OECDpublishing

Please cite this paper as:

Levy, F. (2010), “How Technology Changes Demands for Human Skills”, *OECD Education Working Papers*, No. 45, OECD Publishing.
http://dx.doi.org/10.1787/5kmhds6czqzq-en

OECD Education Working Papers
No. 45

How Technology Changes Demands for Human Skills

Frank Levy

OECD

Unclassified **EDU/WKP(2010)8**

Organisation de Coopération et de Développement Économiques
Organisation for Economic Co-operation and Development **05-Mar-2010**

English - Or. English

DIRECTORATE FOR EDUCATION

EDU/WKP(2010)8
Unclassified

HOW TECHNOLOGY CHANGES DEMANDS FOR HUMAN SKILLS

OECD Education Working Paper No. 45

By Frank Levy

This paper was prepared for the OECD By Frank Levy of the Department of Urban Studies and Planning at MIT.

Contact:
Andreas Schleicher, E-mail: Andreas.Schleicher@oecd.org; Tel: +33 (0) 1 45 24 93 66

JT03279582

Document complet disponible sur OLIS dans son format d'origine
Complete document available on OLIS in its original format

English - Or. English

OECD DIRECTORATE FOR EDUCATION

OECD EDUCATION WORKING PAPERS SERIES

This series is designed to make available to a wider readership selected studies drawing on the work of the OECD Directorate for Education. Authorship is usually collective, but principal writers are named. The papers are generally available only in their original language (English or French) with a short summary available in the other.

Comment on the series is welcome, and should be sent to either edu.contact@oecd.org or the Directorate for Education, 2, rue André Pascal, 75775 Paris CEDEX 16, France.

The opinions expressed in these papers are the sole responsibility of the author(s) and do not necessarily reflect those of the OECD or of the governments of its member countries.

ABSTRACT

This paper places the competencies to be measured by the OECD's Programme for the International Assessment of Adult Competencies (PIAAC) in the context of the technological developments which are reshaping the nature of the workplace and work in the 21st century. The largest technological force currently shaping work is the computer. Computers are faster and less expensive than people in performing some workplace tasks and much weaker than people in performing other tasks. On the basis of an understanding of the kinds of work computers do well, it is possible to describe the work that will remain for people in the future, the skills that work requires and the way that computers can assist people in performing that work. The paper argues that a technology-rich workplace requires foundational skills including numeracy and literacy (both to be tested in PIAAC), advanced problem-solving skills or *Expert Thinking* (similar to the construct of Problem Solving in Technology-Rich Environments to be tested in PIAAC) and advanced communication skills or *Complex Communication* (not being tested in PIAAC).

RÉSUMÉ

Ce document situe les compétences qui seront mesurées dans le cadre du programme de l'OCDE pour l'évaluation internationale des compétences des adultes (PIAAC) dans le contexte des avancées technologiques qui redessinent la nature du travail et le lieu où il est effectué au 21ème siècle. La plus grande force technologique qui actuellement façonne le travail est l'ordinateur. Les ordinateurs sont plus rapides et moins onéreux que les individus dans certaines tâches sur le lieu de travail, mais bien moins performants que les personnes dans l'accomplissement d'autres tâches. Si l'on considère que l'on peut identifier les types de travaux que les ordinateurs remplissent correctement, il est alors possible de décrire ceux qui seront de la responsabilité des individus dans le futur ainsi que les compétentes que ces travaux nécessitent, et la façon dont les ordinateurs peuvent assister les individus à les accomplir. L'argument contenu dans le document est qu'un lieu de travail hautement technologique nécessite des aptitudes fondamentales telles que le calcul et la compréhension de textes (qui seront tous deux testés dans le PIAAC), des compétences avancées à résoudre des problèmes ou *Expert Thinking* (similaires à l'aptitude à résoudre des problèmes dans un environnement hautement technologique qui sera testée dans le PIAAC) et des compétences avancées en communication ou *Complex Communication* (non testées dans le PIAAC).

HOW TECHNOLOGY CHANGES DEMANDS FOR HUMAN SKILLS

Frank Levy
Department of Urban Studies and Planning
MIT[1]

1. It is a characteristic of labour markets that technology can change the nature of work faster than people can change their skills. OECD's Programme for the International Assessment of Adult Competencies (PIAAC) is an ambitious first step toward remedying this problem by constructing a clear picture of the current distribution of the skills required to work in technology-rich environments.

2. If completing the PIAAC required a list of tomorrow's occupations, the project would be hopeless. Innovation is central to market economies and it is impossible to imagine many of the new occupations that will exist in a decade's time. But while we don't know everything about future occupations, we do know something about the skills these future occupations will require.

