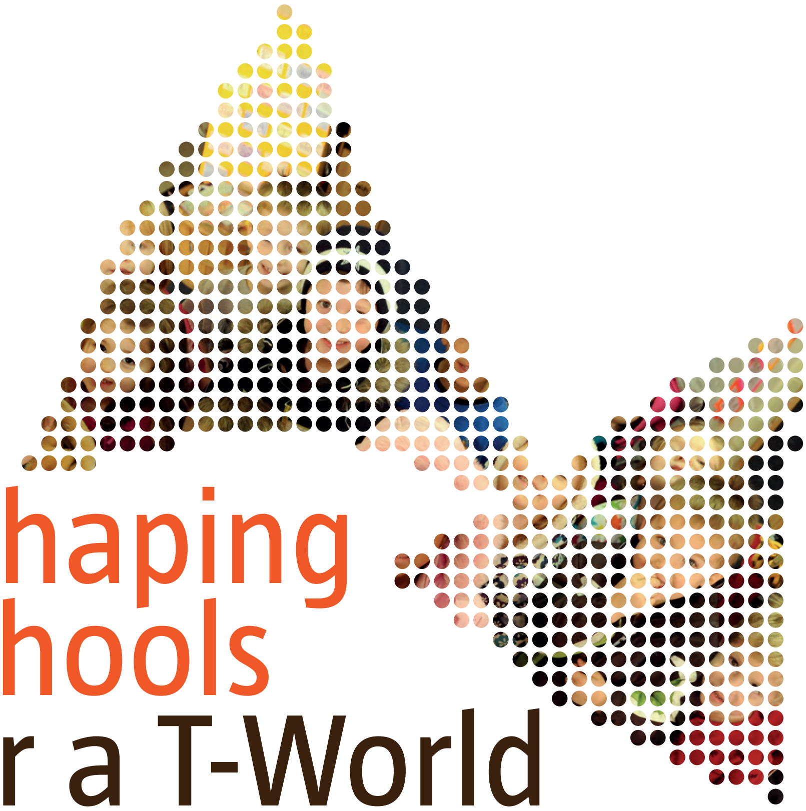
Reshaping Schools for a T-World

Plataforma para o CRESCIMENTO SUSTENTÁVEL



Reshaping Schools for a T-World

Plataforma para o CRESCIMENTO SUSTENTÁVEL

Wilfried Martens Centre for European Studies

FUNDAÇÃO CALOUSTE GULBENKIAN

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ABOUT PCS

The Plataforma para o Crescimento Sustentável (PCS)/ Platform for Sustainable Growth (PCS) was launched in October 2011 as an independent, non-profit organisation, with no party affiliation. With active public participation and in coordination with national and international R&D centers and think tanks, the PCS contributes towards asserting a sustainable development model.

PCS has established partnerships with the following think tanks and foundations: BRUEGEL (Belgium), Centre for European Policy Studies-CEPS (Belgium), ASTRID (Italy), REFORM (United Kingdom), RESPUBLICA (United Kingdom), Wilfried Martens Centre for European Studies (Belgium), ENTORNO (Spain), Konrad Adenauer Foundation (Germany). The leaders of these institutions are members of PCS's Advisory Board, chaired by Francisco Pinto Balsemão.

PCS engages almost 400 members in Portugal – recognised leaders and experts from private sector, academia, government and NGOs – working, as volunteers, within several working groups and thematic areas.

With the publication and public discussion of the Report for Sustainable Growth PCS accomplished its initial mission of identifying key strategic challenges toward the growth of Portugal. After achieving this goal, PCS expanded its annual work plans to include thematic debate series and conferences, original research and policy papers in addition to our original 'crowdthinking' reports based on the ideas and contribution of PCS's members. PCS's main focus and end goal is to generate public policy ideas on the many issues addressed including, but not limited to, climate change, energy, health, education, competitiveness and growth, globalization and citizenship.

The publication Reshaping Schools for a T-World is the fifth in a series of in-house research projects. In-house research consist in original studies produced by visiting research fellows, who remain at PCS throughout the duration of each project.

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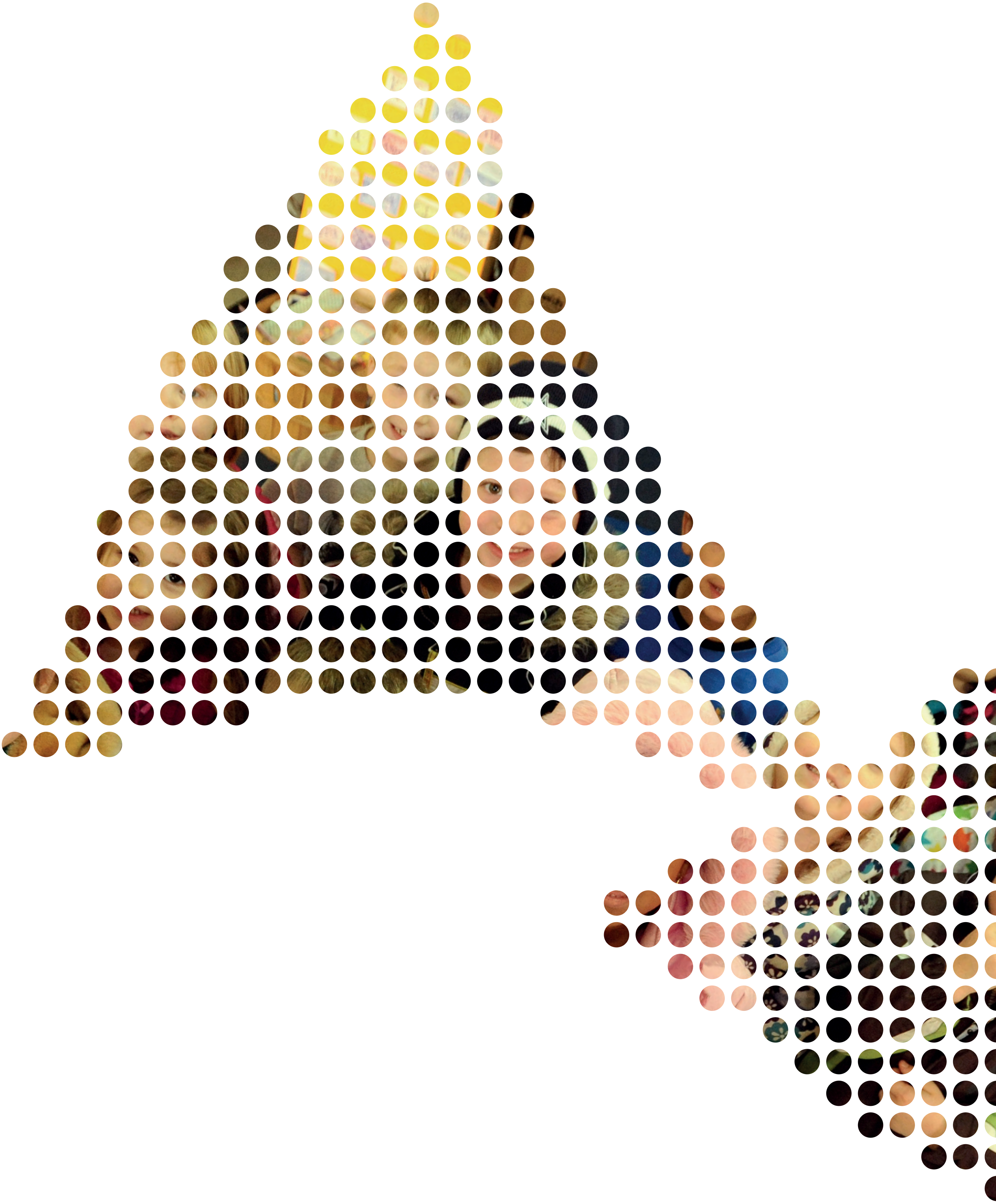
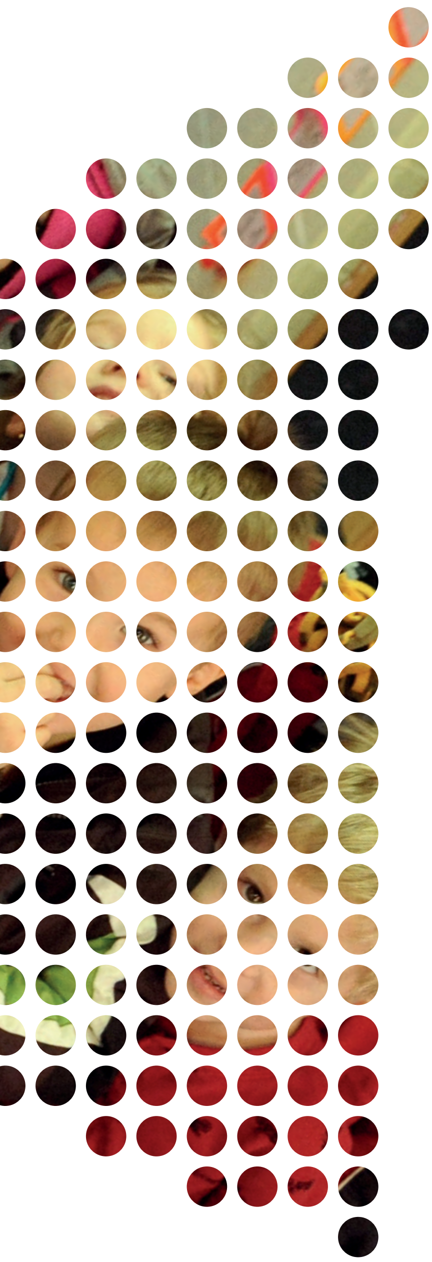




Sumário Executivo

Reshaping Schools for a T-World é um relatório que aborda o papel das escolas e dos professores num mundo tecnologicamente enriquecido. Não se trata de analisar o modo como os sistemas educativos devem incorporar a tecnologia nos processos de ensino e aprendizagem, mas principalmente o modo como a tecnologia está a mudar o papel tradicional das escolas e dos professores. O impacto previsível da 4ª revolução industrial vai muito além das questões associadas à produção e outros aspectos da nossa vida produtiva. O *big data*, a internet das coisas, a inteligência artificial, a robótica, concorrem para mudar radicalmente o modo como trabalhamos, mas também o modo como vivemos e organizamos as nossas sociedades. Estas alterações – a T-Wave – requerem que os humanos adquiram novas capacidades, mas exigem principalmente que nos foquemos no que significa 'ser' humano em termos mais profundos. Os sistemas educativos, porque estão ao serviço das gerações futuras, têm de se preparar para surfar a T-Wave.
No relatório *Reshaping Schools for a T-World* identificamos cinco desafios que os sistemas educativos enfrentam – **missão, estrutura, conteúdo, método** e **tecnologia**, que exigem uma reacção estratégica em cinco domínios. Para cada desafio apresentamos a sua fundamentação, exemplos de práticas em diferentes países e prestadores, e fazemos recomendações. Os cinco desafios são:

- **Missão**: um novo papel para as escolas e os professores. Esta nova função é a de guardiões educativos e implica: desenhar o currículo, alinhar os métodos com as características de cada aluno, certificar resultados educativos, ser tutor e mentor, desenhar o percurso curricular individual dos alunos e apoiá-los ao longo desse percurso, certificar conhecimentos e competências adquiridos.
- **Estrutura:** reestruturar o tempo e o espaço – novos ambientes educativos. Um novo paradigma educational para o T-World exige uma conceção diferente da organização do tempo e do espaço, de modo a promover a flexibilidade, adaptabilidade e inovação. As escolas devem poder organizar ambientes educativos de geometria variável, respondendo a diferentes ritmos de aprendizagem e necessidades cinéticas dos alunos; adaptar o espaço a diferentes processos de aprendizagem; gerir livremente o tempo. Os sistemas educativos necessitam de relevar e integrar formalmente diferentes 'espaços curriculares', para além da sala de aula, tais como museus, jardins, fábricas, universidades e outros equipamentos.
- **Conteúdo:** enfoque na criatividade. Na 4ª revolução industrial, a criatividade é o 'novo capital'. A educação tem de ir para além da transmissão de informação e deve ensinar como transformá-la em conhecimento e promover a criatividade. Isto implica que as próprias escolas se tornem organizações criativas.
- **Método:** interdisciplinaridade, fertilização cruzada de áreas científicas e desenvolvimento integral do aluno. Estes não são desafios novos, mas o advento do T-World torna mais urgente dar-lhes resposta. A economia de base criativa do T-World requer a capacidade de fazer abordagens pluridisciplinares à realidade e de aprender de modo colaborativo. Por outro lado, o foco no que é especifi-

camente humano, por oposição a uma realidade digital cada vez mais alargada, torna essencial uma educação integral.
- **Tecnologia:** integração e desenvolvimento das novas tecnologias digitais. Num mundo tecnologicamente enriquecido, as escolas não podem deixar de utilizar artefactos digitais para aumentar a eficiência dos processos de ensino e de aprendizagem. Mas isso não esgota a questão. É também necessário questionar o que os alunos têm de aprender sobre tecnologia para viver no T-World, quer seja código, ferramentas digitais avançadas ou pensamento computacional.

No **capítulo um** analisamos a T-Wave, os seus impactos no nosso futuro e os desafios que coloca aos sistemas educativos. No **capítulo dois**, apresentamos cada desafio em mais detalhe, argumentando porque é que a tecnologia está a mudar paradigmas na educação. O **capítulo três** é dedicado a exemplos de esforços que estão a ser feitos em diversos países e por diversos operadores, e à apresentação de recomendações. No **capítulo quatro** descrevemos a situação portuguesa. Como o país construiu o seu sistema educativo, o que explica a sua estrutura atual e como se pode preparar para surfar a T-Wave. A partir das recomendações apresentadas no capítulo três, são feitas propostas de iniciativas políticas para responder a cada desafio, fundamentadas na situação atual. As propostas para Portugal são:

Para exercer a sua função no T-World, as escolas portuguesas devem:
1. Recrutar docentes de um conjunto mais alargado de talentos;
2. Diversificar os seus recursos humanos;
3. Deter o poder de desenhar o currículo e avaliar os alunos, reconhecendo o valor das aprendizagens feitas fora da escola e dos percursos educativos individuais.

Para os docentes exercerem a sua função no T-World, o sistema educativo português deve:
1. Seleccionar os candidatos à formação inicial de docentes nos quartis superiores de sucesso no secundário;
2. Requerer o mestrado (2º ciclo de Bolonha) como um ponto de partida da qualificação dos docentes, mas ter como ambição que uma percentagem significativa obtenha o grau de doutor ao longo da carreira;
3. Assegurar que todos os docentes realizam formação contínua e se especializam não apenas na sua área científica, mas também num campo do saber de índole pedagógica (avaliação, metodologia ou neurociências aplicadas ao ensino).

Para aproveitar as possibilidades criadas pelo T-World, as escolas devem:
1. Organizar ambientes educativos que incluam recursos exteriores à escola, integrando a comunidade e ultrapassando os seus muros de cimento;
2. Aceitar o que é aprendido em ambientes informais como parte integral do percurso educativo do aluno.

Para educar alunos criativos, o sistema de ensino português deve:

1. Promover a inclusão das artes e outras expressões no currículo;
2. Promover a diversidade das ofertas de ensino, permitindo a criação de escolas com temas ou escolas de escolha, onde os alunos encontram um foco especial em áreas do seu interesse pessoal.

Para promover no sistema educativo português a interdisciplinaridade, fertilização cruzada de áreas científicas e desenvolvimento integral do aluno, é necessário:

1. Professores com formação alargada a diversos domínios;
2. Que as tarefas, objetivos educativos e avaliação sejam definidos tendo em conta que o mesmo fenómeno pode contribuir para a aprendizagem de diferentes áreas do saber.

Para integrar a tecnologia no sistema educativo português, do modo abrangente como foi definido, é necessário:

1. Repensar o financiamento das escolas, de modo a que possam dispor de meios financeiros suficientes para adquirir, manter e atualizar recursos educativos tecnológicos;
2. Incentivar o desenvolvimento de inteligência artificial para a educação;
3. Integrar pensamento computacional e competências digitais no currículo.

Finalmente, o **capítulo cinco** começa com uma análise das principais questões que se colocam numa reforma educativa e termina focando o principal objetivo dos sistemas educativos no T-World: contribuir para o desenvolvimento de uma sociedade próspera e centrada na pessoa.

