSISTments*, which supports students' homework in order to enable the whole class to move forwards together in the classroom (cf. Chapter 9).

In Germany, the call for personalised learning also has to take into account two conflicting topics, namely individualised support and shared learning experience. To prevent personalised learning from benefiting mainly high-performing students, schools that are successful in implementing technology-enhanced personalised learning also should offer other measures.¹²¹ These may include the application of competency grids, frequent individual learning guidance, as well as supporting students not only in acquiring textbook knowledge but also being taught strategies for self-determined and independent learning and working. Furthermore, personalised learning is combined with cooperative forms of learning and working, as well as with activities that promote a sense of community, such as making music together, sharing meals, celebrating and partying, and solving conflicts together in the class council.

¹¹⁹ Facer et al., 2003

¹²⁰ "For unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken away even that which he hath", Gospel according to Matthew, XXV, 29.

¹²¹ Schöler & Schabinger 2017

Student safety

Technology-enhanced Personalised Learning faces the same challenges as any educational technology innovation. For example, there is a need to educate students on the consequences of using computers at home, how to be safe on the Internet, and on how to resist bullying. With *one child per technology* initiatives, spyware can be used to watch over students' activities, or to control the availability of Internet access (although this might restrict incidental learning that occurs through exploration). According to some researchers¹²² the greater access to digital technologies, and the greater the support provided by schools, the greater the opportunities that students have to lead and influence their own personal learning. Restrictions on Internet access imposed by schools or local authorities, further limit student access to technology-enhanced personalised learning. Finding an effective and appropriate balance between free access to the Internet while ensuring that students are safe online is an enormous challenge. The issue does not, however, stop at the school gate. When students take the technologies home, parents need to be involved and engaged sensitively¹²³. The content and guidance provided need to be purposeful and relevant.

In Germany, the debate about media literacy and education has for decades focused mostly on critical and responsible media use.¹²⁴ Consequently, the latest KMK strategy paper, "Education in a digital world", devotes a separate dimension to "Protection and acting safely" in the proposed media literacy concept.¹²⁵ From this point of view, appropriate handling of the dangers of the Internet cannot include the creation of a "digital safe space" in schools. Education policy instead seeks to use regular lessons to discuss the risks and dangers. However, little is known about the extent to which this is already being done at German schools and /or the extent to which it is feasible during regular teaching sessions. Overall, studies on lesson-integrated media literacy training in German schools show that only a small group of teachers use their classroom time to systematically promote digital media skills.¹²⁶ A concern here is that educational federalism which, due to non-standardised, state-specific target requirements and curricula, prevents mandatory integration of media training in classroom learning.¹²⁷

¹²² Robinson & Sebba, 2010

¹²³ Lewin & Luckin, 2010

¹²⁴ Baacke, 1997; Tulodziecki, 1998; Tulodziecki et al., 2012

¹²⁵ KMK 2016

¹²⁶ Eickelmann et al. 2014

¹²⁷ IBI, 2016

IT security and data privacy

Many technology-enhanced personalised learning solutions offered to schools may be thought of as mass customisation tools (like Amazon and Netflix), in that they collect a wide range of data about students based on their activities and clicks, and involve algorithms that identify patterns in order to offer custom results in the form of pre-defined personalised paths. However, it often is not clear how these algorithms make their decisions, they act as so-called black boxes the inner workings of which cannot be inspected, and they can reproduce existing stereotypes of learning behaviour thus inhibiting rather than enhancing student development.

In fact, some technology-enhanced personalised learning solutions involve the collection of massive amounts of student data, from their achievements to their personal backgrounds (such as their ethnicity)¹²⁸. This new data-driven model of schooling, that is being championed by some Silicon Valley companies (such as *Alt School* but also now *Google* and *Facebook*) is shifting the vision of public education reform to their own industry benefit. According to the US Department of Education¹²⁹, as students increasingly use technology to support their learning, schools are faced with a growing need to protect student privacy while allowing the appropriate use of data to personalise learning, advance research, and visualise student progress for families and teachers. In Europe, new data rules might protect student data more effectively but at the same time might cripple the technology-enhanced personalised learning tools that depend on free access to massive amounts of anonymous student data (assuming that, with big data techniques, data can ever be truly anonymous¹³⁰). Accordingly, school leaders and policy-makers both have critical roles to play in safeguarding student data and student well-being.

The strict privacy and data protection standards that apply to students' personal information mean that German schools have to evaluate very carefully, before implementing technologies to support personalised learning, what type of data is collected from users and how their privacy is protected. Freeware or commercial offerings, which save and store personal information of students outside of a schools' control, therefore often cannot be used at all, or at least only to a very limited extent. Schools need to find solutions that comply with Germany's data protection rules. In the past, responsibility for data protection was generally assumed by the individual schools. Given the increasing complexity of information protection and the legal framework, it is doubtful whether this approach will be considered practicable in the future. This is why Breiter et al.¹³¹ call for shared responsibilities of schools, school boards and states. For personalised learning, this could mean, for example, that the individual tools are provided on a learning platform or central media server hosted centrally by the state or school board in charge.

¹²⁸ Watters (2017)

¹²⁹ U.S. Department of Education (2017)

¹³⁰ Mayer-Schonberger & Cukier (2013)

¹³¹ Breiter et al. 2015

No silver bullet

Taking all these issues into account, it becomes clear that technology-enhanced personalised learning is no silver bullet, and decision makers need to realise the complexity of implementing it in schools and what it might achieve. In particular, technology-enhanced personalised learning provides assistance to very specific tasks (such as pathways through learning activities) and most importantly, it cannot replace teachers.

Technology-enhanced personalised learning therefore faces many implementation challenges, some of which originate from introducing any technological innovation in schools and others relate to the specific promises of personalisation with data-driven algorithms that do not address the fundamental question of *why* students learn. They do offer, however, differentiated options for the motivated student who wishes to follow an individual pathway in order to acquire knowledge or skills.

In summary, implementing technology-enhanced personalised learning raises the following challenges:

1. Implementation needs to be considered as part of whole-school reform, with training that includes misconceptions and time allowances for new practices to settle.
2. Regardless of the vision, existing inequalities may be reinforced not reduced.
3. Protecting student Internet safety can be in opposition to enabling students to take active control of their own learning.
4. Technology-enhanced personalised learning can be at the expense of inclusive support for the class, and social learning opportunities for all students.
5. Infrastructure requirements can be a huge challenge when implementing technology-enhanced personalised learning (for example, what does a teacher do when the technology stops working, as it all too often can do).
6. Technology-enhanced personalised learning can require massive amounts of student data, which can compromise student privacy.
7. Algorithms can reproduce existing stereotypes.
8. Technology-enhanced personalised learning has nothing to say about the *why* question (why something in particular needs to be learned), yet specific learning aims outside the control of the teacher can be implicit within the technology.
9. Technology-enhanced personalised learning also has nothing to say about the *how* question (how something is to be learned), in the sense that (perhaps with the exception of exploratory learning environments which are not yet ready to be used at scale) many use a didactic or instructionist approach to learning that in conventional classrooms is often avoided.





7. Understanding the evidence

One of the challenges in developing evidence-based teaching practices in schools is to identify what evidence is likely to be useful in a specific context. Individual research studies may have potentially valuable findings, but there are countless studies which might potentially be of value, and many that appear to contradict one another. In addition, it is difficult to evaluate the effectiveness of a tool without some kind of benchmark¹³². What are known as *effect sizes* aim to serve this purpose.

Effect sizes

Effect sizes allow us to move beyond the simplistic, 'Did it work?' to the far more important, 'How well did it work?' The bigger the effect size, the larger the impact on the participants, with effects above 0.4 in educational studies thought to be "worth having"¹³³. In fact, effect sizes can also be negative, which would indicate that the tool being evaluated produced worse learning outcomes. Effect sizes can also be used to compare the outcomes of separate studies across a range of contexts.

Although all of this might seem straightforward (large effect sizes are relatively good, while small or negative effect sizes are relatively bad), researchers suggest that effect sizes should be treated cautiously (but taken seriously)¹³⁴. There are several issues. For example, the calculations depend on the numbers of participants, the studies require mature technologies that can be tested at scale, and effect sizes ignore important issues such as the costs of implementation. In any case, and of particular importance for this study, robust effect sizes are rarely given for technology-enhanced personalised learning tools (especially in marketing materials!).

¹³² Higgins & Katsipataki, 2016

¹³³ Hattie, 2008

¹³⁴ Higgins & Katsipataki, 2016

Randomised Controlled Trials (RCTs)

To be useful and reliable, effect sizes are best derived from large numbers of participants in studies known as randomised controlled trials (RCTs). These RCTs involve an *experimental*¹³⁵ group of participants (who use the tool being evaluated) and a *control*¹³⁶ group of participants (who use an alternative but comparable tool), while the effect sizes measure how far the mean of the experimental group is from the mean of the control group¹³⁷. Often, however, control groups do not use any tool. Instead, they just receive their usual teaching (which is referred to as *business as usual*). In this type of RCT, a positive effect size could only be interpreted as meaning that the students engaging with any technology do better than students not engaging with any technology, not that the particular technology being evaluated has had any specific effect. This is why in robust RCTs, the control group uses a comparable but different technology (and why in even more robust RCTs, there are two control groups, one using a comparable technology, the other experiencing *business as usual*).

RCTs raise other issues to consider. For example, who is conducting the study, what are the instruments (the tests) being used, over what period is the intervention, how many participants are involved, and how are the participants randomly allocated to the groups being studied? Independently conducted RCTs are usually thought to be more robust than studies conducted by the researcher or developers. Researcher- or developer-led studies often give overly optimistic results (which is known as *super-realisation bias*¹³⁸). For similar reasons, RCTs using standardised tests are more trustworthy than those using tests devised by the technology's developers. Finally, longer term studies tend to be more robust (because time is given for any novelty factor to wear off), and larger numbers of participants tend to give more accurate outcomes (effect sizes tend to get smaller as experimental interventions are replicated and scaled up¹³⁹).

¹³⁵ Sometimes called a treatment group.

¹³⁶ Sometimes called a comparison group.

¹³⁷ Technically, effect sizes measure how far the mean of the experimental group (the participants who are using the tool being evaluated) is from the mean of the control group (the participants who are using a different but comparable tool or no tool at all), in terms of the pooled standard deviation of the group scores.

