THE ROLE OF TEACHING AND TECHNOLOGY FOR EFFECTIVE EDUCATION IN THE TWENTY-FIRST CENTURY

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A Learnovate Report

The Role of Teaching and Technology for Effective Education in the Twenty-First Century

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About the author

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As a researcher, Ilse consults, and collaborates with a wide variety of clients to help them understand and improve learning design and employee development challenges in their organisations. She cares deeply about enabling great learning experiences that contribute to the development of the learner and performance of the organisation they work in.

Prior to Learnovate she has gained 15 years of experience in learning design, learning strategy and technology-enhanced learning in people development in multinational organisations.

Ilse has a MA in Business Communication from the Radboud University in Nijmegen, the Netherlands and a Post-graduate qualification in Learning Technology & Management from Dublin City University in Dublin, Ireland. A Dutch native, she has adopted Ireland as her forever home where she lives with her husband and 3 children.

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1. Executive summary

Technology, in particular digital technology and the internet, has made its way into schools and the classroom. As this has taken place, scholars and researchers have made bold predictions about how these technologies would revolutionize learning and education, just as the existence of digital technology and the internet has changed the world around us. Many predictions suggested there would no longer be a need for books, and that teachers and schools would be replaced by technology. We know now that these predictions have not been (fully) realized; however, the digitalization of our world and the existence of ever-evolving, ubiquitous technology has impacted learning and education in dramatic ways.

Our approach

In this report, which is the product of a thorough review of the literature, we conclude that the important debate happening today is not about which is better—the teacher or the technology—but rather about what the unique contributions have been and what the opportunities are for further developing the best of both worlds. The important question to ask, then, is how can we converge those insights into an approach toward high-quality education at a scale that ensures the sum is greater than its parts?

Education and EdTech both face complex challenges in their efforts to provide students with a learning experience that is high quality, effective, engaging, and that ultimately prepares them for their role in an ever-changing society. This report discusses the unique expertise and contribution of both teachers and technology that can help ensure education that is grounded in learning-science research. It is placed against the backdrop and in the context of bigger changes in our societies and economies that force educators and policy makers to think about how we (re)organize education systems to meet the demands of the twenty-first century, demands that include imparting to students the skills they'll need to address the societal, economic, and existential challenges they'll continue to face.

The role of the teacher

The role of the teacher is unique in the learning process. Learning is a social process and as social learning theory prescribes, we learn with and from each other. In addition, every individual has a unique mix of experiences, cultural context, values, and behaviors, and that mix forms the basis of how we learn most effectively. Teachers are uniquely placed to understand the nuances of these cultural contexts and to know how to apply the most effective learning methods in every situation, time and time again. (OECD, 2021)

The teaching profession and the role of the teacher have gone through tremendous changes. On the one hand, the expectations of the teacher's ability to lead the learning process for a highly diverse set of students is high. On the other hand, teachers do not seem to receive the training and ongoing professional development opportunities to stay on top of the developments in learning science that provide insights into how students learn best and that show teachers how to teach based on those insights. (OECD, 2021)

Research into learning science, learning neuroscience, and cognitive psychology is developing at a rapid pace and has provided important insights over the last couple of decades into how teaching and learning can be more effective. Translating the knowledge about how people learn from theory to practice, and then incorporating that knowledge into teacher training programs, curricula, and the classroom is difficult. Asking teachers to apply the theory of learning in every classroom interaction and to continuously improve and develop their expertise as teachers is a big request. Teachers might not have the time or opportunity to study the theory. However, as quality teachers are essential to providing the education that students need to help achieve their full potential, it is a request we must make.

Impact of technology in education

The presence of technology in education has been significant. More students than ever are online, devices and applications are widely used by teachers and students to communicate and share, and more educational technology solutions are being developed and implemented at high speed. This adoption of technology has created an industry worth an estimated $227 billion in 2021, with spend set to expand to $404 billion by 2025.[1] However, education and economic research is showing that the current introduction of technology into education has not had a significant impact on student achievement. Despite substantial societal investment in computer technology, it has not measurably increased student performance (OECD, 2015).

As wider policies and plans for education are taking shape (OECD, 2021), it becomes clear that the role of teachers and technology and specifically their collaboration and coexistence will be increasingly important to meet the demands for skills and progress in the twenty-first century. It is important that each continues to develop an understanding of the expertise and added value of the other, and that we continue to look for approaches that leverage the best of both worlds. That means better teacher education focused on the application of learning science in day-to-day teaching, and technological knowledge and solutions that are designed with learning science and the student in mind.

One of the main observations from our research is that the core challenge might well lie in the perception that neither teaching practice or technology solutions for education are developed enough to leverage and combine the unique expertise and added value of both to truly make an impact on education systems across the world.

1 HolonIQ. "Education Technology in 10 Charts," accessed Feb. 28, 2023, https://www.holoniq.com/edtech-in-10-charts.

2. Introduction

Uniquely placed at the intersection of education research, curriculum development, teacher professional development, and big tech, OER Project has become increasingly aware of the important role learning science, teachers, and technology play (both individually and in combination) in delivering high-quality education to all students. To explore the topic in more detail, a literature review, which this report documents, was conducted by the Learnovate Centre, Trinity College Dublin, Ireland.

Research question

The following research question was defined through a collaborative process:

What is the unique value of the teacher in the classroom to the learning process and what role does technology play in providing quality education to students?

What to expect in this report

This report aims to answer this question in detail as follows:

The third section of this report ("The Changing Roles of Teachers and Education Technology") provides context on the changing role of the teacher and the evolution of technology in education, and the role both can play to achieve higher-quality education.

This is followed by the fourth section, "Learning as a Cultural Process," which discusses the importance of educators looking at learning as a cultural and social process, and how we each bring a unique set of experiences, behaviours, and values to our learning. The realization that learning is a cultural and social process represents one of the most widely held theoretical perspectives in learning-science research (starting with Vygotsky's work in the early twentieth century). Educators must find ways to bring their understanding of the cultural and social impacts on learning into the classroom via teaching, curricula, and technology. To be able to do this, a better understanding of the teacher's expertise and knowledge is required as well as an understanding of how technology can play a positive role in enhancing those. The fifth section, "Why Teachers Are Central to Quality Education," provides more detail on this.

"The Role of Technology in Education," the sixth section, expands on the role of technology in education and explores what technologies are relevant to improving effectiveness, equity, and efficiency in teaching, learning, and education systems.

The seventh section, "Learning to Teach for How We Learn," takes a deeper dive into some of the insights that learning-science research has provided, insights that need to be taken into consideration for the development of quality teachers and learning.

The report concludes with a macro look forward on how and why education needs to change, and the specific roles teachers and technology play in the proposed transformation of education.

The objective of this report

After reading this report, we hope you share the understanding that education does not benefit from a simple debate on which method—teachers or technology—is better. Instead, we intend to leave you with the realization that for education to meet future demands, challenges, and opportunities, every element of education (systems, curriculum, policy makers, leaders, teachers, communities, and technology) have to collaborate to deliver education that is inclusive and equitable, and that will likely look very different from today's education experience.

A note on learning sciences terminology

Throughout this report you will find numerous references to insights gained from the learning sciences. We emphasize that the theoretical insights referenced in this report are merely a fraction of the insights of the whole field of learning sciences, which stretches well beyond education alone. Where possible, this report references specific research areas within the learning sciences. Where a more generic term is used, we urge the reader to consider these to be explored for the benefit of highlighting insights from the research field that are specifically related to teaching and learning in a formal education setting.

3. The changing roles of teachers and education technology

Research, theory, and practice in education, teaching, technology, and learning continue to develop and change our perspectives on how disciplines are related. How education, teaching, technology, and learning support each other and how, if implemented properly, their convergence can reform education to best support the societal, economic, and environmental demands of the twenty-first century, and provide every student with the highest-quality education possible. The teacher is central to quality education, which is why the next section provides a deeper insight into the teacher's role in education and how that role has changed and is still changing.

3.1 The changing role of the teacher

The teaching profession has gone through tremendous change, especially in the last decade and a half or so. These changes include higher academic standards and the influx of new technology. Increased digitalization of our world has provided us with immediate access to information (good and bad); divisive rhetoric has made its way into the classroom; fewer people are enrolling in teacher-preparation programs; and the conversation on teacher pay has continued. Many teachers are dissatisfied with their pay, which is less than other similarly-educated professionals.[2]

When we look at the growing need for teaching to be more efficient and effective, the argument or suggestion that technology can replace or at least fill in for parts of the teacher's remit doesn't seem too far-fetched. With all the data that can be collected about a student, personalization of learning might be easier for a machine than for a human. EdTech companies are working hard to prove their solutions make a positive difference, and schools are embracing the use of technology, especially since the COVID pandemic.

Educators and policy makers around the world argue that rather than putting the differences between teachers and technology at the center of the debate, it would be much more effective and revolutionary to look at the opportunities and challenges of each, and find ways for alignment and convergence. This is more likely to achieve the high-quality approach to teaching and education that will develop the skills and knowledge needed to meet the demands of the twenty-first century.

3.2 What is the role of technology in education?

Digitalization opens possibilities for education. Learning can be personalized, and data may be used to lighten the administrative burden of teacher as well as to provide insight for teachers on how to structure learning for their students. Technology can improve student engagement with learning and can also enable students with special needs to participate in education, which will make it more inclusive. (OECD, 2021)

According to an OECD report on the outlook for digitalization in education, the level of automation of actions and decisions for learning and teaching should be thought of as a continuum. A continuum between actions that are fully automated at one end , and at the other end, actions over which humans have full control. This way hybrid systems are formed that are aimed at helping students learn better and teachers teach better.

All smart technologies such as adaptive learning systems, social robots, and blockchain technology

2 Madeline Will, EducationWeek, Dec. 12, 2019, "10 Ways the Teaching Profession Has Changed Over the Past 10 Years," https://www.edweek.org/teaching-learning/10-ways-the-teaching-profession-has-changed-over-the-past-10-years/2019/12.

assume and require a human—a teacher—in the loop. Artificial intelligence (AI) systems remain hybrid and require human intervention (and expertise) at some point in the process. (OECD, 2021) However, it appears these hybrid solutions of technology and teacher have not been implemented. There are not enough technology implementations that consider the expertise of the teacher and the insights from learning science in conjunction with the consistency, speed, and accuracy technology offers.

We argue that the definition of learning adopted by technologists might be too narrow. They

seem to have bought into a neuroscientific model that assumes our brains are wired like computers. But they're not. Or at least, it has not been validated through research that they are.[3]

Education stakeholders have always paid attention to new technologies and have recognized their potential to revolutionize education. However, most uses of innovative technology have been to conserve existing educational practice and sometimes enrich it, but they have rarely transformed it. (OECD, 2021) Despite substantial societal investment in computer technology, it has not measurably increased student performance. (OECD, 2015)

Sawyer (2022) offers a simple explanation for this that is well supported by other researchers: Most educational technology innovations have not been aligned with the science of how people learn.

3.3 How true impact of education technology could be achieved

Traditionally, the education technology sector and even teachers might be taking a too narrow view of learning. Research has demonstrated that engaging students in the learning process increases their attention and focus and motivates them to engage in higher-level critical thinking. Engagement requires cognitive, affective, and behavioral processes to happen simultaneously. Behavior is the most straightforward of these processes in terms of how it might be observed, processed, interpreted, and measured through technology.

However, cognitive and affective processes, both very important to learning, are not so easy to measure and manipulate because they are inherently complex processes that define us as humans. (Christodoulou, 2020)

In addition to behavioral processes, cognitive and affective processes also play a role in learning. Our background, cultural values and habits, emotions, and motivations play a big role in how we process knowledge and indeed learn.

To allow for a learning experience that not only considers but *optimizes* all learning processes to happen, and to be supported and augmented by technology to achieve scale, learning environments and teaching methodologies might have to be reviewed, restructured, and rebuilt to allow for the foundations of education to be based on two fundamental elements that have long been underused: learning science and culture.

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3 Matthew Cobb, "Why Your Brain Is Not a Computer." The Guardian, *February 27, 2020. Accessed December 12, 2020. https://www.theguardian.com/science/2020/feb/27/why-your-brain-is-not-a-computer-neuroscience-neural-networks-consciousness.*

https://www.theguardian.com/science/2020/feb/27/why-your-brain-is-not-a-computer-neuroscience-neural-networks-consciousness

3.4 Understanding the role of teacher and technology

The interest for this literature review lies in exploring existing scholarship that helps us better understand the role of technology and the teacher in the context of developments and insights from learning science, as well as the challenges education systems all over the world face to transform education and learning in a way that will meet the challenges of the twenty-first century.

Many people believe that teachers bring a unique human value to teaching and that learning can most certainly be enhanced by technology solutions.

Education technology holds a lot of value when it comes to supporting and improving learning. Technology can benefit teaching and learning in a multitude of ways and is a key enabler to transform the learning experience of the future. However, technology should augment the learning experience, not replace the teacher; that is, technology should not be expected to provide the learning experience. We are interested in finding the advantages and limitations of teachers and technology by exploring what each can do alone and what they can do together to lift the quality of teaching and learning to improve student outcomes.