Terminamos com uma referência final, mas importante, à inclusão e coesão social. Habitualmente, a tecnologia e os seus impactos são apresentados como instrumentos promotores de iniquidade e exclusão. Claro que há um risco real de aqueles que ficam fora do 'T' acabarem a viver num 'Mundo' paralelo. Mas isto é um risco comum às revoluções industriais anteriores. Então, como agora, o sistema escolar era um meio indispensável de integração e coesão. Se formos bem sucedidos a *Reestruturar as Escolas para o T-World*, temos boas hipóteses de conseguirmos atingir o objetivo de uma sociedade sustentável, humanista e para todos.

Abstract

Reshaping Schools for a T-World is a report about the role of schools and teachers in a technological rich world. It is not only about how education systems should incorporate technology in the educational processes, but mainly about how technology is changing the roles of schools and teachers. The foreseeable impact of the 4th industrial revolution goes far beyond manufacturing and other productive aspects of our life. Big data, the internet of things, artificial intelligence, robotics, all concur to radically change the way we work, but also the way we live and the way we organise our societies. These changes – the T-Wave – will require new skills and competences from humans but will also force us to focus on what it means to be human in a more fundamental way. Education systems, because they cater for the future generations, must be prepared to surf the T-Wave.

We have identified five domains – **purpose, struture, content, method** and **technology** – that pose challenges to educational systems and require strategic action. For each challenge we present the rational, provide examples of good practices from different countries and providers and offer recommendations. The five challenges are:

- **Purpose:** a new role for schools and teachers. This new role is that of educational gateways: curriculum design, aligning methods to the individual student's profile, certification of students' attainments, tutoring and mentoring, designing individual curricular pathways for students, supporting the student through that path and certify knowledge and competencies.
- **Structure:** restructuring time and space – new learning environments. The new education paradigm demands a different organisation of time and space, able to foster flexibility, adaptability, innovation. Schools must be able to organise learning settings in variable ways, responding to different learning rhythms and to kinetic needs of students; to adapt space and time to the different learning processes; and to freely manage time. The education system also needs to consider and to integrate different 'curricular spaces', in addition to the formal classroom, such as museums, parks, factories, universities and other facilities.
- **Content:** focus on creativity. In the 4th industrial revolution, creativity seems to be 'the new capital'. Meaning that education needs to go beyond the role of giving information and teaching how to turn it into knowledge and promote creativity. This implies that schools themselves become creative in their action.
- **Method:** interdisciplinarity, cross-fertilisation of scientific areas and whole child development. Though these are not new challenges, the development of the T-World makes them more urgent. The creative-based economy of a T-World requires greater cross-fertilisation and collaborative learning inside and across specialised areas. The need to focus on what is specifically human makes a holistic approach to education indispensable.

• **Technology:** integration and development of new technologies. In a technology rich world, school are unable to avoid using technological artefacts to boost efficiency of teaching and learning processes. But this does not suffice. We also have the question of what students need to learn about technology to function in the T-World. Be it coding, advanced digital tools or computer thinking.

In **chapter one** we analyse the T-Wave, its impacts on our future and the challenges that arise for education systems. In **chapter two** we present these challenges in more detail, arguing why technology is changing paradigms in education. **Chapter three** is dedicated to examples of efforts being made worldwide to address these challenges and offering recommendations. **Chapter four** is dedicated to the Portuguese context. How did the country build the education system it has today, what explains its current structure and how it may prepare to surf the T-Wave. Based on the recommendations presented in chapter three, we formulate policy proposals for Portugal. Finally, in **chapter five** we briefly address the main issues of educational reform and end focusing on the aim of educational systems in a T-World: contributing to the development of a prosperous human-centred society.
The recommendations presented in chapter three are:

To perform their new rule in a T-World, schools should:

1. Recruit teachers from a larger talent pool;
2. Diversify the human resources that staff or support each school;
3. Have the power to design curriculum and assess attainment, recognising the value of learning outside the school and of individualised learning paths;
4. Include community participation in their governance models to democratically legitimate the schools' curriculum autonomy.

For teachers to perform their new role in a T-World, school system should:

1. Select students going into initial teacher education from the top percentiles of their generation;
2. Require a master degree (2nd cycle of Bolonha) for teacher qualifications, as a starting point with the aim that a reasonable amount of teachers obtain a mid-career PhD;
3. Require that teacher initial education courses are research-based demanding courses; cover both humanities and sciences, notwithstanding specific disciplinary focus;
4. Have alternative certification paths so people may come into teaching from other careers;
5. Assure that all teachers do continuous training and specialise not only in one subject but also in one pedagogical related field (assessment, methods, neurosciences applied to learning).

To restructure for a T-World, schools should:

1. Adopt more flexible ways of grouping students, assessing which is the best at different times and stages of each one's learning path;
2. Structure time according to the specific activities at hand, and the individual needs and stages of each student;
3. Adopt a new architectural paradigm that goes from matchbox-type classrooms organised in long corridors to more flexible and adaptable spaces;
4. Organise learning environments including resources outside the school, embedding the community and overcoming brick and mortar boundaries;
5. Accept what is learned in informal contexts as an integral part of each student's learning path.

To educate creative students, school systems should:

1. Promote the inclusion of arts and other expressions in the regular curriculum and incentivise schools to value arts as much as literacy or numeracy;
2. Promote diversity in the public education offer, allowing the creation of thematic schools or schools of choice, where students have a special focus on their personal interests;
3. Adopt an entrepreneurial approach to education, providing students with tasks and projects that foster a flexible and broad set of competences that will boost their creativity;
4. Broaden assessment instruments so that they encompass soft skills and not only knowledge reproduction.

To foster interdisciplinarity and cross-fertilisation of scientific areas in education systems, we need:

1. A rich and holistic curriculum that encompasses humanities, sciences and arts at all stages of education;
2. Teachers with broad training in different areas;
3. An approach to didactics and methods that, notwithstanding the specific contents of each subject, is focused on larger scientific groupings rather than the individual subjects;
4. Tasks, learning aims and assessment to be defined and executed considering that the same phenomenon may contribute to the learning of different subjects.

To integrate technology in the education system in this broad sense we need:

1. To allocate sufficient funds for schools to acquire, maintain and update technological resources;
2. To incentivise investment in the development of AI applications in education, such as tutors or adaptive assessment systems;
3. To integrate computer thinking and digital competences in the curriculum;
4. To articulate teacher continuous professional development and training with technological developments.

We end with a final, yet important, reference to inclusion and social cohesion. Often, technology and its impacts are presented as an instrument of growing inequity and exclusion. There is, of course, a real danger that those who are left out of the 'T' end up living in a parallel 'World'. But this has been so, even in previous industrial revolutions. And then, like now, schools and school systems are indispensable means of integration and cohesion. If we are successful in *Reshaping Schools for a T-World*, there is a good chance we may meet the goals of a society which is sustainable, humane and for all.

1. The technological wave: challenges for the education system

In 2016, the Platform for Sustainable Growth (Plataforma para o Crescimento Sustentável – PCS) in cooperation with the Wilfried Martens Centre for European Studies (WMCES) published a report on the new technological wave. The report ***Game Changers, Surfing the Wave of Technology Disruption*** [Grilo, 2016] aimed to draw attention to the challenges posed to Portugal by the 4th industrial revolution, considering this country's reality and environment. It discussed how technologies will transform our economy, our jobs and our society and how Portugal must face such transformations. Following this, PCS commissioned a new report, aiming at understanding the challenges brought to education by the new technological wave and, in particular, to the Portuguese education system.

The 4^{th} industrial revolution is not only a matter of technology and production. Due to the speed and reach of change, it also challenges the way society adapts to the new patterns of work, communication and lifestyles. The societal impacts of technology are just as challenging to the way we live in general as they are to the way we work in particular. As we evolve into a technological enriched future, we should think about the people who build and will live in that future with a new and different approach. Until now, societal responses to the T-Wave are inorganic and reactive. We try to keep up with technology, incorporating it in our life, but we do not have a broader strategy for guiding the way. Algorithms are pushing the future; we need to create the androrithms that will shape it [Leonhard, 2016].

The T-Wave, or 4^{th} industrial revolution, spanning the 5 scientific domains identified in the ***Game Changers*** report (digital, robotics, genomics, advanced materials and energy), poses great challenges for governments, policy makers, regulators, corporations and individuals. Even if not completely recognised by national education systems, the disruption caused by these changes has put new strains on education systems. For some authors, because the modern school is a structure typical of the 21th century industrial organization, fine tuning the system is not enough; it needs to be completely redesigned [Sahlberg, 2015].

The depth of change is something for politicians to decide. Our aim here is to pinpoint the challenges brought to education systems by the T-Wave, to propose ways they may be faced and to analyse the Portuguese situation (how we got here and how we can surf this wave). As emphasised in the ***Game Changers*** report, there is a need to set up "an educational contract for the technological wave" [Grilo, 2016: 11]. Change in the education system as discussed in this report is not just a new fad; neither is it simply about competitive advantage. It is an absolute necessity to foster an integrated, peaceful, sustainable society where people may ambition to live a long and happy life. Indeed, education "includes the development of skills, values, attitudes and knowledge that enable citizens to lead healthy and fulfilled lives, make informed decisions and respond to local and global challenges" [Unesco, 2015: 33].

But what is the T-World and why does it imply reshaping schools?

Technology has always shaped the way we work and live. It was so when man learned how to make fire and started dominating other animals, it was so when we learned how to grow crops and came out of the woods and into the cities and so it was when we learned how to mechanise production. What is different about the 4th industrial revolution is: **(i)** the speed of change, **(ii)** the fact that technology has become ubiquitous (it is everywhere), and **(iii)** the unfolding capacity of technology to "work" independently of humans. These characteristics of the 4th industrial revolution have permitted technology to bridge the gap between the digital and the physical worlds playing an even more central and dominant role in our life.
It is no wonder that production lines do not have workers, stores do not have salesmen or cars do not need drivers. But we still distrust newspaper articles without journalists, market analysis without analysts, legal analysis done by algorithms or computer programs being written by the machines themselves. The speed of technological development has reached a point where the possibility that we will live to see singularity (the capability of technology to develop, independent of human intervention) is no longer in the realm of science fiction. "The whole beauty of all these types of algorithms is that because they are learning for themselves, they can go beyond what we, as the programmers, know how to do. And that allows us to make new breakthroughs in areas as sciences and medicine" [Hassabis, 2017].

In previous industrial revolutions, schools have played a central role in preparing workers for the "new world" that was in the making: from basic literacy and numerical skills for the future factory worker, to advanced literacy and numerical skills for the "knowledge worker" [Drucker, 1996]. Likewise, school systems today try to adapt to the foreseeable demands of the T-World. However, the rapid pace of change denies modern school systems the time their predecessors had to prepare students for the challenges of their adult lives. Moreover, in previous industrial revolutions, school's monopoly on teaching and learning was not affected. The incumbent could afford to get it wrong.
This is not so in the T-World. Alternative technological enriched learning environments are available, just a click away. Information, and not only data, is available and affordable. Developments in artificial intelligence promise to customise teaching and learning. As in all other walks of life, schools should not try to beat technology – they would probably lose. The challenge is to do what technology cannot and to integrate technology when doing the rest. "In a nutshell, the kind of things that are easy to teach have become easy to digitise and automate. The future is about pairing the artificial intelligence of computers with the cognitive, social and emotional skills, and values of human beings" [Schleicher, 2018: 14].

The speed of change has made useless our efforts to prepare students for a certain world. It is no longer possible to prepare students for 'the' future; we prepare them for 'a' future, an unpredictable one. On the one hand, this implies a much broader scope of knowledge and competences. On the other hand, it also implies a different set of tools as they will be expected, in a degree unknown to previous generations, to be able to create and determine that future.

"Concurrent to the technological revolution are a set of broader socio-economic, geopolitical and demographic drivers of change, each interacting in multiple directions and intensifying one another, and having profound implications on the way we live, we socialise and the jobs we will have in the future" [World Economic Forum, 2016: V]. Thus, education and training systems need to consider the need to create strategies to regulate the learning experiences and to promote the development of skills, competences and 'languages', so that people can adapt to different ways to relate, communicate, socialise and work, and to different notions of time and space.

Consequently, traditional education approaches, based on knowledge acquisition and reproduction models, are increasingly being replaced by learning strategies based on knowledge creation and innovative and interactive models, making learning more and more adaptive, personalised and blended and contributing to the creation of innovative learning ecosystems [Bonk and Graham, 2006; LLL Platform, 2017]. The development of technology sets new demands for the learning landscape as "learning takes place in both formal and informal environments, locally and globally, both virtually and socially" [Lonka, 2012: 26].

mass education,
mass production,
mass movements,
mass media,
mass consumption
brought us
to where we are.

Millions
have come out
of poverty,
human
development
boosted.

BUT

societal stress, rising disparity
between rich and poor,
ecological strains

THEN

4.0 industrial revolution

=

from mass production to custom made, just in time
from mass movements to individual adherence
boosted by social media
from mass media to individual tailored news consumption

SO

mass education for the 1.0 industrial paradigm is out
– the focus goes from giving tools to function
in a pre-ordained world to developing/helping
people to fulfill their humanity

I. Commitment to the 21st century skills agenda

In such a rapidly evolving landscape, the ability to anticipate and prepare for future skills requirements "is increasingly critical for businesses, governments and individuals in order to fully seize the opportunities presented by these trends and to mitigate undesirable outcomes". To take an example, "in many industries and countries, the most in-demand occupations or specialties did not exist 10 or even five years ago, and the pace of change is set to accelerate. By one popular estimate, 65% of children entering primary school today will ultimately end up working in completely new job types that don't yet exist" [World Economic Forum, 2016: 3].

Recent data from the OECD also indicate that "about 14% of jobs in OECD countries are highly automatable. Another 32% of jobs could face substantial change in how they are carried out. The highest risk is concentrated in routine jobs with low skill requirements and often low wages (...). Entering the labour market may become more difficult for young people as student jobs and entry-level positions have a higher risk of automation than jobs held by older workers" [OECD, 2018c: 1].

Furthermore, on average, by 2020, more than a third of the desired core skill sets of most occupations will be comprised of skills that are not yet considered crucial to a job today. Overall, social skills – such as persuasion, emotional intelligence and teaching others – and cognitive skills – such as creativity, logical reasoning and problem sensitivity – will be in higher demand than narrow technical skills, such as programming or equipment operation and control [World Economic Forum, 2016]. Indeed, more than technical and digital skills, cognitive skills, will be determinant. In this context, computational thinking brings a new insight to the skills of the future. Contrary to one might think, it does not mean getting humans to think like computers, but to think at multiple levels of abstraction; to solve problems, to manage our daily life, to communicate and to interact with other people using computational concepts; to understand intellectually challenging and engaging scientific problems; to develop a fundamental skill which enables us to go on to a multitude of different careers [Wings, 2006].

When one thinks about employment trends, it is evident the necessity to commit with the STEM (Sciences, Technology, Engineering and Mathematics). But it is also evident that the potential net job creation in absolute terms in the STEM field alone will not be enough. "Disruptive changes will have a significant impact on skills requirements in ***all*** job families and that they are creating a range of opportunities and challenges in ***all*** industries, not just narrowly related to 'hard knowledge', technical skills and technology. In order to manage these trends successfully, there is a need for potentially reskilling and upskilling talent from varied academic backgrounds in ***all*** industries" [World Economic Forum, 2016: 25].

Moreover, STEM, together with social and cognitive skills, are not only important for the current job market and for the 'jobs of the future', but for all areas of society and for the citizens living in a world where technology is ubiquitous. In other words, they are crucial to prepare citizens to live and make decisions in a T-World.

Skills commonly referred to as '21st Century Skills' are not all that new. The unprecedented speed and disruption of change caused by the T-Wave make these skills not only desirable but effectively indispensable. Thus, the commitment of international organisations with the 'new skills agenda' is demonstrated by several initiatives, research projects and reports. According to the European Union [2016: 2], skills are "a pathway to employability and prosperity" and "a key to social cohesion".

The ***New Skills Agenda for Europe: working together to strengthen human capital, employability and competitiveness***, a major initiative from the European Union, addresses the skills challenges that Europe is currently facing, stressing priority areas for action. Essentially, it suggests strengthening basic skills, promoting entrepreneurial mindsets, prioritising vocational education and training, focusing on digitals skills, making skills and qualifications more visible and comparable, and improving skills intelligence and information for better career choices [European Union, 2016].

