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The microelectronics training gap in the metal trades

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Introduction

Microelectronics technology is reshaping the industrial landscape everywhere. There is abundant evidence of this in employer and union statements, research reports, press reviews and government policy documents as well as in ILO studies and articles in this *Review*.[1] These publications describe the new technology and its effect on working conditions, employment, collective bargaining and so on. With rare exceptions, however, there is a certain reluctance to discuss the training implications at the shop floor. Yet training is all-important in preparing the workforce for the many new tasks that are continuously emerging in a changing technological environment; indeed the extent to which workers cope with new technology is a measure of the efficacy of training systems. However, the latter need a certain time–some more, others less–to adapt to new discoveries and technologies. It now looks as though the relentless introduction of microelectronics technology–and its unexpected speed–are causing critical training bottlenecks in the metal trades in most countries, and this in turn is threatening to block the diffusion of the new technology.

This article assesses the training challenge in the metal trades created by microprocessors, which are an outcome of advances made in microelectronics technology. The developments in microelectronics resulting in what is called "large-scale integrated circuits" have facilitated the incorporation onto square-centimetre-sized silicon "chips" of circuits that perform the same functions as the central processing unit of a computer, i.e. the functions of logic, calculation and control. Such "chips" are the components of the functionally complete entity known as the microprocessor, which has already revolutionised many products and is now beginning to alter certain processes profoundly and pave the way for many of them to be performed by robots.

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The changing skill pattern and its effect on metal trades

The application of microprocessor technology in the metal trades requires new skills which may make existing ones partly or wholly obsolescent. However, there are no hard-and-fast rules, since several empirical studies have come to opposite conclusions as to the decline of skills and the level of required qualifications, depending on the industrial branch or undertaking under scrutiny. Such phenomena as deskilling or the disappearance of traditional occupations have, indeed, been observed (e.g. in watchmaking and precision mechanics). Some go so far as to affirm that manual skills will gradually become a thing of the past as the accumulated experience of highly skilled workers is transferred to electronic devices.[2] Others deny the validity and realism of any such forecasts.[3] Be that as it may, predictions are hazardous and can be a poor guide to decision making. Nevertheless, a body of informed opinion is emerging which, on the basis of the trends so far observed in industry, is confident that the metal trades will need a more qualified but smaller workforce. There will be more complex jobs with a greater knowledge content than is needed now. There is already a considerable shortage of workers with sufficient know-how to handle the new devices, while plenty of qualified craftsmen can no longer put their traditional skills to use. In this sense it is certainly right to point to an overqualification of workers in many jobs, causing much frustration. There may even be a good deal of overtraining in the wrong skills, an indication that training systems are out of step with changed job requirements.[4]

As current changes at the workplace determine job content and thus training requirements, it is necessary to look at these changes in more detail. Their effect varies from one industrial branch to another; in particular, component manufacturers, equipment manufacturers and industrial users of microelectronics are differently affected. Moreover, one has to distinguish among workplaces in manufacture, assembly, quality control and R and D. In *components manufacturing,* task analysis shows that there is a shift from fabricating and assembling to problem solving, planning and coding tasks. Inspection and control are reduced by automatic devices. An ever higher degree of knowledge, capability and skill is required, particularly in programme development. *Equipment manufacturers* are faced with reduced complexity of production. Precision mechanics and the need for quality control are declining and only simple assembly work, which can eventually be automated, remains. Thus job content is simplified. There is, however, a countervailing trend towards job enrichment, i.e. to require machine operators to co-operate in the collection of production data, which is a new function formerly allocated to those responsible for work preparation or supervisors. At the same time equipment manufacturers have to expand programming and development tasks. The decline of precision mechanics and fitting is resulting in a drastic shift from tactile information intake by workers to visual information intake via visual display units. The *industrial users of microelectronics,* such as those of numerically controlled machine tools, have tended to employ semi-skilled workers to operate the machines and highly skilled toolsetters to adjust the machines for varying production jobs. Generally the importance of operating, steering and control functions is diminished. In the case of more recent installations, however, qualified machine-tool operators are given the task of setting and programming their machines, and this leads to job enrichment. They are in continuous dialogue with the computer, managing production and supervising the operation of the equipment. Numerical-control programmers need tool-room practice and good knowledge of work preparation. At the same time maintenance work requires special competence in electronics in addition to the traditional mechanical and electrical skills, and calls for vigilance, anticipation, preventive action and constant updating of knowledge.[5]

What is the impact of the above evolution on the task pattern of individual skilled occupations in the metal trades? Some tentative answers can be found in a study recently carried out in the Federal Republic of Germany.[6] As regards the skilled (apprenticeable) metal trades, employers considered that practically all were directly affected by microprocessor technology. There was an increasing demand for electrical fitters, electrical equipment assemblers, electrical instrument fitters, electrical switchgear and control apparatus fitters, electronics fitters and measuring and regulating mechanics. There was a stagnating or declining demand for boring-machine setters, lathe setters, precision mechanics, mechanics, radio and television technicians, turret-lathe operators, draughtsmen and milling-machine setters. Thus positive effects on skills can be expected mainly in the electrical and electronic occupations. No evidence was found for the emergence of entirely new occupational specialisations.