4. Learning as a cultural process

Before we look at the specific roles of the teacher and technology in the classroom, we must look at education through a wider lens and consider its objective. Education plays a crucial role in shaping the world's socioeconomic state and progress. The next section explores the context of how people come into, respond to, and progress through education. In particular, in this section we explore the position that learning is a cultural process that is not solely based on acquiring knowledge. All students' learning experiences in the classroom are influenced by their backgrounds and communities.

4.1 Why culture is important to learning

From learning science research, we know that learning does not simply happen by obtaining and developing knowledge. (Nasir, Rosebery, Warren, and Lee, 2006) Learners also need to develop the skills, attitudes, and values that will prepare them to be citizens of the world and make meaningful contributions to society.

While humans share basic brain structures and processes as well as fundamental experiences—such as relationships with family, age-related stages, and many others—each of these phenomena are shaped by an individual's precise experiences. Learning does not happen in the same way for all people because cultural influences are impactful from the earliest stages of our lives.

4.2 The concept of learning as a cultural process

Nasir, Rosebery, Warren, and Lee argued that learning and teaching are fundamentally cultural processes. By culture they mean the "constellation of practices communities have historically developed and dynamically shaped in order to accomplish the purposes they value, including the tools they use, the social networks with which they are connected, the ways they organize joint activity, and their ways of conceptualizing and engaging with the world." (Nasir, Rosebery, Warren, and Lee, 2006, p. 594)

Each learner develops a unique array of knowledge and cognitive resources in the course of life that are molded by the interplay of that learner's cultural, social, cognitive, and biological contexts. Understanding the developmental, cultural, contextual, and historical diversity of learners is central to understanding how people learn. (National Academies of Sciences, Engineering, and Medicine, 2018, pp.2–3)

Nasir, Rosebery, Warren, and Lee (2020) state that a traditional view of learning sees this diversity in students as something that needs to be "overcome." It takes the deficit perspective that encourages nondominant groups to become more like presumed dominant groups. They (the non-majority) are asked to assimilate. The researchers reject this view and argue for a more sophisticated understanding of diversity. They believe learning is enhanced by recognizing the profound cultural and community assets young people bring to learning spaces. They take each student as a whole person and see learning as intimately tied to brain development, socio-emotional development, identity development, and the specific contours and relational aspects of the learning settings. Their claim is supported by Darling-Hammond, Glook, Cook-Harvey, Barron & Osher, 2020; Nasir, et al., 2020; Osher, Cantor, Berg, Steyer, and Rose, 2019.

4.3 Learning is cultural and social

Culture affects cognitive processes that shape learning. (Markus and Kitayama, 1991; Nisbett, et al., 2001); see also Gelfand, et al. 2011; Kitayama and Cohen, 2007; Kronenfeld, et al., 2011; Medin and Bang, 2014)

A body of work in psychology that explores the role of culture in shaping psychological processes has focused on learning as a dynamic system of social activity. This work finds its origins in the work of researchers Lev Vygotsky, Alexander Luria, and Aleksei Leontiev. The underlying principle of this work Is that cognitive growth happens because of social interactions in which children and their more advanced peers or adults work jointly to solve problems. These more advanced peers and adults were referred to by Vygotsky as the "more knowledgeable other." Technology can certainly play this role at times.

The embrace of social cultural theory led to one of the most important theoretical shifts in education research: the proposition that all learning is a social process shaped by and infused with a system of cultural meaning. (Nasir and Hand, 2006; National Research Council, 2009; Tomasello, 2016)

The research has brought important insights about learning that are relevant to understanding all people, from infancy to old age. *Everyone* brings experiences they have acquired through participation in cultural practices in their communities to their opportunities to learn. Learning is a dynamic process that requires coordination of multiple systems within the individual and occurs within a dynamic system encompassing the changing contexts and people that surround an individual through life. Recognizing that is essential to understanding the forces that help shape learning over the life span.

4.4 Social and cultural influences shape how our brains learn

Learning at the individual level involves lasting adaptations of multiple systems to the changing external and internal environment, including changes in the biology of the brain. The biology of the brain provides the physiological platform for learning and is shaped by the social and cultural influences outside of the individual. Two aspects that have an impact on an individual's learning that are shaped by culture are:

1. **The social and emotional interactions an individual experiences**

   Humans have evolved to be highly social interdependent: From birth through old age, no one can manage life without relying on many other people. (Rogoff, 2015; Tomasello, 2009) An individual's brain is critically shaped by social relationships, and the information they learn through these relationships supports both their emotions and their knowledge about facts, procedures, motivation, and interests. (Immordino-Yang, et al, 2014; Nelson, et al., 2007)

   Emotion plays a role in developing the neural substrate for learning by helping people attend to, evaluate, and react to stimuli, situations, and happenings. In the past, it was generally assumed that emotion interferes with critical thinking and that knowledge and emotion are separate. (Gardner, 1985) However, extensive research now makes clear that the brain networks supporting emotion, learning, and memory are intricately and fundamentally intertwined (Panksepp and Biven, 2012), even for experts in technical domains such as mathematics. (Zeki, et al., 2014) Emotions are an essential and ubiquitous dimension of thought, and emotional processing steers behavior, thought, and learning. (Damasio, 1994; Immordino-Yang and Damasio, 2007)

Quite literally, it is neurobiologically impossible to think deeply about or remember information about which one has no emotion because the healthy brain does not waste energy processing information that does not matter to the individual. (Immordino-Yang, 2015).

People are willing to work harder to learn the content and skills they are emotional about, and they are emotionally interested when the content and skills they are learning seem useful and connected to their own motivations and future goals.

2. **The factors related to the individual's physical well-being**

The developing brain is sensitive to physical influences that also affect other aspects of health and development, including nutrition, exposure to environmental toxins, sleep, and exercise. These physical influences can vary dramatically across context and are often shaped by cultural practices, such as the foods we eat.

4.5 Learning and context: social-learning theory

Vygotsky (1978) Leontiev (1931), Luria (1962), Bandura (1976), and Zimmerman (1989) were early proponents of social-learning theory. They, unlike behaviorist and cognitive learning theorists, believed that learning is related to its surroundings and is dependent on contextual factors. Social-learning theorists claim that learning is highly contextual. Central claims of contextualism (an epistemological term to describe the research field of social-learning theorists) are:

1. Person-environment interaction: Individuals make meaning through their interaction and relationships with the broader environment.
2. Events as holistic phenomena: Events in the world are not experienced by the individual as discrete episodes, but rather as "cognitively unified phenomenon." An event is broken down into elements called strands, and the relationships between those strands are called textures.
3. Contextualism is comprehensive and dynamic. The human mind is always reacting to its environment. Therefore, the idea that psychological events can be reduced to a set of basic associations such as computer programs or logic, as early cognitivists did, is rejected by the contextualist. Instead, development is ongoing and diverse.
4. Research methods and goals must be revised.

According to Zimmerman, social-learning theory assumes that reality is dynamic and continuous in flow and that knowledge is the ever-changing cumulative product of one's personal transactions with the proximal and distal environment.

The central idea from Bandura and Zimmerman's work is that people learn through observing others, so it's of vital importance for educators to consider exactly what students will be observing. Most learning does not happen in a context-free way, and generic skill approaches to learning are often ineffective. It is particularly important that context-specific knowledge is gained before attempting most tasks.

Children do, however, need clear modeled examples of how to succeed, and they must already have the prerequisite specific knowledge to unlock the skills from the specific task. (Kirschner & Hendrick, 2020)

Teachers are an essential part of ensuring that education truly transforms, as they are responsible for holding the expertise of effective teaching, and they understand the social and cultural backgrounds of their students to a level of detail that no machine or technology can, to date.

5. Why teachers are central to quality education

Education and schools don't just provide students with knowledge; they also provide students with opportunities to cooperate, collaborate, and socialize with peers from different backgrounds and with different identities and experiences from their own. This prepares them for their professional lives as well as for being citizens of the world we live in. Education opportunities may develop social, behavioral, affective, and cognitive, styles and habits.[4]

5.1 Teachers hold the expertise

In the previous section, we discussed that *everyone* brings to their opportunities to learn, the experiences they have acquired through participation in cultural practices in their communities. This means that every student comes into the classroom with a different set of needs and learning goals, even though there are similarities between them and their peers. Discovering what those learning goals are and how to best achieve them requires value judgments that need to be made for students individually and collectively, as well as for their learning environments.

Teachers hold the professional expertise and are best placed to make decisions about strategies for learning and personalizing learning. They can draw from their knowledge of individual students, classroom dynamics, and learning environments as well as a range of evidence about learning and teaching practice. An array of practices might be needed to achieve different goals for different students.

It is therefore essential that teachers apply evidence-based practices, which is of course, easier said than done. Teachers face a myriad of challenges ranging from budgets, prescriptive practice, narrow curriculum frameworks, and mandatory assessment programs to feelings of isolation and an increasing administrative burden.

This section discusses some of the specific added value of a teacher. The section that follows will discuss the role of technology: How it can help teachers be the best asset to students and education, and what to look out for to make sure technology is in service of the teacher and the student rather than an additional task or burden.

5.2 Technology can enhance teacher expertise

In some ways, technology can mimic or maybe even replace some of the expertise of the teacher—for example, through advanced adaptive solutions that are able to personalize the learning process by giving hints, nudges, and feedback the way a teacher would.

But there are also ways in which teacher expertise cannot be replaced. Technology is not able to take on the emotional side of learning and motivate and support a student (it can make learning fun though, which may motivate the student), and it cannot replicate expertise in the social aspects of learning, nor can it teach tacit knowledge. (Christodoulou, 2020, p. 172)

What technology and the EdTech industry can and should do is look for ways to combine the expertise of teachers and technology in a way that benefits the teacher and the student at scale so that a shift in the education system can be achieved.

4 Charlotte Pezaro, "The Role of the Teacher and the Purpose of Education, Neuroscience, Nov. 3, 2016, https://neurosciencecommunity.nature.com/posts/13089-the-role-of-a-teacher-and-the-purpose-of-education, accessed Feb. 28, 2023.

5.3 Why teacher expertise is important

Hattie (2003) conducted a huge synthesis of metareviews on the variables that influence learning. He identified 138 variables. Six of those are major sources of variance to student achievement: the student (50%); home (5–10%), schools (5–10%); principals (percentage included in the schools variable); peer effects (5–10%); and teachers (30%). It can be concluded that outside of the students' own influence on their learning, the teacher emerges as the most important influence on the learning process. It is what teachers know, do, and care about that is very powerful in the learning equation. (Hattie, 2003)

An OECD report on teacher's pedagogical knowledge and the teaching profession (Guerriero, 2014) states that the imperative to improve student outcomes is also about improving the quality of the teaching workforce. It has however become a major challenge in many OECD countries, including the US, to recruit and retain quality teachers. Other challenges that impact the quality of the teaching workforce and by proxy student outcomes include the ageing of the teaching workforce, high rates of attrition among new teachers, shortages of quality teachers in high demand subject areas and disadvantaged schools, as well as lowering qualification requirements in the certification and licensing of new teachers to attract more high-achieving and motivated candidates into teacher education programs. (Guerriero, 2014)

More recently, a *Forbes* article[5] by Linda Darling-Hammond shared insights and data from the US Department of Education, The National Center for Education Statistics, RAND, and the OECD that make it very clear the challenges around teacher readiness, attrition, and shortages are not solved and are likely getting worse, fueled as they are by decreasing enrolment numbers, low teacher salaries, and poor teaching conditions.

One of the solutions to solve the problem has been to reduce or eliminate standards for entering teaching. While doing this might increase the number of teachers, Darling-Hammond states that it will not solve the chronic challenges and students will be short-changed. This is simply because the most powerful predictor of student achievement is the presence of well-qualified and experienced teachers. (Burns, Darling-Hammond, and Scott, 2019).

According to Darling-Hammond, the solution lies in "addressing foundational issues and deeply committing to professionalizing teaching by developing a well-prepared, well-supported workforce that attracts highly qualified candidates who are motivated to become, and remain, teachers." (Darling-Hammond in *Forbes*, 2023)

The importance of the expertise of the teacher on the learning outcomes of students appears to be strongly supported by thorough research.

Hattie stated that "While teachers have the power—few do damage, some maintain a status quo in growth, and many are excellent. We need to identify, esteem, and grow those who have powerful influences on student learning." (Hattie, 2003)

5 *Darling-Hammond, Linda, 2023. "Policymakers Should Ring in the New Year with Action to End Teacher Shortages."* Forbes Magazine, *January 5, 2023, https://www.forbes.com/sites/lindadarlinghammond/2023/01/05/policymakers-should-ring-in-the-new-year-with-action-to-end-teacher-shortages/?sh=610d1f196d35.*

5.4 What is the expertise of the teacher?

Hattie (2003) recognized there is a difference between expert and experienced teachers, and identified five major dimensions of excellent teachers and 16 associated attributes of expertise that determine that difference. The dimensions and attributes are shown in Table 1.