3. There is no mystery to this. The largest technological force now shaping work is the computer. Computers are faster and less expensive than people in performing some workplace tasks and much weaker than people in performing other tasks. By characterising the kinds of work computers do well, we can begin to describe the work that will remain for people in the future, the skills that work requires and the way that computers can assist people in performing that work.

4. In this paper, I will argue that a technology-rich workplace requires foundational skills including numeracy, literacy and reading ability (all to be tested by the PIAAC), an advanced problem-solving skill I will call *Expert Thinking* (similar to Problem Solving in Technology-Rich Environments to be tested in the PIAAC) and an advanced communication skill I will call *Complex Communication* (not being tested in the PIAAC).

1) Three Opening Examples

We can begin to describe what computers do by considering three workplace tasks:

- In railroad stations, the task of selling tickets to particular destinations, a moderately skilled task, is increasingly performed by self-service kiosks rather than by desk agents.

[1] flevy@mit.edu. This paper is based on ideas that first appeared in David Autor, Frank Levy and Richard J. Murnane, "The Skill Content of Recent Technical Change: An Empirical Investigation" *Quarterly Journal of Economics*, 118, 4 (November 2003) pp. 1279-1334; and Frank Levy and Richard J. Murnane, *The New Division of Labor: How Computers are Creating the Next Job Market,* Princeton University Press, 2005.

- In industrial seaports, the task of recording and tracking the movement of sealed cargo containers is increasingly done automatically using signals emitted from RFID tags. The task used to be done by clerks who inspected containers visually.

- In a doctor's office, the doctor makes a diagnosis using a computer to access a patient's electronic medical record that contains the patient's medical history including procedures performed by other doctors. The doctor then uses computerised search to look for potential treatments for the patient's condition. In the past, the doctor would have worked from a paper medical record that might have omitted other doctors' procedures and he would have searched for potential treatments in his reference books, some of which might have been out of date.

5. Why do we see this particular mix of outcomes? How do we explain the fact that computers *substituted* for human work in issuing tickets and tracking cargo containers while computers *complemented* the doctor's diagnostic skills?

6. The answer begins with two ideas:

- All human work involves the cognitive processing of information. The financial analyst who reads numbers in a spreadsheet, the farmer who looks to the sky for signs of rain, the chef who tastes a sauce, the carpenter who feels his hammer as it hits a nail – all these men and women are processing information to decide what to do next or to update their picture of the world.

- Computers execute rules. Some of the rules involve arithmetic (6 x 9 = 54). Other rules involve logical conditions (If [AGE $\geq$ 35] Go to Statement 13).

- We can think of a properly running computer program as a series of rules that specify an action for each contingency.

7. When these two ideas are combined with common sense, they say that a computer can substitute for a human in processing information when two conditions are present:

- The information to be processed can be represented in a form that is suitable for use by a computer.

- The processing itself can be expressed in a series of rules.

8. The first condition is the common sense. The information processing rules in the second condition rules can be either deductive or inductive. Deductive rules arise from the logical structure of the process. For example, in the case of the railroad ticket kiosk, some deductive rules might be:

  – "If the destination is Philadelphia, the ticket price is $35.50."

  – "Read the person's credit card number."

  – "Send the person's credit card number to the issuing bank to authorise the charge."

Information processing based on deductive rules is often described as rules-based logic.

9. Inductive rules - a more complicated situation - typically refer to equations based on regressions, neural nets and other statistical models where the parameters of the model have been estimated on "training samples" of historical cases. The equations with their estimated parameters are then used to

process new cases. Information processing based on inductive rules is usually described as pattern recognition. It is this pattern recognition that permits a radio receiver to identify the signal from the RFID tag on the cargo container. Other pattern recognition software is used to recognise words in voice recognition software and to recognise potential fraud in credit card purchasing data.

10. The third example is different. A computer can *complement* the doctor's diagnostic skills by providing a full patient history and searching for potential treatments that physician might not otherwise find. At the same time, a computer cannot *substitute* for the diagnostic skills per se.

11. More precisely, the doctor performs two tasks that cannot be easily computerised. The first involves eliciting information from the patient. As any doctor will testify, this is not a simple process. It involves listening to the patient's words. It also means reading the patient's body language – the tone of voice, the avoidance of eye contact or the broken off sentence that indicates the patient is holding something back. The doctor must be particularly alert for the famous "last minute" of an appointment when the patient, on his way out the door, looks over his shoulder and says "By the way, my wife says I should tell you about this pain I have in my stomach."

12. Many other jobs today involve similarly complicated human interaction. We can call these interactions Complex Communication.

