Educating Innovators and Entrepreneurs

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Successful innovation rests on a foundation of education and skills. As the Global Innovation Index (GII) demonstrates, increasing the educational achievement of young people is crucial to a country's ability to generate new knowledge and to innovate. But we should not assume that existing education systems are necessarily aligned with the need to produce the next generation of innovators. Education systems that narrowly focus on test-based academic performance and numbers of students enrolled in science and technology subjects are not necessarily those that will produce young people with the creativity, critical thinking, and communication skills that innovative societies require. In particular, a narrow focus on the acquisition of academic knowledge risks encouraging a teaching model that threatens to dampen innovative and entrepreneurial spirit rather than foster it. Instead, school education should ensure that young people not only acquire excellent knowledge but are also able to apply knowledge in a variety of contexts, and should also ensure that they develop less easily measured skills such as creativity. Decision makers should avoid crowding out arts and non-technical subjects that have an important role to play in developing the skills conducive to innovation in all its forms. The push for academic excellence needs to be combined with quality teaching and learning methods that stimulate a wide range of thinking and behavioural skills.

Aligning education and skills policies with the objective of increasing global innovation capacity is especially pressing in light of recent global economic trends. Over recent decades, rapid technological change has revolutionized many aspects of everyday life. But it has also changed the nature of work, especially in Organisation for Economic Co-operation and Development (OECD) countries. Higher-order thinking skills, such as the ability to process large quantities of information, have become more important in the workplace at the expense of routine skills that can now be undertaken by increasingly sophisticated machines. In this context, education systems need to equip young people with the skills to both participate in and respond to innovation in the workplace. Moreover, especially in light of the recent global economic crisis, improving skills is one of the most important ways to raise innovation, productivity, and economic growth, and to improve social welfare and equality.

This chapter explores the role of education, primarily at the school level, in fostering the dispositions and skills conducive to innovation. It examines what skills are required for innovative societies, how different teaching methods may help foster these skills, what policies and initiatives economies are undertaking in this area, and some of the remaining challenges. Finally, implications for the GII are discussed.

Context and background

Education policies to foster innovation have traditionally focused on increasing participation in science, technology, engineering, and mathematics (STEM) disciplines. Recently, however, a more comprehensive view of innovation, which recognizes the contribution of a wider set of skills and disciplines, has emerged. While STEM specialists are undoubtedly important for certain types of innovation, particularly technological innovation, government policy needs to take a broad view of the competencies used in the innovation process.

Surveys of tertiary-educated employees show that innovation requires a broad range of skills. The international REFLEX survey,[1] which interviews graduates five years after their graduation, shows that innovative employees (whom we define as those working in an organization that innovates

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and participating in the introduction of these innovations) report that they use more of all types of skills in their jobs than their non-innovative counterparts. Among the results from the self-reported use of skills that most distinguish innovative and non-innovative workers are 'coming up with new ideas and solutions' (creativity), 'a willingness to question ideas' (critical thinking), and 'the ability to present new ideas or products to an audience' (communication).

Reflecting this evidence from innovative workers, along with findings from the wider literature,[2] skills for innovation can be grouped into three broad categories:

- Subject-based skills, which represent knowledge and know-how in a particular field.
- Thinking and creativity, including both higher-order skills and creative cognitive habits. These competencies include critical faculties, imagination, and curiosity.
- Behavioural and social skills, including skills such as self-confidence, leadership and management, collaboration, and persuasion.

In terms of qualifications, it is not just graduates of tertiary education who contribute to innovation. Technical skills such as craft, design, and testing play an important role in innovation, especially in the incremental changes that make up a large proportion of innovation in practice.[3] Vocational education and training, in particular, help provide these essential capabilities. Moreover, non-technological innovation (such as new organizational methods and marketing innovations) requires a skill-set very different from that provided by traditional university-level science and engineering training. Again, a mix of qualification levels appears to be important. Balanced innovation systems need doctorate-holding researchers with focused expertise, but also informed users and consumers who have the curiosity and imagination to adapt goods and services to their own needs. Developing a wide set of skills is important for all individuals, not just for the sub-set who will go on to innovate.

Together, these insights help define the role of education in innovation. Developing excellent subject-based knowledge is undoubtedly important for an innovative society, but it is not enough on its own. In addition to raising academic achievement across all levels of education, innovation policies need to pay more attention to what skills young people acquire. Fostering critical thinking, creativity, and behavioural and social skills should be viewed as a central element of the remit of schools, colleges, and universities.

