OECD Science, Technology and Innovation Outlook 2016

Policy Profile

OECD

Strengthening education and skills for innovation

Rationale and objectives

Education policies play a central role in innovation, by supplying the foundations and skills innovative economies require to develop new processes, to adopt new products and to adapt to changes over time. Rising investment in intangible assets (i.e. software, designs, new forms of business organisation) has proved to be important for growth and productivity, and such intangible assets are often a direct manifestation of human capital built on rising educational attainment and investment in skills (OECD, 2015a). The incremental and pervasive nature of innovation also broadens the workforce that can contribute to innovation generation and diffusion. A large educated society enables more user-driven innovation or emerging practices such as do-it-yourself science or crowdsourcing that hold promise for the future.

Skilled people enjoy on average higher earnings, better job satisfaction, better health conditions and better educational outcomes for their children. They also have a better foundation for further skills acquisition and lifetime employability. They demonstrate increased capacity to accept and adapt to technological change, to adopt innovations and benefit from them, and to participate in the design of more responsible innovation policies (see the *Policy Profile on Public engagement in STI policy*).

Skills supply, however, faces several major challenges and policy makers in some countries are concerned that education and training systems might not be maximising the potential for progress in science, research and innovation.

Innovation and technological development in recent decades, especially the spread of the Internet and information and communication technologies (ICTs), have had a profound impact on the labour market and the skills required for many occupations. Digitalisation has changed production processes, business models and supply chains, and many jobs. As an effective use of ICTs requires changes in the firm organisation, the tasks workers perform have evolved, as has their skills profile.

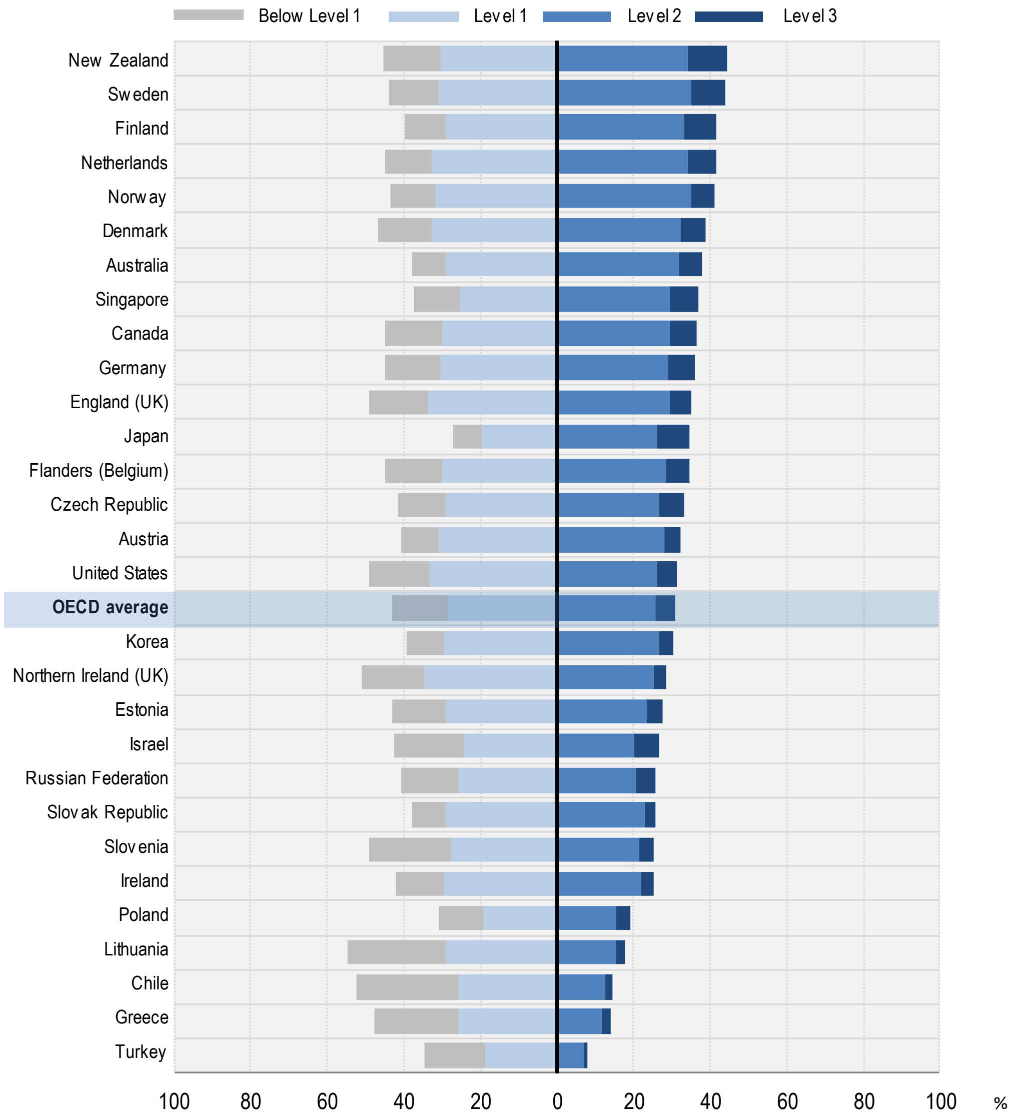
Yet, previous OECD work has highlighted that almost two-thirds of adult population lack the skills to succeed in a technology-rich environment (Figure 1) (OECD, 2013). The gap in ICT-related skills is particularly larger for people in lower-skill occupations who are less exposed to intensive use of ICT at work, to interaction with co-workers and clients, or to problem solving tasks (Spiezia *et al.*, 2016 forthcoming).