Moreover, as a result of microprocessor technology the job content of the following apprenticeable trades would be substantially altered: electrical fitter, electronics fitter, telecommunications electrician, telecommunications electronician, information electronician, measuring and regulating mechanic, turret-lathe setter and radio and television technician. The electrical and electronic occupations are again the most directly concerned.

However, the study showed that the metal-forming jobs are only marginally less affected because the demarcation lines between electrical/electronics and metal-forming trades are becoming blurred. The reason is primarily that microprocessors will take over more and more steering and control functions on machine tools and operators will need to acquire an understanding of their functioning and programming. The maintenance and repair of these complex machines will likewise put new demands on workers. In general, mechanical devices will increasingly be replaced by cheaper and more reliable electronic ones.

Skilled workers in the electrical and electronics occupations will need a solid grounding in microprocessor technology, including software, and must be able to read electronic plans and be familiar with new diagnostic methods and measuring as well as analytical trouble-shooting techniques.

These findings need translation into training requirements. As regards the electrical and electronics occupations, the microprocessor technology entails essentially broadening and deepening knowledge and skills which are already widely taught in this field. In the metal-forming occupations the situation is more serious, since as a rule trainees in these specialisations have previously had little or no contact with electronics involving much abstract and theoretical thinking. In their case microelectronics needs to be added to the existing body of trade knowledge and skills which remain largely valid.

Studies in other countries have come to basically similar conclusions, insisting on a broadening of training in the above key occupations. A report from the United Kingdom[7] adds an interesting caveat. It says that there is a new need for technicians with electromechanical rather than sophisticated electronic knowledge since microprocessor units–should they fail–would simply be replaced, whereas all their applications are likely to involve electromechanical devices.

The response of training systems

Prevailing informed opinion has it that the present level and types of qualification of the workforce in the metal trades are mostly too low or inadequate to facilitate the introduction of microelectronics technology. How do training systems cope with this challenge? At present all of them are groping for solutions best suited to the specific conditions in the countries concerned. Their ability to respond and their reaction time vary, depending on such factors as the organisational set-up, the existing institutional network, the role of industry in training, the availability of resources, the preparation and awareness of teachers and instructors, the determination of syllabi and training standards, links with formal education and, last but not least, the motivation of governments, employers and labour. The complex training systems in various countries react with more or less inertia to technological change depending on the strength of internal and external factors hampering or furthering adaptation to it. There is ample evidence to suggest that in the metal trades the lowering in cost of microprocessors, their rapid rate of introduction in multiple applications, and above all their use in fully automated production systems, have generally taken the training machinery by surprise. This is true even for the training departments of many undertakings. Often the new technology was introduced to raise productivity without giving much thought to the qualifications of workers. The results have thus inevitably been negative, with an acceleration of innovations unaccompanied by a corresponding acceleration of the learning process. This has increased the habitual time-lag between what is taught under prescribed training programmes in vocational and technical schools, training centres and apprenticeship courses and what is actually happening in production.

Undertakings directly involved with microprocessor technology have been the first to make special efforts to overcome the widening education and training gap, since they are not in a position to wait for existing training and education programmes to catch up with their specific training needs, on the satisfaction of which productivity gains and their prosperity depend. There are essentially two types of undertakings in this field: the small specialised high-technology firm staffed with a high proportion of scientists, engineers and technicians, often doing their development work in close co-operation with university laboratories, and the large, well established–as a rule multinational–enterprise with well run R and D and training programmes.

The first category does not have a significant training problem thanks to the composition of its staff. Such firms are very adaptable, though often short of capital. The larger firms with well structured training programmes usually run further training courses for both their personnel and their clients. The length and content of courses tend to vary a good deal. Thus the estimated instruction time to become proficient in the use of microprocessor technology ranges from 40 to 500 hours, depending on the level and thoroughness of training required.

A high degree of training consciousness prevails, for instance, in the Bell System companies based in the United States, consisting of AT & T, Bell Laboratories, Western Electric, Long Lines and 23 telecommunication operating companies with a combined total of over a million employees. The corporation has devised a strategy to manage technological change and is taking microelectronics confidently in its stride.[8] Bell has to its record the development and application of transistors, electronic switching systems, lasers, integrated circuits and bubble memories. Its strategy comprises technology planning, human performance system design, human resources planning, systematic selection and staffing, and training and development. Technology planning aims at identifying and integrating new hardware and software and projecting developments two to five years from the current year. Human performance system design covers a skill inventory, staffing strategies by type of job, identification of training requirements, performance standards and evaluation, work organisation and job design, and transition planning. Human resources planning forecasts determine workforce size and needs of the different companies by occupation and location. Selection and staffing practices aim at the optimum utilisation of existing staff, the identification of transferable skills and the provision of information to workers. Training and development play a key role because staff with the unique skill and knowledge requirements of the corporation can rarely be recruited. Consequently, considerable resources are allocated to training (over $800 million per year). About 7,000 full-time teaching staff are employed, offering several hundred courses.