A number of NGOs and conceptual frameworks have been created to aid national school systems to face this challenge:

- **European Reference Framework *"Key Competences for Lifelong Learning"*** emerges as a reference tool, establishing the key competences for lifelong learning strategies, which mainly entail communication, logical thinking, social and civic competences, cultural awareness, innovation and entrepreneurship [European Union, 2006];

- ***"Lifelong Learning Platform"*** (LLLP), gathering several European organisations active in the field of education, raises awareness about the impact of digital technologies in education as well as challenges faced and opportunities offered by the effects of the digital age [LLL Platform, 2017];

- ***"Digital Competences Framework for Citizens"*** (DigComp), which has been supporting the development and strategic planning of digital competence initiatives, emphasises competences such as: information and data literacy, communication and collaboration, digital content creation, safety and problem solving [Carretero, Vuorikari and Punie, 2017];

- ***"Entrepreneurship Competences Framework"*** (EntreComp) offers a conceptual model to improve the entrepreneurial capacity of citizens and organisations.

The research on learning and skills for the digital era has been harnessing the potential of digital technologies to innovate education and training practices, to improve access to lifelong learning and to deal with the rise of new skills and competences needed for personal development, active citizenship and employment [Carretero *et al*., 2017].

Entrepreneurship competences have the potential "to help citizens to develop their ability to actively participate in society, to manage their own lives and careers and to start value-creating initiatives" [Bacigalupo, Kampylis, Punie & Van den Brande, 2016: 10]. The framework underlines the importance of "ideas and opportunities" based competences, such as: supporting opportunities, creativity and vision; "resources" based competences, such as: self-awareness, motivation and perseverance; and "action competences", such as: taking the initiative, working with others and learning through experience [Bacigalupo *et al*., 2016].

The OECD has also been developing extensive research on innovation in education, on the impact of digital technologies on education, and on the role of digital skills and the education industries in the process of innovation [Foray & Raffo, 2012; Hennessy & London, 2013; OECD, 2010b, 2013a, 2013b, 2014, 2016, 2017; Vincent-Lancrin *et al*., 2017].

According to the OECD Innovation Strategy for Education and Training, the innovative capacity of technology is very much conditioned by the level of digital skills of the population, and that is why there is a very strong correlation between education and skills and that the role of education and skills in promoting innovation is critical [OECD, 2016].

Notwithstanding, despite skills for innovation necessarily comprising technical skills, they also incorporate, as stated above, critical thinking and creativity, and behavioural and social skills that help people pursue their critical thinking and creative skills and put their ideas into action. Furthermore, the "innovation imperative in education" and "the power of digital skills and technologies in education" mean that digital technologies have the huge potential to transform education strategies and practices and open up new horizons, but cannot transform education by themselves [OECD, 2016].

In this context, it is also important to bring subjects such as "education for sustainable development" and "global citizenship education" into "the mainstream of formal, non-formal and informal education through system-wide interventions, teacher training, curricular reform and pedagogical support" [Unesco, 2015: 50]. Likewise, humanities cannot be devalued. Instead, their role needs to be recognised by education organisations and by society at large, namely because they "have a central place in exploring the possibilities, the reach and implications of digital technologies" [Davidson and Goldberg, 2004: 4]. Moreover, precisely because of the rapid developments in science and technology, it is important to have critical civic competences, ways of comprehending cultural and technological values, in short, "ways of world making", which are offered by the humanities.
"A world without the humanities would be one in which science and technology knew no point of social reference, had lost their cultural compass and moral scope" [Davidson and Goldberg, 2004: 5].

Overall, the new educational challenges – as a result of the new nature of relations, jobs and ways of life – demand profound educational changes and reforms, where both technical and digital skills, on the one hand, and social, behavioural and creative skills, on the other, play the leading role.

This report was commissioned with the provisional title "New Skills for New Jobs". However, as work progressed, we understood that, though jobs are very important, the T-Wave is not only about jobs, not even mostly about jobs. The T-Wave is changing societal structure as a whole. Therefore, we should think education much beyond preparation for the workforce. This is important, of course. But understanding the T-World and being competent to humanise it must come first if we aim at a peaceful, sustainable, inclusive society.

Tomorrow's skills will drastically change. First, the frontier between management and economics, technology and international relationships tend to disappear. Problems will have a technological and international context.
Second, having into account the speed of technology, the probability of our skills being replaced by machines is increasingly high. In the words of Jack Ma "teaching how to compete with machines is a lost battle". The capacity to judge, to risk, to lead, to care and to motivate will be harder to replace by algorithms. The capacity to unlearn and the flexibility to learn again will be critical.
Third, in volatile and uncertain times, personal motivation and the definition of personal purposes and goals (together with resilience) will be more and more important.
Daniel Traça, *Dean of the Nova School of Business & Economics,* 2018

The societal restructuring our children will face is the real challenge. One does not know where the T-Wave will take us. But if the scenario of a future without jobs [Ford, 2015] may seem desperate for some, for others it may be an opportunity to create a more humane society. And so the title of this report was changed to *Reshaping Schools for a T-World*. The technological developments described will fundamentally change our relation with work and our relation with each other. We may be on the verge of a new period in human development. A period of human fulfilment described by John Adams in a letter to his wife, Abigail Adams, in 1780:

> "I could fill Volumes with Descriptions of Temples and Palaces, Paintings, Sculptures, Tapestry, Porcelaine, &c. &c. &c. – if I could have time. But I could not do this without neglecting my duty. The Science of Government it is my Duty to study, more than all other Sciences: the Art of Legislation and Administration and Negotiation, ought to take Place, indeed to exclude in a manner all other Arts. I must study Politicks and War [so] that my sons may have liberty to study Mathematicks and Philosophy. My sons ought to study Mathematicks and Philosophy, Geography, natural History, Naval Architecture, navigation, Commerce and Agriculture, in order to give their Children a right to study Painting, Poetry, Musick, Architecture, Statuary, Tapestry and Porcelaine" [Adams, 1780].

In innovation and technology-driven societies, education and training systems must empower people to socialise, communicate, work, think time and space in a different manner. The T-Wave is not simply an industrial revolution; it is also changing the way we live and the way we interact with each other and the planet. And just as impressive as the technology in itself, is the pace at which it grows in complexity. Artificial Intelligence is still in its early stages, but what was once science fiction is now reality. Algorithms that learn, adapt and create new algorithms let us wonder how long it will take until man does not understand the technology. The complexity of systems may overrun our capacity to comprehend and rule them. But even today we already know that understanding the way machines 'think' is a basic skill for all students. To the traditional subjects present in basic education all around the world – languages, natural sciences, geography, mathematics, history and arts – we must today add computational thinking, and a pleiad of soft skills beforehand considered a by-product of growing up. Education for the 21st century must ensure that people/learners do not end up as passive technology consumers but active digital citizens. Indeed, individuals are the real game changers who need to steer the change. "It's not digital technology that creates social change, people do!" [LLL Platform, 2017: 4].

II. Education for a T-World

In this new 'era', education systems face different challenges and the setting-up of a new role for the school and for the teacher is perhaps the major and broadest one. But other challenges arise.

In a T-World, schools challenges that educational systems are facing require strategic action in five domains: **purpose, structure, content, method and technology.**

1. **Purpose:** schools must re-assess what is their core mission. What value do they create for children, parents and society as a whole? Subject specific, teacher based content delivery ignores the fundamental fact that today all necessary information is available online at any time, in any place in any given format, flexible and adaptable to the individual need.
2. **Structure:** schools must rethink what to teach and how to teach it (content, time, space and structure). The traditional 19th century brick and mortar school house, with fixed classes, schedules and subjects are a strange structure when compared to all other environments students live in today and, foreseeably, will live and work in the future.
3. **Content:** schools must become creative agents. Education needs to go beyond the role of giving information and teaching how to turn it into knowledge and promote creativity.
4. **Method:** schools must boost cross-fertilisation and collaborative learning inside and across specialised areas and develop a holistic approach to education.
5. **Technology:** schools must integrate technology in the teaching and learning processes. Integrating technology in work processes has been a key feature of all areas of human activity. Surprisingly (or maybe not), school systems are lagging behind. Despite some hype around LMS, smart boards and tablets, digital teaching resources, online tutoring and APPs, school systems as a whole are still far from integrating technology in a meaningful way.

Each of these five domains translates into a challenge for education systems:
(1) a new role for schools and teachers;
(2) restructuring time and space
(3) focus on creativity;
(4) interdisciplinarity and cross-fertilisation of scientific areas and whole child development;
(5) integrating digital technologies in education.

In the next chapters, we will: **(i)** discuss each of these specific challenges; **(ii)** give examples of initiatives, projects, ideas, theories which approach each of them and propose some policy reforms; **(iii)** analyse the particularities of the Portuguese education system and present some policy proposals that may contribute to help the Portuguese education system to face the challenges; and finally **(iv)** present some concluding remarks and reflexions on how can people build successful education and training systems in a changing society.

Challenges for the education system

2.

The new nature of relations, jobs and ways of life brings new challenges to the education systems. Indeed, the new challenges are very broad concerning the educational dimensions they approach, dissimilar from one another but simultaneously closely interrelated. They embrace challenges regarding the relationships between different scientific areas, the role of teachers, the integration of new technologies in education, the articulation between different educational stakeholders and actors, the role of creativity in the development of a 'class' of learners, and the role of institutional and organisational arrangements, and in the learning process.
This report reflects on the five challenges that seem to be key priorities for action in the preparation of school systems to serve the learners of the 21st century.

I. Purpose: a new role for schools and teachers

In the pre-digital world, information and subject specific content was registered in books and people´s heads, books were found in libraries and knowledgeable people were found in schools. Access to the job market, the church or other social structures was granted according to the level of knowledge a person accumulated and, as a fact of life, access to knowledge and social status were correlated.
The traditional school structure was fit for purpose in the pre-digital world: passing on knowledge from the teacher to the largest number of children possible in an efficient way. The school as a factory is an image very adequate to depict this concept.

The school's monopoly on transmitting knowledge has been broken. It is not that knowledge is not important or that students don't need to acquire and master abstract concepts. But ICT has made information available at any time, in any place, in any given format. And not just that, but current technology has also made access easy, immediate and adapted to the individual need. Schools are no longer the repositories of information and knowledge, nor are they the gatekeepers of learning. With the existing technology, the process of transmitting content is easily digitalised. And because "anything that may be digitalised will be" [Leonhard, 2016], the role of the teacher as a depositary of knowledge that purrs it on the students will be rendered obsolete in the coming future.

Information and knowledge are no longer part of a school centred monopoly.
Access is widespread, cheap and easy. Convenience and individualisation are the trademarks of information in the World Wide Web. However, access to information and knowledge is not enough for the upbringing of children. Basic and secondary education are about sense making and identity, knowing and understanding the fundamentals of language, sciences and arts, preparation to live a happy and productive life. Basic and secondary education play a central role in the development of national identities and building the future of countries and regions.

Therefore, education systems are founded on a balance between democratic control of the curriculum (exercised through public educational authorities), parental fundamental rights in education (exercised by parental participation in governance structures, school choice or the right to found private schools) and the rules of pedagogy. The end of the school system's monopoly in the access to information and knowledge does not mean we do not need schools. We need schools and teachers. But we need them to fulfill a role that is not for technology *per se*. A role we cannot and do not want to give to algorithms because they need a human approach and decision.

Therefore, schools must re-assess what is their core business; what is the value they may create for students, parents and society as a whole. Accordingly, their teachers' role must be adapted to the adjusted mission of the school.

This new role for schools and teachers is that of educational gateways. Curriculum design, aligning methods to the individual student's profile, certification of students' attainments, tutoring and mentoring, all these are functions of the schools and their teachers. Each school should have the autonomy, within national, regional or international agreed frameworks, to design individual curricular pathways for students, support the student through that path and certify knowledge and competences.

Schools and teachers will play a steering role in the education system for society 4.0. But there is a need to make clear and to understand the underlying structures of subjects, to costume the educational path of individuals, to scaffold learning, to define what should be learned, how and when. Giving encouragement and being there to listen and merely accompany the learning process. And then there are societal needs as fostering the acquisition of values, developing civic participation or certifying the acquisition of knowledge and development of skills. Schools and teachers will be gatekeepers of the learning process rather than the content; they will structure the educational paths of students and help 'make sense' of what is learned. Or, in digital terminology, school will be "portals" [City, Elmore & Linch, 2012].

In the digital age, the role of teachers and educators has evolved and will continue evolving. However, moving teachers' practice into the new education context is both 'exhilarating' and 'challenging' [Prensky, 2012: 3]. It is then crucial to invest in teachers, "as transformers and awakeners", and to support teachers and educators in implementing digital technology in learning environments, namely by investing in their initial and continuous professional development and their own digital skills and competences [LLL Platform, 2017: 4].

In this context, teachers must be highly trained "professional pedagogues". This is not to argue that subject knowledge is dispensable. Only knowledgeable teachers are fit to instil in students a will for learning. However, subject knowledge and subject specific didactics are not enough for a teacher in the T-World. Just as we aim for a different student profile at the end of secondary education, we must aim for a different teacher profile.

This implies a new toolkit of skills and knowledge for teachers.

• Masters of pedagogy/methodology
• Research-based training

In this context, there should be a focus on teacher initial and continuous training on curriculum development. Then, teacher training and continuous development should shift from the industrial model of subject based content and method to a more holistic approach to mastering the basic concepts of natural sciences as well as social sciences, as well as pedagogy. Furthermore, besides mastering one or two subject matters (this is a required baseline), teachers must be highly competent in curriculum design and methodology. Finally, schools should recruit, according to their needs, specialised teachers (in areas such as: pedagogy, assessment, neurosciences), which would also foster the collaboration between teachers and their areas of expertise. For this demanding role, teachers must be trained and recruited amongst the best of their generations. Therefore, it is necessary to create the right incentives for the best secondary students to go into initial teacher education [OECD, 2018a].

Likewise, schools must be organised taking into account this new role of educational gatekeeper. Their workforce should be calibrated for the new role of educational gateways.

Today, most schools still are staffed according to educational levels offered (primary, secondary) and the subjects taught (e.g., languages, maths, history, sciences, literature or arts). The assumption is that each teacher is knowledgeable about his or her subject matter and its specific didactics and student assessment, and that this is enough. This assumption misses out on knowledge and competences that we know are important for educational in any situation and are not sufficiently incorporated in the school system (neurosciences, psychology or pedagogy) and rests on another assumption: that teachers work independently of each other teaching a specific subject. Schools for a T-World need a richer mix of competences and human resources. Teachers will not all be equally good at assessing, at teaching math or at helping to overcome special educational needs. Some teachers will follow the latest knowledge in neurosciences, others will be great pedagogues. All the reasons we expect students to learn to work collaboratively apply to teachers. The main one is that if educators work in a collaborative way, schools may: **(i)** organise in a way that each educator spends more time doing what he or she does best (student assessment, tutoring, lecturing, curriculum design) and **(ii)** open their recruitment pools to people with more diverse backgrounds (arts, neurosciences, technology) that are needed for schools to be the said curriculum gateways of the T-World.

With this rich human composition, schools will be equipped to define the curriculum, promote and support learning and assess outcomes.

Current discussions on schools evolve around school autonomy, school governance and schools as learning organisations. The aim is to promote better learning for all students and is based on the idea that schools, because they are closer to the student than the other educational institutions (or authorities), are in a better position to cater for the individual student. This is a manifestation of the subsidiarity principle. However, the challenges of the T-World go a step further. To be curriculum gateways, schools do not only need to be more effective (autonomy, governance and organisational learning), but they also need to have a new legitimacy. To fulfil new tasks, schools need a new legitimacy in the eye of society.

System governance, curriculum design and attainment assessment are traditional tasks of educational authorities. "It is not uncommon to find a few academics and government officials in a country who determine what millions of students will learn. They will often defend the scope and integrity of their discipline rather than consider what students need to know and be able to do to be successful in tomorrow's world" [Schleicher, 2018: 75]. If schools are to be the described curriculum gateways, they must develop most of these tasks. And for that, they need legitimacy and internal competences. What should students learn? When should they learn it? What does creativity look like? How do we assess citizenship, resilience or participation over the system? Schools in a T-World must be able to address these questions and their answers must be grounded in a legitimacy recognised by society. Therefore, we must find a way to give schools the democratic legitimacy of educational authorities (an issue of governance) and the technical legitimacy of higher education institutions (an issue of staffing and structure).