Future technological developments, such as those related to the Internet of Things, big data or artificial intelligence (AI), are expected to have further disruptive impacts on skills needs (see the chapter on "Future Technology Trends"). Digital technologies have started to displace labour away from knowledge-intensive but routine (and therefore codifiable) tasks. A recent OECD study identifies shifts in skill demand due to the application of IT capabilities into occupations where these capabilities can reproduce the full bundle of required skills. The study concludes that there could be significant displacement of workers in the future, creating a need to develop new skills, particularly the higher-level language skills used in professional occupations that computers cannot yet reproduce (Spiezia *et al.*, 2016 forthcoming). Some skills shortfalls around big data specialists have already been identified (OECD, 2015b).

Digitalisation will also affect the functioning of education and training systems as learning methods and strategies evolve, the scope for personalisation enlarges, education courses could be fragmented along the lifetime and the curriculum, and big data brings new knowledge on learning and cognitive processes. Education supply is also subject to growing competitive pressure as it becomes more global (OECD, 2014a).

Figure 1. Adult population by level of proficiency in problem solving in technology-rich environments, 2015

As a percentage of 16-65 year-olds



Note: Problem solving in technology-rich environments requires "computer literacy" skills (i.e. the capacity to use ICT tools and applications) and the cognitive skills required to solve problems. The OECD Survey of Adult Skills as part of the OECD Programme for the International Assessment of Adult Competencies (PIAAC) assesses the proficiency of adults aged 16-65 in literacy, numeracy and problem solving in technology-rich environments. It collects in particular a range of information on the use of information and communication technologies at work and in everyday life, and on a range of generic skills, such as collaborating with others and organising one's time.

Source: Based on OECD (2016b), Source: Survey of Adult Skills (PIAAC) (2012, 2015), Table A2.6. http://dx.doi.org/10.1787/9789264258051-en based on Survey of Adult Skills (PIAAC) (2012, 2015), Table A2.6.

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While a large proportion of the workforce will require new skills in the near future, education and training systems require time to adjust and to train and re-train various generations of workers and citizens. The challenge is particularly sizeable as the nature of future skills is still uncertain and the right mix of skills required will differ across countries, industries and firms. Another policy challenge is related to the definition of skills and their evaluation. Neither skills nor innovation are easily measured (Tether *et al.*, 2005; Toner, 2011). Although there is empirical evidence of the positive effect of human capital on incomes, productivity and growth, the explicit link between specific skills and innovation remains difficult to evaluate (OECD, 2011; 2015a). The skills more directly associated with innovation include specialised knowledge (e.g. engineering, IT, design), cognitive skills (e.g. creativity, general problem-solving and thinking skills), "soft" social, emotional and behavioural skills (e.g. teamwork), entrepreneurship qualities and leadership (OECD, 2011; Hanel, 2008; Tether, 2008). But basic digital-age literacy, a relative technology fluency and multicultural openness are as important for technology and innovation to instil economy and society.