Table 1: Major dimensions that set expert teachers apart. (Hattie, 2003)

Five major dimensions of expert teachers		Attributes of expertise
1	Identify essential representations of their subject.	• Have deeper representations of teaching and learning. • Adopt a problem-solving stance to their work. • Anticipate, plan, and improvise as required by the situation.
2	Guide learning through classroom interactions.	• Proficient at creating an optimal classroom for learning. • Have a multi-dimensionally complex perception of classroom situations. • More context-dependent and have high situation cognition.
3	Monitor learning and provide feedback.	• More adept at monitoring student problems and assessing their level of understanding and progress. They also provide much more relevant, useful feedback. • More adept at developing and testing hypotheses about learning difficulties of instructional strategies. • Cognitive skills become more automatic with extensive practice.
4	Attend to affective attributes.	• Have high respect for students. • Passionate about teaching and learning.
5	Influence student outcome.	• Engage students in learning and develop their students' self-regulation, involvement in mastery learning, enhanced self-efficiency, and self-esteem as learners. • Provide appropriate challenging tasks and goals for students. • Have positive influences on students' achievement. • Enhance surface and deep learning.

Hattie does not claim that the list of dimensions and attributes is a checklist for the perfect teacher. Nor does he disregard other, more minor dimensions of expert teachers. Ultimately, his work is about reflecting on practice, and evidence of impact and understanding of practices. It is about how to put students in the driver's seat of their own learning and how to prepare them for the future.[6]

5.5 The different types of teacher knowledge

An important conclusion that Hattie draws is that the attribute of content knowledge does not have to be present as a key distinguishing factor. He argues that content knowledge is necessary for both experienced and expert teachers, and therefore should not be distinguished. He argues that what is more important is that even though content knowledge does have to be present, pedagogical knowledge is more important as it is the way that knowledge is used in any teaching situation.

Hattie's argument that teachers need to hold both content knowledge and pedagogical knowledge stems from the research of Lee Shulman (1986). Shulman coined the term *pedagogical content knowledge* (PCK), and states that a teacher's optimal knowledge materializes when there is a connection between the content knowledge and pedagogical knowledge. A teacher needs to have knowledge of the subject they teach, but they also need to understand the best methods of teaching that knowledge. It is subject matter knowledge for teaching. Shulman (1986) states: "When I talk about the concept of pedagogical content knowledge, I still speak of content knowledge, but of the particular form of content knowledge that embodies the aspects of content most germane to its teachability."

PCK is the notion of the transformation of the subject matter, to find multiple ways to represent it, and to adapt and tailor the instructional materials to alternative conceptions and student's prior knowledge. (Koehler & Mishra, 2009)

More recently, Koehler and Mishra (2006; 2009) built on Shulman's PCK model. As a result of the increasing digitalization in education, they added the concept of Technical Knowledge (the knowledge of how to work with and apply technological resources) to the mix of Pedagogical knowledge and Content knowledge to provide a more holistic view of what a teacher's expertise should constitute. Their work culminated in the TPACK model of teacher knowledge (Figure 1).

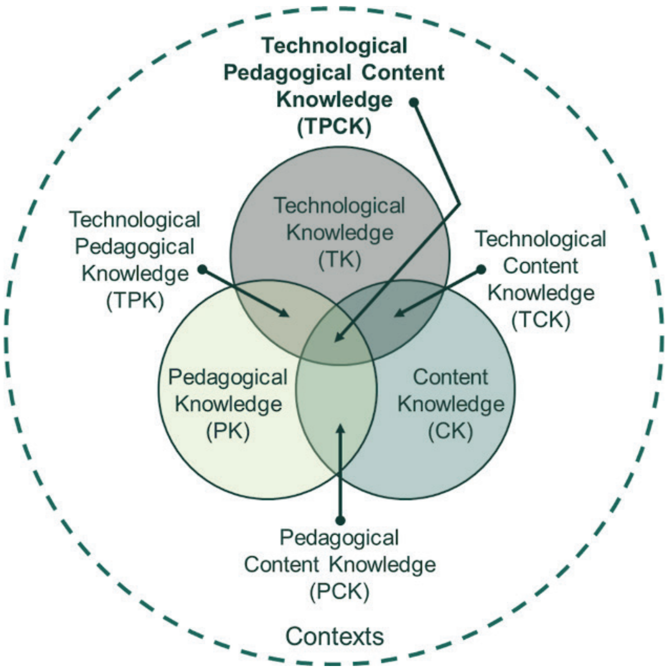

Figure 1: The TPACK model for teacher knowledge (Koehler & Mishra, 2009) Source: http://tpack.org

6 https://www.edweek.org/education/opinion-john-hattie-isnt-wrong-you-are-misusing-his-research/2018/06

Koehler and Mishra state that effective technological integration for pedagogy around specific subject matter requires developing sensitivity to the dynamic, transactional relationship between these components of knowledge situated in unique contexts. No single combination of content, technology, and pedagogy will apply for every teacher, every course or every view of teaching. Good teaching requires an understanding of how technology relates to the pedagogy and content and scholars argue that all components should receive attention in teacher training and continued professional development.

This model for teaching knowledge provides the framework for teachers to be able to manage the complex connection between culture, pedagogy, content, technology, and curriculum that teachers encounter in the classroom every day. The consensus study report on how people learn conducted by the National Academies of Sciences, Engineering and Medicine (2018) shares this opinion. It states that 'effective instruction depends on understanding the complex interplay among learners' prior knowledge, experiences, motivations, interests, and language and cognitive skills; educators' own experiences and cultural influences; and the cultural, social, cognitive, and emotional characteristics of the learning environment (National Academies of Sciences, Engineering and Medicine, 2018).

6 The role of technology in education

6.1 The issue with education technology to date

Despite a large increase in understanding and research on how people learn, much is still unknown and many approaches to instruction and supporting learning technologies have often been developed on the premise of a misconception. Many education technologies have failed as a result of bad ideas about learning.

Christodoulou (2020) states that "If we assume learning styles exist, that cognitive overload doesn't exist, that students can pick up knowledge as they go, and that attention is an infinite resource, we will never improve education, however much, or little, technology we use. If we persist with faulty ideas about how humans think and learn, we will just extend a century-long cycle of hype and disillusionment".

Much education technology is not designed to promote learning. Often, the technology is detrimental to the learning process by overloading our working memory, not allowing for scaffolding of the learning experience or leaving the students to figure out learning by themselves. In all of these cases effective learning cannot happen.

During the pandemic, more technology was brought into the classroom (for example, Zoom, Google Classroom, Microsoft Teams). It allowed schooling to continue during COVID-19 school closures, which has been very positive. However, in many instances, it allowed for the pedagogy to become even more instructionist, a pedagogy where teachers deliver information to passive students rather than teachers applying active, research based pedagogy. While a lot was learned about teaching through and with technology since the pandemic, it also showed that educators need a lot more knowledge, understanding and support to develop teaching practice supported by technology (Sawyer, 2020 p.662).

The dividing line between the more and less effective education technology approaches is the attitude to the teacher's expertise. The more effective approaches seek out what is valuable about teacher expertise and try to copy or even improve on it. The less effective approaches assume it is irrelevant or can be ignored. (Christodoulou, 2020).

The PISA study[7] (OECD, 2015), aimed at assessing the integration of digital technologies in education, concludes that there are no appreciable improvements in student achievement in reading, mathematics, or science in the countries that have invested heavily in ICT for education. Technology is also of little help to bridge the skills divide between advantaged and disadvantaged students. A consequent study by Odell, Galovan, and Cutumisu (2020) reported similar findings that show that the use of ICT in science education in Finnish and Bulgarian schools has a negative impact of student performance and that those students who are more familiar with ICT perform better than those who do not have that same access.

7 OECD, 2015, Students, Computers and Learning: Making the Connection*, PISA, OECD Publishing, https://read.oecd-ilibrary.org/education/students-computers-and-learning_9789264239555-en#page5.*

A systematic evidence map on research in student engagement and educational technology in higher education carried out by Bond, et al. (2020), shows that while educational technology can influence affective states of students in relation to engagement with learning , many of the studies researched did not provide a definition of student engagement, and less than half were guided by a theoretical framework. They also conclude that student engagement through educational technology remains an under-theorized concept that is only considered fragmentally in research.

The PISA study interpretation of these results is that building deep conceptual understanding and higher-order thinking requires intensive teacher-student interactions, and technology sometimes distracts from this valuable human engagement. The report further states that we have not yet become good enough at the kind of pedagogies that make the most of technology. Adding twenty-first century technologies to twentieth century teaching practices will just dilute the effectiveness of teaching.

This could well present the crux of the debate: neither teaching practice or technology solutions for education are developed enough yet to leverage and combine the unique expertise and added value of both to truly make an impact on education systems across the world.

6.2 Ways to digitalize education with smart technologies

Digitalization, the process of converting teaching and learning into a digital format, opens new possibilities for education. Questions on how, have encouraged many nations to include an education element to their digital strategies, especially since it became known in 2015 that technology had not had the desired impact on student outcomes (OECD, 2015).

Countries are now exploring how technology could induce the delivery of education and how technology can support the response to emerging societal and labour-market needs (OECD, 2021).

The OECD report on the digital outlook for technology in education is interested in finding the frontiers of education technology to find out what is already possible with technology in education. The report identifies three main types of technology fields:

1. AI and learning analytics
2. Robotics
3. Blockchain

These technologies can have a transformative effect on teaching and learning in the classroom and on managing educational establishments and systems. Technology can improve education in different ways. The key opportunities are to improve effectiveness, equity, and efficiency.

6.2.1 Effectiveness

Personalization

Effectiveness at the student level can be improved by smart technologies that personalize learning. The OECD digital outlook 2021 (OECD, 2021) highlights some successful measures where technology can be used to improve effectiveness in teaching and learning.

Students can be provided with the appropriate curriculum or task. These tasks are scaffolded based on a diagnosis of their knowledge and knowledge gaps. This does not only take into account the academics of the tasks, but also takes into account how students learn and factors such as self-regulation, motivation or effort. (Molenaar, 2021)

D'Mello researched solutions that keep students engaged within digital or physical learning environments by identifying their affective states during learning and nudge them towards re-engagement when they seem to disengage. (D'Mello, 2021[9])

Social robots can use adaptive learning to tutor students with natural language, but they can also teach, or motivate them to learn by playing the role of a peer student. They support teachers by enabling the implementation of different types of teaching and learning strategies (Belpaeme and Fumihide, 2021).

Finally, smart technologies give students with impairments and special needs access to curriculum materials and allow those students to participate in learning activities to an extent that was not possible before, here again increasing the effectiveness of education (Good, 2020).

Classroom analytics for teachers

A solution that holds a lot of promise for teacher development and which is an area that continues to develop, is the area of classroom analytics. They can support teachers in providing more effective teaching. Classroom orchestration solutions can suggest a teacher to shift to a new learning activity, it would provide insight as to who needs their attention the most, or suggest whole class collaborative learning activities. While they can help teachers in real time, they also provide feedback on the teacher's own practice, for example, how much they talk, or how they divide their time between different types of activities (Dillenbourg, 2021). Technology can also improve teaching practice by digitally observing teachers, providing personal feedback and learning opportunities for the teacher. This would deliver instant professional development opportunities to a teacher wherever they are without them having to engage in formally organized or generic teaching professional development practice.

At the organizational or system level, smart technologies can be implemented at nearly every school activity. They can provide administrators, teachers, and learners with feedback to manage school resources as well as improve the effectiveness of teaching and learning. According to Ifenthaler (2021), the implementation of smart solutions remains quite rare.

AI powered assessment

An area of growth is the rise of a new generation of assessments powered by AI. They open new avenues for recognising and evaluating competencies that were hard to assess through more traditional tests. These solutions support education systems as they move towards emphasizing skills as well as knowledge (Buckley, et al., 2021).

The public release of ChatGPT and other generative AI solutions are generating a lot of debate among educators and teachers at the time of writing this report. One of the most balanced views from educators we have come across is from a group of teaching and learning specialists at Center for Teaching, Research and Learning at the American University. They state that "ChatGPT is a tool that can and should be leveraged within (higher) education settings as it is likely to be used in workplace settings in a few years. Instead of seeing ChatGPT as a threat, we should think about how to utilize the tool to encourage learning and give students the skills they will need as AI tools become more prevalent in education and work settings. Regardless of the tools at our disposal to support learning and education, it is most important to keep learning at the forefront and equity in mind." (Center for Teaching, Research and Learning, American University, 2023).

A recent *New York Times* article[8] concurs with the above viewpoint and details some examples of how ChatGPT technology might be successfully integrated into schools and teaching. There is as much opportunity as there are questions about generative AI and the debate will likely continue as newer, smarter, and faster products are made available. As with any change, the technology needs to be tried, tested, and evaluated before it can be adopted or rejected.

Longitudinal data systems

A final area where digital or smart technology that provides data analysis can have a big impact of effectiveness is through the use of longitudinal data systems. These systems follow students throughout the course of their studies and can lead to more effective decision-making, education policies, and better design of educational offerings. The use of data supports policy design and interventions (OECD, 2019).

6.2.2 Equity

Smart technologies can help education systems provide more equitable learning opportunities, though the use of technology is a little more ambivalent for this purpose as they can both help reduce inequity or make inequity rise.