How can different types of school education develop skills for innovation?

Work by the OECD Centre for Educational Research and Innovation (CERI) highlights several areas where school education can help develop skills for innovation. In general, there are good examples of how schooling may foster innovation, but the link between the two is still not fully understood.

Improving students' knowledge and learning outcomes is an important indicator and target in many national education systems. But evidence suggests that performance in exams or standardized tests—the way these outcomes are usually measured—is not necessarily associated with the skills that matter for innovation. Using data from the 2006 OECD Programme of International Student Assessment (PISA), Avvisati and Vincent-Lancrin (forthcoming) highlight a negative correlation between national-level student test scores in science and interest in science. In fact, few countries successfully manage to combine above-average levels of student interest in science with above-average performance in the PISA science test. Countries range from those with comparatively low test scores and high interest in science (e.g., Mexico) to those with comparatively high scores and low interest (e.g., Finland), but a few do have relatively high scores and high interest (e.g., Japan). Because scientific interest was measured by embedded questions in the PISA questionnaire, these international patterns are unlikely to be simply the result of cultural differences among countries.

Looking at the *within-country* pattern (i.e., among schools in a single country), there is substantial diversity across countries. The negative association between interest and PISA test scores in science holds for around half of OECD countries. In Brazil, Chile, and the United States of America, for example, schools with the best test scores in science tend to have lower levels of student interest in science, suggesting that the prevalent modes of teaching and learning may develop disciplinary knowledge at the expense of interest in the topic or curiosity. But schools with strong science test performance in some other countries, such as Japan or the Republic of Korea, seem to also have students with high levels of interest. (It is noteworthy that this within-country pattern can hold in countries such as the Republic of Korea, where overall student interest

in science topics is low by international standards.)

The apparent trade-off between performance on tests and curiosity of pupils is thus neither universal nor inevitable. Since engagement and motivation is a key aspect of the skills required for innovation, it is important that teaching and learning activities to improve proficiency on science tests do not undermine the development of other skills.

Which teaching practices can foster both competence in scientific knowledge while maintaining students' engagement and curiosity? Analysis of the same PISA data on science teaching points towards the importance of linking classroom topics to real-world applications. Avvisati and Vincent-Lancrin (forthcoming) examine how four different types of science pedagogy (application, hands-on activities, interaction, and investigation) relate to student attitudes and performance. Of the four teaching models, increasing the time dedicated to application-based pedagogies is estimated, controlling for other factors, to have the largest positive association with interest and enjoyment of science, although there is no clear association with performance in the PISA science test. The results indicate that developing positive attitudes among science students in school requires more than just aiming at good test results, and that linking classroom theory to everyday problems is a way of fostering motivation alongside efforts to improve subject knowledge.

The use of classroom technology is also often put forward as a way of helping enhance skills such as creative thinking, engagement, and collaboration. Kärkkäinen and Vincent-Lancrin (2013) outline how technology-enhanced teaching models in STEM education—such as online laboratories or educational gaming—can expand the range of learning opportunities available to students and, in the right circumstances, help develop higher-order thinking. But technology—be it interactive whiteboards, tablet computers, or other tools—is best viewed as facilitating appropriate teaching and learning of these skills rather than replacing the traditional classroom.

In mathematics education, too, increasing attention is being paid to the teaching and learning models that best equip students with useful, long-lasting skills rather than providing them solely with the ability to pass tests and use mathematics within the confines of the classroom. In particular, the skills needed to solve unfamiliar, complex, and non-routine mathematical problems are likely to be important in an innovative society. A particular skill associated with the ability to tackle such problems is metacognition, or one's control of the thought process around learning. In contrast to commonly used techniques such as rote-learning or memorization, metacognitive teaching models guide students to consciously think about the process behind solving mathematical problems. Findings from a number of experimental studies show that metacognitive mathematics teaching can improve test performance in mathematics and, simultaneously, foster important skills such as maths reasoning and motivation, which may contribute to innovation.[4] Though such new instruction models need to be tested on a wider scale, there appears to be scope in many countries to focus on developing a wider set of mathematical skills.