As many of these skills are developed from an early age, they need to be acquired in part through formal education. The increased recognition of the importance of these broader skills has also highlighted the contribution to innovation of training that goes beyond the traditional focus on science, technology, engineering and mathematics (STEM) disciplines, even though these disciplines occupy a prominent position in innovation policies.

Consequently there is an increasing focus on how well the education system equips young people with the skills to participate in and respond to innovation in the workplace and in society at large. A number of OECD countries and partner economies highlight education and skills as key priorities in innovation policy with a view of strengthening future innovative capacity and building a more inclusive growth (see the chapter on "Recent International Trends in STI and Policy").

Major aspects and instruments

Increasing students' participation in STEM remains a primary component of policy measures to strengthen education for innovation. Figure 2 shows the proportion of new entrants to tertiary education who study engineering, science and health. Increasing the number of students in STEM subjects at all levels of education is seen as a way to increase the pool of individuals able to enter research occupations or undertake innovation, as well as to improve general digital-age literacy and public understanding of science.

Despite the continuing focus on science and technology (S&T) education and careers, many OECD countries and partner economies also address the wider skills required for innovation. There is a growing trend to shape school and university curricula and teaching methods to encourage the development of these skills in addition to subject-based knowledge, while extracurricular activities seek to foster competencies such as creativity. Fostering students' entrepreneurial skills is one way to increase innovative entrepreneurship. Policy measures can take the form of dedicated entrepreneurship education or efforts to include entrepreneurial skills in curricula and school subjects.

Reform of education and vocational training institutions' governance arrangements (especially at the higher education level); the maintenance and development of infrastructures, platforms and equipment; or revised funding mechanisms are different policy instruments widely used to improve the outcome of education systems (Kergroach *et al.*, forthcoming-a). These policy efforts may however have limited benefits in the absence of high-quality and motivating teaching in schools. Policies to improve the capacity and incentives of teachers are important complementary initiatives.

Postgraduate and doctoral-level education also needs to foster skills for innovation, partly because many doctoral students go on to undertake innovation in a number of occupations. Figure 3 shows net entry rates into advanced research (doctorate) programmes.

Information on the demand for skills influences curriculum development, the design of teaching methods and teachers' training. Predictions are used to set the number of student places at various levels of education and in various disciplines, and the amounts of public funding allocated.

Policy initiatives also attempt to increase awareness of youth and participation in higher education by providing students with financial support during their studies or career guidance. Information and promotion campaigns help inform young people about career opportunities. Role models and mentors are high-profile referents for guidance and inspiration. Extracurricular activities (science fairs, competitions, hand-on workshops) complete the skills supply system.

Table 1. Skills for innovation: typology of national policy initiatives and country examples