Inequity might rise because access to devices and connectivity by students from lower socio-economic backgrounds might prevent these students from accessing the technology aimed at reducing inequity. In addition, those students who start with stronger prior knowledge can maintain their advantage over other students and make faster progress. This would widen rather than reduce the achievement gap (OECD, 2021, p.26).

Open educational resources

However, there are many reasons to believe that technologies can advance the equity agenda, most notably perhaps because they provide expanded access to learning opportunities. Educational platforms proposing open educational resources (Orr, Rimini, and van Damme, 2015) and massive open online course (MOOC) platforms are good examples. A recent systematic review study by Lambert (2020) showed that MOOCs have a positive impact on decreasing inequity.

Technology for inclusion

Technology can also play a large role in reducing inequity by facilitating the inclusion of students with special needs and by adapting learning to different learning styles. Technology has made it easier to diagnose learning difficulties, and remedial digital responses have been developed. Technology (text to speech, speech to text, automatic subtitles) has made accessing learning materials for visually impaired and deaf or hard-hearing students easier which enables them to perform like any other students.

8 Kevin Rose, "Don't Ban ChatGPT in Schools. Teach with It.", The New York Times, Jan. 12, 2021. https://www.nytimes.com/2023/01/12/technology/chatgpt-schools-teachers.html, accessed on March 3, 2023.

Learning technologies have also enabled the socio-emotional learning of autistic children, which impacts positively on their subsequent academic performance. Technologies have also been developed to help children with attention deficit hyperactivity disorder (ADHD) to self-regulate, and better benefit from their schooling.

All these efforts also have an effect on improving inclusion at a societal level. As students with special needs are enabled to study in traditional and inclusive learning environments, peoples' views on disability and special needs can change for the better, making society more inclusive (Good, 2021).

Warning systems

Other solutions that address equity in education are warning systems. These are focused on reducing inequity by helping students at risk of dropping out of school (mainly high school and university) graduate. These students typically come from disadvantaged backgrounds and the early warning systems allow for designing appropriate interventions by identifying the factors that predict dropout (Bowers, 2021; Ifenthaler, 2021).

Intelligent tutoring systems

Learning analytics can also be used for intelligent tutoring systems that use data to provide personalization at the individual level. What these examples have in common is that they aim to reduce the learning gap between the strongest and weakest students. There is little evidence though that adaptive learning generally reduces achievement gaps among students (OECD, 2021, p. 27).

Classroom analytics can also give feedback to teachers on how they might improve their teaching, especially how and when to pay more attention to different groups of students in their classes based on their academic level, gender, and ethnicity.

6.2.3 Efficiency

Smart technologies are used as a tool to enhance the cost-efficiency of operations by automating tasks and processes, making services faster and cheaper. Education might be behind most other sectors in this respect, but digitalization is making many educational processes more efficient. Whether or not this may also lead to cost savings is a question that has yet to be answered.

6.1 Considerations for moving forward

Digitalization of education still has some way to go. Many of the technology solutions that are suggested in the previous paragraphs are still at an early stage of development.

Generally speaking, most teaching and learning solutions are designed as hybrid human-AI systems and require teacher-student interactions and human oversight of the machine at different points. Molenaar (2021) offers a model (Figure 2) to better understand the continuum between fully automated and teacher-only education.

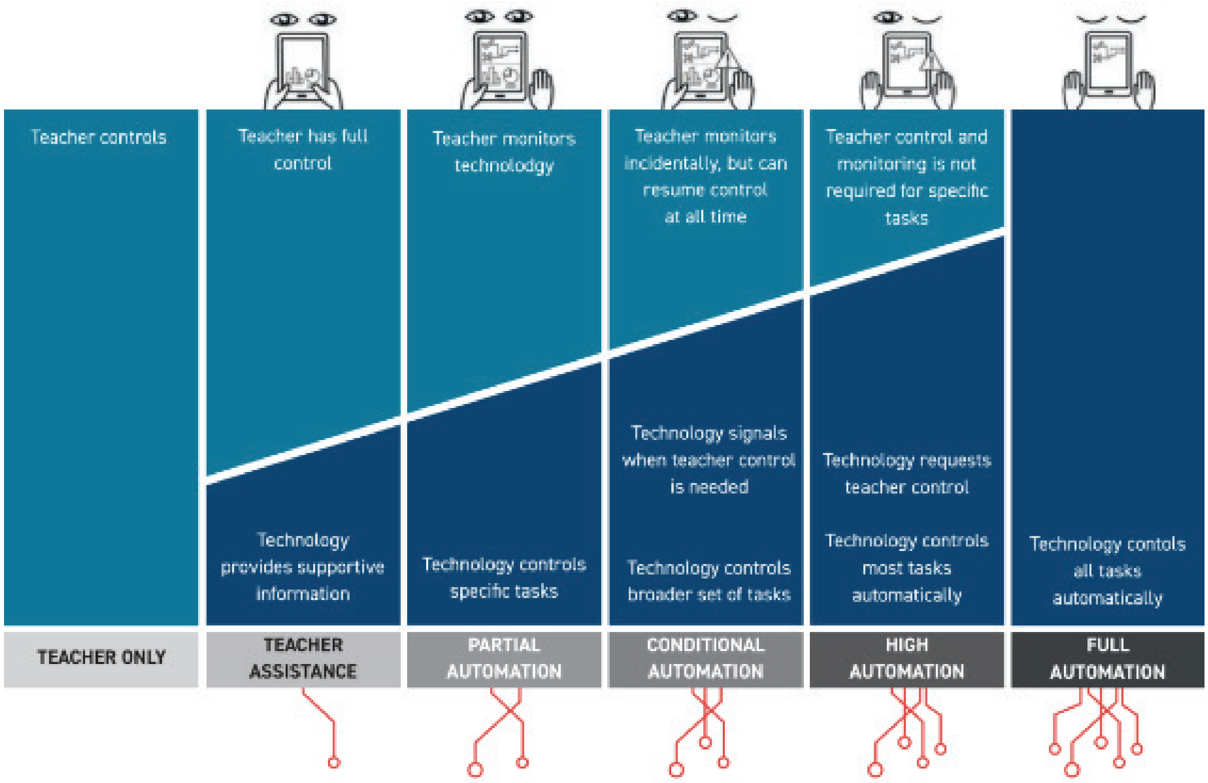

Figure 2: Six levels of automation of personalized learning (Molenaar, 2021.)

Personalization systems, classroom analytics, and early warning systems all make some decisions to enact their next step or recommend one to human beings. But they typically only provide input to decisions. The OECD report suggests it might be helpful to look at smart technologies as sociotechnical systems. This means systems in which social and technical features interact and are shaped together. For technology to play a bigger, more meaningful role in the future, the OECD outlook report suggests two things need to be considered:

1. Teachers, students, and other users of technology should be involved as co-designers in the research and development process to ensure the usefulness and use of smart digital solutions for education.
2. Public-private partnerships between government, technology researchers in universities and companies, and the education technology industry should be a key characteristic of most research and development projects in this area.

6.2 Considerations for designing useful technology solutions

Sometimes, education technology solutions are designed and proposed because they are possible rather than because they are useful and provide clear benefits to end users in education. One reason for this lack of use lies in the design of the smart technology solutions or in an insufficient understanding of how teachers can use them in their professional practice in ways that support rather than distract them.

The OECD digital outlook report (OECD, 2021, pp. 31–32) identifies key considerations that will enhance the usefulness and usage of smart technologies in education. These are:

1. Cost-benefit analysis should guide the design and adoption of smart digital solutions for different types of problems.
2. Both the expected costs and benefits of smart technologies should be clearly identified and estimated through research evidence or a good theory of action.
3. The design of the interface between human and smart education is often a key aspect of the usability and impact of the digital solutions on learning or other targeted goals.
4. Smart technology solutions should aim to be low cost and run on widely available platforms/devices to be as affordable as possible, perhaps by using open standards. This is essential in order to avoid reinforcing the digital divide.

6.3 Scenarios for digitalization of education

Several scenarios for digitalization in education have been put forward by the OECD (OECD, 2020) and Holoniq (2018).[9] While in reality these scenarios may play out differently, they ask interesting questions of all stakeholders in education.

Scenario 1: Education will look very similar to today and change minimally. Education technology would mostly be available in out-of-school and informal education and in corporate training. The question is whether out-of-school learning could become as important or more important than in-school learning.

Scenario 2: Education will look similar on the surface but will actually be different as smart technologies supporting students, teachers, and administrators enable them to make decisions to improve their teaching, learning, and management practices. At home, learning might be supported by intelligent tutoring resources that are available to everyone.

Scenario 3: Education is built on smart technologies and social trends related to digitalization and reshapes as a social institution. More schoolwork will happen at home with more involvement of parents and communities, and social time in school may become used mainly for individual tutoring and collective learning.

9 HolonIQ, "Building Scenarios for Education in 2030," https://www.holoniq.com/2030/building-scenarios-education-in-2030, 2018, accessed on May 19, 2021.

7 Learning to teach for how we learn

As mentioned earlier, learning science is constantly evolving and researchers have discovered more about how we learn in the last few decades than ever before. In this section, we discuss the extent to which the discoveries of learning science are having an impact on teaching practice, as teaching is the proxy for all the insights to be applied to student learning.

7.1 We all learn differently

We know from research that learning needs to be appropriate to the level of expertise that students have. A pre-schooler is typically a novice when it comes to reading and writing, whereas a student in twelfth grade may have mastered the technicality of reading and writing, but may still need to develop expertise in comprehension, interpretation, and application.

Table 2, published in Kirschner and Hendrick (2020), shows the differences between novices and experts based on research by Chi, Glaser & Rees, 1982; De Groot, 1965; Kalyuga, Kalyuga, Chandler & Sweller, 1998; Schneider & Shiffrin, 1977; Wilson & Cole, 1991.

Table 2: Differences between experts and novices.

Novices	Experts
No access to relevant schema	Possess schemata for encoding elements into a single entity
Attempt to remember and process individual elements	Skills acquisition without needing to recall the rule
Need to apply cognitive capacity to inefficient problem solving	Automation important for complex problem-solving transfer
Work backwards (means—end)	Work forward

For optimal learning, new knowledge must be related to the knowledge that students have already acquired. New knowledge must be integrated into existing schema. This is called assimilation and accommodation, as phrased by Piaget. (Piaget, 1976)

What is needed for effective learning is teaching methods that require high levels of mental activity where the mental activity is directed toward important features that are not too big to overwhelm working memory.

7.2 Teacher knowledge of techniques and approaches that work

Most students don't really know the best way to learn or study, skills that should be taught by teachers. However, teachers themselves don't always know what the most effective learning techniques are, as they may not have been taught how to teach this as pre-service or in-service teachers.

A recent report by Deans for Impact (2022) explains that all teachers employ a theory of learning when they teach. Teachers have a set of beliefs and expectations about how their instructional decisions will foster learning with their students. Deans for Impact believes that all teachers should understand the basic principles of learning science. They developed a Learning by Scientific Design assessment in collaboration with educators and teachers and gained some valuable insight from its administration with teachers in participating pre-service programs in the US. The assessment indicated that the integration of learning science principles in teaching and learning design is not quite where it should be:

1. Future teachers are unfamiliar with the basic principles of learning science and struggle to connect its principles in practice.
2. Future teachers recognize the critical role background knowledge plays in learning.
3. Future teachers struggle to identify effective forms of practice and they appear to conflate student engagement with learning.
4. Teacher candidates hold beliefs about teaching and learning that align to principles of learning science, but there are areas for improvement.
5. Teacher candidates' understanding of learning science does not vary as much as we might expect based on key categories.
6. Teacher educators in the Learning by Scientific Design network do better at identifying learning-science principles in practice than just the principles in the abstract.

The authors of the report highlight that there is work to be done to ensure teachers start their career with a solid understanding of learning science. The findings of the Deans for Impact report highlight that the professionalization of the teaching profession has a long distance to go before teachers will be the knowledge workers they are expected to become (Sawyer, 2020, p. 669).

This conclusion highlights another big challenge in education. While the teacher holds the unique expertise to understand and consider the nuance of learning as a social and cultural process, their understanding of learning and teaching might not always meet that unique ability in the output of their teaching practice. Similar to the need for technology proponents to understand how technology contributes positively to learning, it could be said that teachers have a way to go before they too understand their true contribution to learning and the pedagogical, content, and technological knowledge and skills they need to develop to teach effectively.

7.3 Biggest influences on student learning

Hattie conducted a synthesis of a very large number (more than 800) of meta studies on what works best for learning. He issued a list of variables that have the largest difference on student learning overall. (2003) We mentioned them already briefly in paragraph 5.3 of this report.

These are:

- Student
- Curricula
- Home
- School
- Classroom (added by Hattie in 2009)
- Teacher

While the student is the most important factor for determining individual student outcomes, the teacher is the next most influential factor. This emphasizes how important it is for teachers to understand the most effective teaching influences as well as be able to demonstrate and structure their teaching methods based on them.