13. The doctor's other non-computerised task involves constructing a diagnosis from multiple sources of information: what the patient has told him, the patient's medical history, his knowledge of the medical literature, his experience with past cases, and so on. This task has not been computerised because it cannot be expressed in a set of step-by-step rules.[2] Many other jobs today also involve solving problems that lack rules-based solutions. We can call this style of problem solving Expert Thinking.

14. A few additional comments on Complex Communication and Expert Thinking help to explain their importance and the challenges they raise for education and training.

2) Complex Communication

15. A dozen years ago, at the height of the dot.com mania, experts predicted that the internet would eliminate millions of jobs in management, teaching and sales – jobs that involved communicating information. Networked computers, people assumed, could communicate the information at much lower cost than traditional modes of person-to-person communication.

16. In practice, these jobs are as numerically important as they ever were. The reason why lies in a basic cognitive principle: information is inherently ambiguous and we give information meaning by imposing a context. Without a shared context, there is no guarantee that the recipient of information will interpret it as the author intended. A good example of this principle comes from what may still be the shortest correspondence on record.

17. The correspondence began with a telegraph consisting of a single character - **?** -and the reply was a telegraph consisting only of **!**.[3]

---

2 See for example, Marsden S. Blois, "Clinical Judgment and Computers", *New England Journal of Medicine*, 303 (July 24, 1980), pp. 192-197.

3 This example is adapted from Tor Norrestradners, *The User Illusion: Cutting Consciousness Down to Size,* Viking Penguins, 1998. The example has appeared in *The Guiness Book of Records* as the shortest correspondence.

18. We don’t do many telegraphs these days but what would you think if you received a letter consisting only of “?”. If you had a child away at school you might assume the letter was about money. If you hadn’t called your mother recently, you might assume the letter was a pointed reminder. Read by itself – taken out of context - the question mark tells you little.

19. In fact, this particular question mark was written by Victor Hugo. In 1862, Hugo finished *Les Misérables*. Exhausted, he dropped the manuscript off with the publisher and left for vacation. Though Hugo wanted to relax, he also wanted to know how the book was selling and so he telegraphed “?” to his publisher. The book was a smash hit and so the publisher could telegraph back “!”

20. Hugo and his publisher each knew what was on the other’s mind – they shared a context.

21. This was the point the dot.com forecasts missed: the job of managers, teachers, sales people and others is not to convey information per se but to establish a context in order to convey a *particular interpretation* of information. When a salesperson says you look perfect in lime-green pants, you cannot know, based on the verbal information alone, whether the salesperson is being honest. The other things the salesperson does – reading your body language, quickly correcting misunderstandings, smiling at appropriate times – are designed to establish a context in which you assume you are hearing the truth.

22. In the same way, writing down formulas on a blackboard is a small part of a calculus teacher’s job. The teacher must use examples and back-and-forth conversation to create a context in which students can understand what the formulas mean. And asking “What seems to be the problem?” is only the start of the doctor’s work to discover and diagnose the patient’s symptoms.

23. Mastering Complex Communication – the ability to establish a common understanding of information – is a highly valuable skill particularly in technology-rich environments where information is abundant and circumstances can change rapidly.

3) Expert Thinking

24. When a problem can’t be solved by rules, it is necessary to look for other solution methods – what can be called Expert Thinking. Expert Thinking is a collection of specific solution methods that vary with the problem at hand. One frequently used method is what cognitive scientists call case-based reasoning. The method is illustrated by an example from automobile repair.

25. A customer brings in a recently purchased Fiat - a new model - with a non-functioning power seat. A technician uses a computerised diagnostic tool to search for problems. We noted earlier that any software program, including the software in the diagnostic tool, is a set of rules specifying actions for various contingencies. But automotive engineers who write the software can only write rules for the contingencies they have anticipated: a faulty switch, a break in the wire connecting the switch to the seat motor, a faulty seat motor, and so on.

26. In other words, the diagnostic tool can solve “known” problems but solving “new” problems remains something for humans to do. In a new car, the many new electronic components can interact in ways engineers have not foreseen. If the seat problem is caused by one of these unanticipated interactions, the factory-programmed rules will detect no error and the technician must solve the problem another way.

27. In case-based reasoning, the mechanic begins with a kind of pattern recognition in which he recognises points of similarity between the current problem and other problems he has solved in the past. He uses his previous solutions as a starting point for constructing a new solution – for example, looking for failure points that he had seen in analogous problems but that the diagnostic tool did not cover. It is likely

that the doctor, diagnosing a patient, uses case-based reasoning in a similar way to start constructing a diagnosis, comparing points of similarity between this patient and other patients he had treated in the past.

28. What stands out about this problem is that there is no straightforward solution path. That is no accident. Problems with straightforward solution paths are increasingly performed by computers and complex problems like this will comprise an increasing fraction of human work. It is that fact that makes Expert Thinking important.