II. Structure: restructuring time and space – new learning environments

The new technological wave challenges the way schools organise time, space and internal structure. Schools, in traditional education systems, have a homogeneous pattern of organisation. The buildings are made of classrooms, each classroom has a group of 15 to 25 students of the same age, each group of students is taught by one teacher (standing in front of the class), each teacher teaches during a 45 to 70 minutes lesson, and each day has an average of 5 lessons. Lessons are separated by recess and this goes on from Monday to Friday for the whole of the school year (give or take some study visits and field trips). Teachers assess (usually through a written test) what students have learned in the lessons and three times a year each student is given a grade on each subject taught. It's "the same thing over and over" [Hess, 2010].

Like we pointed out before, this paradigm of school structure is based on the assumption that schools and teachers have the social monopoly of access to knowledge, that the school's role is to pass on knowledge to the next generation and that the most efficient way to pass this knowledge to the students is through an industrial structure of lecturing.

But changes brought to society by technology challenge these assumptions. Knowledge is ubiquitous, schools and teachers have new roles and technology has opened new and multiple paths to learning. So, it is fair to contest that this structure is no longer fit for purpose. Having students organised in fixed groups of the same age is the best way to organise students? Are fixed schedules of 45 to 70 minutes of class the best way to arrange time? Are brick and mortar classrooms the best places to learn? The answer to all these questions is no. Both – the more cautious, who prefer incremental changes, and the more ambitious, who go for disruption – agree that there is no "one best way".

The industrial model school is a learning environment characterised by chairs and tables in rows, age specific groups of students, a fixed timetable for the whole of the school year, 1 hour classes summoned and ended by a bell, three nicely distributed school periods in a year (or two semesters), long corridors with doors on both sides that open to rectangular rooms, a library, a cafeteria, a gym, labs and recess areas.

The traditional structure of grouping students by age was fit because we did not find any other efficient way to teach all children other than joining them together in groups with one adult for each group, doing the same thing, all at the same time. This structure is so embedded in educational common sense that the main difference between educational systems in third world countries or in first world countries is the number of children in each class and the age range. Technology made it possible to overcome this obstacle. We now have the means to give thousands of students access to individualised teaching (and learning), all at the same time. Khan Academy is the most notorious example of how technology opened new perspectives. So, now we do not need to group students in classes according to age. We may group them according to interests, to difficulties or not group them at all.

The same goes for time. Class blocks are needed to allocate teachers to groups of students and specific classrooms, when teaching is addressed along well defined scientific fields. If history, mathematics, natural sciences, languages, arts are each a mostly independent discipline taught by one teacher, class blocks rock. However, to foster creativity, comprehension of the various dimensions of the phenomenon studied or individualise teaching and learning, class blocks may not suffice or even be a burden. Some students perform better in the morning; some students need more time to complete certain tasks. Some students learn better when they get the big picture and then go into the details, other don't like to go ahead before get all the details. Some students have the ability to focus on the task for much longer than others. When the teacher teaches to the average, these students never develop their already good concentration capabilities. And the others are always in stress because they cannot keep up with them. If the aim of basic education is to get all students through the same keyhole, the industrial way of organizing time is enough. But when we aim for the human development of each and every student, it is no longer enough. In a technology enriched world, schools should not be prisoners of the block schedules.

The definition of classrooms as the ultimate learning spaces is also a consequence of the industrial way of organising education. The classroom, with the teacher and the group of students of the same age, was the place where the transmission of knowledge occurred in an orderly, sequential way. Educators recognised that the world outside the classroom was an important resource for learning. So schools organised field trips and study visits for students to experience what they were learning in the classroom. But in order for schools and teachers to keep control over the learning process, the classroom is the place where these excursions into the 'real' world are prepared and, afterwards, analysed. So classrooms have a fundamental role in a pre-digital world and in the realm of teacher centred pedagogies.
In a T-World, the classroom may still be an important learning environment, but it is no longer the only one or even the most important. Students learn in a much wider ecosystem, both physical and digital, and a large part is done outside the classroom and even the school. As argued in the previous section about the new roles of schools and teachers, schools' importance in education systems is no longer that of a learning space but that of the curriculum gatekeeper. Therefore, schools may decide to group students, only if needed, and according to other criteria rather than their age. They may even re-group students every month, week or day according to their individual learning paths. Schools may keep block class schedules or use them half the day or not use them at all. Learning may be done by different students at different times of the day, at different rhythms. Digital Learning Management Systems (LMS) help schools and teachers keep track of each students work, developments and needs. Learning resources and environments that exist outside the schools may now be fully integrated in the learning environment.

The T-World not only opens new possibilities of tracking and supporting each student's educational path, it also calls for different ways of sharing knowledge inside and outside the classroom due to the contents and competences needed for a T-World.

It is then important to redesign physical learning environment of educational institutions and to create dynamic learning spaces through inclusive and reflective digital innovation on the organisational level [Lonka, 2012]. The OECD [2017: 22] proposes fundamental principles for innovative learning environments "to all schools and learning settings as offering the building blocks of design, improvement and innovation." Indeed, a learning environment is more than "just a location where learning takes place", but "an organic whole embracing the experience of organised learning", which "includes the activity and outcomes of learning" and "enjoys a common leadership making design decisions about how best to optimise learning" [OECD, 2017: 16]. Consequently, the learning environment: "recognises the learners as its core participants, encourages their active engagement and develops in them an understanding of their own activity as learners"; "is founded on the social nature of learning and actively encourages well-organised co-operative learning"; "is acutely sensitive to the individual differences among the learners in it, including their prior knowledge"; "devises programmes that demand hard work and challenge from all without excessive overload"; "operates with clarity of expectations and deploys assessment strategies consistent with these expectations"; "strongly promotes 'horizontal connectedness' across areas of knowledge and subjects as well as to the community and the wider world"; and "the learning professionals within the learning environment are highly attuned to the learners' motivations and the key role of emotions in achievement" [OECD, 2017: 22-26].

The new education paradigm demands a different organisation of time and space, able to foster flexibility, adaptability, innovation. In this paradigm, the autonomy of schools to manage and organise their time and space is indispensable. Schools must be able to organise learning settings in variable ways, responding to different learning rhythms and to kinetic needs of students; to adapt space and time to the different learning processes; and to freely manage time, with continuous adult supervision and age appropriate schedules. In educating for the T-World, teachers would benefit from restructuring their education and training as well as from restructuring their teaching time, which would also imply restructuring of the learning time of students [Sahlberg, 2015].

The education system also needs to consider and to integrate different 'curricular spaces', in addition to the formal classroom, such as museums, parks, factories, universities and other facilities.

However, student's autonomy, independence and flexibility are, in this context, also determinant. "The main strategy of modern education should focus on the student's independent activity, the organisation of self-learning environments and experimental and practical training, where students have a choice of actions and can use initiative as well as flexible training programs where students can work in a comfortable rhythm" [Yakovleva & Yakovleva, 2014: 75].

In general, we would argue that learning environments should be redesigned, not only at a micro level, which is particularly related to the redesign of learning resources, formal and non-formal spaces, teaching and learning processes and pedagogical approaches, as highlighted above; but also, at a meso and macro level, involving networks, communities, chains and initiatives which help growing and sustaining innovative learning [OECD, 2017].

Furthermore, learning outside school should be promoted. As stressed before, museums, parks, factories, universities and other institutions should be embedded in the curriculum, not only as a place to go with the school but also as formal education resources. Similarly, school activities should be embedded in the community, and community activities and events embedded in the school curriculum.

The articulation between educational stakeholders also influences the effective integration of new technologies in education, i.e. to effectively integrate digital technology into the education systems, "better and stronger cooperation of all stakeholders is a prerequisite, ensuring convergence, synergies and a cross-disciplinary expertise" [LLL Platform, 2017: 4]. Consequently, "educational institutions and local communities need to work in partnership, together with a variety of different actors and partners, to address the need for convergence, synergies and a cross-disciplinary expertise" [LLL Platform, 2017: 8].

III. Content: focus on creativity

In the 4th industrial revolution, creativity seems to be 'the new capital'. This new era is perhaps the most creative and positive era of societal evolution. With the increase of access to technology, there is also an increase of access to information. Meaning that education needs to go beyond the role of giving information and teaching how to turn it into knowledge and promote creativity – as it will be creativity and other competences that will make a difference, because information is easily accessible. This fact has led Florida (2014) to talk about the rise of a creative class. According to the author, it is not just the Internet, or the rise of new technologies, or even globalisation that are changing our jobs, lives and communities. Beneath the surface it is the rise of creativity as a fundamental economic force and the rise of a new social group, the 'creative class'. In general, the creative class can be described as the class of workers in science and technology, arts, culture and entertainment, whose occupations are based on the use of imagination or original ideas to create something new. According to Florida's vision, the creative class will usher in a new era where our employability will depend on being a 'creative type'. "It was the rise of this new class and of creativity as an economic force that was the underlying factor powering so many of the seemingly unrelated and epiphenomenal trends we had been witnessing; from advent of whole new industries and businesses, to changes in the way we lived, worked, and consumed, extending even into the rhythms, patterns, desires, and expectations that governed our daily lives" [Florida, 2012: Preface].

Florida's words highlight not only the relevance of creativity in the context of the rise of a new 'class', but in a much broader sense. They stress creativity in the way people work, learn, live, interact and socialise. In such a context, creativity should be 'taught' and fostered by the education system from early childhood. The school and the university, as well as other institutions inside and outside the education system must promote new teaching and learning approaches and initiatives in order to promote and develop creativity and other related 'competences' and 'values', such as entrepreneurship and critical, independent and creative thinking.

But the importance of creativity in the T-World goes much beyond its economic value. Following the philosopher Agostinho da Silva's idea that "human beings were not born to work; they were born to create", the development of this competence is core to human development in itself [Silva, 1990]. Creativity may be seen as a pillar of human autonomy in a T-World; something we may do that is not digitally centred. So, creativity is not only about using one's imagination or original ideas to create something new with economic value, but also about doing it to express oneself. Creativity in the broad sense adopted here encompasses an entrepreneurial mindset and meta-skills like critical thinking and problem solving. To create something original or new, students need to know things but with a view to act in a meaningful way. Acquiring knowledge for action is a mindset that is not developed in the industrial model school. As Ken Robinson famously asks in his Ted Talk in 2006: "do schools kill creativity"? [Robinson, 2006].

In a T-World, schools must have, as a role, to ignite creativity. This does not mean that creativity was not always important; but it has been an add-on on the schools' primary mission of passing information. Creativity is a workshop or a club outside regular school hours, except in artistic schools or artistic education. But now, regular schools should learn from the others and help students develop creative competences. Education system need to foster creativity and entrepreneurship from an early age. Not only by integrating arts in the formal curriculum, but also by promoting and rewarding creative thinking by students.

This implies that schools themselves become creative in their action. Teachers must be allowed to experiment new teaching and learning approaches, to emphasise independent thinking, to be creative. The ultimate goal is to develop individuals' thinking beyond getting a job and prepare them for the future [Portuguese Startup Manifesto, 2016].

The development of a creative 'class' of learners for a T-World implies recognising and building on each person's strengths and weaknesses, making sure all learners leave compulsory education with a complete 21st century skills toolkit. Schools that foster creativity are schools that promote diversity and develop each student to his or her full potential. The traditional model goes from diversity to uniformity. When whole human development is the aim, diversity and personalisation must be brought into the process. To catch the wave of the T-World, we must flip the process.

IV. Method: interdisciplinarity, cross-fertilisation of scientific areas and whole child development

The creative-based economy of a T-World requires greater cross-fertilisation and collaborative learning inside and across specialised areas, namely by blending disparate knowledge domains: engineering with genomics, business with arts, materials with digital, etc. [Dalrymple & Miller, 2006]. The debate around interdisciplinarity is not new; it is though particular pertinent in the current economic, social and work context. Today interdisciplinarity is both desirable and inevitable, mainly because: **i)** creativity often requires interdisciplinary knowledge; **ii)** some worthwhile topics of knowledge and research fall in the interstices between the traditional disciplines; **iii)** many intellectual, social and practical problems require interdisciplinary approaches; **iv)** and the development of general (cross-disciplinary) skills are widely valued in employment [Nissani, 1997; Chettiparamb, 2007]. In other words, interdisciplinarity encourages multilogical thinking and high level analytical skills, which is what employers are often looking for rather than a discipline-specific expertise [Dalrymple & Miller, 2006]. Moreover, as argued by the EU Commissioner Moedas, "social scientists, from anthropologists to cultural-heritage experts, will have a huge contribution to make in virtually all of the societal challenges, because the societal impacts are going to be far-reaching and public acceptance crucial. Moreover, "interdisciplinary teams get better results, but (...) it requires scientists to change their mindsets and mentality and social scientists to get out of their silos and join the challenges that society has identified as important" [Moedas, 2015].

To follow these needs and this trend, the curriculum in primary and secondary education should have an interdisciplinary approach. This means giving students a learning process where different areas, from humanities to sciences, and disciplines arenas are taught together in an interrelated and integrated way. The traditional approach of teaching different disciplines separately – different teachers, with different books, in different classes, at different times with different assessment – does not help students comprehend the phenomena being studied as complex systems that may be looked at from diverse perspectives.

It is then crucial "to imagine and re-imagine (...) how to unlock the enormous potential of blending the humanistic and holistic vision of education with the innovative approaches that digitalisation can bring about" [LLL Platform, 2017: 6]. The collaboration between different scientific areas which drives to collaborative learning is necessary to acquire the competences demanded by a technological society. Thus, the education system should provide students with the opportunity to customise their selection of courses at high school level and to let them pursue multi-disciplinary curricula (e.g. business and sciences, design and engineering) [Portuguese Startup Manifesto, 2016]. "In the late 1990s, Japan responded to this situation by removing almost a third of the material in the national curriculum with the aim of creating space for greater depth and interdisciplinary learning" [Schleicher, 2018:76].

Closely linked to the interdisciplinary approach is the need to promote more holistic curricula. Curricula that encompass not only natural and human sciences but

also the development of personal and social competences as resilience, curiosity, critical thinking, collaboration, empathic behavior and the acquisition of values as justice, solidarity or commitment to the common good.
Holistic education is a broad concept that has been used to encompass diverse pedagogical approaches that have in common the integration of non-disciplinary knowledge and competences in the curriculum, at the same level of importance as numeracy and literacy. The work of pedagogues like Rudolf Steiner, Maria Montessori or Paulo Freire, all fall within this broad definition of holistic education. As well as do various pedagogical projects and approaches followed in schools all over the world. In this report we do not assess or value these different approaches. What we argue is that for students today, who will live most of their lives in a T-World, a holistic education is of utmost importance. Numeracy and literacy are important, but they are only half of what a good education for the 21st century looks like. "Schools all over the world are looking for new ways of doing things; of helping students go to their maximum potential" [Aragay, 2018].

Reinforcing the human development aspects of education is ever more important because of the discussed impact of digital technology in all counts of life. A holistic and complete curriculum is essential to develop the capacity to impose androrithms over algorithms and live a truly human life in a digital world.

V. Technology: integration and development of new technologies

Integration of digital technology in education was the initial scope of this report commissioned by PCS. For the reasons explained in the introduction, the focus shifted to a more fundamental analysis of the challenges a T-World poses to education systems. The result is a broader view on what it means to integrate new (digital) technologies in education. On the one hand, we have the question of how technological artefacts may be used to boost efficiency of teaching and learning processes. On the other hand, we now have the question of what students need to learn about technology to function in the T-World.

Regarding the first question, the challenge to integrate technology as an instrument of the teaching and learning process, Hess [2010] analyses the fact that, unlike most other human activities, formal education systems have stubbornly kept technology away from the core of their business: the learning process. Efforts in integration have been made all over the world. At the classroom level, it has been mostly about putting smartboards in the classrooms, giving devices to students or fostering the use of digital resources instead of textbooks. At the school level, the use of learning management systems (LMS), digital communication (mail, chats) and school management software are the results of these efforts. In school systems where transmissive pedagogy is the norm, this use of digital resources does have some impact. Using powerpoint is better than using transparencies, showing small videos helps engage students in what the teacher is saying, email is more efficient then snail mail, with a LMS it is harder to lose your homework. But what the literature concludes is that "the medium seldom influences teaching, learning, and education." Technological tools alone will not change education beyond recognition, but the correct use of tools and resources nevertheless does have the potential to change education [De Bruyckere, Kirschner, & Hulshof, 2018]. Thus, the way the integration of new technologies in primary and secondary education should occur and, more broadly, the role technology should play in the learning process are not straightforward. At least, if technology is to support schools and teachers in developing their new roles, to foster creativity, to promote interdisciplinarity and cross-fertilisation of scientific areas.