In 2009, Hattie's work, which is still ongoing, resulted in a ranking of the 132 most effective ways of teaching that have an impact on student achievement. By 2013, this list had grown to 252 influences. [10]

The full list of influences on student learning can be found in Appendix A. Appendix B shows the most significant influences categorized by the most important variables for effective student learning. Finally, Appendix C shows what is effectively a barometer of the most significant influences of student learning, ranked from worst to best. We recommend the reader to have a closer look at these resources as they provide a wealth of evidence and might disprove some beliefs held about the most effective teaching and learning methods.

7.4 Visible learning: Teachers need to take responsibility for their own learning

Hattie's work is sometimes considered the holy grail for effective learning and teaching and is embraced by educators, curriculum designers, and policy makers, as it provides a strong evidence base for what works best to improve learning for students.

Following on from the earlier synthesis work, Hattie developed the concept of "visible learning." Visible learning means an enhanced role for teachers as they become evaluators of their own teaching. Visible teaching and learning occur when teachers see learning through the eyes of students and help them become their own teachers.[11] So not only do teachers need to find the best methods and approaches for teaching their students, they themselves need to be students as well and continue to learn. This of course supports the call for a greater investment in teacher pre-service training as well as continued professional development for teachers that focuses on the three categories of knowledge described through the TPACK model. This call is likely to get stronger as education systems recognize the responsibility they hold to meet twenty-first century demands and the central role of the teacher to achieve this change.

The next and final section discusses the implications of social, economic, technical, and environmental change, and the challenge for education to ensure continued global progress for everyone.

10 Visible Learning, "Hattie Ranking: 252 Influences and Effect Sizes Related to Student Achievement," Visible Learning website, https://visible-learning.org/hattie-ranking-influences-effect-sizes-learning-achievement/, accessed on March 12, 2023.
11 See: Visible-learning.org (https://visible-learning.org/).

8 Education technology in context

So far, we learned that the pedagogical content knowledge of the teacher supported by their content and technological knowledge makes them instrumental to quality teaching and learning (Shulman, 1986; Koehler & Mishra, 2006, 2009). The level of technical, pedagogical, and content knowledge a teacher has determines how they choose the best teaching strategies for their students to learn most effectively. As learning science research provides more insights on how teachers can provide a higher-quality teaching experience, it is becoming increasingly important to ensure that teachers have access to quality training and professional development.

From Hattie's work (2003; 2013), we learned that the teacher is the most important influence on a student's learning after the student themselves. Research by Nasir, et al., (2006) argues that learning is a social and cultural process, and that each student brings their own set of experiences, values, and behaviors to their learning, which impacts what and how they learn.

So where does technology fit into all this?

Earlier in this report, we mentioned that education technology might not have had the impact that futurists and educators once predicted. Several approaches to integrating technology in education have failed and even led to the opinion held by some that the use of technology might not have an impact on improving teaching, learning, and student outcomes at all.

Sawyer attributes the limited impact of technology in education to the previously mentioned observation that technology use in schools has rarely been aligned with learning sciences findings. Instead, new technologies, such as online instruction (which we saw an increase of during the COVID-19 pandemic), continue to be aligned with instructionism. It is based on a model of transmission that is exactly the opposite of what learning sciences research would advise. Computers will never realize their full potential if they are merely add-ons to the existing instruction classroom. That is why learning scientists are engaged in the hard work of designing entire learning environments, not just standalone computer applications, as previous generations of educational software designers did (Sawyer, 2020, p.660).

8.1 Why is it so hard to change education?

Education, teaching, and education systems have been notoriously hard to change, and for good reason. According to a recent OECD report on the future of education, education systems have developed into major engines of economic growth and prosperity, state and community building, and social progress. By developing the knowledge, skills, attitudes, and values on which societies rely (and thereby forging social cohesion and preparing people to become and remain competent workers and active citizens), education has shaped the world we live in today (OECD, 2021, p. 3).

Because of this immense responsibility of preparing young people for their entire lives, education tends to be a conservative social system. But it is also the most important social system for anticipating and preparing for the future. That tension between the past and the future is typical for education. (OECD, 2021, p. 4)

The world's evolution through the fourth and fifth industrial revolutions[12] sees countries and industries overhaul their strategies in the face of unprecedented challenges, including an exponentially faster rate of technological change (OECD, 2019). This gives rise to new opportunities and changing demands on education. Education needs to be able to keep up with the transforming businesses and markets, the nature of work and the demand for skills, as well as the ways in which we participate in physical or virtual communities and engage in personal relationships. Education communities have a role to play in shaping the implications of disruption to our world.

8.2 Technology is an important driver of change in education

Technology has the potential to be a great enabler of change in education. It can:

- Enable reaching new populations who are not in employment, education, or training, or those with special needs
- Allow educators and learners to access knowledge in multiple formats in ways that bridge space and time
- Support new ways of teaching that focus on learners as active participants

During the COVID-19 crisis, the most advanced systems discovered technologies that enhance experiential learning and inquiry-based teaching methods. The most advanced and proactive systems discovered technologies that enhance experiential learning by supporting project- and inquiry-based teaching methods, facilitating hands-on activities and cooperative learning, and delivering formative real-time assessments (OECD, 2021).

These are the learning tools that are necessary to develop twenty-first-century knowledge and skills. The pandemic has accelerated the digital transformation of education. The change is coming abruptly and many lessons are still to be learned, but the change itself is irreversible.

Sawyer's outlook for education reform supports further digitalization in education that will transform schooling. In his view, learning scientists are committed to improving schools and believe that true school reform should involve working together with teachers, engage in professional development, and integrate new software into classrooms. Learning science research, combined with new technologies, might lead to more radical schooling (Sawyer, 2020, p. 661).

This view appears to be supported in the strategic direction set out in the OECD's "Future of Education and Skills 2030" strategy. The strategy assumes that for education to keep abreast with technological and other social and economic changes, changes in education are urgently needed to achieve more inclusive and sustainable development for all, not just for the privileged few (OECD, 2019).

To shorten the period of social pain and maximize the period of prosperity for all, education systems need to undergo transformative change. Figure 2 depicts the ongoing race between education and technology over time, as explained by Goldin and Katz (2010). They argue that technological change, education, and inequality have been involved in a kind of race over time.

They also argue that human capital is essential for continued economic growth. If that human capital is in too short supply because the quality of education is declining or the labor market requires

12 Xu, Xun, Yuqian Lu, Birgit Vogel-Heuser, and Lihui Wang. "Industry 4.0 and Industry 5.0—Inception, Conception and Perception." Journal of Manufacturing Systems *61 (2021): 530-–35.*

new skills (because of technological developments, for example), then governments need to invest in education to develop the skills that can keep up with the developments in technology that drive economic growth. If education cannot keep up with technology developments, social pain is felt. If human capital is ahead of technological developments, prosperity and economic growth are achieved.

Their theory emphasizes the importance of future-focused investment in education so that human capital and their skills can keep up with technological and economical change.

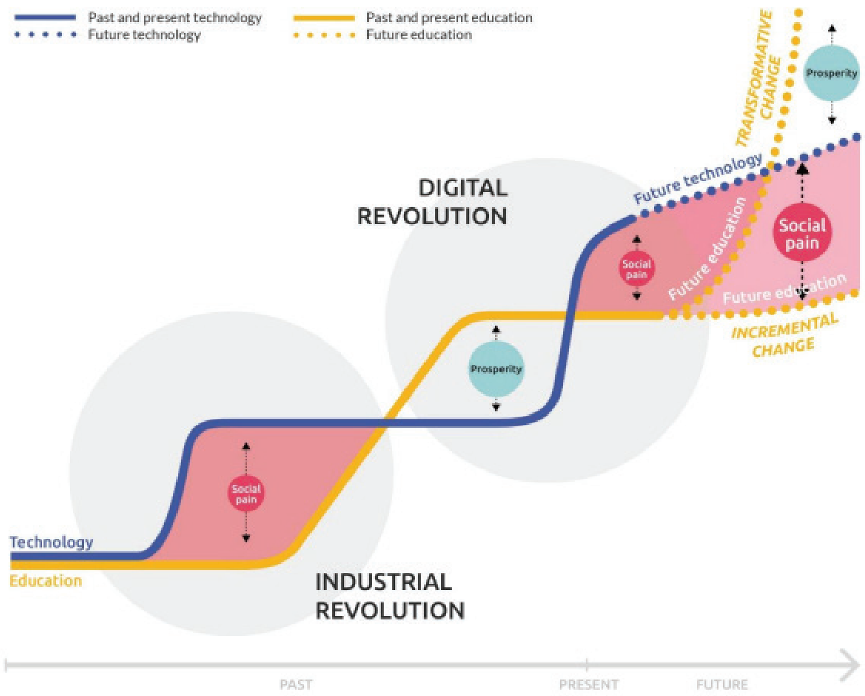

Figure 2: The race between technology and education. Source: OECD Future of Education and Skills 2030. Inspired by "The Race between Technology and Education," Goldin and Katz (2010).

8.3 What is the role of technology in education transformation?

In order for education to achieve the transformational change that is predicted to be necessary by the OECD, the role and responsibility for technology and further digital transformation of education and learning is enormous, and would extend beyond supporting the experience of the learning and the teacher. The OECD states that "Perhaps the most distinguishing feature of digital technologies is that they not only serve individual learners and educators but can also build an ecosystem of learning predicated on collaboration. Technology can build communities of learners that make learning more collaborative, thereby enhancing goal orientation, motivation, persistence, and the development of effective learning strategies. Similarly, technology can build communities in which educators share and enrich educational resources and practices, and collaborate on professional growth and the institutionalization of professional practice. It can also help system leaders and governments develop and share best practice around curriculum design, policy, and pedagogy. However, there may be tensions between digital ecosystems of learning, the social functions of education and physical learning environments."

Transforming education to meet the demands of twenty-first century knowledge and skills development is going to require huge change, bravery, and international collaboration between stakeholders in education, technology, and communities.

It will also require highly professional educators and technology that supports insights from the learning sciences. Both have a unique role to play in providing the learning experiences and learning environments that support lifelong learning—which contributes to personal development, sustainable economic growth, and social cohesion—for all.

9. Discussion and recommendations

As mentioned at the start of this review, OER Project is situated at a unique intersection of research, technology, and teaching that is at the heart of the debate of how education can be improved to meet the needs of the future.

From this vantage point, and from the literature we reviewed, it's clear that the teacher holds unique expertise that is essential to efficient and effective learning. The role of the teacher as the catalyst for student achievement is more important than ever. However, despite being expected to hold this expertise, the research we explored suggests that teachers do not always have the pedagogical, content, and technological skills necessary to be the expert teachers they are expected to be, both now and in the near future.

One of the key challenges is that the teaching profession is resource-poor and stretched in many ways. High numbers of teachers will retire, and there is lower enrolment in teacher training programs, for example. The teacher training programs that are available do not always offer the best or most up to date learning opportunities for teachers, and school systems lack the resources to properly support teachers as they provide learning opportunities to students from increasingly diverse backgrounds. Add the administrative burden of assessment, providing feedback, and setting learning goals and teachers are served with plates that are beyond full.

The following sections contain some suggestions that OER Project might consider emphasizing through its professional-development activities for teachers.

9.1 Evidence-based professional development for teachers

The Deans for Impact report (2022) highlights the need for teachers to be better versed in the insights from learning science and associated evidence-based teaching and learning practices.

Using the TPACK model of teacher expertise and Hattie's influences on student achievement as a basis, OER Project could develop a professional development for teachers offering that concentrates on the intersections of content knowledge, pedagogical knowledge, and technological knowledge, and provide learning opportunities for teachers to better understand how the areas of pedagogy, content, and technology can be combined to deliver good results for students. An idea would be to launch a special collaborative PD development initiative that brings together teachers, educators, and technologists to uncover best-practice teaching approaches for OER Project curricula for both experienced and early-career teachers.

The existing OER curriculum, PD framework, and teacher community of practice can be leveraged as well as the existing technology platform and reporting capability.

9.2 Policy drive for better integration of education and technology

Technology in education might to some extent still hold an unfulfilled promise, but integrating technology in education still holds the potential to transform education systems by applying insights from data analytics, further exploring AI to personalize learning, and implement technologies at scale that drive effective management of education. OER Project and Gates Ventures could play a role in moving the discussion on improved collaboration between education, teachers, and technology companies forward. Rather than coming at education from the respective own areas of expertise, it would be highly beneficial to converge expertise, experience, strategies, and ambitions from all stakeholders by simply facilitating the conditions for conversation and collaboration at this point, which feels like a tipping point for the impact of technology on education and teaching. OER Project, backed by Gates Ventures, could create a platform for collaboration by organizing stakeholder gatherings, at whichever scale deemed appropriate, and take a leading role in the campaign for more effective, learning-science–based use of technology in education that is going to truly make a difference and transform education.

The challenges to solve are enormous, and disruption and innovation does not happen overnight. However, to quote Clayton Christensen: "Until the way we are taught matches the way we learn, the job will not be done."

9.3 Develop a better understanding of the educational technology market

Throughout the literature reviewed, there is a consistent call for further research on how technology can be implemented in ways that either truly contribute to better learning outcomes or support higher-quality teaching.

It would be interesting for OER Project and Gates Ventures to conduct a state-of-the-art/state-of-the-market analysis to discover where the research in these areas is happening with a view to establish research and industry partnerships to drive any worthy and innovative developments forward.