4) The Educational and Training Implications of Advanced Skills

29. It is useful to step away from the argument for a moment to see the educational and training implications of these advanced skills. Every teacher knows that rules-based skills are relatively easy both to teach and to test. The problem, as we have seen, is that skills that can be codified in rules can also be performed by a computer. By their nature, Complex Communication and Expert Thinking cannot be reduced to rules and so they are relatively difficult to both teach and assess.

30. With respect to Expert Thinking, begin with the fact that everyone agrees that children need "problem-solving skills." In practice, however, problem-solving skills have often meant focusing only on rules-based solutions like the rules of algebra. The rules of algebra are very important but applying algebraic rules is just the second step of a two step problem-solving process. The first step – the step computers can't do – involves examining the messy set of facts in a real-world problem to determine which set of algebraic rules to apply – the Expert Thinking.

31. Today, the labour market values a mechanical engineer's ability to formulate a problem as a particular mathematical model. Once the model is formulated, a computer – not the engineer – will apply rules to calculate the actual solution. How does the engineer choose the correct mathematical model? As with the earlier cases of the auto mechanic and the doctor, she likely relies on analogies with problems she has solved in the past. It follows that her education must include numerous real-world problems to give her experience on which to draw – a relatively time-intensive process.[4]

32. Similarly, the skill of Complex Communication cannot be learned by simply reading the right book. It requires extensive practice and teacher-student interaction. Similarly, because formulating good communication is not a rules-based process, assessments are not easily reduced to multiple choice, machine-graded tests.

5) Advanced Skills and Foundational Skills

33. Common sense says that advanced skills like Expert Thinking and Complex Communication must be preceded by a strong foundation in literacy, numeracy and reading, all skills tested in the PIAAC. Nonetheless, it is useful to review several mechanisms through which computerisation makes foundational skills particularly important.

34. There is, first, today's rapid pace of change. An example of the relationship between literacy and the rate of change occurred some years ago in a plant assembling electronic controls for missiles. The plant was located in the U.S. South and much of the assembly was performed by men and women who had worked as agricultural labourers. Many were illiterate and so they could not read assembly diagrams but

[4] Alan Lesgold argues that computer simulations can be useful in teaching subjects like electronics repair because the simulations can generate unusual problems faster than the student would encounter them on the job. See Alan Lesgold and Martin Nahernow, "Tools to Assist Learning by Doing", working paper, Learning and Research Development Center, University of Pittsburgh, August 29, 2005.

they learned to assemble specific components by watching their neighbours. This method of learning broke down because engineers were constantly changing components to address performance problems. The result was a stream of change orders from the engineering division to the assembly line. The illiterate workers were lost because they could not read change orders. Today, as computers accelerate workplace change, being able to understand descriptions of new procedures becomes an ever-more frequent task.[5]

35. A second mechanism linking computerisation and foundational skills involves the way computers have transformed concrete processes into numerical abstractions. Some years ago, the Ford Motor Company experienced this problem in the course of changing from mechanical carburettors to computer-controlled fuel injection. Repairing the computerised modules required an ability to read manuals and the ability to mentally connect digitised read-outs on diagnostic tools and the (now invisible) processes they represent. A number of mechanics, who were quite skilled repairing physical carburettors, could not make this transition.

36. More generally, as computers have lowered the cost of calculation, numerical tools and models now permeate many jobs and holding one of those jobs requires becoming a mathematics consumer. A clothing store manager uses a quantitative model to forecast dress demand. A truck dispatcher uses a mathematical algorithm to design delivery routes. A bakery worker monitors production using digital readouts rather than the smell or feel of the bread. Employees of all kinds are expected to use web-based tools to help manage their retirement plans. Each of these tasks involves some aspect of numeracy. In most cases, a computerised tool does the actual calculation, but using the model without understanding the mathematics leaves one vulnerable to potentially serious misjudgements.

37. Note that the numeracy, literacy and reading skills described in these examples go well beyond what might be called “basic skills”. Being able to multiply and divide will always be important, but they are not sufficient to deal with the abstraction of a computerised fuel injection module. Similarly, a typical definition of “basic reading skills” is not sufficient to absorb the pages or web views of a repair manual including searching for the parts of the manual that apply to the case at hand.

38. The need for foundational skills applies beyond the workplace to personal and civic life. Consider the statement that in 2009, the municipal government of Phoenix, Arizona spent a record amount on household garbage collection. In fact, annual spending on garbage collection can reach a record level for a variety of reasons – a profligate city government, a growing city population, general inflation, households generating more garbage. A citizen can resolve this ambiguity only if he understands that the statistic has multiple possible meanings and he knows how to use the web-based resources that provide information like population growth. This knowledge, however, requires skills well beyond most definitions of “basic” reading and mathematics.