¹³⁸ Cronbach et al., 1980

¹³⁹ Slavin & Smith, 2008

In fact, because of these and other requirements, RCTs can be very difficult, time-consuming and expensive to conduct (they also answer only very specific evaluation questions, have outcomes that are rarely transferable to other settings, and in themselves cannot answer *why* a particular outcome occurred). This is perhaps why few technology-enhanced personalised learning tools have undergone such robust evaluations. Some developers have conducted alternative efficacy studies as an attempt to quantify their learning potential, usually with smaller numbers of participants and often without robust controls. In addition, in these studies, considerable care is usually taken to ensure that the intervention is implemented faithfully in the research setting, but this might not be scalable to real classroom settings. Accordingly, these studies are not as trustworthy as independent RCTs.

In summary, comparing efficacy studies of technologies (even RCTs) is not straightforward (although effect sizes from RCTs are still probably our best bet). If only for this reason, in this study we cannot state which technology-enhanced personalised learning tools are the *best* or, more importantly, which will work best in particular classrooms. That is not possible. Instead, we provide a set of indicators and a framework of analysis to enable you to draw your own conclusions, relevant to your practice and your students' needs, about any technology-enhanced personalised learning tools that you encounter. To demonstrate how this might work, we describe a range of technology-enhanced personalised learning tools but, first, we describe our framework of analysis.

Framework of analysis

Our framework of analysis is designed to help you draw your own conclusions about the suitability of any technology-enhanced personalised learning tool for your professional practice and students, and whether to try it in your classroom. The framework comprises a set of indicators (tag, domain, ages, language, cost, impact and evidence) together with brief descriptions of any other (non-RCT) evidence that is available. The aim of this approach is to provide you with a range of evidence, that includes factors beyond learning gains, to support your decision making. In addition, because so few of the technologies have robust RCT evidence or effect sizes, we also give brief descriptions of the evidence that is available and we also make some recommendations.

Tag	The type of technology-enhanced personalised learning tool. As discussed earlier, these are: <ul style="list-style-type: none"> • Intelligent Tutoring Systems • Exploratory Learning Environments • Smart Learning Management Systems • Learning Network Orchestrators 	
Domain	The school subject (e.g. mathematics or literacy) that the tool covers.	
Ages	The age range of the students for whom the tool is designed. This report only covers tools designed for school students.	
Language	The language(s) (e.g. German or English) used by the tool.	
Cost	The likely costs of implementing and running the tool in a classroom of 30 students (including teacher training costs).	
	€	Low cost (up to €10 per student per year)
	€€€	Moderate cost (up to €50 per student per year)
	€€€€€	High cost (more than €100 per student per year)
	NB Information around cost is not widely available. When no information about cost is available, we show "unknown".	
Impact	The effectiveness of the tool, as suggested by the evidence.	
	§	Low impact (effect size of 0.2 or below)
	§§§	Moderate impact (effect size around 0.4)
	§§§§§	High impact (effect size of 0.6 or above)
	NB Effect sizes are not always available. When no effect size is available, we show "unknown".	
Evidence	The robustness (trustworthiness) of the evidence.	
	@	Low robustness (e.g. developer-run trial, low student numbers, learning gains measured by non-standard instruments)
	@@@	Moderate robustness (e.g. higher numbers of participants, <i>business as usual</i> control group)
	@@@@@	High robustness (e.g. independently conducted randomised controlled trial, standardised instruments, control group using a comparable technology)
	NB Information to infer robustness is not always available. When no suitable information is available, we show "unknown".	

Table 1: Framework of analysis

8. Examples of technology-enhanced personalised learning tools

Our research has identified a broad range of technologies from around the world that have been used to personalise learning, a critical appraisal of which will enable us to infer valuable evidenced-based principles for teachers, and will help teachers make evidence-based decisions about which tools might be suitable for their classrooms.

To begin with, to help understand the range of what is available, we put the top 25 tools that we identified (*top* in terms of the amount of supporting evidence that is available) into a matrix (see Table 2). This arranges the tools according to the school subject that they cover (e.g. mathematics, science, literacy) and the learning context (whole school, in class, out of class, or out of school), in other words according to the continuum question of where the learning takes place. Once the matrix was in place, we used it to help us identify gaps (the matrix illustrates that the most common domain for technology-enhanced personalised learning tools is mathematics, while there were surprising gaps in languages, and unsurprising gaps in the arts), which we then tried to fill by finding other relevant tools (a process which was not always successful).

EXAMPLES OF TECHNOLOGY-ENHANCED PERSONALISED LEARNING TOOLS

Domain	Whole school	In class	Out of class	Out of school
All domains	<ul style="list-style-type: none"> • Spectra Secondary school • Alt School • Schoology¹⁴⁰ • Google Classroom • Diler 	<ul style="list-style-type: none"> • IBM Watson • Knewton¹⁴¹ 		<ul style="list-style-type: none"> • Smart Learning Partner • Florida Virtual School
Maths		<ul style="list-style-type: none"> • Cognitive Tutor • Maths-Whizz • Dreambox¹⁴² • TenMarks • Bettermarks • Kapiert.de 	Third Space Learning <ul style="list-style-type: none"> • Maths-Whizz • Khan Academy¹⁴⁴ • EdReady¹⁴⁵ • Bettermarks • Kapiert.de 	<ul style="list-style-type: none"> • Thinkster Math¹⁴³ • ASSISTments
English literacy		<ul style="list-style-type: none"> • WriteToLearn • TenMarks¹⁴⁶ 	<ul style="list-style-type: none"> • Accelerated Reader • OpenEssayist 	
German		<ul style="list-style-type: none"> • conText (literacy) • Kapiert.de 	<ul style="list-style-type: none"> • conText (literacy) • Kapiert.de 	
Languages		Kapiert.de (Englisch)	Kapiert.de (Englisch)	<ul style="list-style-type: none"> • Busuu • Duolingo
Sciences		<ul style="list-style-type: none"> • Crystal Island¹⁴⁷ • TECH8¹⁴⁸ • The Mystery of Taiga River¹⁴⁹ 		Khan Academy ¹⁵⁰

Table 2: Technology-enhanced personalised learning tools (by domain and learning context).

From the matrix shown in Table 2, we identified and investigated further 15 technology-enhanced personalised learning tools, aiming to cover a broad range of approaches, domains, and origins, to illustrate how the framework of analysis might most effectively be used by practitioners (some tools were excluded, such as OpenEssayist, because they were designed for use in universities, not schools). These 15 tools are given alphabetically in the following section. First, however, we arranged them in a second matrix (see Table 3), to illustrate how the the various tools relate to the dimensions of personalisation (the continuums discussed in Section 2). However, where they fit on the continuums is not always clear from the accounts given, and there is sometimes a confusion between interim goals (e.g. mastery of specific knowledge or skills) and long-term goals (e.g. progressing to the next grade level)¹⁵¹

¹⁴⁰ <https://www.schoology.com/k-12>

¹⁴¹ <https://www.knewton.com/approach/courses/>

¹⁴² <http://www.dreambox.com/>

¹⁴³ <http://blog.hellothinkster.com/>

¹⁴⁴ <https://www.khanacademy.org/>

¹⁴⁵ <https://edready.org/home>

¹⁴⁶ <https://www.tenmarks.com/>

¹⁴⁷ <http://projects.intellimedia.ncsu.edu/crystalisland/about/>

¹⁴⁸ <https://doi.org/10.1016/j.compedu.2014.12.010>.

¹⁴⁹ Barab et al. (2013).

¹⁵⁰ <https://www.khanacademy.org/>

¹⁵¹ Bulger, 2016

Nevertheless, we can see that ITS tend to focus on specific content (e.g. algebra) and personalise the pathways and pace. Meanwhile, learning network orchestrators may also facilitate grouping, while exploratory learning environments support students' agency to make choices over how they learn. Unfortunately, however, we could not identify any exploratory learning environment that had been implemented at scale, and so we have not included any in our 15 examples.

Type of tool (tag)	Personalisation continuum: Tool:	aim	approach	content	group	pathway	pace
ITS and other adaptive technologies	Cognitive Tutor			x		x	x
	ASSISTments	x		x		x	x
	WriteToLearn	x		x		x	x
	Accelerated Reader			x		x	x
	Maths-Whizz			x		x	x
	IBM Watson			x		x	x
	conText			x		x	x
	Bettermarks			x		x	x
Learning network orchestrators	Busuu			x	x	x	
	Third Space Learning			x	x	x	
	Smart Learning Partner	x			x	?	?
ELEs	Crystal Island		x	x	x		
	iTalk2Learn		x		x		
Smart LMS	Spectra Secondary Schools			x		x	x
	Florida Virtual School			x	x		
	AltSchools			x		x	x
	Google Classroom				x	x	
	Kapiert.de			x		x	x
	Snappet			x		x	x
	DiLer	x	x	x	x	x	x

Table 3: Technology-enhanced personalised learning tools arranged by type (tag) and dimension/continuum of personalisation.

Accelerated Reader

www.renaissance.com/products/practice/accelerated-reader-360

Tag	Domain	Age(s)	Language(s)	Cost	Impact	Evidence
ITS	Literacy	12–13	Englisch	€€	§§§	@@@

DESCRIPTION

Accelerated Reader is a progress-monitoring, assessment, and practice tool that aims to support reading instruction. The software includes information on 2,000 books, helping students choose ones that are consistent with their interests and abilities. It also facilitates goal setting, monitors students' understanding of what they read, and provides individualised feedback. The system works by showing the student a bookshelf of titles from which they choose. Then, later, when they have finished reading the book, the student answers a quiz (drawn from a database of more than 190,000 available quizzes). Like Netflix, the more the student reads and the more quizzes that they answer, the better the software adapts to the individual student's abilities and interests. The teacher also has access to diagnostic reports of class and individual performance.

IMPACT and EVIDENCE

An RCT study¹⁵¹ completed in 2010 by the *What Works Clearinghouse*, an independent research evaluation center funded by the U.S. Department of Education, involved around 350 students aged 6-10-year-olds across 3 schools. Two groups (experimental and control) used the same class time for reading and language arts instruction over 24 weeks. While the experimental group used *Accelerated Reader* as a supplement to their core reading programme, the control group teachers maintained their normal classroom reading routines (i.e. *business as usual*). The participating students were assessed three times with the *STAR Reading Test* (a standardised assessment developed by *Renaissance Learning*, the developers of *Accelerated Reader*), which showed that, on average, the students in the experimental group (who used *Accelerated Reader*) made greater reading gains than the control group (who experienced *business as usual*). The effect size was a healthy 0.38.