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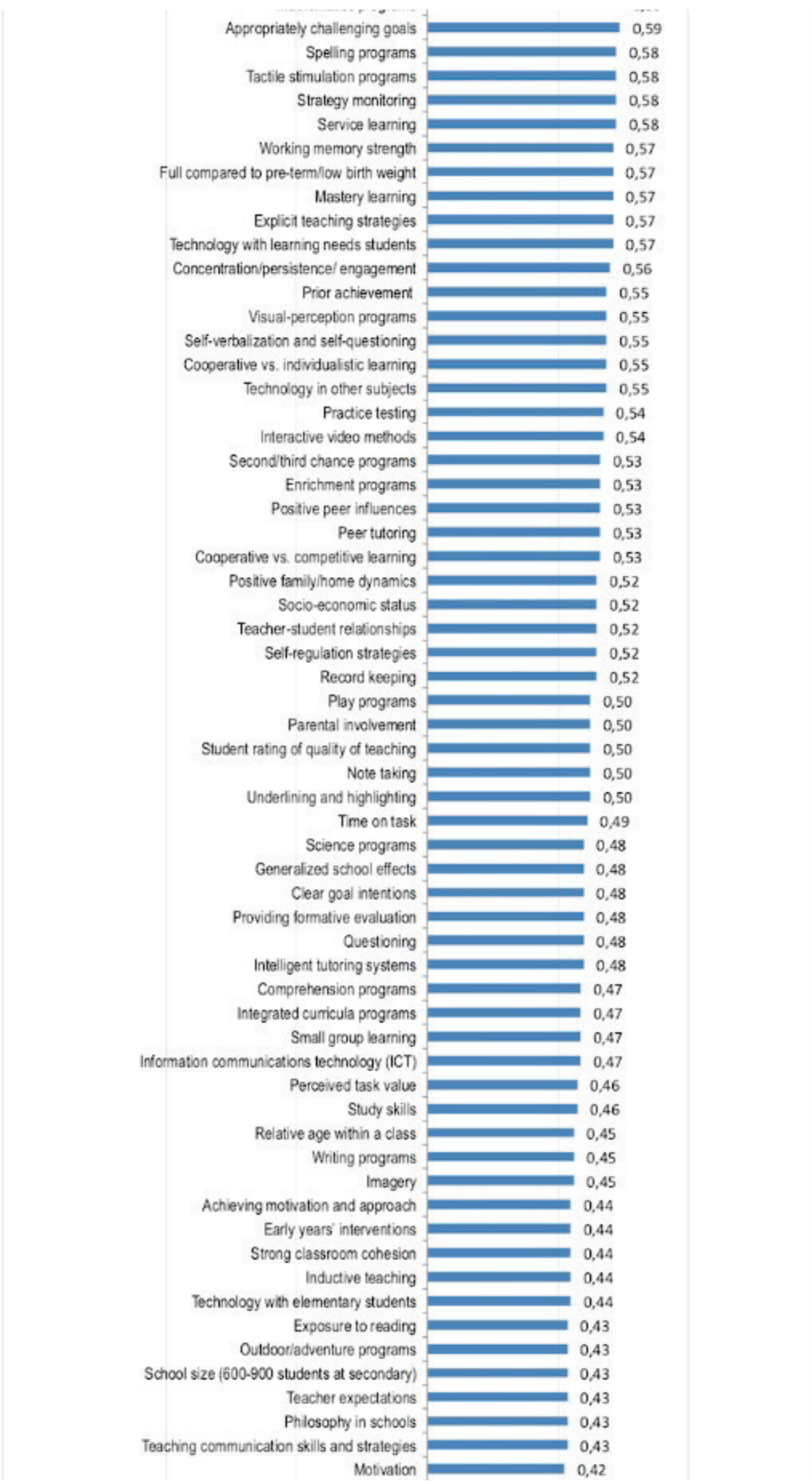
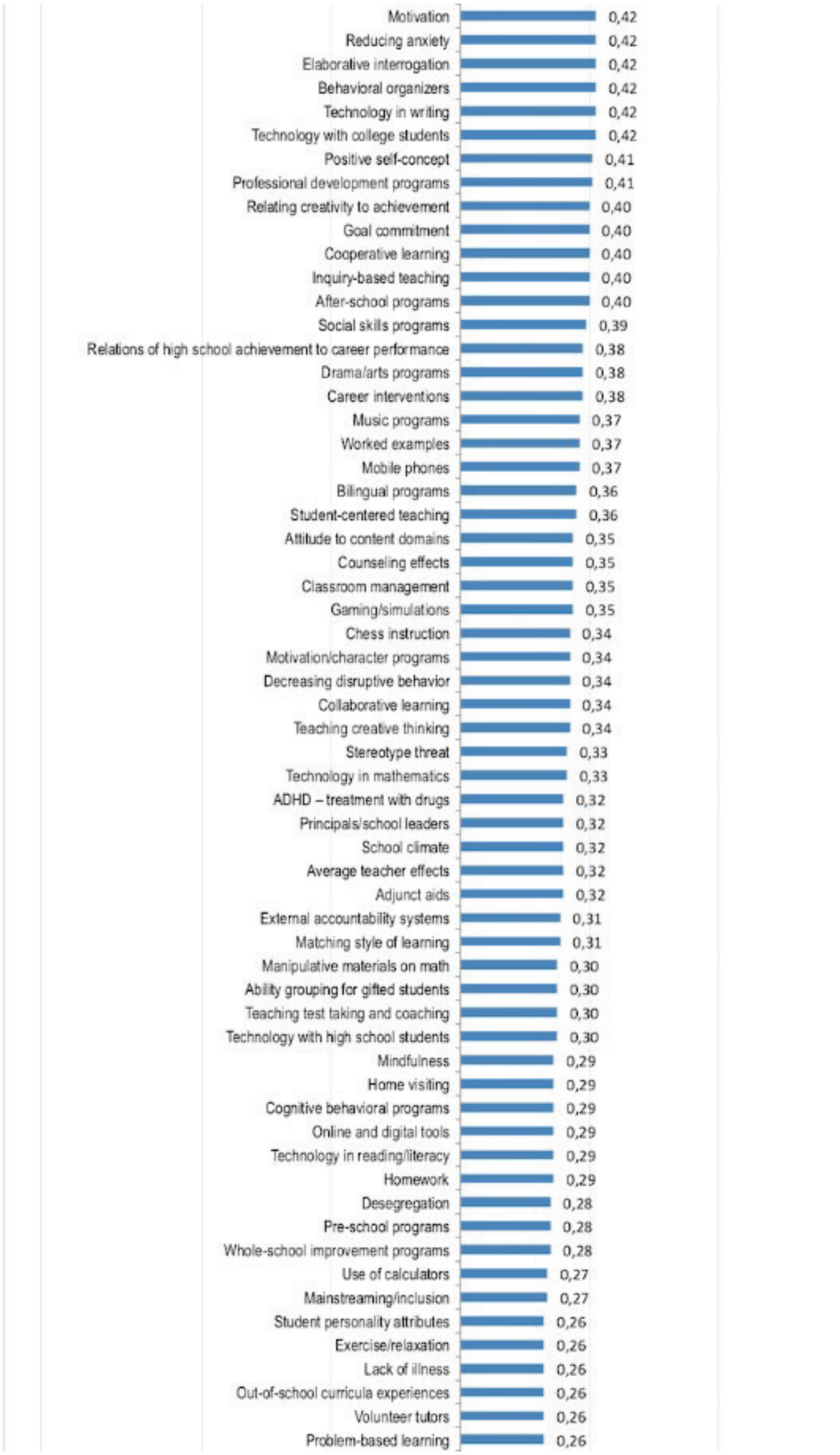
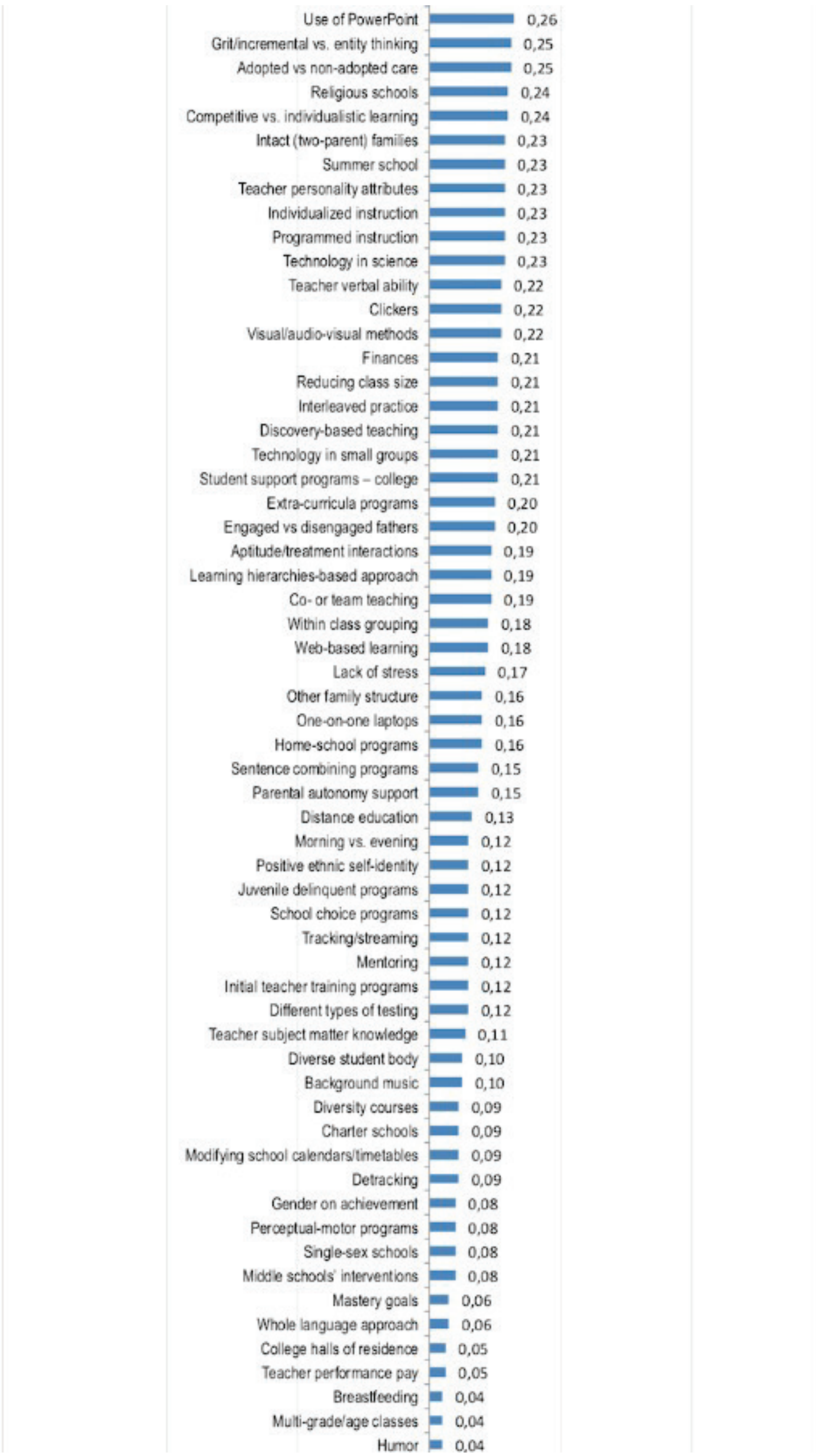
Appendixes

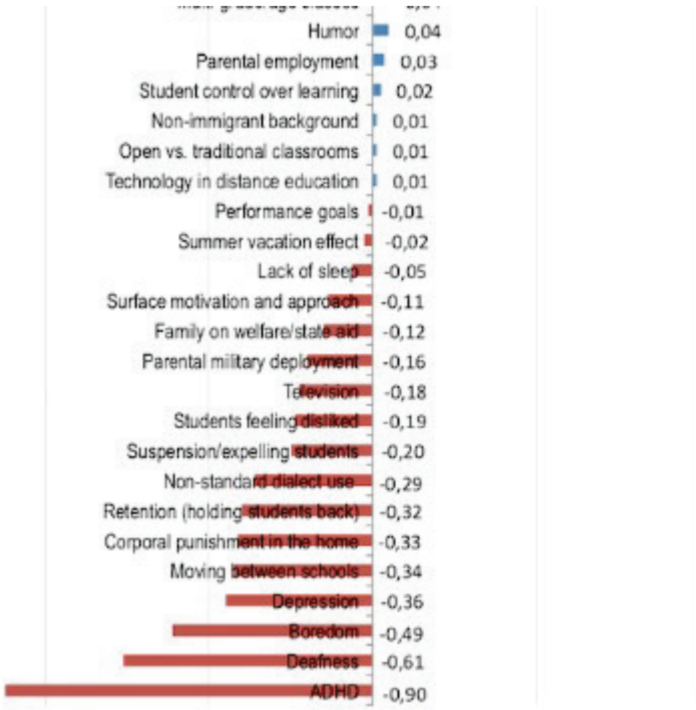
Appendix A. Full ranking of 252 influences on student learning