I return to the issue of foundational skills below.

How Important Are the Advanced Skills?

39. Complex Communication and Expert Thinking are only two of the skills used in the economy but they are growing in importance. To see this, it is useful to classify all labour force tasks into five broad categories:[6]

5 See also, Theodore Schultz, *Transforming Traditional Agriculture,* Yale University Press, 1964.

6 This categorization was initially developed by Autor, Levy and Murnane, op. cit.

- **Tasks Requiring Expert Thinking**: Solving problems for which there are no rule-based solutions. Examples include constructing a diagnosis of a patient's illness, repairing an automobile problem that is not addressed by diagnostic tools, and so on. While computers cannot substitute for humans in these tasks, computers can complement human skills by making information more readily available.

- **Tasks Requiring Complex Communication**: Interacting with humans to acquire information, to explain it, or to persuade others of its implications for action. Examples include a manager motivating the people whose work she supervises, a sales person gauging a customer's reaction to a piece of clothing, a biology teacher explaining how cells divide, an engineer describing why a new design for a DVD player is an advance over previous designs.

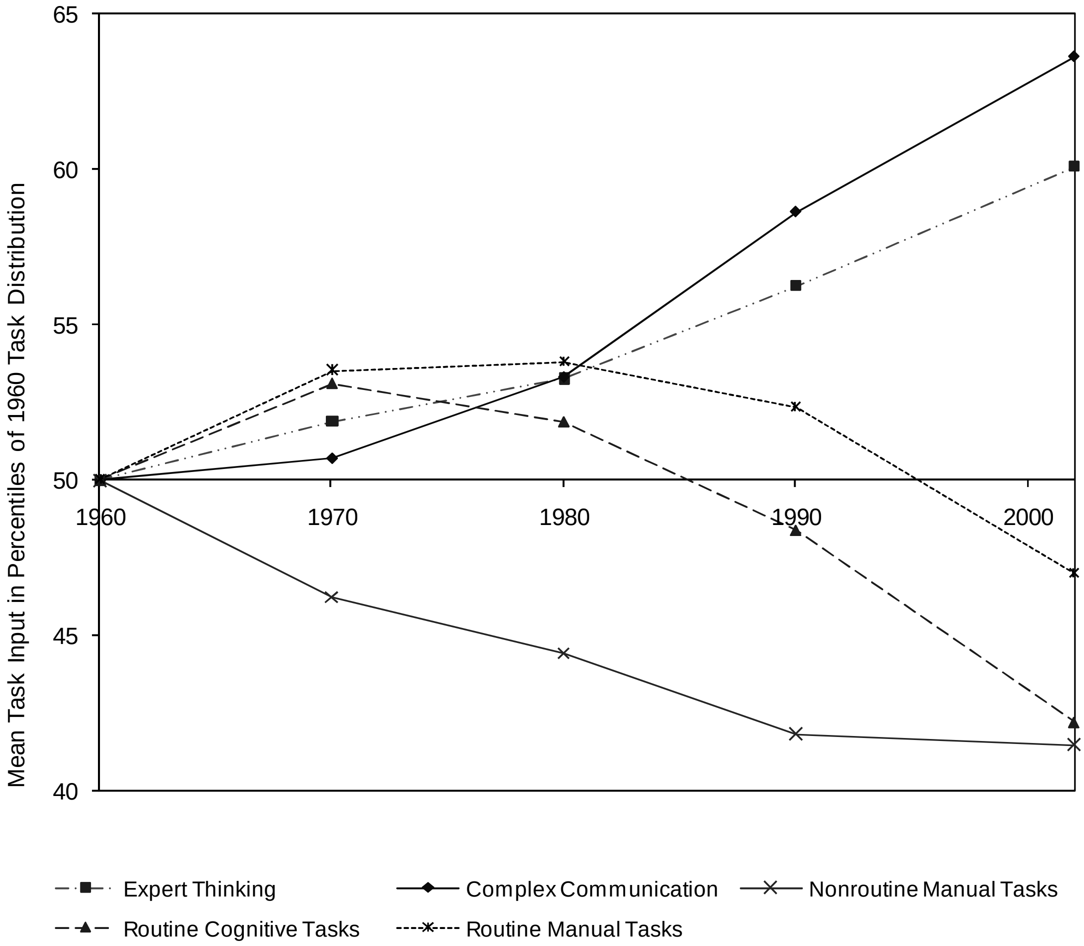
- **Routine Cognitive Tasks**. Mental tasks that are well described by deductive or inductive rules. Examples include maintaining expense reports, filing new information provided by insurance customers, and evaluating applications for mortgages. Because these tasks can be accomplished by following a set of rules, they are prime candidates for computerisation.