RECOMMENDATION

The *Accelerated Reader* approach clearly shows great promise, although the decent effect size needs to be moderated by the fact that the assessment used was developed by the same company and was tailored to measure the same aims as the technology (rather than the aims of the curriculum). Nevertheless, although the use of an independent standardised test would have given more confidence, the approach is definitely worth exploring further. *Accelerated Reader* is not available in German.

¹⁵² Shannon et al. (2015).

AltSchools

www.altschool.com

Tag	Domain	Age(s)	Language(s)	Cost	Impact	Evidence
Smart LMS	any	5–14	Englisch	unknown	unknown	unknown

DESCRIPTION

ALT Schools is a for-profit venture founded by a former Google executive and funded by the Chan Zuckerberg Initiative (in other words, it has emerged from Silicon Valley). Their schools use a whole-school Big Data-driven approach to deliver individualised learning to students. Interestingly, only around half the staff in ALT Schools are educators while the other half are technologists. Each week, the students are given an individual *playlist* of 25 activities that are designed to encourage increasing amounts of student autonomy over what they work on and when. Meanwhile, teachers have an online dashboard, which gives them access to information about each student's strengths, weaknesses and progress, and to video footage of classroom activities captured by classroom wall-mounted cameras (to monitor student engagement and to prevent poor behaviour).

IMPACT and EVIDENCE

To date, there is no publicly-available efficacy study.

RECOMMENDATION

The ALT School Open platform is neither free nor open. In particular, how the Artificial Intelligence algorithms decide and manage the student *playlists* (how it decides what content and pathways to provide to individual students) is not open to inspection. It is also not clear how the *playlists* support student choices and progress. The use of wall-mounted cameras to record everything that goes on in the classroom also raises data-protection and ethical issues (one particular worry is that this digitised surveillance could exacerbate social inequalities). Interestingly, ALT Schools are already closing some of their schools, which suggests (although there is no confirmation of this from the company) that the approach might ultimately be financially unsustainable¹⁵². ALT School has been included in this report because its ground-breaking big-data approach is likely to become more common in future.

¹⁵³ Satariano, 2017

ASSISTments

www.assistments.org

Tag	Domain	Age(s)	Language(s)	Cost	Impact	Evidence
ITS	Maths	12–13 (Grade 7)	Englisch	€	\$\$\$	@@@@@

DESCRIPTION

ASSISTments is a free online Intelligent Tutoring System designed to be used for mathematics homework. While other ITS typically lead to students progressing at different rates in the classroom, which can make the teacher’s job more difficult, ASSISTments is designed to help students catch up in the evenings, so that in the classroom everyone remains roughly in synch. In ASSISTments, artificial intelligence techniques ensure that students receive personalised pathways through the materials, supported by personalised and immediate feedback and hints. The system also provides teachers with reports about students’ progress.

IMPACT and EVIDENCE

ASSISTments has been evaluated by SRI International, a leading independent, nonprofit research center. An RCT, involving 2,850 students across 43 schools over a school year, showed that ASSISTments increased student scores on a standardised mathematics assessment (when compared with a second group of students who continued with existing homework practices – i.e. *business as usual*). The effect of ASSISTments was ‘small’ (0.27) but worthwhile and statistically significant (i.e. it was statistically trustworthy), and students with low prior mathematics achievement benefited most. The authors of the report concluded: “Interventions like this one can also bring new personalised options to schools. Schools tend to have a uniform homework policy for all students, and teachers can assign mathematics homework to all students in ASSISTments. However, students’ assignments need not be identical.”¹⁵⁴

RECOMMENDATION

ASSISTments is unusual in having robust independent evidence of its effectiveness, and its approach (personalised homework to assist the teacher in the classroom by keeping students more in synch with one another) is worth serious consideration (particularly for students who are lower attaining). Like all technology-enhanced personalised learning, however, it requires sufficient time, resources and training to enable teachers to use it effectively. There are three other caveats: the study only involved one school district, ASSISTments requires students to have a laptop computer for use at home (in the study, this was provided by the school district), and it is currently not available in German (although the developers are open to working with German partners).

¹⁵⁴ Roschelle et al., 2017

bettermarks<https://de.bettermarks.com>

Tag	Domain	Age(s)	Language(s)	Cost	impact	Evidence
ITS	Maths	Grades 4–10	German etc.	€	\$\$\$	@@@

DESCRIPTION

bettermarks is an adaptive learning software for maths lessons. Based on assessment tests and final exams, the student's learning needs are determined. The exercises comprise adaptive learning tools, sample solutions with explanations, different entry and visualisation tools, as well as intelligent error diagnosis with feedback customised to the respective error made. The system identifies equivalent solutions, accepts alternative approaches, and offers a high degree of flexibility. Furthermore, based on the students' entries, the application determines potential knowledge gaps and provides individual educational content. For teachers, the programme offers overviews of the completion status and solution frequency of tasks performed by their students. .

IMPACT and EVIDENCE

The effect of bettermarks was tested in an independent study with control groups, in which a total of 76 classes participated. Half of the classes worked with the application for half a school year (N=864).¹⁵⁴ Students who used bettermarks for learning performed better than the students in the control group (an effect that was statistically significant). Further analyses showed, however, that this effect was mainly due to improved performance of already high-performing students.

RECOMMENDATION

The present evaluation confirms the programme's effectiveness for high-performing students in particular. Why exactly this group benefits from the application is hard to judge as the study did not monitor how teachers connected the use of the programme with classroom lessons. In a comparative (though supported by bettermarks) evaluation of mathematics education by Stein¹⁵⁵, the application received an excellent rating, due to its differentiated learning process diagnostics. As to its tutorial scope, bettermarks can be compared to English-language programmes such as Maths-Whizz. Its user interface, however, is less playful than Maths-Whizz, which makes sense considering the target group (grades 4–10).

¹⁵⁵ Scharnagl et al., 2014

¹⁵⁶ Stein, 2012

Busuu

www.busuu.com

Tag	Domain	Age(s)	Language(s)	Cost	Impact	Evidence
Learning network orchestrator	Language learning	any	German, English, Spanish ...	€	unknown	@

DESCRIPTION

busuu is a language learning app that offers courses in German, English, Spanish and nine other languages, at CEFR¹⁵⁶ levels A1, A2, B1 and B2. Features include study materials, a vocabulary trainer, enhanced grammar units, and instruction in the four language skills of reading, writing, listening and speaking. However, what is unique about *busuu*, and why we have identified it as a *learning network orchestrator*, is that it encourages collaborative learning by connecting users with native speakers of their target language. In this way, students support each other and correct each other's progress, with every *busuu* user acting both as a student of a foreign language and as a tutor of their own mother tongue. Recently the company reports that they have developed *busuu PRO*, a platform designed for schools that is yet to be evaluated. In this version, instructors can create classrooms, invite students, access the full *busuu* curriculum and follow student progress in an interactive dashboard.

IMPACT and EVIDENCE

An independent study¹⁵⁷ has been conducted with a random sample of 196 *busuu* users learning Spanish. The students were assessed at the beginning of the study and two months later, at the end of the study, on their writing and oral proficiency. The study showed that, for more than 84% of participants, writing proficiency improved (although it is not clear by how much), while more than 75% of participants improved their oral proficiency by at least one CEFR level. Although it indicates promising outcomes, this study was not an RCT, and the authors report inconsistent metrics (e.g. oral performance increased by one level, while written proficiency improved for 84% of users) making it more difficult to interpret.

RECOMMENDATION

busuu adopts a unique approach (collaborative language learning), and its efficacy study has indicated that it is worth considering. However, the app was developed to be used by independent users and the platform tools that make it more suitable for use in schools (and that require a premium membership) have not been evaluated. A school version also raises ethical issues (if young students are to be connected with students in other countries) which would need to be carefully managed. *busuu* is available in German and has potential (although not yet confirmed) for German students learning other languages.

¹⁵⁷ https://en.wikipedia.org/wiki/Common_European_Framework_of_Reference_for_Languages

¹⁵⁸ Vesselinov & Grego, 2016

Cognitive Tutor

www.carnegielearning.com

Tag	Domain	Age(s)	Language(s)	Cost	Impact	Evidence
ITS	Maths	13–17	English	unknown	§	@@@

DESCRIPTION

Cognitive Tutor is a suite of technology-based mathematics curricula with textbook materials and an automated computer-based cognitive tutor for each course¹⁵⁸. Individualised instruction is built into the software. Students engage with real-world problem solving and are supported to progress from concrete to abstract thinking. The developers recommend that students spend two days per week of their class time using the computer-based individualised software, while the teacher works with individual students as needed, and three days on classroom group-based activities, guided by the teacher and textbook. The company provides a comprehensive range of materials, within which the *Cognitive Tutor* software plays a relatively small part.

IMPACT and EVIDENCE

In an RCT¹⁵⁹ conducted by RAND Education, a leading independent research center, *Cognitive Tutor* Algebra I was introduced to nearly 18,700 students in high schools (mainly aged 14) and nearly 6,800 students in middle schools (aged 13–14) over two years. The study, which examined the groups separately in two parallel experiments, found a significant positive effect in high schools in the second year of implementation, when teachers were allowed to divert from the prescribed curriculum. However the effect size was small (0.19) and, due to financial limitations, the study did not include a full control group (the algebra post-tests were administered only to study participants). Nevertheless, *Cognitive Tutor* was shown to have improved the average student's performance (from 50% to 58% success in a standardised test).

RECOMMENDATION

Cognitive Tutor is unusual in having independent evidence of its effectiveness, and its approach (adaptive feedback to keep students more engaged with the subject matter) is worth serious consideration (particularly for students who are lower attaining). Like all technology-enhanced personalised learning, however, it requires sufficient time, resources and training to enable teachers to use it effectively. *Cognitive Tutor* is not available in German.