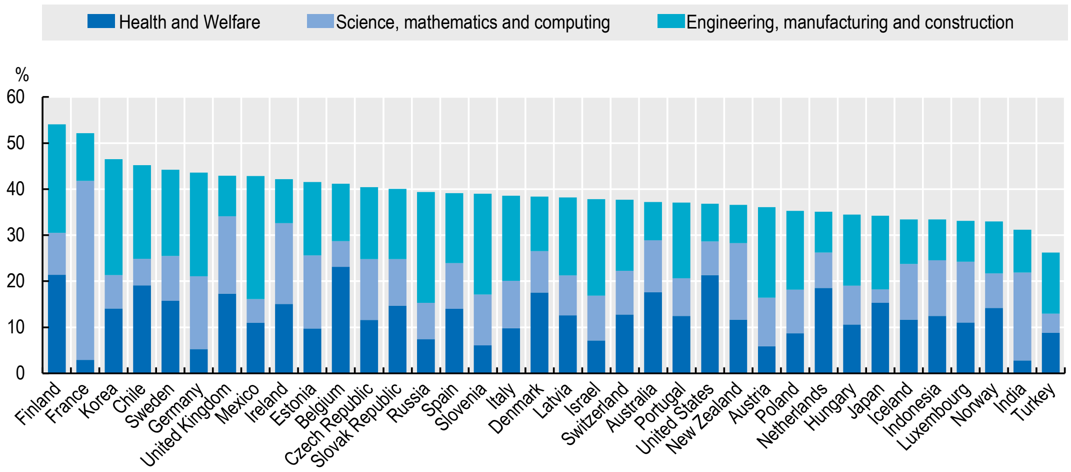
Key features		Key policy instruments	Some country examples
Expanding STEM education	Supply of STEM	Increasing participation in STEM in primary and secondary education; Greater funding of places on STEM courses in tertiary education. Financial support for STEM doctorates; Greater industrial collaboration in doctorate training	United States (2016 Federal Budget); Turkey (PhD programmes in priority science and innovation areas)
	Extracurricular activities	Science Fairs; Competitions; Hands-on workshops; reformed curricula.	New Zealand ('Futureintech'); Germany(Jugend Forscht competition)
Developing wider skills	Technology and ICT skills	Greater use of technology in teaching (e.g. to target digital learning and computational thinking); dedicated ICT teaching and ICT coordinators; promotion of online learning.	Czech Republic (Strategy for Digital Education); Portugal ('Apps4Good')
	Creativity and soft skills	Reforms of teaching methods to encourage development of cognitive and non-cognitive skills; Promoting extracurricular activities or workshops; Promotion of student-centred learning.	Spain (Erasmus+); Korea (promotion of problem-solving in Engineering Colleges)
	Entrepreneurship and business skills	Dedicated entrepreneurship training; Raising the awareness of entrepreneurship and innovation; Promotion of work-based learning (e.g. to narrow the gap between formal education and the workplace)	Finland (incorporation of entrepreneurship in curriculum); New Zealand (ICT graduate schools)
	Improving skills of teachers	Reformed access to teacher training (STEM and non-STEM); Financial provision to undertake training (e.g. to update subject knowledge) and lifelong learning for existing teachers; Collaboration between teachers and external professionals; Recruitment of teachers with industry experience.	Croatia (Croatian Teachers programme); Norway (teacher training admission requirements)
System-level policies	Increasing the flexibility of education provision	Greater personalisation of education; greater access to lifelong learning and re-training; Expansion of higher education.	Korea (Program for Industrial Needs- Matched Education)
	Forecasting skills needs	Using predictions to set numbers of places at different education levels and funding; Improving understanding of future education needs.	South Africa (modelling future demand for postgraduates)
	Reform of institutions	Reform of higher education governance; Revised funding structures; Maintenance and development of infrastructures, platforms and equipment;	Norway (Science and Mathematics Municipalities); Iceland (Quality Enhancement Framework for higher education)
	Improved information	Career guidance for young people; Promotion of career opportunities; Role model and mentor programmes; Information to disadvantaged pupils; Promotion of postgraduate education	

Note: This table draws upon recent analytical works on the innovation policy mix carried out for the OECD STI Outlook under the aegis of the OECD Committee for Scientific and Technological Policy. Country information is drawn from the EC/OECD International Science, Technology and Innovation Policy (STIP) Database, edition 2016, https://www.innovationpolicyplatform.org/topic-menu/sti-policy-database.

Source: Kergroach, S., J. Chicot, C. Petroli, J. Pruess, C. van OOijen, N. Ono, I. Perianez-Forte, T. Watanabe, S. Fraccola and B. Serve, (forthcoming), "Mapping the policy mix for innovation: the OECD STI Outlook and the EC/OECD International STIP Database", *OECD Science, Technology and Industry Working Papers*.

Figure 2. New entrants to tertiary education in engineering, science and health fields, 2014 or latest year available

As a percentage of total new entrants, all fields of study



Notes: New Entrants as a percentage of all tertiary education entrants according the International standard Classification of Education ISCED2011.The tertiary education refers to the aggregation of short-cycle tertiary education (ISCED2011-level 5) , bachelor's equivalent level (ISCED 2011- level 6), Master's or equivalent level (ISCED2011 level 7) and Doctoral or equivalent level (ISCED2011-level 8). For further information, national country methodologies are available at http://www.oecd.org/edu/EAG2015-Annex3-ChapterC.pdf.

Source: OECD (2016), *Education at a Glance 2016: OECD Indicators*, OECD Publishing, Paris.