When integrating technology in education, there are at least two important dimensions one needs to consider: **i)** the speed with which technology now moves, which too often drives technology to become obsolete before it can even add value; **ii)** the uselessness of technology without proper integration in the educational and pedagogical environment, which is to say that "technology only helps when it supports a pedagogy of 'partnering'" [Prensky, 2012: 7]. The push to get education up-to-date frequently leads educators to add technology before teachers know, pedagogically, what to do with it. Consequently, "teachers and students will need to work together in new forms of 'partnering' in which students (...) use technology, find information, and create products that demonstrate their understanding and in which teachers guide students by (...) asking the right questions, putting things into the proper context, and ensuring quality and rigor" [Prensky, 2012: 3]. In general, the efficient use of technology in schools relies on including it in strategic planning and school culture, empowering, participatory teaching and learning methods, flexible curricula, dedicated leadership/management, as well as the strong capacity and commitment of teachers and other educators [LLL Platform, 2017; Niemi, Kynäslahti, & Vahtivuori-Hänninen, 2013]. In the end, digital technology must be carefully integrated in education systems and not "dumped onto learners" [LLL Platform, 2017: 4].

The integration of digital tools and technologies should go hand-in-hand with a proper education and training of teachers, an effective students' supervision and support, and an adequate integration of technologies in curricula methods, content and purposes. Above all, technology must work as a learning tool to enhance students' learning experiences, and not be an end in itself.
It is however important to recognise the role that a human teacher will always play in the classroom. They have a unique and personal insight into each learner's progress, serving as a role model and local expert, and providing inspiration in a way technology itself cannot [Frezzo, 2017].

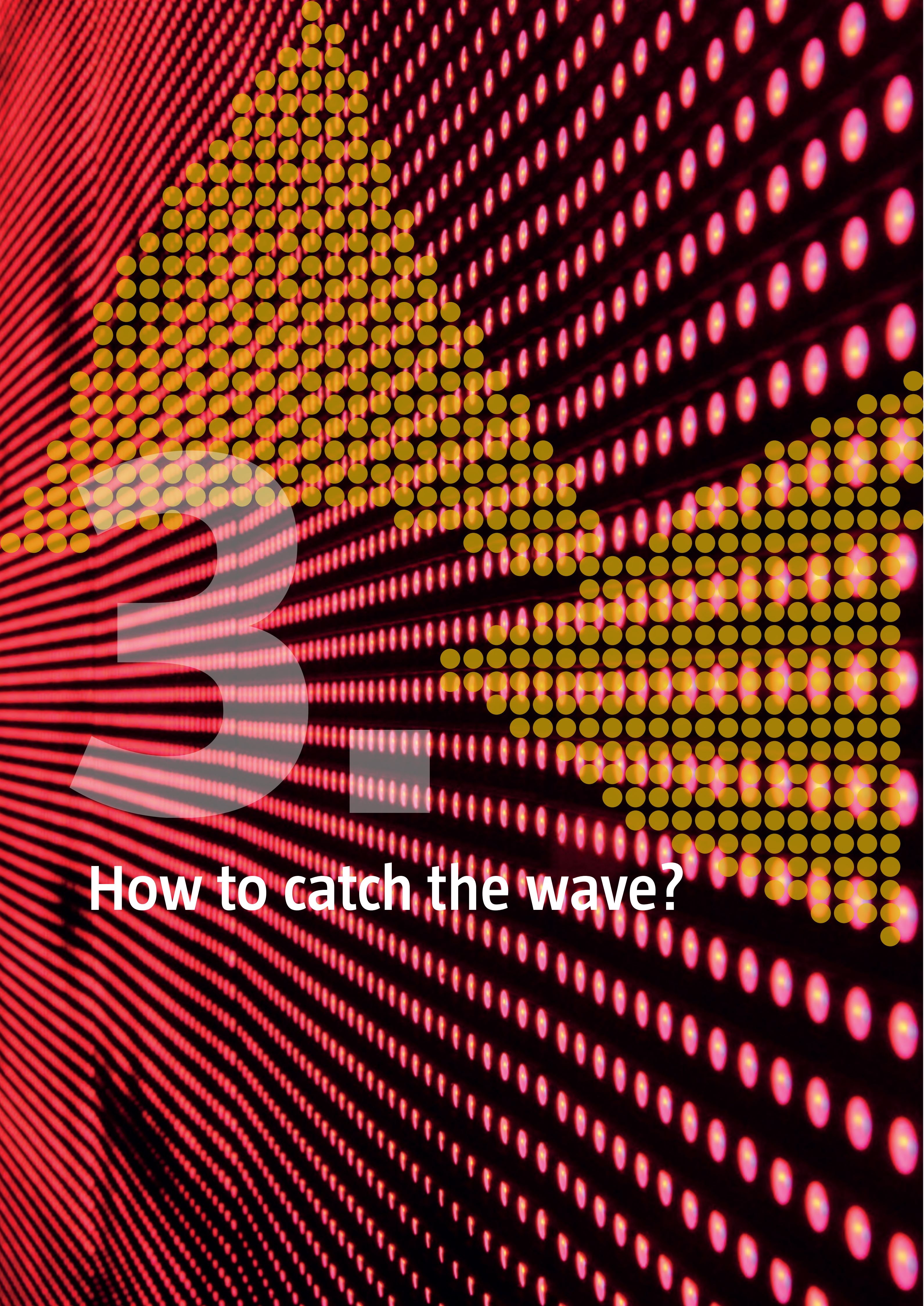
One feature of the T-World that deserves special attention in education is artificial intelligence (AI). It is possible to find literature from the 80's addressing the application of AI in education. In 1985, Jones (1985), in analysing systems of computer-assisted instruction, concludes that "although the systems discussed herein still fall short of what we would like to see placed within the regular school environment [...] advances made within the central AI research areas [...] will undoubtedly be reflected within the educational field (...)".
Since then, we have gone from concept to product. A simple search on the World Wide Web brings back numerous offers of AI applied to education: smart content (digital resources that adapt to the student using them), intelligent tutoring systems, virtual learning environments. One only wonders what may come out of Sumatra Mitra's self-organised learning environments[1] crossed with AlphaGo like AI[2]. It is not to say that algorithms will substitute teachers (bear in mind Sugatra Mitra's nanny cloud); but if a machine can beat humans at Go, it probably will be able to support learning in a very human-like manner.

1. https://www.ted.com/talks/sugata_mitra_build_a_school_in_the_cloud/up-next?language=en

2. https://deepmind.com/research/alphago/

The second question – what students need to learn about technology to function in the T-World – is of a different nature. Integrating technology resources in the learning process is only instrumental for living in a T-World. Education systems must go beyond this instrumental aspect of technology integration. To be active and free citizens in the T-World, students must learn the "grammar" of the T-World. Today there is general consensus that all students must learn geography, history, physics, mathematics, civics. The aim is that students acquire knowledge about the structures and rules of the world they live in so that they may not only understand that world, but may also be actors in shaping the future.

In a T-World, there is a new language to learn: computational thinking. Students must be prepared to understand the fundamental structures of the digital world. Not all of them will be computer engineers or create software. But to be able to lead the T-World rather than be led by technology, all of students should understand how computers think. Why they get certain search results and not others, what happens to the personal data they leave in their digital print, how algorithms go about giving them suggestions or how and why news are collected and presented in social media. This is on the content side of education. But also when looking at the competences students must develop, the importance of gaining digital skills is undisputable. In this sense, curricula, from early education to university, need to be adapted, namely by including coding and advanced digital tools.



3. How to catch the wave?

After discussing the challenges posed to education systems, we describe a few (of many) national and international initiatives and experiences of how people and systems are trying to face those challenges. They are not universal 'solutions'. Instead, they aim to contribute to the debate on how education systems may lead the technological revolution. Such ideas, approaches, projects and initiatives are not necessarily new, since they have already been discussed and proposed by several educational actors and organisations.
The main novelty of this report is its aim to propose the adoption of those ideas, projects and initiatives as an integral part of the education system, i.e., to reflect on when and how decoupled initiatives and projects can be integrated in the system. However, it is worth stressing that each example, each initiative and each policy must be contextualised and should not be implemented without a proper discussion of its strengths and weaknesses.

In a rapidly evolving landscape, change is indeed inevitable and the ability to anticipate it will dictate the difference between countries leading or simply following the pack. Having that in mind, we come forward with recommendations for the reform of school systems, which must be able to proactively respond to the challenges brought by technology disruption.

Globally, we believe that education systems must be more 'plastic', adaptive and flexible; be able to teach students how to learn and how to think; promote students' autonomy, independence and creativity; embrace simultaneously technologies, humanities and arts; boost multi-environment learning and learning in the community; and invest in high level teachers' continuous training.

Bellow, we present, for each challenge:
a) the initiatives and experiences being developed national and internationally and
b) recommendations to respond to the challenge.

I. Purpose: a new role for schools and teachers

DISRUPTIVE SOLUTIONS FOR A DISRUPTIVE REALITY

Finnish education system – the importance and recognition of teacher education

Finnish Phenomenon-based Learning education system highlights a 'new' role for the teacher, which requires a 'new' teacher profile, intrinsically linked to a research-based teacher education.

Phenomenon-based Learning and teaching is a multidisciplinary teaching and learning approach, where students study a topic according to a holistic approach instead of to a subject-based approach. In Phenomenon-based Learning and teaching, phenomena are studied in their real context and the information and skills related to them are studied by crossing the boundaries between subjects [Silander, 2015]. Finnish schools have been using Phenomenon-based Learning for several decades, but it was with the Finnish curriculum reform in 2016 that the Phenomenon-based Learning spread to all Finnish basic schools, which must compulsorily teach 18 subjects [Finnish National Board of Education, 2016]. This and other changes of the Finnish National Curriculum mainly fall upon the teacher, who must play an extremely challenging and demanding role. As it is well known, even before Finnish curriculum reform, and since late 1970s, "all teacher education programs became a part of the academic higher education", while "scientific content and educational research advances began to enrich teacher education curricula". Thus, Finnish teacher education is a "research-based teacher education" embracing the "systemic integration of scientific educational knowledge, didactics (or pedagogic content knowledge) and practice to enable teachers to enhance their pedagogical thinking" [Sahlberg, 2015: 108]. Consequently, and dissimilarly to other countries, teacher education is an important and recognised part of the education system in Finland and the basic requirement for an employment as a teacher in basic and general upper secondary education is a researched-based master's degree [Ministry of Education and Culture & Finnish National Agency for Education, 2016].

tMail project

The tMail project is an example of how a technological tool can help teachers and educators integrating technology in the teaching and learning process.
Developed by the European Distance and E-Learning Network, tMail aims to develop and test a mobile application supporting decision makers, teacher educators and primary school teachers in implementing classroom practices that stimulate students' self-regulated learning [LLL Platform, 2017]. Although teachers mostly believe in the strengths of self-regulated learning, they often lack the necessary skills and tools to accurately support students' self-regulated learning. tMail aims to address the challenges those different target groups face when try to implement self-regulated learning policies, by designing activities to support the development and testing of a mobile app. In addition to the mobile application for teachers, tMail develops a monitoring platform for teacher educators and policy makers.

Teacher educators can use the platform to monitor the learning activities of their teacher trainees. Policy institutions will be given access to a policy platform where they can access the same information in an aggregated and anonymised format. The data can be used to monitor the implementation of self-regulated learning, and to adapt their policy instruments based on actual empirical data [Andrés *et al.*, 2017]. The report on the results of the tMail project between 2015 and 2017 show that overall tMail succeeded in supporting the implementation of self-regulated learning into European primary education and in stimulating the mainstreaming of educational innovation (self-regulated learning) in Europe [Peeters, Pérez & Lombaerts, 2017].

Teach For America

Teach For America (TFA) is an example of an effort of developing alternative paths to become teachers and of fostering ways to bring the best to teaching and to educational leadership. TFA is a diverse network of leaders in the US working to confront educational inequity through teaching and at every sector of society.

TFA 'believes' that it is necessary for shools to have sustained leadership challenging the status quo from inside and outside the classroom; a broad and diverse coalition – advocates, entrepreneurs, policymakers, community members, educators – pushing to change a school system which was not designed for today's children, who face systemic racism and poverty and count on school to access opportunity and reach their potential.

TFA is based on a four-part approach: it starts with finding promising leaders who commit to teach for two years in a low-income community; it supports leaders to make an impact, by advancing students' growth and helping strengthen schools; it develops system-change leaders through classroom teaching; and finally it supports and fosters collective leadership.

TFA has a 28-year track record of advancing educational excellence and equity in the United States. With nearly 60,000 alumni and corps members in 51 regions around the country, the TFA network includes 14,000 teachers; 3,700 school principals, assistant principals, and deans; more than 300 school system leaders; 500 policy and advocacy leaders; nearly 200 elected leaders; and almost 200 social entrepreneurs.

TFA is one of the largest and most studied teacher-preparation and educational leadership development organizations in the US. Today 85% of TFA alumni are working full time in education or in careers that impact low-income communities. Among them are 471 school systems leaders, leading districts, state departments and state boards of education, working together and alongside many others to create the conditions for more schools to produce better outcomes for more children [TFA, 2018].

RECOMMENDATIONS FOR A SYSTEM REFORM

For schools to perform their new rule in the T-World, we need:

- to recruit teachers from a larger talent pool;
- to diversify the human resources that staff or support each school;
- to grant schools the power to design curriculum and assess attainment, recognising the value of learning outside the school and individualised learning paths;
- to make sure that the schools' governance models have some form of community participation to democratically legitimate schools' curricular autonomy.

For teachers to perform their new role in the T-World, we need:

- to select students going into initial teacher education from the top percentiles of their generations;
- that teacher qualifications require a master degree (2nd cycle of Bologna) as a starting point, with an aim that a reasonable amount of teachers obtain a mid-career PhD;
- that teacher initial education courses are research-based demanding courses;
- that teacher initial education courses cover both humanities and sciences, notwithstanding it's specific disciplinary focus;
- to have alternative certification paths so people may come into teaching from other careers;
- that all teachers do continuous training and specialise not only in one subject but also in one pedagogical related field (assessment, methods, neurosciences applied to learning).

II. Structure: restructuring time and space – new learning environments

DISRUPTIVE SOLUTIONS FOR A DISRUPTIVE REALITY

Self-Organised Learning Environments (SOLE)

A Self-Organised Learning Environment is a disruptive learning approach aiming to provide self-directed education to students through internet access mainly, but not exclusively, in remote or troubled areas. SOLE experiments were performed by the education scientist Sugatra Mitra, who has been developing extensive research in order to measure the impact of the experiments. It concludes that while SOLEs promote collaboration, teamwork, empowerment and engagement and allow students to advance at their own pace, also faces problems, namely regarding the absence of coaching and orientation. Research on how mediation effectively improves SOLEs' impact on students is being developed, through the concept of 'Self-organised Mediation Environment' (SOME) [Mitra & Dangwal, 2010]. Mitra and Dangwal [2010: 685] also present the hypothesis that "the approach could be employed in conventional, well-resourced and well-staffed schools to reinforce and enhance traditional teaching, for example where there are very large classes and/or where lesser qualified teachers' aides are employed. It may even be possible to develop a model for future schooling where children working in groups with access to the Internet and a friendly mediator, can complete large parts of the school curriculum through autonomous or semi-autonomous study". The replicability and sustainability of SOLE's, namely in different educational and cultural contexts, is yet to be demonstrated, although there is research illustrating that, for example, the general results obtained in a village in Southern India are like the ones obtained in Northeast England.

Kunskapsskolan (The knowledge schools)

Kunskapsskolan is a chain of independent secondary schools which functions as a comprehensive platform for personalised education, known as the Kunskapsskolan programme (KED programme). It presents a personalised education according to students' individual needs and abilities, where the resources in the school are designed and organised around the student and where all the elements of learning are defined (from teachers' roles to schools' architecture) in order to facilitate personalised learning. KED schools personalise students' education through a combination of goal setting, weekly coaching, personalised scheduling and timing and a unique curriculum maintained on the web-based Learning Portal Students [Eiken, 2011]. Currently, over 80 KED schools and KED inspired schools are operationalised in Sweden, UK, the Netherlands, USA, India and the Middle East, where the schools follow the curriculum of each country and grade student performance according to national standards. Despite the diversity of educational and cultural contexts where KED schools operate, the international recognised impact of 'the knowledge schools' seems to be limited to the Swedish context, where they are among the leading schools of Sweden, with students' performance higher than the Swedish national average.