¹⁵⁹ Anderson et al., 1995

¹⁶⁰ Pane et al., 2010

conText

<https://www.psychometrica.de/context.html>

Tag	Domain	Age(s)	Language(s)	Cost	impact	Evidence
ITS	German literacy	Secondary Level I	German	€€€	\$\$\$\$\$	@@@@@

DESCRIPTION

conText is an intelligent tutorial system designed to improve the reading comprehension of students at secondary level. The application contains 20 non-fiction texts of varying degrees of difficulty. Students are asked to write a summary of a text on the computer. *conText* analyses these summaries automatically and provides personalised feedback, detailing whether individual sections are redundant or irrelevant, or whether key contents of the original text are missing. Students are then given the opportunity to gradually improve their summaries. This way, the application involves the students in an intense study of the texts. At the same time, it guides them how to represent the content of the original texts in a more compact, coherent and comprehensive way. The software is designed to encourage the acquisition of cognitive processes and strategies applied in reading comprehension.

IMPACT and EVIDENCE

To examine its effectiveness, students who studied with *conText* were compared with a control group who solely participated in their regular German classes and those who used a learning programme explicitly designed to promote reading strategies.¹⁶⁰ The examination involved 226 sixth-graders from 14 classes at Secondary Level II. The intervention covered an entire school year, and the application was used for one lesson every other week. Improvements in verbal intelligence, reading fluency, declarative knowledge of reading strategy, and reading comprehension were assessed with standardised tools in a pre- and post-test design. The students who had worked with *conText* demonstrated consistent improvements compared to the control group (reading fluency: $d = .60$; reading strategy knowledge: $d = .49$; reading comprehension: $d = .59$).

RECOMMENDATION

While the effect of the application has been evaluated mostly for lower-performing students at secondary level, it might be useful for all types of schools and different age groups. According to the authors, the programme (with a different selection of texts) was also successfully used with university students. The texts included in the version for schools vary in length and linguistic complexity. The programme also offers teachers an editor to enter their own selection of texts.

¹⁶¹ Lenhard et al., 2012

DiLer<https://digitale-lernumgebung.de>

Tag	Domain	Age(s)	Language(s)	Cost	impact	Evidence
(Smart) LMS	all	all	German	€	unknown	unknown

DESCRIPTION

The DiLer learning platform is an open source software. Its pedagogic objective is to support students in their independent, personalised learning activities. At the core of the platform is a competency grid in which competencies and learning levels, marked by icons and/or colour coding, can be freely chosen. This way, the platform allows teachers to put together individual packages of exercises and tasks for their students based on the competency grid. To this end, the platform provides online and offline exercises and tests with evaluations, as well as a display of progress. Third-party offerings can be incorporated into curricula as well. Furthermore, the platform establishes several communication channels – among students, between teachers and parents (text messages, video chats), as well as school organisation features such as a calendar with timetable function, a customisable grade sheet form for text- and grade-based assessments, etc. Teachers are also given access to a network of materials that can be applied to develop and exchange learning materials among each other. The software does not include learning analytics and therefore does not fully qualify as smart LMS.

IMPACT and EVIDENCE

So far, the effectiveness of DiLer as a learning tool has not been empirically studied.

RECOMMENDATION

Compared to other learning platforms, what makes DiLer noteworthy is its support of curricula based on competency grids, which seems particularly suitable for personalised learning. Although the platform has not been evaluated yet, positive feedback from a case study at Alemannenschule Wutöschingen is available.¹⁶¹

¹⁶² Zylka, 2017

Florida Virtual School

www.flvs.net

Tag	Domain	Age(s)	Language(s)	Cost	Impact	Evidence
Smart LMS	all	all	English	€	unknown	unknown

DESCRIPTION

Florida Virtual School¹⁶² is a state-funded online school that caters for part-time students from all backgrounds (e.g. from schools and home-schooling) and of all school ages (from kindergarten through to 18 years old). It provides access to more than 150 online courses, from which students can choose, each of which includes step-by-step video demonstrations, activities with corrective feedback, and interactive games, together with practice tests that match the Florida End of Course format. The system also provides opportunities for student collaboration through online messaging systems and video conferencing.

IMPACT and EVIDENCE

Data collected from 462,000 Florida Virtual School students in 2013 was compared with data from Florida's face-to-face schools¹⁶². The study showed that the virtual school students performed better on the Grade 8 state mathematics and reading tests. Fewer absences from the virtual school also suggested that the students were better motivated to engage with their learning.

RECOMMENDATION

Virtual schools claim to be useful because they are able to provide more subject and learning pathway choices for students (in contrast to face-to-face schools that might, because of their size, have a much more limited choice). This clearly has some promise, a greater choice for students might enable them to personalise their own learning to good effect, but the lack of any RCT or similar efficacy study makes it difficult to draw any robust conclusions. Nevertheless, the approach might be considered for other contexts (such as Germany) although the costs will be significant.

¹⁶³ Chingos & Schwerdt, 2014

¹⁶⁴ Barbour, 2014

Google Classroom

edu.google.com/k-12-solutions

Tag	Domain	Age(s)	Language(s)	Cost	Impact	Evidence
Smart LMS	any	6–15	English	unknown	unknown	unknown

DESCRIPTION

Google Classroom is Google's major entry into education. Using the *Classroom* tools, teachers can create classes, set individual assignments, and send feedback. The system also enables teachers to monitor student assignments, for example letting them know when students have submitted an assignment late and when they have made a revision. *Classroom* tools also offer students a choice of teaching materials, alternative tools to help them complete those materials, and opportunities to communicate directly with their teacher (either privately or as part of a whole-class discussion). However, what particularly distinguishes *Google Classroom* is that it is designed to connect directly with a large variety of external tools (i.e. it uses a collective app approach). These include school management systems (such as *Aladdin*), interactive teaching tools (such as *Classcraft*), apps to improve reading and writing skills (such as *ActivelyLearn*), apps to teach coding (such as *Tynker*), and interactive videos (such as *Khan Academy*).

IMPACT and EVIDENCE

To date, there is no publically-available efficacy study (only testimonials from individual schools).

RECOMMENDATION

Google Classroom's comprehensiveness means that it can be difficult for inexperienced users to find their way around (although there is a large amount of documented support). Other problems center on who has access to the student data. In any case, as there are no efficacy studies, it is not possible to make any recommendation about whether teachers should explore Google Classroom or not. It has been included in this report because it is an approach designed by... the Internet giant Google, and history suggests that Google products have a habit of being taken up widely!

IBM Watson Education Solutions

www.ibm.com/watson/education

Tag	Domain	Age(s)	Language(s)	Cost	Impact	Evidence
ITS	all	all	English	unknown	unknown	unknown

DESCRIPTION

The IBM Watson Education Solutions software uses artificial intelligence algorithms that answer questions posed in natural language. It aims to provide teachers with a toolset to support adaptive education in order to improve educational outcomes. The system enables teachers to monitor student progress during lessons, supports lesson planning, and gives advice about what to include based on student needs. It uses a model of the *whole learner* (which includes background information about the student, plus information from across classrooms and different teachers) to generate suggestions on how best to help each student in the classroom, so that students receive targeted support more quickly. Data-driven insights help the system to identify learning gaps for each student and to map them to tailored remedial content. The system also provides teachers with student performance data, such as improvements over time and student achievements against state standards.

IMPACT and EVIDENCE

IBM has contracted IDC, a leading market intelligence organisation, to independently assess its education intervention. For this, IDC has collected data from 140 teachers in Coppell ISD, a school district in Texas, who have been using the IBM Watson Education approach. However, outcomes are (at the time of writing) very limited¹⁶⁴. Initial survey results focus on the teachers' impressions of the software and its approach, with one conclusion being that "teachers reacted very positively to predictive capabilities within Watson that help proactively guide, or alert, teachers to a learner's difficulties in a subject area.". Currently, there is no information about student outcomes. However, a second assessment is due to be conducted by the end of the 2018 school year.

RECOMMENDATION

Without any substantive results, it is not possible to draw any useful conclusions about the efficacy of this software. However, given that it is from IBM and it uses the ground-breaking IBM Watson Artificial Intelligence technologies, we recommend that educators watch this space. The possibilities are intriguing but some proper evidence is needed.

¹⁶⁵ <http://idc.idcimpshowcase.com/showcase/showfile.cfm?id=301>

Kapiert.de<https://www.kapiert.de/>

Tag	Domain	Age(s)	Language(s)	Cost	impact	Evidence
(Smart) LMS	Maths, German, English	Grades 5 – 10	German	€	unknown	unknown

DESCRIPTION

Kapiert.de is a textbook-based learning platform developed by the school book publishers Westermann, Schroedel and Diesterweg for maths, German and English. It offers additional interactive exercises and explanatory videos to supplement the textbooks of the individual publishers. Furthermore, the software creates personal support plans on select topics based on diagnostic tests. For extracurricular exercise sessions and as a tutoring platform, a personal video chat with a tutor can be added. For in-school use, the platform allows teachers to assign specific educational videos, interactive exercises and training courses to their students and view their completion status and solutions. The software does not strictly speaking include learning analytics and therefore does not fully qualify as smart LMS.

IMPACT and EVIDENCE

So far, the effectiveness of Kapiert.de as a learning tool has not been empirically studied.

RECOMMENDATION

Although the effectiveness of Kapiert.de has not been empirically evaluated yet, the learning platform has won numerous awards and distinctions since 2015, among them the Comenius EduMedia Siegel and the German educational media award, digita (second place).

Maths-Whizz

<https://www.whizz.com/>

Tag	Domain	Age(s)	Language(s)	Cost	Impact	Evidence
ITS	Maths	6–15	English	€€€	unknown	@

DESCRIPTION

Maths-Whizz is an online ITS for mathematics that assesses each student across multiple topics and then sets a programme of learning. It includes active teaching, interactive exercises and tests of the student's level of understanding. Students progress through the system based on the answers that they give, the time that they take and the level of encouragement that they need. Parents and teachers have access to reports in real-time, that gives visibility to each student's strengths and weaknesses and can also be used to inform future teaching. The reports are based on the Whizz's *Maths Age* metric, which is a measure of student progress, and can be used to compare performance between classes, schools, and districts. Finally, Maths-Whizz has been used in the UK, USA, NZ, Kenya and other countries.

IMPACT and EVIDENCE

An independent study¹⁶⁵ involved 2,542 students across 15 participating elementary schools. During the 5-week study, students used the system for an average of 23 minutes per week, which resulted in an average improvement of 0.4 years in *Maths Age*. Although this study involved a large number of students, it was not a randomised controlled trial. However, interestingly, the study did appear to show that there was little impact on closing the gap between low- and high-performing students (both groups made similar progress: "students who begin the year with higher mathematics ability are more likely to score high on the end-of-course mathematics assessment. Similarly, the low-performing students who demonstrated the greatest improvement across the year were more likely to be low scorers on the end-of-course mathematics assessment.").