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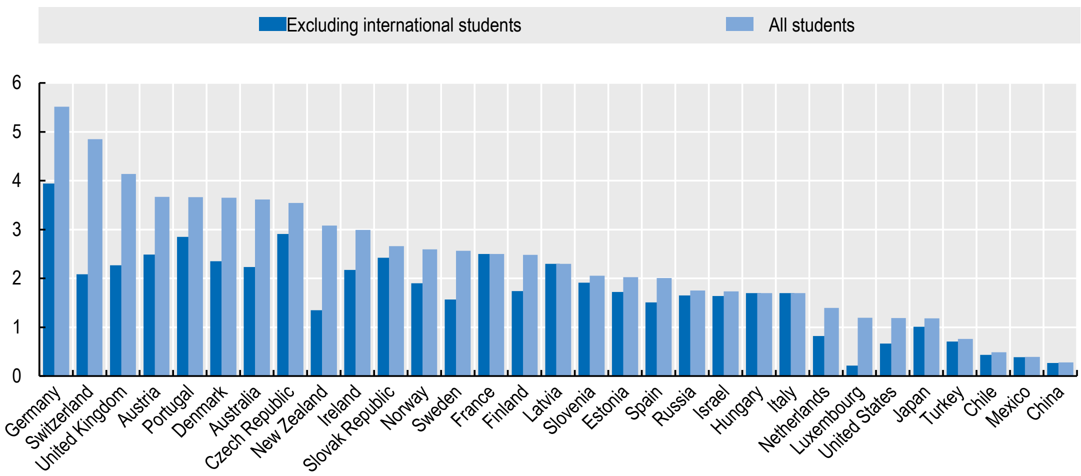
Figure 3. Net entry rates into doctoral (or equivalent) programmes, 2014 or latest year available



Notes: Net entry rates are sum of age-specific entry rates to ISCED 5, 6, 7 or 8. It represents the proportion of people of a synthetic age-cohort who enter the tertiary level of education. The net entry rate of a specific age is obtained by dividing the number of first-time entrants to each type of tertiary education of that age by the total population in the corresponding age group. The net entry rate is defined as the sum of net entry rates for single ages. For further details, please refer to http://www.oecd.org/edu/EAG2015-Annex3-ChapterC.pdf.

Source: OECD (2016), Education at a Glance 2016: OECD Indicators, *OECD Publishing, Paris.*

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Recent policy trends

Expanding STEM education remains a foundation of many OECD countries and partner economies' strategies towards improving education for innovation. The 2016 Federal Budget in the United States contains a goal to increase, over the next decade, the number of well-prepared college graduates with STEM degrees by one third, or one million. South Africa is increasing the budget for bursary values funded and the number of students awarded bursaries by the National Research Foundation. The Croatian Strategy for Education, Science and Technology 2014-20 contains measures to increase the supply of graduates and postgraduates in STEM disciplines. Belgium (Federal) and Latvia also note recent initiatives to boost STEM places.

In addition, many countries have attempted to make the subjects more interesting and attractive to young people. "A Nation of Curious Minds" was launched in New Zealand in July 2014 to encourage and enable better engagement of education with S&T. New Zealand's Futureintech programme brings people in science, technology and engineering careers into schools. Since 2014 a new Junior Cycle (secondary education structure) in Ireland features newly developed subjects on a phased basis in science, as well as short courses that can be developed by teachers to suit the specific needs and interests of their students. Portugal updated in 2015 its curricula of vocational science and engineering curricula.

Some countries have introduced or reformed nationwide student and youth competitions to generate curiosity and interest in STEM disciplines. In Germany, Federal competitions include the "Jugend Forscht" young researchers competition, the nation-wide competitions in computer sciences, the nation-wide mathematics competitions. Portugal runs a National Skills Competition for vocational students. Turkey runs competitions including the "National Secondary School Research Projects Contest" and "National Science Olympiads".

Other recent policies target teachers and aim to change how STEM subjects are taught. Croatia is modernising STEM initial teacher training programmes in order to update the skills of current teachers and equip them with up-to-date pedagogical methods and resources. The "Croatian Teachers" Programme involves training teachers to effectively collaborate with external STEM professionals. Innovation 2020 in Ireland contains a programme to provide continuing professional development for science teachers. Since 2015 Norway gives selected municipalities a special status as Science and Mathematics Municipalities, with support to develop local strategies for science education and for networking and skills development for teachers. Since 2016 Norway also requires higher grades for admission to teacher education in mathematics. Sweden is introducing short (one year) pedagogical programmes for specialists in STEM to be qualified as teachers. Korea is developing plans to recognise industry experience in the recruitment of engineering professors and reform professor evaluation criteria.