Future Classroom Lab

The Future Classroom Lab is a learning environment formed by six different learning spaces. Each space highlights specific areas of learning and teaching and helps to rethink different points: physical space, resources, emerging technology, students' and teachers' skills and roles, learning styles, learning environment design. In general, it leads to rethink the role of pedagogy, technology and design in their classrooms and how conventional classrooms and other learning spaces can be reorganised to support changing styles of teaching and learning. Investigate, create, exchange, develop, interact and present constitute the mottos for teaching and learning. In the future classroom, students are encouraged to investigate, explore, create, plan, design, present, deliver, share, communicate, interact, exchange and develop their own work [European Schoolnet, 2016]. The Future Classroom Lab was developed by the non-profit organisation 'European Schoolnet', a network of 34 European Ministries of Education who have been working with industry partners, teachers, researchers, schools and other education stakeholders to develop visions for the school of the future and strategies on how to realise these [European Schoolnet, 2016].

Advanced Placement Courses

Advanced Placement Courses are an example of students' assessment and evaluation by an external entity to the education system. Created by the College Board (a non-profit organisation created to expand access to higher education in the United States), Advanced placement Courses offers college-level curricula and examinations to secondary school students. American colleges and universities may grant placement and course credit to students who obtain high scores on the examinations.

International Baccalaureate

International Baccalaureate programmes are examples of international education offered by a non-profit educational foundation. International Baccalaureate offers a continuum of international education for students from age 3 to 19, comprising four programmes (primary years programme, middle years programme, diploma programme and career-related programme) which aim to encourage students to excel personally and academically and to teach them to think critically and to prepare them to live in a global world. Nowadays, International Baccalaureate programmes are taught by over 5000 schools in over 150 countries, teaching over one million students worldwide. The International Baccalaureate and the diploma programme in particular seem to enjoy a high level of respect and recognition among international higher education institutions. For students, success in the International Baccalaureate often results in advanced standing, course credit, scholarships and other admission related benefits at several universities.

Open schools for Open Societies (OSOS)

Open schools are based on more engaging learning environments, on making a vital contribution to the community, on fostering collaboration, and finally on creating more meaning and more motivation for learners and teachers. In open schools, student projects meet real needs in the community outside school, are presented publicly and draw upon local expertise and experience. The OSOS open schooling model provides a framework for school leaders to engage, discuss and explore: how their schools need to evolve, transform and reinvent; how schools will facilitate open, more effective and efficient co-design, co-creation, and use of educational content, tools and services for personalised science learning and teaching; and how schools can become innovation incubators and accelerators. The OSOS project will create a core network of 100 open schooling hubs in 12 countries. Each one of these schools will develop a network of at least 9 additional schools to form a national network of schools where the Open School Culture is introduced. Overall more than 1000 schools will be involved in the project in two implementation phases (school year 2018-2019, and school year 2019-2020). The consortium of the OSOS project is composed of a total of 19 partners representing 10 European (Greece, Finland, Germany, Spain, Netherlands, Bulgaria, Italy, France, Portugal, Ireland) and 3 non-European countries (Israel, Australia and USA). OSOS partners vary from school authorities, to science centres and museums, policy making organisations, universities and European associations. In Portugal, the project was launched in October 2017 and envisages the initial participation of 10 schools, and subsequently of more 9 schools to form a national network of schools.

RECOMMENDATIONS FOR A SYSTEM REFORM

To better take advantage of the possibilities opened by a T-World, schools should:

- adopt more flexible ways of grouping students, assessing which is the best at different times and stages of each one's learning path;
- structure time according to the specific activities at hand and the individual needs and stages of each student;
- adopt a new architectural paradigm that goes from matchbox-type classrooms organised in long corridors to more flexible and adaptable spaces;
- organise learning environments including resources outside of the school, embedding the community and overcoming brick and mortar boundaries;
- accept as an integral part of each student's learning path what is learned in informal contexts.

III. Content: focus on creativity

DISRUPTIVE SOLUTIONS FOR A DISRUPTIVE REALITY

Youth Start – Entrepreneurial Challenges

The Youth Start – Entrepreneurial Challenges project involves institutional coordination to promote education for entrepreneurship and twenty-first century competences. It intends to have a significant impact on practical experiential learning programs at the compulsory school level by developing an innovative, transferable and scalable program through the collaboration of the high-level public authorities of Austria, Luxembourg, Portugal and Slovenia. The Program is designed to be flexible in its application and has intensive and extensive programs making it possible for teachers in all kinds of schools and from various disciplines to use Youth Start Entrepreneurial modules with their students. The main benefits from the project are: exchange of knowledge in the fields of education, training and youth; policy dialogue and implementation; support for policy reform; and stimulation of innovative policy development. The project aims to have also implementation benefits in the different countries where the project is implemented: development of new skills for students; sharing good practices; development of a joined project between primary and secondary schools; provision of technical assistance to schools; promotion of transversal skills at schools; and training and support to schools' teachers.

Entrepreneurship education (Swedish example)

Sweden adopted an entrepreneurship education strategy in 2009, which has been revised in 2012. Entrepreneurship education is embedded across all levels and types of education. It is part of compulsory education as a cross-curricular objective in primary, lower secondary and vocational education. It is often taught as a separate subject. Upon completion of education, students are expected to be able to understand what entrepreneurship means for individuals, organisations, businesses and communities. Although harmonised expectations exist, due to the decentralised structure of the Swedish school system, the teaching and learning methods and provisions vary across the country and even from school to school. Entrepreneurship education aims to stimulate children's creativity and ability to take initiatives; to support children at thinking independently and creatively; to extend children's knowledge by letting them work with their own inventions; to help the schools' learning processes to become more entrepreneurship-orientated [School Education Gateway, 2014]. Research shows that the Swedish case seems to succeed in facilitating a more entrepreneurial way of thinking among pupils [Fuchs, Werner & Wallau, 2008]. Within the scope of entrepreneurship education, several initiatives can be mentioned. **Future seeds** offers a complex approach to entrepreneurship at primary schools, supporting and training teachers and providing different tools to make it easier to start working with entrepreneurship in schools. **Finn up** is a traditional Swedish competition where students must identify a problem in their everyday life and then try to solve it with an invention. The goal is to increase interest in science and technology among young people, but also to learn about society and about themselves. The competition is open for both advanced technical inventions as well as simple and smart solutions to everyday problems, where a range of pedagogical methods (brainstorming, design and implementation) can be applied [School Education Gateway, 2014].

"Student's profile at the end of compulsory education" – Portugal

The "Student's profile at the end of compulsory education" is a broad and transversal reference document with principles, vision, values and competences for the Portuguese education system, aiming at guiding its organisation and management, and particularly, the definition of pedagogical strategies, methodologies and procedures. "Students' Profile" asserts that the education system must help "global generation students" to build and anchor "a scientific and artistic culture with a humanistic base", by mobilising values and competences which enable them to intervene in society, to make free and sustained choices and to develop a civic, active, conscious and responsible participation [Ministério da Educação, 2017: 5]. In this context, "Students' Profile" boosts interdisciplinarity and cross-fertilisation of different areas and disciplines. Amongst other capacities, students should be able to acknowledge and understand the importance and the combined and collaborative role played by arts, humanities, sciences and technologies for the social, cultural, economic and environmental sustainability [Ministério da Educação, 2017].

RECOMMENDATIONS FOR A SYSTEM REFORM

To educate creative students, school systems should:

- promote the inclusion of arts and other expressions in the regular curriculum and incentive schools to value arts as much as literacy or numeracy;
- promote diversity in the public education offer, allowing the creation of thematic schools or schools of choice, where students have a special focus on their personal interests;
- adopt an entrepreneurial approach to education, providing students with tasks and projects that foster a flexible and broad set of competences that will boost their creativity;
- broaden assessment instruments so that they encompass soft skills and not only knowledge reproduction.

IV. Method: interdisciplinarity, cross-fertilisation of scientific areas and whole child development

DISRUPTIVE SOLUTIONS FOR A DISRUPTIVE REALITY

Great Hearts Academies

As the General Studies study programme in higher education, General Hearts Academies support interdisciplinarity in primary and secondary education in the North American education system. Great Hearts, founded over one decade ago, delivers a classical liberal arts curriculum in public schools, 5 in Texas e 23 in Arizona and emphasises that students' knowledge should be rooted in the humanities, sciences and fine arts. Great Hearts Academies operate classical K-12 charter schools, aiming to prepare students for the 21st century, by teaching the skills necessary for success: the ability to innovate through creativity, the ability to communicate clearly, the ability to apply critical thought through analysis and questioning the world.

Statistics show that Great Hearts Academies surpass the best public and private schools from the United States in academic outcomes, students' moral formation and co-curricular participation, by setting a new standard for academic achievement.

Big History Project

Big History Project, an idea that arose from a desire to go beyond specialised and self-contained fields of study to grasp history as a whole, is an example of articulation between subjects and professionals from different scientific fields. It is a joint effort between teachers, scholars, scientists, and their supporters to bring a multi-disciplinary approach to knowledge to secondary school students and lifelong learners. It is a course that fits virtually any environment and any classroom. Big History examines the past of the universe using the best available ideas from disciplines such as astronomy, chemistry, biology and history, and explores human history from new angles. It incorporates insights of more than a dozen disciplines over 10 units teaching billions of years of history. Behind the project is the idea that when we integrate multiple perspectives into our thinking, we come up with new questions and insights. Over the 2014/15 school year, the Big History Project conducted studies to measure: student growth in writing, student understanding of content drawn from history and the sciences, student and teacher attitudes about and toward Big History Project courses, and possible impact of Big History Project on students in subsequent years. Globally, the research project concluded that Big History courses help students learn to write better and think more critically, engage students and prepare them for future studies. Students report that the courses had a long-lasting and positive impact on their learning, their ability to recall content, and their capacity to apply skills to new content and courses as well as to their lives outside of school. Moreover, it appears that both teachers and students are energised and engaged by the way the Big History Project courses uses big questions and multidisciplinary content [Big History Project, 2015].

Digital Humanities

Unlike previous examples, Digital Humanities is neither a project nor an initiative dealing with the need to an interdisciplinary approach in education, but rather an emerging field and a flourishing cumulative set of experiences, practices and models combining humanities and digital technologies [Svensson, 2013]. As the name suggests, it is "a field at the intersection of computational technology and traditional humanities disciplines" and "a set of conceptual and practical approaches to digital engagement with cultural materials" which is changing the ways in which humanists develop their work [Drucker, 2013]. "Digital Humanities represents a major expansion of the purview of the humanities, precisely because it brings the values, representational and interpretive practices, meaning-making strategies, complexities, and ambiguities of being human into every realm of experience and knowledge of the world. It is a global, trans-historical, and transmedia approach to knowledge and meaning-making" [Burdick, 2012: vii].

RECOMMENDATIONS FOR A SYSTEM REFORM

To foster interdisciplinarity and cross-fertilisation of scientific areas, we need:

- a rich and holistic curriculum that encompasses humanities, sciences and arts at all stages of education;
- teachers with broad training in different areas;
- an approach to didactics and methods that, notwithstanding the specific contents of each subject, is not focused on the individual subjects but on larger scientific groupings;
- tasks, learning aims and assessment to be defined and executed considering that the same phenomenon may contribute to the learning of different subjects.

V. Technology: integration and development of new technologies

DISRUPTIVE SOLUTIONS FOR A DISRUPTIVE REALITY

Education Technological Plan

Education Technological Plan (ETP) was a technological modernisation programme for Portuguese schools, approved in 2007 and aimed to technologically equip public schools and innovate the teaching and learning process. Regarding the knowledge, technology and innovation domains, ETP defined the following goals: to assure the IT system at schools; to support content development; to promote ICTs teachers training; to promote the spread of digital activities portfolios; to promote the development and the use of ICTs by citizens with special needs; to strengthen the dissemination of good practices; to promote open source and to reinforce ICTs privacy, security and reliability [Governo de Portugal, 2007].
However, a research on ETP's implementation concluded that the initial goals were only partially accomplished and implemented. Globally, the goals more directly linked to the introduction of digital equipment and to the implementation of technological resources at schools were more easily accomplished than the goals associated with the pedagogical level and the teaching and learning contexts [Duarte, 2015]. The limited success of this initiative seems to demonstrate how technological tools, without proper integration in the educational contexts, have a limited potential to change such contexts.

Khan academy

Khan Academy is a learning tool offering practice exercises, instructional videos and a personalised learning dashboard, that empower learners to study at their own pace in and outside the classroom. It tackles several areas, such as: math, science, computer programming, history, art history and economics. Its 'math missions' guide learners from kindergarten to calculus using state-of-the-art, adaptive technology that identifies strengths and learning gaps. Research on the impact of this learning tool tends to show very positive results, namely regarding students' success in secondary and higher education. A study of a statewide pilot of Khan Academy in Idaho with 173 teachers and 10,500 students during the 2013-14 school year concluded that students who complete 60% of their grade-level math on Khan Academy experience 1.8 times their expected growth on the Measures of Academic Progress Test (a popular assessment test) [Phillips & Cohen, 2015]. The Stanford Research Institute conducted a two-year study with 20 public, private, and charter schools; 70 teachers; and 2000 students during the 2012-13 school year and concluded that student use of Khan Academy correlates with score gains on standardised achievement tests [Murphy, Gallagher, Krumm, Mislevy & Hafter, 2014]. The New England Board of Higher Education conducted a two-year study of Khan Academy with 1226 students in developmental math classes at 12 community colleges in five states and concluded that Khan Academy reduces the number of remedial courses students need to take [Chan, O'Connor & Peat, 2016]. In Portugal, there is no research on the impact of Kahn academy, since the Portuguese platform was only released one year ago, exclusively with Math contents. The pilot project in Portugal involved 5 school groups, 30 teachers with specific training and 850 students, and the goal was to extend it to more Portuguese schools.

IBM Watson' cognitive computing technology and Sesame Street

IBM Watson's cognitive computing technology and Sesame's curriculum developed an intelligent play and learning platform. The platform, hosted on the IBM Cloud, enables software developers, researchers, publishers, educational toy companies, and educators to create individualised learning experiences. Georgia's Gwinnett County Public Schools (in the United States) has piloted a new adaptive cognitive vocabulary app that's enabled by this new platform. During the pilot, kindergarten students and their teachers had the opportunity to engage with the app, which is focused on enhancing students' vocabulary development. IBM and Sesame expect the platform to support educational toys, apps, and games that will feature Watson's speech-and image-recognition capabilities.

National curriculum in England: computing programs of study

In 2014, the UK government instituted the National Curriculum for Computing. This new curriculum framework substituted teaching ICT in schools by computer sciences. The rational supporting this change was that ICT is only about learning how to use a computer, whilst computer sciences is about learning how to be an active citizen in the T-World. "A high-quality computing education equips pupils to use computational thinking and creativity to understand and change the world. Computing has deep links with mathematics, science, design and technology, and provides insights into both natural and artificial systems.

The core of computing is computer science, in which pupils are taught the principles of information and computation, how digital systems work and how to put this knowledge to use through programming. Building on this knowledge and understanding, pupils are equipped to use information technology to create programs, systems and a range of content. Computing also ensures that pupils become digitally literate – able to use, express themselves and develop their ideas through information and communication technology – at a level suitable for the future workplace and as active participants in a digital world" [Department for Education, 2013]

This curricular reform may be a game changer but still has a long way to go.

In 2017, only 11% of students take GCSE Computer Science, 54% of schools do not offer it. Teacher training and support are needed and communities of practice must be developed [Humphreys, 2018]. To support this national effort, on November 7th, 2018, the Department for Education announced a National Centre for Computing Education with a €94 million budget.

RECOMMENDATIONS FOR A SYSTEM REFORM

To integrate technology in education we need:

- to allocate sufficient funds for schools to acquire, maintain and update technological resources;
- to incentive investment in the development of AI applications in education, such as tutors or adaptive assessment systems;
- to integrate computer thinking and digital competences in the curriculum;
- to articulate teacher continuous professional development and training with technological developments.

4.

The Portuguese education system

I. Are we catching the wave?

Portuguese education system is a paradoxical example in Europe. Though presenting negative educational indicators in the early 80's and 90's, being one of the lowest ranked countries among developed countries, it showed rapid and profound improvements in the last quarter of the twentieth century, making it a success story in international evaluations and benchmarks.