RECOMMENDATION

Maths-Whizz clearly has potential to support mathematics learning, although it appears less successful in closing the performance gap. In addition, the difference between Whizz's *Maths Age* metric and standardised metrics makes it difficult to fully compare the tool with other systems (such as *Cognitive Tutor*). Nevertheless, Maths-Whizz is worth consideration, especially as the study also indicated that the system is successful at supporting student confidence and self-esteem in mathematics. Maths-Whizz is not available in German.

¹⁶⁵ Clark & Whetstone, 2014

Smart Learning Partner

<http://slp.bnu.edu.cn> (NB Only available to students with accounts)

Tag	Domain	Age(s)	Language(s)	Cost	Impact	Evidence
Learning network orchestrator	all	all	Chinese	€	unknown	unknown

DESCRIPTION

Smart Learning Partner is the result of a collaboration between Beijing Normal University's *Advanced Innovation Center for Future Education* and Tongzhou district of Beijing. It is a comprehensive digital innovation that involves two key parts. First, it is a smart learning management system, incorporating a repository of online videos covering all subjects and school levels, and a suite of artificial intelligence tools that adapt the content as students progress through the system. Second, and this is what we are focusing on here, it is a mobile platform that enables students to connect with one of thousands of tutors via their mobile phones (in other words it is a learning network orchestrator). It works a bit like a dating app (although between students and tutors). The student uses the app at any time of the day or night to search for a tutor, all of whom have been rated by other students, to ask them specific questions about a school topic for which they need help. They choose their tutor and get 20 minutes of one-to-one mobile online tuition (sharing only voice and screens), helping them through the problem area. *Smart Learning Partner* is fully funded by Tongzhou district of Beijing (all the tutors are paid and the service is free for students).

IMPACT and EVIDENCE

Smart Learning Partner is a prototype service that has not yet been fully evaluated. However, the amount of time that students voluntarily spend using the service and in-app student ratings suggest that it is worth watching.

RECOMMENDATION

Although there is as yet no RCT evidence for the success of *Smart Learning Partner*, it has been included in this report because it is a novel example of enabling students to take full control of their own learning. Unlike most of the tools included in this report, which decide *on behalf of the student and teacher* what content or feedback to serve to the student, with *Smart Learning Partner* it is the student who decides what they want to learn about and what support they need. The technology is relatively straightforward but it is this approach that is unique. Unfortunately, *Smart Learning Partner* is only available in Beijing and in Chinese, but its innovative approach should be considered carefully by policy-makers.

Snappet

<http://dasschultablet.de/>

Tag	Domain	Age(s)	Language(s)	Cost	Impact	Evidence
(Smart) LMS	Maths, German, German as a second language, media literacy	Grades 1–6	German	€€€€€	\$\$\$	@@@

DESCRIPTION

Snappet is a learning platform for primary schools with a learning offering aligned with the curricula of the various German states, focusing on maths and German. The software continuously creates individual learning status analyses for the students, which provide the basis for teachers to identify their students' current need for support and to assign personalised exercises for them to work through on the platform. Furthermore, the platform can adapt the level of difficulty of the tasks based on the learners' input and /or suggest competency elements for further exercise. If required, Snappet can also provide schools with tablet PCs and Internet access.

IMPACT and EVIDENCE

The effectiveness of Snappet was evaluated in a randomised field experiment at 79 Dutch primary schools with 1,800 third-graders, based on standardised performance tests for maths and spelling.¹⁶⁶ The test showed a positive effect that was statistically significant in maths, although the best results were achieved by high-performing students. In spelling, no effect on the performance of students could be identified. However, a positive impact on learning motivation was reported.

RECOMMENDATION

Snappet's USP is that the platform is designed to support personalised learning during classroom lessons – which means that students' completion status can be checked in real time and specific exercises from the programme can be visualised directly on the interactive whiteboard for class discussion. As a diagnostic tool, the platform provides different features to determine the learning status of a class as well as the progress made by individual students. While the difficulty levels of the exercises vary, the analysis of students' responses and the programme feedback are limited to correct solution finding, so that Snappet therefore does not fully qualify as smart LMS.

¹⁶⁷ Faber & Visscher, 2017

Spectra Secondary School

www.spectra.edu.sg

Tag	Domain	Age(s)	Language(s)	Cost	Impact	Evidence
Smart LMS	all	11–16	English	unknown	unknown	unknown

DESCRIPTION

Spectra Secondary School is a mathematics and ICT specialist school that caters for some of the lowest performing students in Singapore. It uses an approach designed to support student diversity, student self-pacing, and student choice, with students being encouraged to learn independently. In particular, the school rewards students based on effort rather than academic results. The school has developed their own smart LMS, which includes a knowledge map that links up all of the school's teaching resources. The LMS also records student progress and suggests individualised learning pathways. The school has adopted a *flipped classroom*¹⁶⁷ approach: before each class, students watch a video of the teacher talking about the topic; then during the class, students complete online activities for the teacher to mark.

IMPACT and EVIDENCE

In the four years of operation, the school has not conducted any efficacy study. They will, however, receive national examination results at the end of the 2018 school year. Nevertheless, anecdotal evidence suggests that the school has unusually few behavioural problems, and that there has been good student progress, especially in ICT. In particular, teachers report seeing engaged students trying to become independent and enjoying their learning.

RECOMMENDATION

Spectra provides a good example of how personalised learning can be implemented in a school. However, rather than the personalised learning being provided by a technology, here it is the result of the school focusing on giving students choice over what they learn, and when and how fast they learn it (in other words, it is an example of a school focusing on the *aims* continuum). At Spectra, the technology only has a supporting role. It is the overall school approach which is the crucial ingredient.

¹⁶⁸ Alvarez, 2011

Third Space Learning

www.thirdspacelearning.com

Tag	Domain	Age(s)	Language(s)	Cost	impact	Evidence
Learning network orchestrator	Maths	10 -11	English	€€€€€	unknown	@

DESCRIPTION

Third Space Learning uses technology to connect math tutors from India and Sri Lanka to children at risk of failure in mathematics in primary schools across England. It supports online 1-to-1 tutoring, plus choosing the lessons and receiving regular progress reports. The system introduces tutors to the student profile and the UK education system. Before each session, the student's usual classroom teachers are able to select lessons from the Third Space Learning mathematics curriculum, to target individual learning needs. Tutors and students communicate with each other using a secure virtual classroom with two-way audio and a shared whiteboard. The technology includes diagnostic assessment of the students, classroom resources and online professional development for the tutors.

IMPACT and EVIDENCE

Third Space Learning conducted a study with 28 ten year-old students in danger of not meeting expected levels of progress, across three English primary schools. A standardised test was used before and after the programme to generate a mathematical age for each student. On average, students were found to have made 7 months progress over the 14 week programme. Seven of the students were found to make more than one year's progress, three made no progress, and only one showed a decrease. Since Third Space Learning started their service, 3500 students have participated. 78% of a sample of those students, all of whom had participated because they were at risk of not meeting national standards, either met or exceeded those national standards at the end of the intervention.

RECOMMENDATION

The approach adopted by Third Space Learning, connecting students who are in danger of not meeting expected levels of progress with online tutors from countries such as India and Sri Lanka, is innovative and clearly shows promise. One issue that needs to be addressed is that, if students are engaging with tutors outside of their usual class, what classroom activities are they missing out on? In any case, the results reported by Third Space Learning are very positive, but for us to know how effective the approach is we do really need to have an independent evaluation. Currently, Third Space Learning is only available in some schools in England and is not available in German.

WriteToLearn

www.writetolearn.net

Tag	Domain	Age(s)	Language(s)	Cost	Impact	Evidence
ITS	Literacy (essay writing)	12–13	English	unknown	unknown	@

DESCRIPTION

WriteToLearn is a web-based writing environment that uses Artificial Intelligence techniques to automatically respond to student writing (in terms of narrative, exposition, description, and persuasion). It also provides prompts and summaries of texts in order to build reading comprehension, scores the writing, and provides writing advice based on three rubrics (*College and Career Readiness*, *English Language Learning*, and the *Six Traits of Writing*).

IMPACT and EVIDENCE

Teachers reported that using the *WriteToLearn* software twice per week led them to assign more writing, enabled them to focus more on the content and less on the grammar and mechanics of students' writing, and improved student writing. Before the intervention, 56% of students met or exceeded writing standards, but after the *WriteToLearn* intervention, this had increased to 79% of students. In addition, Seventh-grade scores improved by 23% in the first year of using *WriteToLearn*. However, teachers have expressed some frustration that the software was optimised for use with canned prompts, while it provided less detailed feedback on teacher-generated prompts.

RECOMMENDATION

WriteToLearn appears to be effective because it seems to motivate students to spend more time reading, writing, and revising. Instantaneous feedback and seeing immediate progress appears to have helped engage the students in the tasks. It also appears to allow teachers to focus on different aspects of literacy, such as developing an argument, while giving more comments on more essays. However, although its innovative approach definitely deserves more attention, *WriteToLearn* has not been tested in an RCT or compared with other approaches. Also, it is not currently available in German.