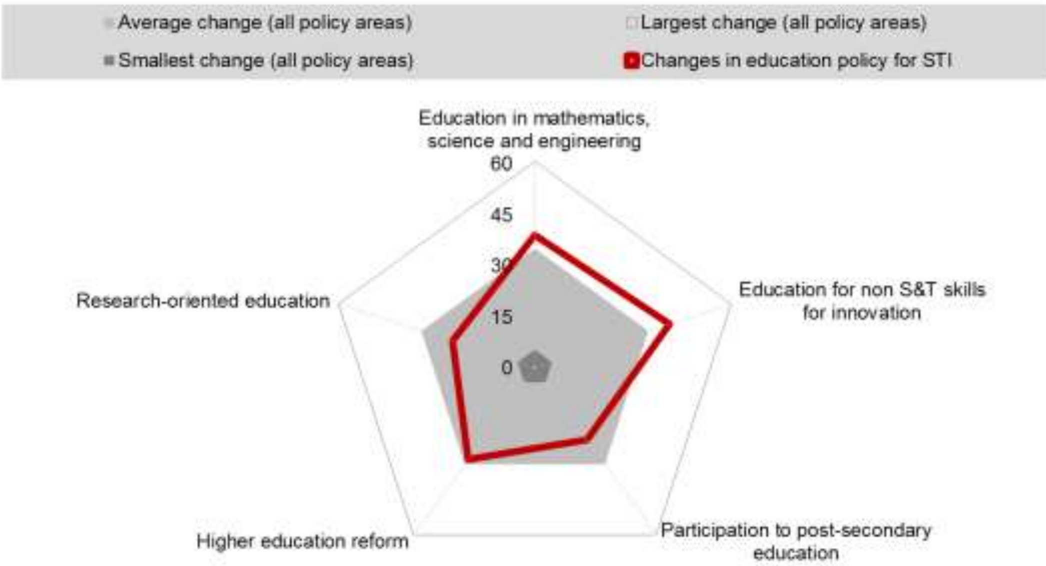
Introducing technology into schools and universities has become a popular policy measure for facilitating the acquisition of new skills, or fostering students' interest in topics such as computer programming. However, it is clear that such policies require careful design and evaluation – OECD PISA (Programme for International Student Assessment) results show no appreciable improvements in student achievement in reading, mathematics or science in the countries that had invested heavily in ICT for education (OECD, 2015b). Nevertheless IT-enabled tools and the Internet may help reach a larger pool of talent, for instance in remote areas or abroad, and increase institutions' services and reputation. The Strategy for Digital Education (2014-20) in the Czech Republic aims to ensure access to digital learning resources in order to improve information and digital technology skills and computational thinking among students. Ireland's Digital Strategy for Schools (2015–20) details measures to embed ICT into teaching, learning and assessment practices in schools. Lithuania is planning in 2016 to allow schools to employ an ICT coordinator who can assist teachers and students on technologies for teaching and learning and digital technologies. In partnership with an international NGO, Portugal has piloted a programme "Apps4Good" that aims to transform the way technology is taught in schools and encourage digital entrepreneurship. At the tertiary level, Spain has promoted the development of massive open online courses (MOOCs) and innovative teaching methods in higher education, while the Federal Targeted Programme for Education Development in Russia (2016–20) encourages greater use of technological innovations in the vocational and higher education systems.

A range of wider non-S&T skills for innovation are recognised in number of recent education policy developments in the OECD and beyond. Non S&T education has actually been one of the most changing STI policy areas between 2014 and 2016 (Figure 4). Korea has revised the curricula of engineering colleges to offer field-oriented education and cultivate students' problem-solving capabilities. Spain is promoting student-centred learning through "Erasmus+" to promote generic skills such as communication, leadership and active citizenship. Croatia's Strategy for Education Science and Technology contains measures on curriculum reform, including the definition of non-cognitive skills for innovation such as of attitudes creativity, critical thinking, responsibility and entrepreneurship. Ireland's reforms to school education include greater focus on students' creativity and entrepreneurial behaviour. Some recent policies target entrepreneurial thinking among young people. In basic education and upper secondary core curricula in Finland, entrepreneurship is linked to participatory, active citizenship and constitutes a cross-curricular theme, not a subject per se. Russia and Turkey both also report recent initiatives on promoting entrepreneurship and raising awareness of innovation.