THE GENERALISATION OF THE ACCESS TO EDUCATION

In 1960, Portuguese illiteracy rate was 65.6%. In 2011 it came down to 5.2% (See Table 1).

years	Total	Men	Women
1960	65.6	26.6	39
1970	25.7	19.7	31
1981	18.6	13.7	23
1991	11	7.7	14.1
2001	9	6.3	11.5
2011	5.2	3.5	6.8

Table 1: Illiteracy rate in Portugal (1960-2011) Source: PORDATA

In mid-19th century, South and East European countries, traditionally poorer, more rural and predominantly Catholic or Orthodox, had very high illiteracy rates when compared to Northern European countries. However, they made significant progress in the beginning of the twentieth century, decreasing the gap between South and central Europe [Unesco, 2006; Teodoro & Graça, 2007].

Shortly after 1974 revolution, Portuguese education system initiated a deep process of change. Education policies became central for the development of national public policy, while increasingly influenced by European and international benchmarks (mainly after the integration of Portugal in the European Union in 1986). The opening of the education system to the participation of more students was the most relevant and visible consequence. Nowadays, Portugal has approximately ten times more students in secondary education than it had in 1974 and the illiteracy rate is only around 5% (still one of the highest in Europe) (See Table 2).

academic year	basic education	Secondary Education
1970/71	83.7	4.3
1980/81	100.0	12.4
1990/91	100.0	31.0
2000/01	100.0	62.5
2010/11	100.0	72.5
2015/16	97.7	75.3

Table 2: Enrolment rates – population in school age who is actually enrolled – according to education level and academic year (1970/71-2015/16)
Source: DGEEC

AN AVERAGE OR EVEN OVER PERFORMING EDUCATION SYSTEM... STILL WITH MAJOR FLAWS

In the last 20 years, the Portuguese educational system has evolved from an underperforming system, aimed primarily at bringing all school aged children to school and diminishing the rate of early school leavers, to a system performing within the OECD average. The rate of early school leavers has dropped drastically, from 63% in 1991 to 14% in 2015. Globally, the retention and dropout rates have been continually decreasing (See Table 3).

ACADEMIC YEAR	PRIMARY EDUCATION 1st cycle	BASIC EDUCATION 2nd cycle	BASIC EDUCATION 3rd cycle	SECONDARY EDUCATION
2000/01	**8,8**	**12,7**	**18,2**	**39,5**
2010/11	**3,3**	**7,4**	**13,3**	**20,5**
2015/16	**3,7**	**6,7**	**10,0**	**15,5**

Table 3: Retention and dropout rates, according to education level (2000/01-2015/16) (*)
Source: DGEEC
(*) though retention and dropout are different realities, if a student that drops out does not notify the school, and they usually don't, official databases do not allow to distinguish from the two realities. The estimated dropout rate is very low because education is compulsory for 12 years of schooling or until a student turns 18 years old.

The *average performance of Portuguese students* in the three main PISA subjects – science, mathematics and reading – in 2015 was better than the OECD average and has been improving (See Tables below). Also the share of top-performing students in science, mathematics and reading has been increasing since 2006, 2003 and 2009, respectively [OECD, 2018b].

YEAR	PERFORMANCE
2015 Portugal	**501**
2015 OECD average	**488**
2012	489
2009	493
2006	474
2003	468
2000	459

Table 4: Performance evolution – Science, 2000-2015 Portugal. Source: OECD

YEAR	PERFORMANCE
2015 Portugal	**498**
2015 OECD average	**487**
2012	488
2009	489
2006	472
2003	478
2000	470

Table 5: Performance evolution – Reading, 2000-2015 Portugal. Source: OECD

YEAR	PERFORMANCE
2015 Portugal	**492**
2015 OECD average	**478**
2012	487
2009	487
2006	466
2003	466
2000	454

Table 6: Performance evolution – Mathematics, 2000-2015 Portugal. Source: OECD

The *results of TIMSS* – Trends in International Mathematics and Science Study – which evaluates students' results in the end of primary school in mathematics and science, have been globally improving in Portugal since 1995, the first year of the international comparative study of student achievement. Despite the worsening of the results in sciences between 2011 and 2015, they have been improving and, after 2011, have been above the average (500) [Marôco *et al.*, 2016a] (See Table 7).

SUBJECT	YEARS	PERFORMANCE
mathematics	2015	**541**
	2011	532
	1995	475
sciences	2015	508
	2011	**522**
	1995	480

Table 7: TIMSS results, 1995-2015, Portugal. Source: Marôco *et al.*, 2016a

The results of TIMSS Advanced, which evaluates the results of students in the last year of secondary school in advanced mathematics and in physics, are also very positive for Portugal in 2015, the first year Portugal has participated in the study [Marôco *et al.*, 2016b] (See Table 8).

SUBJECT	PERFORMANCE
mathematics	482
physics	467

Table 8: TIMSS Advanced results, 2015 Portugal. Source: Marôco *et al.*, 2016b

To diminish the rates of early school leavers and promote equity within the system, governments have implemented targeted programs, given schools more administrative autonomy and also extended the compulsory education to 12 years, since 2013. In 2018, the government took a broader step and gave all schools autonomy to determine and manage the curriculum. Simultaneously, following the international trend for the development of 21st Century Skills, the government launched a curricular reform based on the definition of a student profile at the end of compulsory education. This profile offers a holistic approach to education, aiming schools at the development of artistic and civic as well as disciplinary knowledge and competences. External assessment of students now includes arts and physical education in lower primary, and national examination at 8th grade will have an interdisciplinary nature. Some opposition has been voiced against the new model of student external assessment in basic education. There is a challenge here to have more holistic assessment without losing comparability through the years and keeping the regulatory function of student assessment.

However, retention in primary and secondary education is very high (34% of 15 year old students have repeated at least one school year) when compared to the OECD average (12%), strongly correlated to social status (50% of underprivileged 15 year old students have repeated at least one school year), which is largely promoted by an ‘one size fits all system’.

TEACHER PROFESSION: UNATTRACTIVE, CANDIDATES WITH UNDER AVERAGE QUALIFICATIONS

The number of (basic and secondary) teachers significantly increased from 1974 (70.123) to 2017 (145.549). This is a direct result of the fact that all school aged children are today at school. However, in the late 70s, well under 10% of the active population had completed high school and under 8% had a higher education degree. So, staffing of schools was done with, according to our present day standards, underskilled workers. Since then, the levels of teacher qualifications have risen. The evolution during the last decade is considerable and today the great majority of teachers has, at least, a bachelor degree (See Table 9). Nevertheless, only 11% have a master degree or a PhD. In 2012, only about 0,27% teachers had a PhD.

EDUCATION LEVEL		TOTAL		MASTER OR PhD		BACHELOR		SHORT CYCLE	
		2003/04	2015/16	2003/04	2015/2016	2003/04	2015/16	2003/04	2015/16
1ST CYCLE BASIC EDUCATION	N	37251	28806	298	1851	24459	24177	12494	2778
	%			1	6	66	84	34	10
2ND CYCLE BASIC EDUCATION	N	34754	23757	664	2100	28728	19833	5362	1824
	%			2	9	83	83	15	8
3RD CYCLE AND SECONDARY EDUCATION	N	82099	74348	3176	9938	70878	61652	8045	2758
	%			4	13	86	83	10	4
TOTAL	N	154 104	126911	4 138	13 889	124 065	105 662	25 901	7 360
	%			3	11	81	83	17	6

Table 9: Basic and secondary education teachers, according to qualifications (2003/04 and 2015/16). Source: DGEEC

The underqualification of schools' teaching staff still influences Portuguese education system. It was only in 1997 that having a bachelor degree became mandatory to be a pre-school or primary education teacher. Until then, this post-secondary degree was only mandatory for teachers of the 2nd and 3rd cycles of basic education and teachers of secondary education [Portugal, 1997b]. Following the Bologna Process, the minimum requirement for all teachers is now a master degree (2nd cycle of Bologna). This aims to assure better qualifications of basic and secondary education teachers and, simultaneously, to reinforce their socio-professional status.
Still, career options in education and teaching seem to be non-competitive and unattractive. Candidates to initial teacher training are the second less qualified of high school graduates (Table 10).

STUDY AREA	AVERAGE GRADE/200
Mathematics and statistics	158.0
Veterinary sciences	157.2
Technical engineering	153.7
Health	153.2
Law	153.0
Social sciences	152.4
Journalism	150.5
Life sciences	149.1
Arts	147.5
Architecture	146.1
Humanities	145.2
Business sciences	143.4
Physics	143.3
Informatics	140.4
Manufacturing industries	138.7
Transportations services	138.0
Agriculture, forestry and fishing	135.3
Environment protection	133.9
Personal services	133.8
Security services	131.1
Teachers education and training	**130.7**
Social services	129.1

Table 10: Admission grades to higher education, according to study area, 2017.
Source: Observador 18-01-18 with data from DGEEC

So teachers' training is one of the less competitive study areas and one of the easiest gateways to higher education. This data shows that, in Portugal, the best high school graduates do not aim to become teachers. Moreover, the worst students at secondary level are the ones who pursuit teacher training. PISA 2015 results also highlight those trends: Portuguese students pursuing teacher training perform significantly worse than their counterparts from other European countries (Table 11). The differences are particularly noteworthy between Portugal and countries such as Finland, where teachers are especially high qualified and well trained and where teaching is a highly prised profession.

COUNTRIES	PERFORMANCE
Finland	**570**
Netherlands	550
Czech Republic	545
Denmark	545
Sweden	525
France	520
Luxembourg	515
Ireland	512
Poland	502
Spain	498
Portugal	**450**

Table 11: Performance in mathematics of students aiming to become teachers, 2015. Source: Pisa 2015, OECD

DECENTRALISATION OF CURRICULA MANAGEMENT BUT CENTRALISED TEACHING STAFF RECRUITMENT

With regard to basic and secondary education, there has been an evolution towards higher decentralisation of the decision-making process and towards higher school autonomy. The territorial dimension of school autonomy was reflected in the creation of an organisational and administrative unit which groups different schools, from different school levels, situated in the same territory – the 'School Cluster'. A 'horizontal school cluster' was started in 1996 and has grouped different pre-schools and 1st cycle basic education schools (primary schools) [Portugal, 1997a] (See Table 12).

ACADEMIC YEAR	SCHOOL CLUSTERS	SINGULAR SCHOOLS
2001/02	667	4 811
2010/11	794	280
2015/16	713	95

Table 12: Schools in Portugal (2000/01 and 2015/16). Source: DGEEC

In 2002, a 'vertical school cluster' placed all mandatory levels of education under the same organisational management, namely in order to overcome the pedagogical and organisational discontinuity and to rationalise the school network, eliminating isolation and dispersion of smaller schools [Formosinho, 2010].

In addition to a 'territorial' dimension, decentralisation in basic and secondary education and school autonomy seems to have been reflected in other 'dimensions':

- 'formal', with the integration of parents and community representatives in an administration body [School Assembly, in 1998 and School Council, in 2008];
- 'evaluative', with an integrative evaluation, in 1999 (based on the idea of organisational development and of dialogue between evaluators and school bodies) and an external evaluation, after 2002;
- 'curricular', with a flexible management of the national curriculum, where schools can autonomously organise, manage and build their curricular project, according to their students', local and regional needs and characteristics.

Nevertheless, there seems to be a gap regarding the dimensions of 'human resources' and 'financing' (of equipments and facilities) [Formosinho, 2010; Rodrigues, 2014]. Indeed, in Portugal, teaching staff recruitment is still a centralised process, assured by the Ministry of Education and coordinated by the Directorate General for Public Administration, in which schools have a very limited role. This national recruitment is the result of a centralised intervention from the State, but it is also an instrument to legitimise its power [Rodrigues, 2014]. Afonso (2007) stresses that this human resources situation is inadequate and that public schools need to have a crucial role in teachers' recruitment, or at least to share that role with other entities. Moreover, schools need to have a role in the management of their teaching staff career and in the content of teaching and non-teaching staff work, and to be capable of organising the teaching staff service distribution according to the particularities of their context.

As for the financial dimension of management, schools have little say on investment in equipment, teaching materials or infra-structures. Almost all of the schools' budget is earmarked by external authorities.

A FOCUS ON AN INFLEXIBLE COMPETENCES ASSESSMENT PROCESS

Much has been researched and discussed around the best way to assess students' competences and abilities and about the (dis)advantages of rigid/formal versus flexible/informal assessment processes and tools. This is especially important in a constantly changing world where what is true today might not be so tomorrow.

In Portugal, we seem to be moving towards a more flexible assessment process [Ministério da Educação, 2017]; but the education system still seems to be focused on a rigid 'right or wrong' assessment model. Particularly, the high focus on national secondary education exams that frame students' access to higher education. At the end of high school, students wanting to go to higher education must enter a national contest where places are awarded according to a mark. This mark is composed by the grades schools gave the student through secondary education (school years 10 to 12) and the average on two national exams. So exams in fact administratively block pedagogical autonomy at secondary education.

In addition, other two gaps of the Portuguese education system are worth mentioning: the lack of accountability on schools and teachers' performance and the lack of diversity within the system and, particularly, the lack of school choice within public schools.

THE USE OF INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT) IN EDUCATION: A LATE AND UNIQUE BOOST WITH POSITIVE RESULTS

In a technological world, the use of ICT in education is an indispensable and important (though not exclusive) indicator to assess whether the education system is preparing students for such a world where technologies are unavoidably relevant teaching and learning tools.

In this regard, it should be highlighted that Portugal has approved, in 2007, the Education Technological Plan, to technologically equip public schools and to innovate the teaching and learning process.

Until then, Portugal presented very poor standards concerning the use of ICT in education:
- the majority of the few computers at schools were outdated;
- the use of other support equipment (such as: printers, projectors, interactive boards) was limited and outdated;
- internet access was very limited;
- local networks existed in more than 90% of the schools, but they were inefficient and disarticulated;
- schools used digital equipment as management tools, but only 32% of the schools had intranet, comparing to 60%-70% in most developed European countries;

- 58% of the schools had systems that used student cards for access, buying materials, etc, but they were inefficient and limited;
- the use of digital content and applications for teaching and learning was largely insufficient;
- the use of virtual learning platforms was limited;
- at the level of the administrative management of schools, only 5% of the schools used electronic documental management systems;
- less than 1/3 of the schools provided e-mail for teaching and non-teaching staff;
- teaching and non-teaching staff were underqualified and undertrained as regards to new technologies [GEPE, 2008].

The programme has mainly boosted the implementation of digital equipment and of technological resources at schools. Indeed, in the last decade, ICT indicators in education have considerably improved, as we can observe in the tables bellow.

	2004-2005	2015-2016
Number of students per computer	11,7	3,5
Number of students per computer with internet access	16,1	4,0

Table 13: Number of students per computer in schools (2004/05 and 2015/16). Source: DGEEC

	2015
Portugal	75
OCDE	61

Table 14: Students using internet, at least once a week, to do homework (%).
Source: DGEEC & OCDE/Programme for International Student Assessment (PISA)

	2015
Portugal	50
OCDE	35

Table 15: Students using e-mail to communicate with colleagues about homework (%).
Source: DGEEC & OCDE/Programme for International Student Assessment (PISA)

	2015
Portugal	45
OCDE	49

Table 16: Students using the computer to do homework (%).
Source: DGEEC & OCDE/Programme for International Student Assessment (PISA)

	2015
Portugal	75
OCDE	61

Table17: Students accessing, at least once a week, school pedagogical material (%).
Source: DGEEC & OCDE/Programme for International Student Assessment (PISA)

	2015
Portugal	42
OCDE	28

Table 18: Students using e-mail to communicate with teachers and to send school work (%)
Source: DGEEC & OCDE/Programme for International Student Assessment (PISA)

	2015
Portugal	82
OCDE	67

Table 19: Students feeling comfortable with using non-familiar digital equipment (%).
Source: DGEEC & OCDE / Programme for International Student Assessment (PISA)

Despite the improvement of the majority of the ICT indicators in education, the Educational Technological Plan seems to have failed to achieve the goal related to the improvement of the pedagogical processes and the innovation of teaching and learning [Duarte, 2015]. On another note, the speed of change in technology makes equipment become obsolete probably quicker than the depreciation period of the equipment. Currently, resources to invest in equipment and software are limited.

In general, the Portuguese education system has made significant progresses over the last decades, but fragilities remain. After decades of public policies in education aiming at having a school for every child, present day policies aim at the fundamental goal of ensuring that the education every child has access to is of good quality.