Reflecting the breadth of competencies used in innovation, efforts to foster innovative skills among school students should also look beyond science and mathematics. The link between arts education and innovation, especially, is often recognized. Indeed, graduates of tertiary arts programmes are among the most likely to contribute to product or service innovation.[5]

As summarized in Winner et al. (2013), arts education can influence the skills used in innovation in a number of ways. Different types of arts education help develop verbal or visual-spatial skills, which in turn play an important role in non-artistic fields such as verbal competence (speaking, reading, and understanding written text) and in some maths or science activities. Most notably, experimental studies show that one-to-one music lessons have a positive effect on IQ and academic achievement, and that music education enhances verbal skills. Theatre education leads to an improvement in verbal skills; visual arts education improves observational skills and probably visual-spatial skills and geometrical reasoning, while more tentative evidence suggests that dance education enhances visual-spatial skills. Experimental research also shows that theatre education has a positive impact on the development of some social and emotional skills such as empathy, perspective taking, and emotion regulation—skills that are key dimensions of communication.

Although there is as yet no clear evidence, good arts teaching probably also typically develops some of the habits of mind that are crucial for innovation. And although most studies that have examined the link between arts education and creativity (measured by paper-and-pencil tests such as the Torrance Tests of Creative Thinking)[6] find a positive association, it is too early for general conclusions to be drawn. But a recent ethnographic study of high-standard

visual arts teaching shows that good teachers explicitly try to develop not only technical artistic skills but also creativity, critical thinking, and persistence.[7] Moreover, the typical teaching methods are highly personalized and include class projects, individual consultations with teachers, mid-project critiques, peer review, and a presentation of one's work to other students or a wider audience. Teaching methods in visual arts (and many other art forms) thus seem closer to the teaching practices that can nurture skills for innovation than those generally used in academic subjects.

Another pillar in innovation and education policy is aimed at increasing the rate of entrepreneurship. Entrepreneurship education is a popular policy tool to develop entrepreneurial skills and encourage a more favourable culture and attitude towards innovation and the creation of new firms. The content of entrepreneurship education often varies. School-level entrepreneurship education often involves trying to foster entrepreneurial skills through problem-solving activities and contextual learning based on interactive projects and games. By contrast, entrepreneurship education for upper-secondary school pupils and young adults is more typically based on providing information and developing the practical knowledge and skills needed to run a business. For example, the INJAZ Junior Achievement programme in the Middle East aims to provide business skills and financial literacy to students in Egypt, Jordan, Lebanon, Morocco, Saudi Arabia, and the United Arab Emirates through a mixture of classroom and extracurricular activities.[8]

However, the relative importance of education compared to other underlying determinants of entrepreneurship is still uncertain. The pervasive 'jack-of-all-trades' theory of entrepreneurship posits that successful entrepreneurs are generalists with skills in a variety of fields rather than specific expertise in one area.[9] This theory points to the importance of broad-based schooling. But many of the thinking and behavioural skills required for innovation are also central to entrepreneurship, in addition to characteristics such as the ability to adapt to change and to tolerate risk and uncertainty. Therefore, the lessons from the different teaching methods discussed above are also highly relevant for fostering entrepreneurial as well as innovative potential.

Evidence of the effectiveness of school-level entrepreneurship education programmes is mixed. Oosterbeek et al. (2010) showed that a 'mini-company' initiative in the Netherlands had no statistically significant effect on the entrepreneurial skills of students and a significant negative effect on their willingness to start a business. But other studies suggest that entrepreneurship education in school can develop non-cognitive entrepreneurial skills (including persistence, creativity, and proactivity), at least in the short term.[10] More work is needed to draw general conclusions and determine the successful elements of this type of intervention.

What are countries doing to foster innovation skills in school education?

By influencing what and how children learn, school curricula play a central role in developing skills from an early age. The role of skills for innovation in national curricula appears to have become more prominent in recent years in many countries. A survey of OECD countries in 2009 found that all responding countries included at least some aspects of 21st-century skills in primary and lower-secondary curricula.[11] Most primary and secondary education curricula in developed countries refer to critical thinking, creativity, problem-solving, and social skills.

Different country efforts take many forms. Denmark's 2012 National Innovation Strategy,[12] for instance, promotes the integration of innovation and entrepreneurship into the mainstream curriculum and increases practice-based teaching in schools and innovation courses in teacher training programmes. In addition, some countries—including Finland, Portugal, and Sweden—have embedded entrepreneurship education into primary and secondary school curricula, while a number of OECD countries, including Australia and Ireland, encourage the integration of information and communication technologies into schools. However, although national curriculum efforts to boost entrepreneurship and innovation skills appear to be pervasive across OECD countries, it can be hard to identify their impacts. Despite national policies, implementation can vary significantly across countries, and teaching tends to vary widely on a school-by-school basis. Though national curricula are important, maintaining school diversity and a variety of different teaching approaches can have many advantages.