- **Routine Manual Tasks**. Physical tasks that can be well described using deductive or inductive rules. Examples include installing windshields on new vehicles in automobile assembly plants, and counting and packaging pills into containers in pharmaceutical firms. Since these tasks can be defined in terms of a set of precise, repetitive movements, they are also candidates for computerisation.

- **Non-routine Manual Tasks**: Physical tasks that cannot be well described as following a set of If-Then-Do rules because they require optical recognition and fine muscle control that have proven extremely difficult to program computers to carry out. Examples include driving a truck, cleaning a building, and setting gems in engagement rings. Computers do not complement human effort in carrying out most such tasks. As a result, computerisation should have little effect on the percentage of the workforce engaged in these tasks.

40. Figure 1 displays, for the U.S. economy, a picture of the evolution of each of these task categories relative to its level in 1959. As the figure shows, tasks requiring Expert Thinking and Complex Communication have grown substantially over time while routine tasks – particularly routine cognitive tasks that are easily computerised – are now declining sharply.

Figure 1: Trends in Routine and Nonroutine Task Input in U.S. Occupations: 1960 to 2002



Source: Autor, Levy and Murnane (2003) updated to 2002 by David Autor.

41. The task trends in Figure 1 correspond to a "hollowing out" of the job structure with the largest job losses coming among clerks, assembly-line workers, low-level accountants, customer service representatives – jobs in the lower middle of the earnings distribution that require rules-based processing of information and rules-based repetitive physical motions[7]. By contrast, jobs requiring Expert Thinking and Complex Communication – jobs with relatively higher wages - are growing at rapid rates[8]. As computers are increasingly absorbed into the labour market, these trends will almost certainly continue.

7 Because repetitive physical motions can be expressed in rules, they are candidates for being performed by robots. In developed countries, their rules-based nature also makes the tasks candidates for being sent offshore to lower wage countries. See Levy and Murnane (2005) for further discussion.

8 Actual trends are likely sharper than those shown in Figure 1.Figure 1 is based on occupational shifts in the economy from 1959-99. Due to data limitations, the task content of each occupation is assumed to be constant at its 1978 level. This limitation obscures the task shifts that have occurred *within* occupations – for example, the way in which the development of the automatic teller machine has sharply reduced the amount of time a bank teller spends on cashing checks and accepting deposits and has increased the time spent on more complicated transactions.

The PIAAC Frameworks

42. To this point, we have been discussing the evolution of the demand side of the labour market. A corresponding question applies to the labour market's supply side: How well are national populations prepared to meet the current job market evolution? The PIAAC Frameworks are designed to start to answer that question by assessing the levels of three Foundational Skills – Numeracy, Literacy and Reading – and one Advanced Skill, Problem-Solving in Technology-Rich Environments.

43. We saw earlier that Foundational Skills are themselves are both deep and broad. Consider the meaning of literacy. In today's society, effective literacy involves the ability to understand the language on an insurance contract, to follow web-based instructions on assembling a chair, to assess the accuracy of a candidate's argument and so on.

44. The PIAAC Literacy Framework is designed to capture this variety. In the Literacy Assessment, individuals will be asked to process information from different media (e.g. printed text, hyper-linked web-based text), information in different formats (continuous text, outlines), information serving different purposes (argumentative, narrative, instructions), information that includes graphics as well as text, and information that arises in different settings including the workplace and the home. The processing assignments will include identifying specific information, understanding and integrating relationships among different parts of a text, and evaluating and reflecting on a text's content. It is easy to be put off by the assessment's complexity until one remembers that literacy in today's society involves all of these situations.

45. The PIAAC Framework for assessing Numeracy involves a similar breadth of tasks. Many daily applications of mathematics are obvious: being able to use postal zone codes, estimating the cost of a shopping cart of groceries, understanding the meaning of compound interest in a savings account or a loan document. Less obvious are frequent applications of probability and chance. For example, in the fall of 2009, a number of newspapers and websites described an unpublished Canadian study suggesting that receiving the traditional flu vaccine doubled a person's chances of getting the H1N1 virus.[9] It required a basic knowledge of probability to recognise that the actual chance of acquiring the H1N1 virus was never mentioned in these articles – only that the chance was doubled.[10]

46. The PIAAC Framework on Problem-Solving in Technology-Rich Environments is similar in many respects to our discussion of Expert Thinking. In both cases, the problems being posed do not admit to rules-based solutions. Where the our examples of Expert Thinking described an individual relying on his own past experience (case-based reasoning), the PIAAC Framework focuses on problems where the individual relies more heavily on the experience and knowledge of others by using digital technologies – acquiring and evaluating information from internet, using email to communicate with others, using digital tools to process data where appropriate and so on. The Problem-Solving assessment will examine both how the individual uses these skills in work and how the individual solves posed problems.