Measures have been implemented with a view of encouraging the expansion of the whole higher education system. Some countries have set explicit targets for that purpose. Croatia is creating additional places during the academic year 2015/16 to increase the accessibility of higher education and steer demand towards occupations within sectoral priorities. The Strategy for Education Policy in the Czech Republic aims to enrol around two-thirds of each cohort of school leavers within the tertiary education system (including short courses); France has set the objective for 50% of the cohort should graduate from a higher education institution; and Strategy 2020 in Spain has set a target to achieve a percentage of 44% of the population with tertiary education.

Figure 4. Education policy for STI among other areas of STI policy change, 2014-16

Percentage of policy initiatives that have been newly introduced, revised or repealed over the period



Note: The EC/OECD STI Policy survey 2016 aims to review on a biennial basis major changes in national policy portfolio and governance arrangements for STI. The survey builds on the conceptual work carried on under the aegis of the OECD Committee for Scientific and Technological Policy (CSTP) for mapping the policy mix for innovation and therefore covers a broad range of policy areas (Kergroach et al., forthcoming-a). 52 economies participated in 2016, including OECD countries, key emerging economies (e.g. Argentina, Brazil, the People's Republic of China, Colombia, Costa Rica, Egypt, India, Indonesia, Malaysia, Peru, the Russian Federation, South Africa and Thailand), non-OECD EU Member States, and the European Commission. Taken together, countries covered in the STIP survey 2016 account for an estimated 98% of global R&D. Responses are provided by CSTP Delegates and European Research and Innovation Committee (ERAC) Delegates for EU non-OECD countries.

This is an experimental indicator inspired from analytical work done on firm demography. It accounts for the number of major policy initiatives that have been implemented, repealed or substantially revised over 2014-16, as a share of total policy initiatives that were active at the beginning of the period (Kergroach et al., forthcoming-b). Although simple counts do not account for the magnitude and impact of policy changes, this ratio reflects STI policy focus and activity in specific policy areas and over specific periods of time. The chart above shows the intensity of changes in the policy area(s) under review as compared to the whole mapping. Changes in the whole mapping are represented by the smallest, the largest and the average change policy area that changed the less, the policy area that change the most.

Source: Based on EC/OECD (2016) and Kergroach, S. et al. (forthcoming-b).

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Recognising the contribution of doctorates to the science system, doctoral education has been reformed and reinforced in a number of countries. The Science and Technology Policy and Action Plan 2014-16 in Iceland targets greater collaboration between higher education and research organisations and firms on research-based graduate education, increased funding for doctoral studies from competitive funds; and a faster application process for non-European PhD applicants.

In 2015 Turkey started to develop a new support scheme for university PhD programmes dedicated to priority science and innovation areas, support of PhD thesis supervisors, and certain firms that employ PhD-educated researchers. As part of reforms of PhD programmes in 2015, Latvia is introducing joint degree PhD study programmes, developing PhD and post-doc research laboratory networks and developing joint principles for the promotion.

Finally, policy towards education and skills for innovation can be designed to bridge the gap between formal education and the workplace (see also the *Policy Profile on Labour market policies for the highly skilled*). Many of these policies promote work-based learning by students, but also include reforms to vocational and technical education. New work-based learning will be reinforced and integrated within secondary education in Belgium (Flanders). Vocational education and training curricula in Finland include on-the-job learning in business environments and training in entrepreneurship. Three ICT Graduate Schools have been selected to operate in New Zealand, designed to produce graduates with work-relevant and business-focused skills and provide more direct pathways from education into employment. Korea has announced plans to introduce four major S&T specialized educational institutes (2015) designed to support core industry innovation and to develop creativity and problem-solving capabilities needed by industries. The "Marshall Plan 4.0" in Belgium (Wallonia) aims to strengthen dual apprenticeships to strengthen the link between the supply of training and the occupations of the future over 2015-19.

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