Source: https://visible-learning.org/hattie-ranking-influences-effect-sizes-learning-achievement/


Appropriately challenging goals 0,59
Spelling programs 0,58
Tactile stimulation programs 0,58
Strategy monitoring 0,58
Service learning 0,58
Working memory strength 0,57
Full compared to pre-term/low birth weight 0,57
Mastery learning 0,57
Explicit teaching strategies 0,57
Technology with learning needs students 0,57
Concentration/persistence/ engagement 0,56
Prior achievement 0,55
Visual-perception programs 0,55
Self-verbalization and self-questioning 0,55
Cooperative vs. individualistic learning 0,55
Technology in other subjects 0,55
Practice testing 0,54
Interactive video methods 0,54
Second/third chance programs 0,53
Enrichment programs 0,53
Positive peer influences 0,53
Peer tutoring 0,53
Cooperative vs. competitive learning 0,53
Positive family/home dynamics 0,52
Socio-economic status 0,52
Teacher-student relationships 0,52
Self-regulation strategies 0,52
Record keeping 0,52
Play programs 0,50
Parental involvement 0,50
Student rating of quality of teaching 0,50
Note taking 0,50
Underlining and highlighting 0,50
Time on task 0,49
Science programs 0,48
Generalized school effects 0,48
Clear goal intentions 0,48
Providing formative evaluation 0,48
Questioning 0,48
Intelligent tutoring systems 0,48
Comprehension programs 0,47
Integrated curricula programs 0,47
Small group learning 0,47
Information communications technology (ICT) 0,47
Perceived task value 0,46
Study skills 0,46
Relative age within a class 0,45
Writing programs 0,45
Imagery 0,45
Achieving motivation and approach 0,44
Early years' interventions 0,44
Strong classroom cohesion 0,44
Inductive teaching 0,44
Technology with elementary students 0,44
Exposure to reading 0,43
Outdoor/adventure programs 0,43
School size (600-900 students at secondary) 0,43
Teacher expectations 0,43
Philosophy in schools 0,43
Teaching communication skills and strategies 0,43
Motivation 0,42

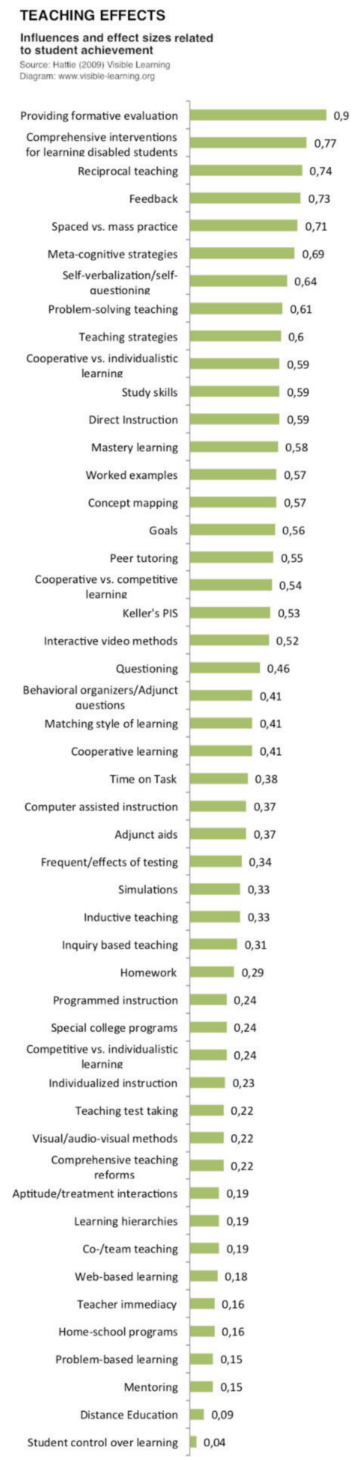

Motivation 0,42
Reducing anxiety 0,42
Elaborative interrogation 0,42
Behavioral organizers 0,42
Technology in writing 0,42
Technology with college students 0,42
Positive self-concept 0,41
Professional development programs 0,41
Relating creativity to achievement 0,40
Goal commitment 0,40
Cooperative learning 0,40
Inquiry-based teaching 0,40
After-school programs 0,40
Social skills programs 0,39
Relations of high school achievement to career performance 0,38
Drama/arts programs 0,38
Career interventions 0,38
Music programs 0,37
Worked examples 0,37
Mobile phones 0,37
Bilingual programs 0,36
Student-centered teaching 0,36
Attitude to content domains 0,35
Counseling effects 0,35
Classroom management 0,35
Gaming/simulations 0,35
Chess instruction 0,34
Motivation/character programs 0,34
Decreasing disruptive behavior 0,34
Collaborative learning 0,34
Teaching creative thinking 0,34
Stereotype threat 0,33
Technology in mathematics 0,33
ADHD – treatment with drugs 0,32
Principals/school leaders 0,32
School climate 0,32
Average teacher effects 0,32
Adjunct aids 0,32
External accountability systems 0,31
Matching style of learning 0,31
Manipulative materials on math 0,30
Ability grouping for gifted students 0,30
Teaching test taking and coaching 0,30
Technology with high school students 0,30
Mindfulness 0,29
Home visiting 0,29
Cognitive behavioral programs 0,29
Online and digital tools 0,29
Technology in reading/literacy 0,29
Homework 0,29
Desegregation 0,28
Pre-school programs 0,28
Whole-school improvement programs 0,28
Use of calculators 0,27
Mainstreaming/inclusion 0,27
Student personality attributes 0,26
Exercise/relaxation 0,26
Lack of illness 0,26
Out-of-school curricula experiences 0,26
Volunteer tutors 0,26
Problem-based learning 0,26

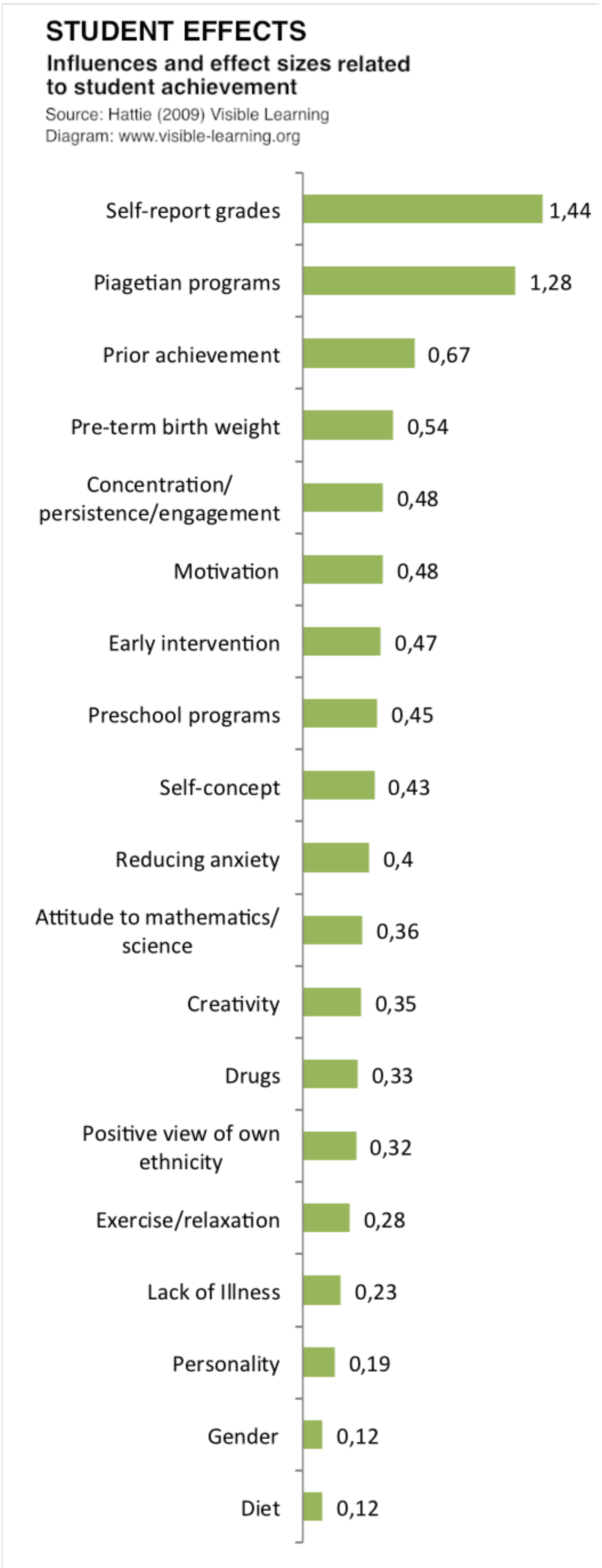

Use of PowerPoint 0,26
Grit/incremental vs. entity thinking 0,25
Adopted vs non-adopted care 0,25
Religious schools 0,24
Competitive vs. individualistic learning 0,24
Intact (two-parent) families 0,23
Summer school 0,23
Teacher personality attributes 0,23
Individualized instruction 0,23
Programmed instruction 0,23
Technology in science 0,23
Teacher verbal ability 0,22
Clickers 0,22
Visual/audio-visual methods 0,22
Finances 0,21
Reducing class size 0,21
Interleaved practice 0,21
Discovery-based teaching 0,21
Technology in small groups 0,21
Student support programs – college 0,21
Extra-curricula programs 0,20
Engaged vs disengaged fathers 0,20
Aptitude/treatment interactions 0,19
Learning hierarchies-based approach 0,19
Co- or team teaching 0,19
Within class grouping 0,18
Web-based learning 0,18
Lack of stress 0,17
Other family structure 0,16
One-on-one laptops 0,16
Home-school programs 0,16
Sentence combining programs 0,15
Parental autonomy support 0,15
Distance education 0,13
Morning vs. evening 0,12
Positive ethnic self-identity 0,12
Juvenile delinquent programs 0,12
School choice programs 0,12
Tracking/streaming 0,12
Mentoring 0,12
Initial teacher training programs 0,12
Different types of testing 0,12
Teacher subject matter knowledge 0,11
Diverse student body 0,10
Background music 0,10
Diversity courses 0,09
Charter schools 0,09
Modifying school calendars/timetables 0,09
Detracking 0,09
Gender on achievement 0,08
Perceptual-motor programs 0,08
Single-sex schools 0,08
Middle schools' interventions 0,08
Mastery goals 0,06
Whole language approach 0,06
College halls of residence 0,05
Teacher performance pay 0,05
Breastfeeding 0,04
Multi-grade/age classes 0,04
Humor 0,04


Humor 0,04
Parental employment 0,03
Student control over learning 0,02
Non-immigrant background 0,01
Open vs. traditional classrooms 0,01
Technology in distance education 0,01
Performance goals -0,01
Summer vacation effect -0,02
Lack of sleep -0,05
Surface motivation and approach -0,11
Family on welfare/state aid -0,12
Parental military deployment -0,16
Television -0,18
Students feeling disliked -0,19
Suspension/expelling students -0,20
Non-standard dialect use -0,29
Retention (holding students back) -0,32
Corporal punishment in the home -0,33
Moving between schools -0,34
Depression -0,36
Boredom -0,49
Deafness -0,61
ADHD -0,90

Appendix B. Hattie's ranking of learning influences by category

Source: https://visible-learning.org/hattie-ranking-influences-effect-sizes-learning-achievement/




STUDENT EFFECTS
Influences and effect sizes related to student achievement
Source: Hattie (2009) Visible Learning
Diagram: www.visible-learning.org
Self-report grades
1,44
Piagetian programs
1,28
Prior achievement
0,67
Pre-term birth weight
0,54
Concentration/ persistence/engagement
0,48
Motivation
0,48
Early intervention
0,47
Preschool programs
0,45
Self-concept
0,43
Reducing anxiety
0,4
Attitude to mathematics/ science
0,36
Creativity
0,35
Drugs
0,33
Positive view of own ethnicity
0,32
Exercise/relaxation
0,28
Lack of Illness
0,23
Personality
0,19
Gender
0,12
Diet
0,12

Appendix C. Influences on student achievement by category

Visible Learning™ 250+ Influences on Student Achievement

CLASSROOM		ES
Classroom composition effects		
Detracking	yellow	0.09
Mainstreaming/inclusion	green	0.25
Multi-grade/age classes	yellow	0.04
Open vs. traditional classrooms	yellow	0.01
Reducing class size	yellow	0.15
Retention (holding students back)	red	-0.32
Small group learning	light blue	0.47
Tracking/streaming	yellow	0.12
Within class grouping	yellow	0.18
School curricula for gifted students		
Ability grouping for gifted students	green	0.30
Acceleration programs	light blue	0.68
Enrichment programs	light blue	0.48
Classroom influences		
Background music	yellow	0.10
Behavioral intervention programs	light blue	0.62
Classroom management	green	0.35
Cognitive behavioral programs	green	0.29
Decreasing disruptive behavior	green	0.34
Mentoring	yellow	0.12
Positive peer influences	light blue	0.53
Strong classroom cohesion	light blue	0.53
Students feeling disliked	red	-0.19