9. Implementing Technology-enhanced Personalised Learning

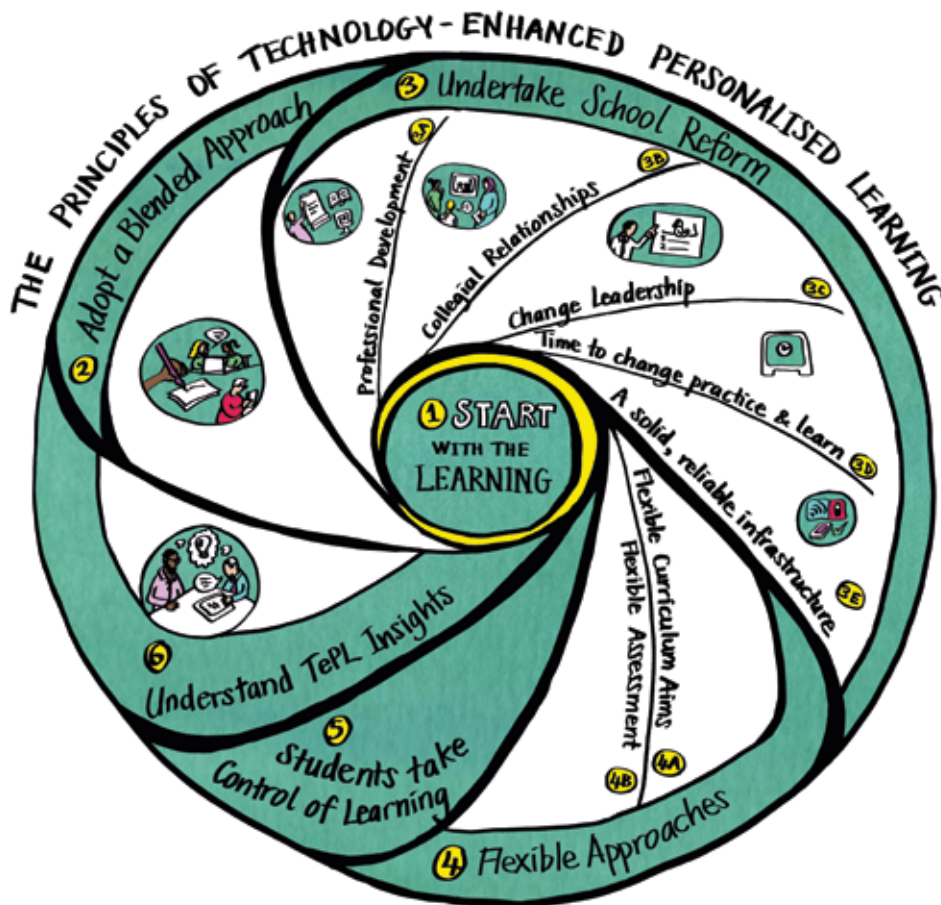
Throughout this report, we have repeatedly encountered the argument that personalised learning is complicated (and, indeed, not always the most appropriate way to support learning). We have also seen how many have argued that the judicious use of new technologies can support personalisation in classrooms (despite robust evidence often being difficult to find). Finally, we have identified multiple challenges that policymakers and teachers need to address, if personalised learning is to be implemented effectively in classrooms, and if technology is to play a useful role.

In this penultimate section of the report, we will be drawing these discussions together, filtered through the collective experience of this report's authors. Accordingly, here, we introduce some *evidence-based principles for the implementation of technology-enhanced personalised learning in classrooms*, principles that have emerged from our research and the examples we have explored and that aim to address the various challenges we have identified (see Section 6 “Technology-enhanced personalised learning in classrooms: the challenges”).

However, as with our discussion of the indicators and framework of analysis, these evidenced-based principles, many of which inevitably overlap, are *guidance* to inform decisions not *rules* to slavishly follow. The aim again here is to help you to draw *your* own conclusions, relevant to *your* practice and *your* students' needs – with one important caveat. Technology-enhanced personalised learning has nothing to say about the *why* dimension (why something in particular needs to be learned). This is ultimately a political decision, which determines the pedagogical context within which those dimensions of personalisation over which teachers do have some control must be positioned.

Throughout this section, we use footnotes to reference the source of each principle (i.e. from where in this report the principle has emerged). We finish this section with some questions that you might ask yourself, if and when you are considering buying into (investing your money or time into) a technology-enhanced personalised approach or tool.

Evidence-based principles for the implementation of technology-enhanced personalised learning for policymakers, schools and teachers



PRINCIPLE 1: Start with the learning

Whatever decisions are being made (whether about professional development, physical infrastructure, flexibility or student safety), we need to *start with the learning* (as implicated in the *what* and *how* dimensions of personalisation). All too often, we can be seduced by the lure of exciting new technologies. However, if we are to leverage the potential power of technology-enhanced personalised learning, we need to consider carefully what we are trying to achieve (the *why* dimension of personalised learning), and focus our implementation decisions on addressing those aims (we should, for example, learn from fiascos like the failed roll-out of iPads in Californian schools¹⁶⁹). We also need to recognise that, as mentioned several times, *personalised* learning may miss the benefits that can be achieved with *collaborative* learning. Learning is far more than an individual engaging with learning content. It also involves addressing social needs (learning how to be part of a learning community), learning from others and collective understanding. This is not to suggest that personalised learning should be rejected; only that it must be recognised as being just one way, albeit a potentially powerful way, to promote effective student learning.

¹⁶⁹ Newcombe 2015

This is why technology-enhanced personalised learning must be part of a comprehensive pedagogical approach that focuses on supporting each and every student, without dropping the idea and actual practice of shared learning. Case studies that describe successful implementations of technology-enhanced personalised learning generally combine personalised learning phases with cooperative, shared learning.¹⁷⁰



PRINCIPLE 2:
Implement technology-enhanced personalised learning as part of a blended approach¹⁷¹

Technology-enhanced personalised learning, like any technology-enhanced learning, usually works best when it is facilitated by a teacher and is integrated with traditional face-to-face classroom methods. This approach is known as blended learning. In other words, technology-enhanced personalised learning should not only involve a student being in front of a computer screen, interacting only with the adaptive software (however effective that software is). Instead, it should also involve interactions with a teacher and other students in the class, collaborative activities and working with pen and paper. Blended learning where the technology is just one part of the learning experience has been shown¹⁷² to be particularly effective in promoting student learning.

This is why technology-enhanced personalised learning should not be considered as a stand-alone approach but be embedded in more comprehensive measures of individualisation. Here, one option would be to structure learning by competency grids, which help students plan and reflect upon their learning progress. As the DiLer example shows, competency grids can serve as the structural foundation of a digital learning environment. Alternatively, technology-enhanced individualised learning could be a sub-task in working with competency grids. Furthermore, the data situation demonstrates that technology-enhanced personalised learning absolutely requires guidance by teachers. Providing students with frequent learning guidance sessions and systematically introducing them to independent learning are vital cornerstones to successfully tap the full potential of digital technologies for personalised learning.

¹⁷⁰ Zylka 2017; Muuß-Merholz 2015

¹⁷¹ See Section 4 “Personalised learning in classrooms: the challenges” and Section 6 “Technology-enhanced personalised learning in classrooms: the challenges” and how Cognitive Tutor is recommended to be used. They suggest to use the software twice per week and the other three times in a week to include interactions with teacher and peers.

¹⁷² Means et al. (2013): p.35 “Effects were larger when a blended rather than a purely online condition was compared with face-to-face instruction”

PRINCIPLE 3: School reform¹⁷³

As discussed earlier, implementing effective personalised learning in schools actually requires reform of the curriculum and potentially reform of school timetables and even the school's physical infrastructure, all reforms that are mostly out of the control of teachers. This would begin to address the *why*, *how* and *what* macro dimensions of personalisation. However, the *when*, *who* and *where* dimensions can also require reform across the whole school. Importantly, this involves not only providing resources such as technology-enhanced personalised learning tools but also the changing of classroom practices.



PRINCIPLE 3A: Professional development (to facilitate successful school reform)¹⁷⁴

Any new technology introduced into school should be accompanied by professional development for teachers and administrators, including appropriate training materials and courses, to help everyone prepare for the impact on practice (evidence¹⁷⁵ suggests that teachers who have received training on a technology are more likely to implement that technology effectively in their classrooms). Professional development ought to consider including:

- Guidance about how the technology can facilitate specific curriculum aims.
- Example lessons, using the technology in question, that have clear objectives aligned with the curriculum.
- Guidance to address pedagogy misconceptions (e.g. the concept of 'learning styles' that has been thoroughly debunked¹⁷⁶), that may be reinforced by particular technologies.

¹⁷³ See Section 4 "Personalised learning in classrooms: the challenges" and Section 6 "Technology-enhanced personalised learning in classrooms: the challenges"

¹⁷⁴ See Section 4 "Personalised learning in classrooms: the challenges" and the technology-enhanced personalised learning examples: ASSISTments, Cognitive Tutor, IBM Watson Education Solutions, Maths-Whizz and Third Space Learning.

¹⁷⁵ Mundy et al, 2012

¹⁷⁶ Coffield et al. 2004

Given the need for many teachers to develop further in two areas, namely the pedagogically meaningful use of digital technologies in classroom lessons on the one hand and strategies and methods of personalised learning on the other, teacher training sessions will have to achieve the feat of getting teachers started and engaged in both areas. This is why it would be important to plan these training sessions with a clear view to the added benefit that digital technologies can offer in implementing personalised learning and teaching concepts. Furthermore, they would need to offer teachers specific help and tools that allow them to tap synergies between personalisation and digitalisation.



PRINCIPLE 3B:
Collegial relationships
(to facilitate successful school reform)¹⁷⁷

Professional development also provides opportunities for reflection-in-action¹⁷⁸ that supports developing collegial relationships, another prerequisite of successful implementation. Other ways in which this could be promoted include:

- Ad hoc sessions through the year, with teachers across disciplines sharing experiences and peer-based troubleshooting.
- Novice teachers advising their otherwise more experienced colleagues (i.e. reversing the usual approach to mentoring) on the use of appropriate tools (although we must not be suckered into assuming that younger teachers are *always* more digitally-savvy than their older colleagues¹⁷⁹).
- Documenting best practices (and *failures*) and building a repository of what works (and *what does not work*) in the school's particular circumstances.

Once again, when it comes to schools, several interconnected requirements apply that refer to both technologies and inclusive school development: Both necessitate structures for peer exchange. In addition to the measures listed, these include the implementation of formalised team structures. Both year-specific and multi-professional teams can help coordinate comprehensive learning support as well as the use of digital technologies to personalise the learning experience, as well as share and discuss lessons learned.

¹⁷⁷ See the technology-enhanced personalised learning example: Spectra Secondary School

¹⁷⁸ Schon, 1984

¹⁷⁹ Papallo 2015

**PRINCIPLE 3C:****Change leadership (to facilitate successful school reform)¹⁸⁰**

School reform needs effective change leadership, someone with authority who can facilitate and coordinate reform efforts. They can act as a *key instigator of change*, someone who takes responsibility for facilitating the changing role of teachers. Innovative practice from the bottom up can be powerful, but sustainable changes require the buy-in of senior management. In addition, policymakers and school leaders need to be clear about how much of the decision making is delegated to teachers and students, while addressing potential conflicts of interest.