47. The PIAAC Framework recognises that solving problems in this way involves two kinds of skill: a knowledge of how to use digital tools like email and the internet, and a knowledge of how to structure the problem: how to set goals, how to measure progress toward those goals, how to practice what is often

9 See for example, Patrick White, "Study Prompts Provinces to Rethink Flu Plan", *The Globe and Mail* available at http://www.theglobeandmail.com/news/technology/science/study-prompts-provinces-to-rethink-flu-p%3E%20lan/article1303330/

10 Because the study was under review by a journal, the authors were unwilling to share the specific results with the press – only the "headline" of the doubling.

called “metacognition” – reflecting on one’s thinking process - in which an individual decides whether to continue with a particular approach to a problem or abandon it in favour of a different approach.

48. Consider the problem of determining the most effective steps to reduce energy consumption in an old house. What step should come first? Triple-pane windows? Putting insulation into the walls? Changing the furnace? Are there consistent expert answers to these questions? And do the answers vary by the climate in which the house is located? An individual’s ability to make progress on this type of problem is one good indicator of their ability to succeed in today’s economy.

Conclusion

49. We opened this paper by arguing that technology can change the nature of work faster than people can change their skills. The problem is compounded because a nation’s educational system can grow out of touch with job market trends. OECD’s PIAAC Frameworks and Assessments are an important step toward closing this gap by describing the skills increasingly needed in the labour market and estimating those skills’ prevalence in the population.

50. No single assessment is the final word on this subject and PIAAC should be seen as a work in progress. The current version of PIAAC contains no testing for what we have called Complex Communication. Similarly, the computer software in the PIAAC Numeracy Assessment precludes testing for an individual’s ability to structure a mathematical problem – an important element of numeracy.

51. We can expect these problems to be remedied over time. In the interim, PIAAC will serve as an important early warning system on the ability of a country’s workers to deal with rapid technical change.

EXISTING OECD EDUCATION WORKING PAPERS

No. 1 *Teacher Demand and Supply: Improving Teaching Quality and Addressing Teacher Shortages* (2002), Paulo Santiago.

No. 2 *Teacher Education and the Teaching Career in an Era of Lifelong Learning* (2002), John Coolahan.

No. 3 *Towards an Understanding of the Mechanisms That Link Qualifications and Lifelong Learning* (2003), Friederike Behringer and Mike Coles.

No. 4 *Measuring Educational Productivity in Standards-Based Accountability Systems: Introducing the SES Return on Spending Index* (2005), Martin Hampel.

No. 5 *PISA 2000: Sample Weight Problems in Austria* (2006), Erich Neuwirth.

No. 6 *Funding Systems and their Effects on Higher Education Systems – International Report* (2007), Franz Strehl, Sabine Reisinger and Michael Kalatschan.

No. 7 *On the Edge: Securing a Sustainable Future for Higher Education* (2007), OECD/IMHE-HEFCE.

No. 8 *Globalisation and Higher Education* (2007), Simon Marginson and Marijk van der Wende.

No. 9 *Understanding the Regional Contribution of Higher Education Institutions: A Literature Review* (2007), Peter Arbo and Paul Benneworth.

No. 10 *Effects of Tertiary Expansion – Crowding-out Effects and Labour Market Matches for the Higher Educated* (2007), Bo Hansson.

No. 11 *Skilled Voices? Reflections on Political Participation and Education in Austria* (2007), Florian Walter and Sieglinde K. Rosenberger.

No. 12 *Education and Civic Engagement: Review of Research and a Study on Norwegian Youths* (2007), Jon Lauglo and Tormod Oia.

No. 13 *School Accountability, Autonomy, Choice, and the Level of Student Achievement: International Evidence from PISA 2003* (2007), Ludger Wössmann, Elke Lüdemann, Gabriela Schütz and Martin R. West.

No. 14 *School Accountability, Autonomy, Choice, and the Equity of Student Achievement: International Evidence from PISA 2003* (2007), Gabriela Schütz, Martin R. West, Ludger Wössmann.

No. 15 *Assessment of learning outcomes in higher education: a comparative review of selected practices* (2008), Deborah Nusche.

No. 16 *Approaches and Challenges to Capital Funding for Educational Facilities* (2008), Ann Gorey.

No. 17 *Recent Developments in Intellectual Capital Reporting and their Policy Implications* (2008), W. Richard Frederick.

No. 18 *Employers' Perspectives on the Roles of Human Capital Development and Management in Creating Value* (2008), L. Bassi and D. McMurrer.