Even in many Asian economies, where education systems have typically been associated with traditional learning models and a narrow focus on STEM subjects, there are signs of new efforts to emphasize creativity and critical thinking in national curricula. Since 2009, the Republic of Korea (an OECD country) expects its schools to foster creativity as part of subject-based learning, but also to devote almost 10% of overall school

time to projects and other transversal activities that foster creativity. By the end of secondary school, students in Singapore are expected to have developed critical and inventive thinking skills as well as social and emotional abilities such as being 'resilient in the face of adversity'. Singapore has also adopted a mathematics curriculum based around metacognitive approaches to complex problem solving. In China, since 2009, more emphasis has been placed on changing traditional teaching models. In Indonesia, the practice of 'lesson study' aims to promote professional learning among teachers and help them to reflect on their teaching methods and align those methods with the needs of students.[13]

In many other countries across the world, education systems start from different positions and face different challenges in curriculum reforms. In India, for example, the rote learning system (i.e., repetition as a technique for memorization) that still prevails in many Indian schools impedes the development of curricula focused on skills for innovation. But encouraging examples of curriculum reform and organizational innovation have started to appear in India—the Apeejay school network, for example, promotes educational programmes for creativity and innovation, with practices such as enquiry-based projects designed to develop creativity and original thinking.[14] Not all efforts need to take place in the classroom, however. In Costa Rica, for example, the Innovating at Home programme aims to teach parents how to develop their children's creativity from an early age.[15] These examples show there is increasing emphasis and interest in developing wider skills in a variety of country contexts.

Developing skills for innovation in school: Remaining challenges

Despite policy efforts in many countries to place more attention on the skills that school students acquire, a number of shared challenges remain. One potential barrier to developing skills for innovation is student assessment.

Assessment processes at the school level are typically poorly aligned with skills for innovation. Despite the fact that curricula in an increasing number of countries emphasize a wide range of skills, student assessment tends to focus heavily on content knowledge and cognitive skills.[16] This might reflect the fact that assessments focus on the competencies that are most understood or are easiest to measure, or that assessment is limited to formats that are easy for teachers to mark and those that allow different pupils, schools, and regions to be easily compared.

High-stakes examinations generally imply that teaching and learning activities become conditioned on preparing and passing tests. Often teaching becomes focused on the mechanical learning of what is tested rather than on developing student skills across the board. The potential benefits from, say, application-based or metacognitive teaching may become apparent only when assessments try to measure factors such as problem solving or reasoning. This has been shown in studies of problem-based learning in higher education, and may also be true in primary and secondary education. Although one might expect that 'teaching to the test' could foster positive outcomes if tests were appropriately designed to reflect different competencies, it is not possible to design (short) tests that reflect all the competencies that society values.[17] The inclusion of a broader range of competencies in new forms of assessment would, however, give all stakeholders greater incentives (see Box 1).

More progress is required across the world to ensure that educational assessment encourages schools to produce well-rounded students. This will require efforts not only from policy makers and school decision makers but also from teachers, who may need to be trained to assess a variety of student skills. Innovations such as formative assessment tools or curriculum-embedded assessments can help to ensure that teachers are

Box 1: Assessing creativity in schools

A study commissioned by the OECD and the CCE (Creativity, Culture and Education) examines how creativity could be assessed by primary school teachers. Lucas et al. (2013) propose a prototype tool for assessing creativity in schools that maps the habits of mind or dispositions associated with creativity along five principal dimensions: inquisitive, persistent, imaginative, collaborative, and disciplined. Two field trials of the assessment tool in 17 primary schools in England showed that the tool allowed teachers to be more precise and confident in developing pupils' creativity, while children showed signs of better understanding and being able to record their progress. Although the focus is on creativity, the tool is broad enough to capture other skills such as 'collaborative' competencies, which have a strong bearing on behavioural and social skills. For schools, the tool had the advantage of reminding teachers of the importance of a broad set of competencies and what they mean in the school setting. Further development of such formative assessment tools could increase teachers' and students' awareness of skills for innovation and help these skills be monitored in school learning.