TEACHER		ES
Teacher attributes		
Average teacher effects	green	0.32
Teacher clarity	dark blue	0.75
Teacher credibility	dark blue	1.09
Teacher estimates of achievement	dark blue	1.29
Teacher expectations	light blue	0.43
Teacher personality attributes	green	0.24
Teacher performance pay	yellow	0.05
Teacher verbal ability	green	0.22
Teacher-student interactions		
Student rating of quality of teaching	light blue	0.45
Teachers not labeling students	light blue	0.44
Teacher-student relationships	light blue	0.48
Teacher education		
Initial teacher training programs	yellow	0.10
Micro-teaching/video review of lessons	dark blue	0.88
Professional development programs	green	0.37
Teacher subject matter knowledge	green	0.23

STUDENT LEARNING STRATEGIES		ES
Strategies emphasizing student meta-cognitive/ self-regulated learning		
Elaboration and organization	dark blue	0.75
Elaborative interrogation	light blue	0.56
Evaluation and reflection	dark blue	0.75
Meta-cognitive strategies	light blue	0.55
Help seeking	dark blue	0.72
Self-regulation strategies	light blue	0.52
Self-verbalization and self-questioning	light blue	0.59
Strategy monitoring	light blue	0.58
Transfer strategies	dark blue	0.86
Student-focused interventions		
Aptitude/treatment interactions	yellow	0.11
Individualized instruction	green	0.23
Matching style of learning	green	0.32
Student-centered teaching	green	0.36
Student control over learning	yellow	0.02
Strategies emphasizing student perspectives in learning		
Peer tutoring	light blue	0.51
Volunteer tutors	light blue	0.51
Learning strategies		
Deliberate practice	dark blue	0.79
Effort	dark blue	0.77
Imagery	light blue	0.51
Interleaved practice	light blue	0.47
Mnemonics	dark blue	0.80
Note taking	light blue	0.51
Outlining and transforming	light blue	0.66
Practice testing	light blue	0.46
Record keeping	light blue	0.52
Rehearsal and memorization	dark blue	0.73
Spaced vs. mass practice	light blue	0.65
Strategy to integrate with prior knowledge	dark blue	0.93
Study skills	light blue	0.45
Summarization	dark blue	0.74
Teaching test taking and coaching	green	0.30
Time on task	light blue	0.44
Underlining and highlighting	light blue	0.44

TEACHING STRATEGIES		ES
Strategies emphasizing learning intentions		
Appropriately challenging goals	light blue	0.59
Behavioral organizers	light blue	0.42
Clear goal intentions	light blue	0.51
Cognitive task analysis	dark blue	1.29
Concept mapping	light blue	0.64
Goal commitment	light blue	0.40
Learning goals vs. no goals	light blue	0.51
Learning hierarchies-based approach	yellow	0.19
Planning and prediction	dark blue	0.76
Setting standards for self-judgement	dark blue	0.75
Strategies emphasizing success criteria		
Mastery learning	light blue	0.61
Worked examples	green	0.37
Strategies emphasizing feedback		
Classroom discussion	dark blue	0.82
Different types of testing	yellow	0.12
Feedback	light blue	0.66
Formative evaluation	green	0.34
Questioning	light blue	0.48
Response to intervention	dark blue	1.09
Teaching/instructional strategies		
Adjunct aids	green	0.35
Collaborative learning	green	0.34
Competitive vs. individualistic learning	green	0.24
Cooperative learning	light blue	0.40
Cooperative vs. competitive learning	light blue	0.53
Cooperative vs. individualistic learning	light blue	0.55
Direct instruction	light blue	0.59
Discovery-based teaching	green	0.21
Explicit teaching strategies	light blue	0.57
Humor	yellow	0.04
Inductive teaching	light blue	0.44
Inquiry-based teaching	light blue	0.46
Jigsaw method	dark blue	1.20
Philosophy in schools	light blue	0.43
Problem-based learning	green	0.35
Problem-solving teaching	light blue	0.67
Reciprocal teaching	dark blue	0.74
Scaffolding	light blue	0.58
Teaching communication skills and strategies	light blue	0.43

TECHNOLOGY, SCHOOL, & OUT-OF-SCHOOL STRATEGIES		ES
Implementations using technologies		
Clickers	green	0.22
Gaming/simulations	green	0.34
Information communications technology (ICT)	light blue	0.48
Intelligent tutoring systems	light blue	0.51
Interactive video methods	light blue	0.54
Mobile phones	light blue	0.43
One-on-one laptops	yellow	0.16
Online and digital tools	green	0.26
Programmed instruction	green	0.23
Technology in distance education	yellow	0.01
Technology in mathematics	green	0.33
Technology in other subjects	light blue	0.55
Technology in reading/literacy	green	0.29
Technology in science	green	0.23
Technology in small groups	green	0.21
Technology in writing	light blue	0.42
Technology with college students	light blue	0.42
Technology with elementary students	light blue	0.44
Technology with high school students	green	0.30
Technology with learning needs students	light blue	0.57
Use of PowerPoint	green	0.26
Visual/audio-visual methods	green	0.22
Web-based learning	green	0.33
Implementations using out-of-school learning		
After-school programs	light blue	0.40
Distance education	yellow	0.14
Home-school programs	yellow	0.16
Homework	green	0.29
Service learning	light blue	0.58
Implementations that emphasize school-wide teaching strategies		
Co- or team teaching	yellow	0.19
Interventions for students with learning needs	dark blue	0.77
Student support programs – college	green	0.21
Teaching creative thinking	green	0.37
Whole-school improvement programs	green	0.28

Key for rating

- ● (dark blue) Potential to considerably accelerate student achievement
- ● (light blue) Potential to accelerate student achievement
- ● (green) Likely to have positive impact on student achievement
- ● (yellow) Likely to have small positive impact on student achievement
- ● (red) Likely to have a negative impact on student achievement
- **ES** Effect size calculated using Cohen's *d*

The Visible Learning™ research synthesises findings from **1,600+** meta-analyses of **95,000+** studies involving **300** million students, into what works best in education.

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Visible Learning™ 250+ Influences on Student Achievement

STUDENT		ES
Prior knowledge and background		
Field independence	dark blue	0.94
Non-standard dialect use	red	-0.29
Piagetian programs	dark blue	1.28
Prior ability	dark blue	0.98
Prior achievement	light blue	0.59
Relating creativity to achievement	green	0.35
Relating high school to university achievement	light blue	0.60
Relating high school achievement to career performance	green	0.38
Self-reported grades	dark blue	1.33
Working memory strength	light blue	0.66
Beliefs, attitudes and dispositions		
Attitude to content domains	light blue	0.46
Concentration/persistence/ engagement	light blue	0.54
Grit/incremental vs. entity thinking	green	0.25
Mindfulness	green	0.28
Morning vs. evening	yellow	0.12
Perceived task value	light blue	0.46
Positive ethnic self-identity	yellow	0.12
Positive self-concept	light blue	0.47
Self-efficacy	dark blue	0.71
Stereotype threat	red	-0.33
Student personality	green	0.30
Motivational approach, orientation		
Achieving motivation and approach	light blue	0.42
Boredom	red	-0.47
Deep motivation and approach	light blue	0.57
Depression	red	-0.26
Lack of stress	yellow	0.17
Mastery goals	yellow	0.06
Motivation	green	0.38
Performance goals	red	-0.01
Anxiety	red	-0.44
Surface motivation and approach	red	-0.14
Physical influences		
ADHD	red	-0.90
ADHD – treatment with drugs	green	0.32
Breastfeeding	yellow	0.04
Deafness	red	-0.61
Exercise/relaxation	green	0.21
Gender on achievement	yellow	0.08
Illness	red	-0.44
Lack of sleep	red	-0.05
Full compared to pre-term/low birth weight	light blue	0.57
Relative age within a class	light blue	0.45
Bullying	red	-0.20

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CURRICULA		ES
Reading, writing and the arts		
Comprehensive instructional programs for teachers	dark blue	0.72
Comprehension programs	light blue	0.55
Drama/arts programs	light blue	0.42
Exposure to reading	light blue	0.43
Music programs	green	0.30
Phonics instruction	light blue	0.60
Repeated reading programs	dark blue	0.75
Reading Recovery	light blue	0.53
Sentence combining programs	yellow	0.15
Spelling programs	light blue	0.58
Visual-perception programs	light blue	0.55
Vocabulary programs	light blue	0.63
Whole language approach	yellow	0.06
Writing programs	light blue	0.46
Math and sciences		
Manipulative materials on math	green	0.30
Mathematics programs	light blue	0.59
Science programs	light blue	0.56
Use of calculators	green	0.27
Other curricula programs		
Bilingual programs	green	0.36
Career interventions	green	0.38
Chess instruction	green	0.34
Conceptual change programs	dark blue	0.99
Creativity programs	light blue	0.64
Diversity courses	yellow	0.09
Extra-curricula programs	green	0.20
Integrated curricula programs	light blue	0.47
Juvenile delinquent programs	yellow	0.12
Motivation/character programs	green	0.35
Outdoor/adventure programs	light blue	0.43
Perceptual-motor programs	yellow	0.08
Play programs	light blue	0.50
Social skills programs	green	0.37
Tactile stimulation programs	light blue	0.58

HOME		ES
Family structure		
Adopted vs non-adopted care	green	0.25
Engaged vs disengaged fathers	green	0.21
Intact (two-parent) families	green	0.22
Other family structure	yellow	0.16
Home environment		
Corporal punishment in the home	red	-0.33
Early years' interventions	light blue	0.44
Home visiting	green	0.29
Moving between schools	red	-0.30
Parental autonomy support	yellow	0.12
Parental involvement	light blue	0.45
Parental military deployment	red	-0.16
Positive family/home dynamics	light blue	0.52
Television	red	-0.18
Family resources		
Family on welfare/state aid	red	-0.12
Non-immigrant background	yellow	0.01
Parental employment	yellow	0.03
Socio-economic status	light blue	0.52

SCHOOL		ES
Leadership		
Collective teacher efficacy	dark blue	1.39
Principals/school leaders	green	0.37
School climate	light blue	0.43
School resourcing		
External accountability systems	green	0.20
Finances	green	0.21
Types of school		
Charter schools	yellow	0.04
Religious schools	green	0.24
Single-sex schools	yellow	0.08
Summer school	yellow	0.19
Summer vacation effect	yellow	0.02
School compositional effects		
College halls of residence	yellow	0.05
Desegregation	green	0.28
Diverse student body	yellow	0.10
Middle school internventions	yellow	0.18
Out-of-school curricula experiences	yellow	0.07
School choice programs	yellow	0.12
School size (600-900 students at secondary)	light blue	0.43
Other school factors		
Counseling effects	green	0.35
Modifying school calendars/ timetables	yellow	0.09
Pre-school programs	green	0.28
Suspension/expelling students	red	-0.20

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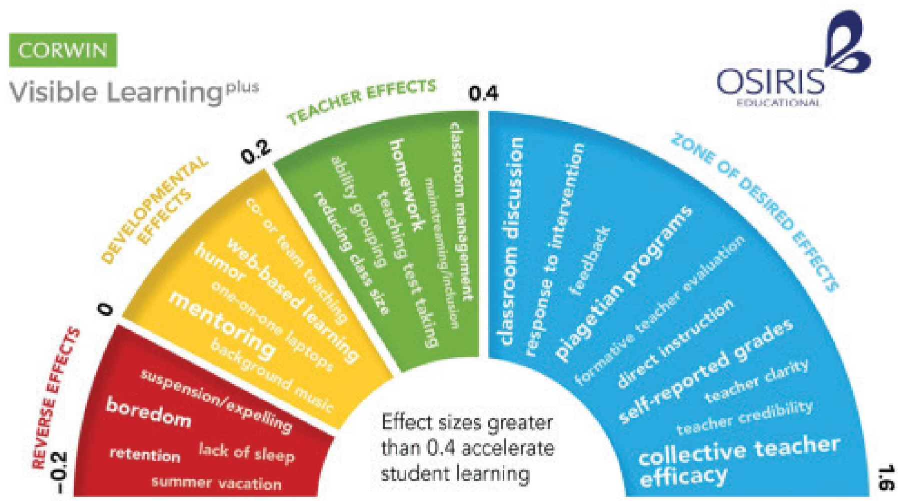
Appendix D. Visible Learning barometer of influences

Source: https://visible-learning.org/wp-content/uploads/2022/01/Influences-overview-Visible-Learning.pdf



Desired Effects

Collective teacher efficacy	1.57	Classroom discussion	.82
Self-reported grades	1.33	Teacher clarity	.75
Response to intervention	1.29	Feedback	.70
Piagetian programs	1.28	Direct instructions	.60
Teacher credibility	.90	Formative teacher evaluation	.48

Typical Teacher Effects

Classroom management	.35	Homework	.29
Ability grouping	.30	Mainstreaming/inclustion	.27
Teaching test taking	.30	Class size	.21

Developmental Effects

Co-/team teaching	.19	Mentoring	.12
Web-based learning	.18	Background music	.10
One-on-one laptops	.16	Humor	.04

Reverse Effects

Summer vacations	-.02	Suspension/expelling	-.20
Lack of sleep	-.05	Moving Between Schools	-.34
Retention	-.32	Boredom	-.49