No. 19 *Job-related Training and Benefits for Individuals: A Review of evidence and explanations* (2008), Bo Hansson.

No. 20 *A Framework for Monitoring Transition Systems* (2008), Rolf van der Velden.

No. 21 *Final Report of the Development of an International Adult Learning Module (OECD AL Module)* (2008), Bo Hansson and Helmut Kuwan.

No. 22 *What Works in Migrant Education? A Review of Evidence and Policy Options* (2009), Deborah Nusche.

No. 23 *Teacher Evaluation: Current Practices in OECD Countries and a Literature Review* (2009), Marlène Isoré.

No. 24 *Assessment and Innovation in Education* (2009), Janet Looney.

No. 25 *Do quasi-markets foster innovation in education? A comparative perspective* (2009), Christopher Lubienksi.

No. 26 *International Adult Literacy and Basic Skills Surveys in the OECD Area* (2009), William Thorn.

No. 27 *Learning Organisations* (2009), Nathalie Greenan and Edward Lorenz.

No. 28 *Les compétences bien sûr, mais pas seulement. L'influence des compétences cognitives en lecture sur la participation aux études postsecondaires chez les jeunes Canadiens* (2009).

No. 29 *Impact of proficiency on early entrants to the labour market: evidence from the YITS* (2009).

No. 30 *How does academic ability affect educational and labour market pathways in Canada?* (2009).

No. 31 *Does reading proficiency at age 15 affect pathways through learning and work?* (2009).

No. 32 *PISA and TIMSS: similarities and differences* (2009).

No. 33 *PIAAC Reading Components: A Conceptual Framework* (2009), John P. Sabatini and Kelly M. Bruce.

No. 34 *PIAAC Literacy: A Conceptual Framework* (2009), PIAAC Literacy Expert Group.

No. 35 *PIAAC Numeracy: A Conceptual Framework* (2009), PIAAC Numeracy Expert Group.

No. 36 *PIAAC Problem Solving in Technology-Rich Environments: A Conceptual Framework* (2009), PIAAC Expert Group on Problem Solving in Technology-Rich Environments.

No. 37 *Literacy, Numeracy and Problem Solving in Technology-Rich Environments: What Skills will be Measured by the Programme for the International Assessment of Adult Competencies (PIAAC)?* (forthcoming), William Thorn.

No. 38 *ICT in Initial Teacher Training: Research Review* (2009), Ann-Britt Enochsson and Caroline Rizza.

No. 39 *Education and Obsesity in Four OECD Countries* (2009), Franco Sassi, Marion Devaux, Jody Church, Michele Cecchini and Francesca Borgonovi.

No. 40 *Estimating the Marginal Effects of Education: on Health and Civic and Social Engagement: A Feasibility Study* (2009), Don Kenkel.

No. 41 *21st century skills and competences for New Millennium Learners in OECD countries* (2009), Katerina Ananiadou and Magdalena Claro.

No. 42 *School Evaluation: Current Practices in OECD Countries and a Literature Review* (2009), Violaine Faubert.

No. 43 *Summary of the June 2009 educationtoday crisis survey - initial reflections o the impact of the economic crisis on education* (2010), Kiira Karkkainen.

No. 44 *International conference on 1-1 in Education: Current practices, international comparative research evidence and policy implications* (Forthcoming, 2010).

RECENT OECD PUBLICATIONS OF RELEVANCE TO THIS WORKING PAPER

No. 26 *International Adult Literacy and Basic Skills Surveys in the OECD Area* (2009), William Thorn.

No. 33 *PIAAC Reading Components: A Conceptual Framework* (2009), John P. Sabatini and Kelly M. Bruce.

No. 34 *PIAAC Literacy: A Conceptual Framework* (2009), PIAAC Literacy Expert Group.

No. 35 *PIAAC Numeracy: A Conceptual Framework* (2009), PIAAC Numeracy Expert Group.

No. 36 *PIAAC Problem Solving in Technology-Rich Environments: A Conceptual Framework* (2009), PIAAC Expert Group on Problem Solving in Technology-Rich Environments.

THE OECD EDUCATION WORKING PAPERS SERIES ON LINE

The OECD Education Working Papers Series may be found at:

- The OECD Directorate for Education website: www.oecd.org/edu/workingpapers
- The OECD's online library, SourceOECD: www.sourceoecd.org
- The Research Papers in Economics (RePEc) website: www.repec.org

If you wish to be informed about the release of new OECD Education working papers, please:

- Go to www.oecd.org
- Click on "My OECD"
- Sign up and create an account with "My OECD"
- Select "Education" as one of your favourite themes
- Choose "OECD Education Working Papers" as one of the newsletters you would like to receive

For further information on the OECD Education Working Papers Series, please write to: edu.contact@oecd.org.