But it is not clear that the challenges of a T-World are at the centre of policy decision making. It is crucial to consider our strengths and weaknesses, building on the former and overcoming the latter. But when we think about reform of the education system, we must be able to bring into the equation the demands of a technological society. Portugal and the Portuguese desire not only to reach other European countries in educational outcomes, but also to lead the change regarding the T-World and be an example to others. Giving every child a good education by the standards of the 2nd and 3rd industrial revolutions is not enough.

II. What can we do to catch the wave? Policy proposals for Portugal

In this chapter we will build on the recommendations presented in chapter three and offer policy proposals considering the context of the Portuguese education system. These proposals are not a list of what to do to ameliorate the Portuguese educational system nor do they focus on some of the current challenges it faces (retention rates, unequal quality of schools, teacher shortages or lack of school choice for all). They are what we find to be priority measures that should be addressed in reshaping Portuguese schools for a T-World.

The proposals have public schools in mind (schools owned and operated by state authorities). Firstly, these schools represent 80% of students in K-12 education in Portugal. Secondly, they have little autonomy in deciding on and implementing paradigm shifts. However, the challenges presented are faced also by private schools and they would also benefit from some of the policy proposals presented.

According to OECD data, Portugal is the country that has the highest percentage of students in compulsory education going to private schools with no financial support from the state authorities. Therefore, for Portugal as whole, the way in which the private sector in education prepares for the T-World is also very important.

PURPOSE: A NEW ROLE FOR SCHOOLS AND TEACHERS

As argued, schools and teachers will have a new role in a T-World. They will come from information and knowledge transmitters to curriculum gateways and educational certificators.

To perform their new role in the T-World, Portuguese schools should:

- recruit teachers from a larger talent pool; in Portugal, only certified teachers may by recruited for schools and there are no paths to certification other than a master's degree in teaching. Therefore, teachers are almost exclusively to be recruited from the group of people that decided to be a teacher at 18, do not have other professional experiences and whose higher education credentials are not valued in the labour market. Certified teachers are not bad teachers. But schools need greater talent diversity. Portugal should define alternative paths to teacher certification and foster career changes from other professionals into education.
- diversify the human resources that staff or support each school; to perform their new role in the T-World, schools need continuous support from professionals other than teachers (or from teachers that do other things then formal teaching). At present, the only non-teaching professionals that schools may get support from (even if in limited ways) are related to special education and healthcare: nurses, therapists, psychologists. But schools need to work with assessment specialists, techys, artists. Portugal should establish the freedom of schools to staff or acquire support from other specialists even if within contractual limits regarding public administration.
- grant schools the power to design curriculum and assess attainment, recognising the value of learning outside the school and individualised learning paths; Portugal has taken important steps in this direction. Namely, with the new law on curriculum from July 2018 that grants schools the right to define 25% of the curriculum, adopt flexible classes and offer inter-disciplinary subjects.

Nevertheless, the law still rests in the brick and mortar paradigm of teaching and learning, and therefore does not value learning spaces outside school.

> *The teaching and learning system is 'multi-polar', 'multi-intelligent' and 'multi-time'. School is one of the poles, one of the times, one of the agents. There are many other 'teaching and learning stages'. The school is: the institution where teaching and learning modes are taught, tested and where the pedagogy's (pedagogies') masters are; the institution where theory is built, and where one reflects; the institution where the fundamental societal algorithms are taught.* Carlos Liz, Researcher, 2018

For teachers to perform their new role in the T-World, the Portuguese school system needs:

- to select students going into initial teacher education from the top percentiles of their generations; as shown in Table 11, high school graduates going into teacher education do not perform well in secondary education and Portuguese teachers underperform in maths when compared to teachers from other OECD countries. Raising the bar for entry to teacher training courses would be a way of overcoming this situation.
- to require for teacher qualifications a master degree (2nd cycle of Bolonha) as a starting point with an aim that a reasonable amount of teachers obtain a mid-career PhD; at present all new teachers in Portugal must obtain a master degree. However, there are no incentives for teachers to obtain a PhD. This should be an important focus of Rh educational policy. Each school should have the aim that at least 10% of the staff has a PhD.
- to assure that all teachers do continuous training and specialise not only in one subject but also in one pedagogical related field (assessment, methods, neurosciences applied to learning).

As in all other professions, lifelong learning is essential for teachers to keep up with developments in their field. But to perform their role in the T-World, teachers must specialise in one education related field besides their subject matter(s). This will improve the schools' resources and allow, through more collaborative and articulated work, schools to develop their role in the T-World.

> *The role of teachers has profoundly changed. New technologies are an unavoidable reality and we cannot simply give them to teachers and expect them to learn what to do with it. They have to be taught how to use new technologies, new teaching, learning methods and practices and why they are important for students and for the teaching and learning process. Consequently, training is crucial… training, training, training is the key! We have to provide teachers with all the information and with the right tools!* Bárbara Beck, Private School Principle, 2018

STRUCTURE: RESTRUCTURING TIME AND SPACE – NEW LEARNING ENVIRONMENTS

Restructuring time, space and the school itself is a challenge still to be met. As is a challenge including learning in the community in the school curriculum.

To better take advantage of the possibilities opened by a T-World, schools should:

- organise learning environments including resources outside the school, embedding the community and overcoming brick and mortar boundaries; this challenge is still to be addressed. Study visits and other activities done outside the schools are still regarded as a sideshow or a way of engaging students for what really matters: the classroom. Physical education is not entangled with participation in sports outside the school, going to museums and concert halls is not embedded in the curriculum. Again, public policy measures would be welcome, incentivising schools to open to the community.
- Accept as an integral part of each student's learning path what is learned in informal contexts; Portugal had an important experience in assessing and recognising learning done outside the school system. It was the New Opportunities Initiative, targeted at adults with low qualifications. The methodology used may be adapted to students and used as a baseline for this challenge.

> *How and where will we learn in the future? Everywhere! Although the school will continue to be the privileged learning space, where students systematise their learning, beyond what is in the curriculum.* Filinto Lima, Public School Principle, 2018

CONTENT: FOCUS ON CREATIVITY

Creativity is a centre piece of life in a T-World. The ability to bring together things or ideas in a new way, to find new solutions for problems, to express in new ways.

To educate creative students, the Portuguese school system should:

- promote the inclusion of arts and other expressions in the regular curriculum; music and visual arts have been part of the general curriculum for decades. However, with little time and in a very light manner. Over 22,000 students have access to specialised artistic education; 1,6% of students in basic and secondary education. We should at least triple that number and double the number of schools that have an artistic integrated curriculum.
- promote diversity in the public education offer, allowing the creation of thematic schools or schools of choice, where students have a special focus on their personal interests; with some exceptions – namely artistic vocational schools and professional schools – basic and secondary schools all look alike. Their pedagogical projects and the curriculum they offer are not differentiated. To foster creativity, engage students and offer deep learning, the school system should make place for schools' definition of special features or characteristics. Secondary STEM, artistic or humanities schools would greatly contribute to a more differentiated school system.

METHOD: INTERDISCIPLINARITY, CROSS-FERTILISATION OF SCIENTIFIC AREAS AND WHOLE CHILD DEVELOPMENT

To foster interdisciplinarity and cross-fertilisation of scientific areas in the Portuguese education system, we need:

- teachers with broad training in different areas; teacher training – initial and on the job – is a challenge the Portuguese education system is still to tackle. Portugal needs to assess teacher training courses and creating incentives for the best to go on with their work, and the others to ameliorate or shut down.
- tasks, learning aims and assessment to be defined and executed considering that the same phenomenon may contribute to the learning of different subjects; from September 2018 on, schools have to possibility to integrate subjects in the same class. This is a step forward in the right direction.

> ***First, the idea was to invest in science, technology and computer programming. Nowadays, the discourse is reversed and it is now important to emphasise communication and flexibility. We need to rethink the role of soft skills. Scientifically and mathematically speaking, machines can make better than humans. However, relational skills cannot be replaced by machines. We need to find a balance: on the one hand, to train and to educate good technicians; on the other hand, to invest in skills such as team work and critical thinking.*** Ana Sofia Carvalho, European Group on Ethics in Science and New Technologies, 2018

TECHNOLOGY: INTEGRATION AND DEVELOPMENT OF NEW TECHNOLOGIES

By definition, a T-World is a world impregnated by technology. Education systems, to be part of this world, will also imbed technology in their core processes. But, as argued, integrating technology in education is not only, or mainly, about this instrumental aspect of technology. It is mainly about offering a curriculum that prepares students to understand and be main actors in the T-World.

To integrate technology in the Portuguese education system in this broad sense we need:

- to rethink budgeting so that schools may allocate sufficient financial resources to technological resources; school budgets do not have resources earmarked for digital technology. Following the Portuguese Technological Plan effort, computers and other hardware in schools became obsolete or were replaced at a very slow pace. In the future, this challenge must be addressed in a robust way, allocated resources for schools to invest in technology and in digitalisation of their operations.
- to incentivise investment in the development of AI applications in education; this challenge must be faced by the system as a whole. In face of existing technology, the market is not yet mature for schools to act individually. So a public policy decision is needed. If the Portuguese government was to allocate public resources

and create incentives for private resources to join the effort, Portugal could lead the way in developing AI in education.

- to integrate computer thinking and digital competences in the curriculum; as argued, schools must have freedom to define the curriculum within a broad national framework. Computer thinking and digital competences, due to their importance for citizens of the T-World, should be part of those broad standards. It may be up to each school to decide age appropriate integration (the when and how) but they may not decide not to include these issues in education.

> *Another major challenge for schools is the need to find a balance between skills and knowledge; between the need for an holistic approach which develops social, creative and cognitive skills and a more 'traditional' approach to knowledge 'demanded' by schools' disciplines and schools' curricula; between knowledge, content and facts and the skills which enable students to 'use' that knowledge to solve complex problems of a constant changing world. Moreover, there are crucial skills which will enable students to succeed, to contribute to a better world and to be changemakers.* Bárbara Beck, Private School Principle, 2018

5.

Finding the right balance to surf the wave

The challenges that a T-World poses to education systems and the rapid pace of change make reshaping schools a necessity. However, school systems are big and complex social systems with high levels of inertia.
In many countries and for large portions of the population, the focus is on day-to-day needs and trying to get some security for the future. The challenges of the 4th industrial revolution are an abstraction and what they expect from schools is that they teach their kids so they may get a job. And if this is done like it always has been, what's the problem? Furthermore, teachers and managers are also not all on the same tone when it comes to reshaping schools. The clash between transmissive pedagogies and participatory pedagogies is recurrent in many countries. At the school level, not knowing what the future looks like is sometimes tantamount to go on doing things as before.

In the end, it is all about finding the right balance(s) between coexisting demands, realities and needs: between global and local, collective and individual, demand and enjoyment, sciences and humanities, technical skills and soft skills, ultimately, *technology and humanity*, overall, between incremental and disruptive change.

There are no universal solutions to the challenges posed by technological disruption to education systems. It is important to keep an ongoing discussion within each school system on how to 'surf' this technological wave, according to different contexts and realities; and the best ways to *make education reform happen*.

I. Policy and practice: implementing education reforms

Policy implementation is not the focus of this report. But having proposed policy measures for a reform of education systems, some brief considerations about policy implementation challenges in the education sector are due. It is imperative to discuss policies for education reform, but it is equally important to understand the challenges to the implementation of those policies.

It is well known that, irrespective of the particular sector, policies tend to face several challenges when they are being implemented, as the literature has been documenting [OECD, 2010]. This is especially true in the education sector for several reasons: education systems are large and complex; the time gap between policy conception and implementation is big; there is a lack of reliable and accepted indicators of the quality of outcomes and their value; there is little agreement about what constitutes best practice; some stakeholders, mainly teachers and school leaders, have enormous power over the reform process and an effective implementation often needs their co-operation [OECD, 2010].

Having this in mind, there are several aspects which need to be taken into consideration when implementing education reform:

- a successful policy implementation necessarily requires consensus building, participative decisions and stakeholders' engagement. Teachers and school leaders are a crucial group of stakeholders who have the potential to harness education reform. Thus, mobilising the knowledge and experience of "the people who can make the practical connections between the classroom and the changes taking place in the outside world" is a "fundamental challenge of policy implementation today" [Schleicher, 2018: 207].
- successful reform also requires capacity development, i.e. significant investment in staff development, or clustering reforms to build capacity in related institutions.
- education reform needs to align the respective responsibilities and roles of different players and the different governance levels, from local to national.
- evidence from different data sources, namely comparative data tend to help reform in education and should be used to guide policy making, though a great deal depends on consensus regarding the value and meaning of such evidence.
- there needs to be progression from initial reform initiatives towards building self-adjusting systems with feedback at all levels, incentives to react and tools to strengthen capacities to deliver better outcomes.
- last but not least, as education can be included in more comprehensive reforms, it is essential, though extremely difficult, to co-ordinate policy development across levels of government and to align the perspectives of different government departments [OECD, 2010; Schleicher, 2018].

II. Technology and people: building a prosperous human-centred society

"It is not digital technology that creates social change, people do! Therefore, future investment in technologies has to be accompanied by investment in people and widening their access to lifelong learning opportunities" [LLL Platform, 2017: 7].

As highlighted above, to achieve enhanced learning experiences and outcomes of learning, the education system needs to conform to the needs of learners, and not the other way around [Green, Pearson, & Stockton, 2006]. People must not be passive technology consumers but active digital citizens through "constructing and reconstructing the nature, place, pace and timing" of their learning experiences [Nunes, 2006].

The emphasis on people rather than on technology is particularly relevant given our aim of drawing attention to what we would call the 'human era' of societal evolution; a positive and creative stage where the fundamental traits of human nature may be nurtured. Again, as the philosopher Agostinho da Silva once wrote "human beings were not born to work; they were born to create" [Silva, 1990]. Consequently, the role of education and training systems and, particularly, of the school, as the (virtual and psychical) 'place' to learn par excellence, is facing enormous changes. Thus, "school becomes the tool which refines individuals into reflective citizens and

prioritises opportunities for emerging human dignity" and digital tools become especially useful because they nurture individuals' sense of agency and responsibility [Shapiro, 2014].
The challenges and changes which we have been discussing in our report are the result of a societal evolution. Indeed, society has evolved over the centuries and it will continue to evolve; and each evolutionary stage is characterised by different driving forces, values and purposes.

We can describe Society 1.0 as 'the hunting society' where groups of people hunted and gathered in harmonious coexistence with nature; Society 2.0 as the agrarian society, based on agricultural cultivation, increasing organisation and nation-building; Society 3.0 as the industrial society, promoting industrialisation through the Industrial Revolution, making mass production possible; Society 4.0 as an information society that realises increasing added value by connecting intangible assets as information networks. Many would argue that we are now living in a Society 4.0 marked by a technological disruption and revolution. What we argue here is that we are living in a Society 4.0, but already building a Society 5.0, in which the main differentiating element is the human centrality and the focus on human happiness and prosperity. Thus, Society 5.0 (a concept arisen in Japan) can be defined as an information society built upon Society 4.0, aiming for a prosperous human-centred society.

Here, the various needs of the society are finely differentiated and met, by providing the necessary products and services in the required amounts to the people who need them, when they need them, and all people can receive high-quality services and live a comfortable, vigorous life that makes allowances for their various differences such as age, sex, region or language. It is a new society created by transformations led by scientific and technological innovation, following hunting society, agrarian society, industrial society, and information society [Harayama, 2017].

In Societies 4.0 and 5.0, digitalisation is a means, but humans are central actors. However, in Society 4.0 (too) often technology drives the change and humans follow it. And here remains the main change: technology is only an instrument used by humans who lead and build social and societal change. Humans are the true game changers, not technology. Traditionally, innovation driven by technology has been responsible for social development. In a Society 5.0 this way of thinking is reversed, focusing on how to build a society that makes us happy and provides a sense of worth, a society which is the foundation for human life [Harayama, 2017].

We end with a final, yet important, reference to inclusion and social cohesion. Often, technology and its impacts are presented as an instrument of growing inequity and exclusion. There is, of course, a real danger that those who are left out of the 'T' end up living in a parallel 'World'. But this has been so even in previous industrial revolutions. And then, like now, schools and school systems are indispensable means of integration and cohesion. As stressed in previous chapters, 65% of children entering primary school today will ultimately end up working in completely new job types that don't yet exist [World Economic Forum, 2016]. If we are successful in *Reshaping Schools for a T-World*, there is a good chance we may meet the goals of a society which is sustainable, humane and for all.

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Reshaping Schools for a T-World

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