It is evident that head teachers and school administrators play a key role in implementing technology-enhanced personalised learning. Their responsibility does not only extend to organisational and personnel development measures. Given that schools often enough break new ground when introducing personalised learning support and stepping up the application of digital technologies, they are also tasked with opening their schools to try out new pedagogical approaches and establishing the framework needed to make everybody a part of initiating and implementing changes. According to Prasse¹⁸¹, head teachers and school administrators play a key role in determining a school's climate for innovation by demonstrating an appreciation for change, promoting the development of shared targets and setting the respective priorities. Furthermore, they have to serve as role models, which means engaging personally in the implementation of innovations (for example by using digital technologies themselves to promote personalised learning at their schools).

¹⁸⁰ See the technology-enhanced personalised learning example: Spectra Secondary School

¹⁸¹ Prasse 2012



PRINCIPLE 3D:

During reform, time is needed for teacher practices to adjust¹⁸²

In addition to time for teachers’ professional development, time is needed for personalised curricula to be practised and adapted to local circumstances. Results will not happen instantly (as mentioned earlier, it can take as much as three years for a school reform to take full effect¹⁸³). Teachers also need time to learn from their mistakes (after the inevitable but often productive failures), time to make the changed practices the new normal, and time to scale up the innovation for the whole school.



PRINCIPLE 3E:

Successful implementation of technology-enhanced personalised learning depends on solid and reliable infrastructure¹⁸⁴

Infrastructure requirements can be a huge challenge when implementing technology-enhanced personalised learning:

- Technology-enhanced personalised learning can put heavy demands on physical infrastructure. For example, the number of appropriate computers remains insufficient in many schools. In any case and in addition, all too often computers are kept in separate computer suites (or computer labs) and are only available to classes for a few hours a week. While there are entirely understandable organisational and financial reasons for this, if technology-enhanced personalised learning is going to have any chance of improving student success, computers must be emancipated from the computer suite, giving students access to computers (desktops, laptops, Chromebooks or tablets) throughout their school day. However, having made the point, this report’s authors are among the first to admit that giving students anytime 1:1 access to computers is not at all easy.
- The chosen computer systems should be able to integrate software and data of multiple types and from multiple sources (iPad tablet computers, for example, do not support Flash, which remains a common online technology).

¹⁸² See Section 4 “Personalised learning in classrooms: the challenges” and the technology-enhanced personalised learning examples: *ASSISTments*, *Cognitive Tutor*.

¹⁸³ As mentioned earlier, the effect sizes achieved by both *ASSISTments* and *Cognitive Tutor* did not appear until the second year of intervention.

¹⁸⁴ See Section 6 “Technology-enhanced personalised learning in classrooms: the challenges” and the technology-enhanced personalised learning examples: *ASSISTments*, *Third Space Learning*.

- Schools must be equipped with a reliable and secure high-performance network infrastructure as a vital prerequisite for the use of most digital solutions and applications in a way that supports rather than impedes personalised learning.
- The chosen technology-enhanced personalised learning tool should not depend on fast online access. Many schools still struggle to provide the Internet bandwidth needed for multiple simultaneous users, and so some offline access remains essential (for example, to allow materials to be prepared out of school, and so that classes can continue when the inevitable Internet outage occurs).

PRINCIPLE 4:
Technology-enhanced personalised learning requires flexibility¹⁸⁵

As we have seen, technology-enhanced personalised learning involves teachers and students making choices - which, if the choices are to be genuine choices, requires considerable flexibility (in, for example, curriculum aims, infrastructure, and assessments).



PRINCIPLE 4A:
Technology-enhanced personalised learning requires flexibility in curriculum aims¹⁸⁶

To ensure the success of technology-enhanced personalised learning, school leaders and teachers should consider:

- allowing a variety of learning and teaching approaches to be used in class;
- enabling a diversity in the size and makeup (e.g. mixed ages) of student groups (while ensuring this does not admit streaming by the back door);
- ensuring that social interactions (such as group work, study groups, and peer reviews) are included in daily activities;
- designing lessons based on principles of good pedagogy (for example, by relating the topic to the school context, using self-paced learning and providing prompt and implementable feedback); and
- emphasising participation and collaboration, through being open, safe and inviting (for example, if new practices take place in open spaces, welcome other students who approach out of curiosity).

¹⁸⁵ See Section 4 "Personalised learning in classrooms: the challenges"

¹⁸⁶ See Section 4 "Personalised learning in classrooms: the challenges" and the technology-enhanced personalised learning examples: *Spectra Secondary School* and *Third Space Learning*.



PRINCIPLE 4B:
Technology-enhanced personalised learning requires flexibility in assessment¹⁸⁷

To ensure the success of technology-enhanced personalised learning, school leaders and teachers should consider:

- the impact of assessment on learning (how best for teachers to accommodate new approaches);
- exploring widely how assessment might be enhanced to show progress in competencies (are examinations the most effective approach?); and
- communicating widely changes to measurements of student achievement (to be successful, there needs to be wide agreement).



PRINCIPLE 5:
For students to take active control of their own learning, being safe is a prerequisite.¹⁸⁸

As mentioned earlier, providing access to the Internet while ensuring that students are safe online is a big challenge. However, a common approach, implementing spyware software to monitor what students are doing online, can interfere with student ownership. In other words, protecting students on the Internet can contradict enabling students to take active control of their own learning.

However, there are some simple approaches that teachers can consider, which, although much of the following is well-known, are worth restating in the context of technology-enhanced personalised learning.

- Co-develop with students an acceptable technology use policy, that is clear, consistent and explicit.
- Engage students in investigating the consequences of using computers at home and being safe on the Internet.
- Empower students to address online bullying.
- Engage with the students particularly in the earlier stages of their use of a new tool, to foster a productive learning environment. Activities provided to students at an appropriate level (which is the *raison d'être* of *Intelligent Tutoring Systems*) most often lead to greater improvements in student achievements.

This way, technology-enhanced personalised learning can also contribute to the development of media literacy, which has been incorporated in the curricula of all German states.

¹⁸⁷ See Section 4 “Personalised learning in classrooms: the challenges”, Section 6 “Technology-enhanced personalised learning in classrooms: the challenges” and the technology-enhanced personalised learning example: *ALT School* and *Spectra Secondary School*.

¹⁸⁸ See Section Section 6 “Technology-enhanced personalised learning in classrooms: the challenges” and the technology-enhanced personalised learning examples: *Third Space Learning* and *Smart Learning Partner*.

**PRINCIPLE 6:****Understand how technology-enhanced personalised learning provides insights.¹⁸⁹**

Although a key aim of technology-enhanced personalised learning is to enable each student to achieve their potential, some tools inevitably reproduce existing inequalities and stereotypes (the algorithms they use might have been developed by technologists with little understanding of pedagogy, and in any case they might reproduce rather than challenge unintended biases). For this reason, policymakers, school leaders and teachers need to do all they can to familiarise themselves with the potential problems. Having said that, none of these stakeholders should be expected to understand how the technology works, instead it is important for developers to use transparent or ‘inspectable’ approaches. Nevertheless, school leaders and teachers should aim to:

- be aware of the type of data that the system uses to provide its *insights* (for example, does it involve audio or video recordings, or other data that might make the students identifiable?);
- be aware of the system’s underlying assumptions (which might be very difficult to achieve, as those assumptions are rarely made explicit);
- be aware of how the system uses data (where does *trust* reside, with the tech or with the teacher?);

Finally, school leaders and teachers should ensure that:

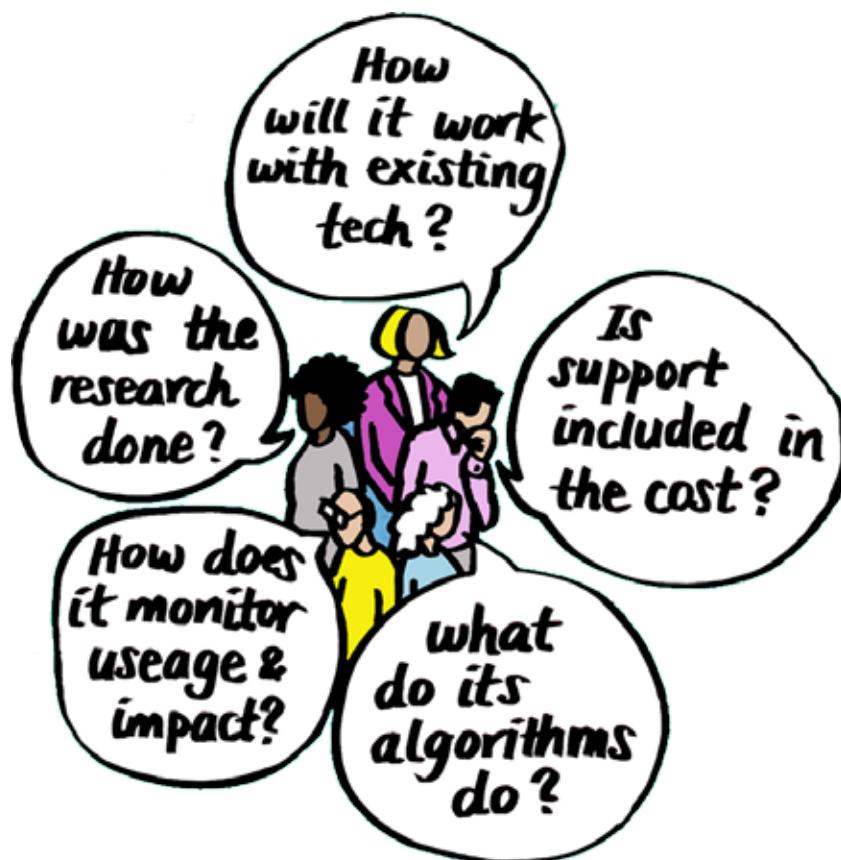
- student data is safeguarded (taking full account of the EU General Data Protection Regulations¹⁹⁰).

In this context, transparency is of vital importance, as schools must be able to provide parents with information about what and whose personal data is stored where. As recommended in Principle 3E, it is necessary to develop solutions together with the responsible school boards to meet the data protection requirements of schools.

¹⁸⁹ See Section 6 “Technology-enhanced personalised learning in classrooms: the challenges”.

¹⁹⁰ <https://www.eugdpr.org/>

Thinking of buying into a technology-enhanced personalised learning approach or tool?
What questions should you ask?