equipped to assess real student learning in a timely manner.[18] In addition, advances in software development have increased the potential for computer-based assessments (both formative and summative), increasing the capability for a wide range of skills to be assessed in a flexible manner. Finally, the development of longitudinal information systems that track students' progress over time represent a good vehicle that can be used to monitor progress in acquiring a variety of skills over time and to design appropriate and personalized interventions for that purpose.[19]

Opportunities and challenges for the Global Innovation Index

The issues discussed in this chapter raise some interesting issues for the GII. At present the Index uses (if available) a number of school-level education indicators, including expenditure on education; school life expectancy; pupil-teacher ratios; and PISA results in reading, maths, and science. Given current data availability and measurement challenges, these indicators adequately capture the role of education in innovation, but there could be scope to broaden the range of indicators in the future.

The first point to note is that, in many countries, the first priority in widening the pool of individuals available to take part in innovation is to strengthen educational participation and the foundation skills of individuals. Changes in indicators that reflect these fundamental priorities remain relevant for the GII.

Second, the ongoing development of the OECD PISA assessment should, over time, allow the GII to draw from a wider set of indicators on pupil skills. Since 2003 PISA has included a paper-based measure of problem-solving skills, defined as an individual's ability to use cognitive processes to confront and resolve real, cross-disciplinary questions. In PISA 2012 the definition of problem solving was revised and assessment moved to a computer-based test. The computer-based testing can assess how willing a student is to engage with a problem rather than just checking for a right answer. In 2015, PISA will include a computer-based assessment of collaborative problem-solving skills, measuring the capacity of an individual to a group's success in problem solving by sharing effort and understanding.

But other existing and yet-to-be-developed indicators could, in the future, help better capture how well countries' education systems support innovation. First, more international data are needed on student outcomes in the areas of creativity, critical thinking, and behavioural and social skills. Many of these skills can be measured but indicators on a wider scale are still lacking. Tests for creativity, for instance (such as the Torrance tests) already exist, but widespread and field-specific measures would help assess the different aspects of student creativity in diverse fields. Data on student attitudes towards entrepreneurship (which already exist in many countries) could also contribute to the GII, though caution is needed as attitudes can reflect a number of issues. The second main opportunity for new indicators is proxies of educational processes conducive to developing skills for innovation. The fact that school assessment processes tend to be poorly aligned to skills for innovation means that a wider range of information on how schools in different countries operate is needed. Indicators of national curricula, assessment mechanisms, the use of active teaching models, university entrance exams, and work organization in the education sector could all shed light on the conditions for skills development.

Concluding remarks

In the context of a globalized world where innovation is a main driver of long-term economic growth, one of the key challenges for education and training systems is to find effective ways to equip more people with the skills to contribute to innovation in all its forms. Evidence points to a range of skills that are required for innovation, with these requirements varying by innovation type. Education in many disciplines can contribute, but the way subjects are taught is as important as the subject matter—linking content to real-world applications and teaching students the skills to address new problems are important. Although many countries are addressing the kinds of skills needed for innovation in their curricula, school assessment methods may provide a barrier to their development. More metrics are needed for policy makers to gauge progress in fostering innovative and entrepreneurial competencies and to allow the GII to capture a broader range of student learning outcomes. Addressing these issues is one of the key ways education systems can produce young people able to adapt to and engage in the global knowledge economy.

Notes

1 The REFLEX survey is a large-scale survey of higher education graduates in 14 European countries and Japan. It was conducted in 2005 and financed by the Sixth Framework Programme of the European Union. See http://www.fdewb.unimaas.nl/roa/reflex/.

2 See, for example, Tether et al., 2005.

3 Toner, 2011.

4 Mevarech et al., 2010.

5 Avvisati et al., 2013.

6 Torrance, 1998.

7 Hetland et al., 2013.

8 Reimers et al., 2012.

9 Lazear, 2004.

10 For example, Rosendahl Huber et al., 2012.

11 Ananiadou and Claro, 2009.

12 See http://ufm.dk/en/publications/2012/files-2012/innovation-strategy.pdf.

13 OECD, 2013.

14 See OECD, 2012.

15 This example comes from the response from Costa Rica (unpublished) to the OECD Science, Technology and Industry Outlook 2014 survey.

16 Ananiadou and Claro, 2009.

17 Looney, 2009.

18 Schleicher, 2012; Kärkkainen and Vincent-Lancrin, 2013.

19 OECD, 2010.

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