At this point in this report, you have encountered a wide range of issues to explore when considering implementing personalised learning in general or technology-enhanced personalised learning in particular. We have also looked at various examples of current tools and identified some key implementation principles. We finish by suggesting a few specific questions that you might choose to ask, before investing your time or your school's money, of the advocates of any particular technology-enhanced personalised learning approach or tool (whether the researcher, the developer, the policymaker, or the school leadership).

Question the technology

- Ask how this particular technology will help you achieve curriculum aims, and how it is aligned to curriculum objectives and assessment criteria.
- Ask how this particular technology will support students to achieve their full potential.
- Ask how the proposed technology works in simple terms, what its algorithms do, what data it uses, and how it uses that data.

Question the integration

- Ask how this particular technology will fit with existing infrastructure (e.g. Internet bandwidth or existing computers), and what will need to be adjusted or replaced.
- Ask about logins (for example, how are student passwords, or other methods of secure access, managed?).
- Ask who would be accountable for dealing with everyday queries from teachers and troubleshooting.
- Ask about the costs (the technology, your investment in time, students' investment in time, technical support...).

Question the professional development

- Ask how much time is recommended for professional development, and whether that is included in the purchase costs.
- Ask how you might be supported in planning your lessons, so that you use the technology to best effect?
- Ask how you can monitor student usage (not just how much time they are using it, but their achievements and misconceptions) without impacting on student agency.

Question how the technology-enhanced personalised learning addresses the dimensions of personalised learning

- Ask how the system personalises the learning approach (the **how** dimension).
- Ask how the system personalises the learning content and the learning pathways (the **what** dimension).
- Ask how the system personalises the learning pace (the **when** dimension).
- Ask how the system enables appropriate learning groups (the **who** dimension).
- Ask how the system enables appropriate learning contexts (the **where** dimension).
- While always recognising that the personalisation of **why** something is to be learned depends on the policymakers.

10. Concluding remarks

As we have seen, attempts to adopt personalised learning and technology-enhanced personalised learning in classrooms have become increasingly common, because of the benefits personalisation is thought to bring to education. We have also noted that personalised learning is complex and difficult to implement at scale, while the use of technology does offer at least a partial solution. However, as we have also discussed, technology-enabled personalised learning is unlikely to succeed without addressing the fundamentally human dimensions of learning. In addition, all stakeholders (policymakers, school leaders, teachers and students) need to understand why personalisation is important (but not sufficient) and what it takes to maximise its potential.

Here, we have considered the various dimensions of personalisation. In particular, we have acknowledged that a key dimension, the *why*, is ultimately a political decision and outside the control of school leaders or teachers; whereas teachers should consider carefully how the other dimensions (the *how*, *what*, *when*, *who*, and *where*) impact on what technology-enhanced personalised learning might bring to their classrooms and how it might best be implemented.

We have also introduced some examples of technology-enhanced personalised learning approaches and tools, thought through some of the many challenges, and proposed a framework of analysis. Our examples of technology-enhanced personalised learning were not introduced as specific recommendations but rather to provide an approach for you (teachers) to evaluate any technology-enhanced personalised learning approaches or tools that you encounter, and to make decisions based on your practices, your educational context and your students' needs. And as you do so, we urge you to keep in mind a basic principle of scientific research – that research findings contribute to the ongoing refinement of hypotheses but do not represent any proven conclusion. Positive results merit continued and even expanded use but ongoing evaluation is needed to build a body of evidence upon which we can rely.

As we have repeated, choosing and implementing technology-enhanced personalised learning is a complex and multidimensional task, that needs to consider the human dimensions of learning (personalisation is important but not a sufficient condition of learning). In addition, if students are to truly benefit and the investment (expertise and resources) is to be properly rewarded, the implementation needs to be considered not only in terms of the particular technology but also in terms of what reforms are necessary for the school (infrastructure, professional development, flexibility in curriculum aims and assessment, and so on).

With that in mind, recommendations for necessary next steps in several areas can be derived:

At the **education policy level**, it is true that the promotion of individualised learning has become a key concern in Germany, as a consequence of both the apparent educational inequality of the German track system, revealed by the PISA studies and the ratification of the UN Convention on the Rights of Persons with Disabilities (CRPD). All the same, the use of digital tools still plays only a negligible role in German schools. The KMK strategy paper on digitalisation in education calls for increased use of digital technologies in schools. However, the focus here is on acquiring computer and information skills. Although the personalisation of the learning experience is included, it is not strategically substantiated. So far, policy calls for stronger personalised learning support and for greater use of digital technologies in schools still seem to be relatively unconnected to one another.

To tap the full potential offered by the use of digital technologies in the personalisation of the learning experience, a strategic education policy framework that combines the strategic targets of personalisation and inclusion with digitalisation in education would be helpful. Given the enormous importance of school-related parameters and pedagogical support that the various studies have repeatedly shown, it is vital not to focus exclusively on the promotion of technical solutions. Instead, a strategy should pursue a holistic view of the technology and its pedagogical use as well as the personnel aspect at schools. This way, it could offer an opportunity to drive equally pedagogical and technological developments in personalised learning. These include opening up conventional school concepts to try out new teaching methods and approaches, as well as developing and providing open educational resources that support personalised learning. Especially when it comes to the development of software solutions, it would be advisable for development teams to cooperate closely with schools and educational practitioners to ensure the applicability of the developed software. Preference and support should primarily be given to the development of applications that (1) offer intelligent adaptivity; (2) are modular and configurable, particularly with regard to curriculum content; and (3) include comprehensive learning process diagnostics to give teachers insights into their students' current learning levels as well as performance advantages and deficits.

At an **administrative level**, the provision of an adequate IT infrastructure and compliance with data security regulations are among the major challenges for implementing technology-enhanced personalised learning. As shown above, technology-enhanced personalised learning is difficult to implement if students (and teachers) don't have flexible access to the respective technologies. In terms of the funding of equipment, one possibility is to champion a 1:1 student-device ratio and bring-your-own-device concepts in schools (as well as the necessary network infrastructure). In addition, providing schools with learning platforms should be another focus for funding. With a view to the personalisation of learning, preference should be given to such platforms that provide personalised learning tools or facilitate the easy integration of such tools.

In Germany, as elsewhere, getting to this point would require states, municipalities and schools to partner up and develop new equipment strategies and support concepts that will allow them to move towards a 1:1 computer / student ratio that is guaranteed for the long term. In addition, technology-enhanced personalised learning concepts must be developed under shared responsibility to provide schools with affordable applications that can be personalised and learning platforms that also meet all privacy and data security requirements. As part of its DigitalPakt#D, the Federal Ministry of Education and Research has launched a school cloud¹⁹¹ that may be a viable option. However, supporting documents for the development of the school cloud do not yet prioritise any personalisation of the learning process,¹⁹² which is why we recommend including the support for personalised learning as an additional development target of the school cloud. As suggested in this study, an evidence-based evaluation and / or documentation of the effectiveness of the tools and applications provided via the school cloud would also be desirable, as it would help teachers decide which tools to use.

With regard to teacher qualification, another important measure would be to demonstrate stronger support for sharing lessons learned and materials between schools that are pursuing technology-enhanced personalised learning. Various school networks, such as the materials network of the *DiLer* learning platform, show that the peer learning approach can be very beneficial in training school staff and supporting school development processes.

Concerning **research**, most funded innovation projects usually aim at the development of a technology rather than its robust evaluation. In fact, especially in technology-heavy projects, a great deal of resources are required even for prototype testing with small groups. Accordingly, evaluations tend to focus on usability and student attitudes in small settings, rather than effectiveness and sustainability at scale (which is needed by stakeholders to facilitate decision-making).

- Developers and researchers should consider using a design-based research approach, to produce effective educational interventions combined with theory.
- Teachers, students, and parents should be involved in the heart of the research and development process (i.e. researchers should employ a participatory design process, which will lead to technology-enhanced personalised learning tools that better meet real needs).
- The research and development process should include both ongoing formative and summative evaluations at scale, using both qualitative and quantitative approaches.

¹⁹¹ BMBF (2017).

¹⁹² HPI, https://hpi.de/fileadmin/user_upload/hpi/dokumente/publikationen/projekte/schul-cloud_beschreibung_website.pdf

Finally, we would like to give recommendations for **policy-makers, foundations and NGOs**, as examples of additional stakeholders. As we have seen throughout this report, there are multiple approaches to technology-enhanced personalised learning, and very many different technology-enhanced personalised learning tools. Further, as noted elsewhere, “developments tend to take place in small pockets and at modest scale, mostly by researchers with limited funding and without commercial partnerships. The result is that many of the applications that are developed never move beyond the prototype stage, at which point much of what has been learnt is lost.”¹⁹³

- Governments and philanthropists should consider guaranteeing longer-term funding and a market for TEPL tools that have been shown to work in real life settings (albeit at small scale).
- Policy-makers and funders should consider funding capacity building (including teacher training), helping to ensure that technology-enhanced personalised learning research is both sustainable and cumulative: projects should be funded that build on previous innovations, as well as intelligent evaluation in real world settings at scale.
- A range of stakeholders should be involved throughout a research project’s life.

A final comment. It is clear, from the evidence that we have reviewed, that the promise of technology-enhanced personalised is worth pursuing, and that some extraordinary tools have been built (ranging from sophisticated technologies like *ASSISTments* and *WriteToLearn*, that respond to individual learning needs, aiming to reduce achievement gaps, to relatively simple technologies like *Smart Learning Partner* and whole-school approaches like *Spectra Secondary School*, that put the student in control of their learning). However, the evidence also clearly shows that technology-enhanced personalised learning is not a silver bullet. Time, effort, resources and a cultural shift are needed to realise and implement the necessary reforms, in order that schools, teachers and students can best leverage the many potential benefits of technology-enhanced personalised learning. Put simply, we would argue in conclusion, that it is important not to be seduced by exciting technologies, especially if there is little supporting evidence, and to always start with the learning.

¹⁹³ (Luckin et al. 2016, p. 51)

11. Appendices

Recent Reports on Technology-enhanced Personalised Learning

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List of abbreviations

ICILS	International Computer and Information Literacy Study
ILS	Integriertes Learning System
ITS	Intelligent Tutoring System
LMS	Learning management system
PISA	Programme for International Student Assessment
RCT	randomised controlled trial



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