The conversion from electromechanical to electronic switching, for instance, was an operation in which the strategy proved its usefulness. As the skill and knowledge requirements were increased and emphasis shifted from manual to more cognitive skills, training performed a vital function. A three-day screening course was developed to measure employees' ability to assimilate the new knowledge and test their suitability for the new jobs. Selected electromechanical technicians were sent to a company school course lasting six-and-a-half months to learn electronic switching technology. On their new jobs they received special job aids (Task Oriented Plant Practices) to facilitate the transition.

As microprocessor technology is spreading to all areas of manufacture and has become an essential element in automation and robotics the effort made by major users to assimilate it and its application jointly with other technologies may be exemplified by the training programme of the automobile manufacturer Renault.[9]

This company considers that the preparation of the existing workforce must be an integral part of any automation plan. Its training programme therefore covers all staff, but more specifically *(a)* production personnel, *(b)* maintenance personnel, and *(c)* technicians. As regards *(a)*, training is aimed at *machine operators,* who need to learn to understand and apply procedures, operate and control work cycles and react to machine signals and breakdowns; at *machine-tool setters,* who set the tools and control the functioning of the machinery; at *supervisors,* concerned with automatic planning and production and stock statistics; and at *draughtsmen,* who have to adapt to working with a computer and visual display units. As for categories *(b)* and *(c)*, *maintenance personnel* need to understand the systems and learn new techniques such as computer-assisted trouble-shooting and planned parts replacement, while *technicians* need to know about problem-solving methods and the features and comparative advantages of new equipment offered on the market. Training is important in a whole range of technologies used in automatic production, of which microprocessor technology is an essential part. The content and level of training are adapted to the various categories of personnel. Thus there is *specialised training,* geared to the operation of systems (e.g. robots, numerically controlled machines, computer-assisted design); *general training,* putting emphasis on the various technologies used in automation; and *basic training,* which imparts fundamental knowledge for specialists. Some 60 different courses of varying intensity are organised at present. The company stresses that for training to be effective it must be closely linked to the specific needs of the staff and neither excessively in advance of developments on the shop floor nor too far behind them.

In 1979 the central training service of Renault gave about 1,000 persons a total of 84,000 hours of instruction. Much of the training is computer-assisted, since the computer can simulate complex and dynamic systems and is useful for the learning of procedures and execution of exercises. It permits decentralisation of training and an intake of large numbers of staff. However, investment is relatively significant. About 100 hours are needed to prepare one hour of computer-assisted instruction. Moreover, the suitable training of trainers and their co-operation must be assured. Since capable and up-to-date trainers in this field are scarce, a great deal of effort is devoted to the preparation of teaching materials which ensure an appropriate progression of instruction and learning according to the level of trainees. Although the cost of such training may be considered high, it must be set against the possible cost of breakdowns in the operation of sophisticated capital-intensive production systems.

The above examples should suffice to demonstrate that the leading high-technology undertakings have recognised the vital role of training, are willing to invest in it and, as a rule, have a flexible and up-to-date training infrastructure corresponding to their specific needs. They have assimilated microprocessor technology with ease and are aware that the provision of staff adequately trained in it finally depends on their own initiative and internal development schemes. They know that production systems are only worth as much as the people who manipulate them.

The situation of small and medium-sized undertakings is more precarious. They have no comparable training organisation or specialised knowledge in the field and are as a rule unprepared for the onslaught of the microprocessor. They largely depend on outside support from such sources as vocational schools, training centres, engineering and technician schools and further training courses run by a great variety of institutions. Some of these undertakings may use manpower poaching as a short cut. However, this does not solve the retraining problems of the rest of the workforce. The great majority of metalworkers are, in fact, employed in such undertakings, and this is where the most glaring training gap exists.

Depending on the country, more or less intensive and often freewheeling efforts have been made to remedy the shortfall. First of all, suppliers have been expanding training for their clients, and other forms of co-operation, such as training agreements between large and small undertakings, have been developed. Client training is, of course, a great asset in marketing. Numerous training consultancy bureaux have sprung up. Moreover, in many countries a multitude of courses and self-study programmes are offered by a variety of institutions. In the United Kingdom there were over 200 different microprocessor courses available in 1980, mainly provided by colleges and polytechnics at engineer and technician level.[10] In the Federal Republic of Germany a similar variety of further training courses is offered.[11] In the United States the most frequent forms of further training and retraining are courses organised by equipment suppliers for their clients, which concentrate on information on systems and software application and staff training in programming, operation and electrical/electronic and mechanical maintenance. They aim at instilling a basic understanding of the microprocessor technology and leave special applications to on-the-job training. Undertakings also send their staff on external courses organised by colleges or consultancy firms if the need arises. Generally speaking there is a rather unco-ordinated, decentralised and pragmatic reaction to the training requirements of microprocessor technology.[12] In Japan, where the willingness to innovate appears to be the most widespread and sustained, undertakings bear the brunt of training, retraining and further training in microprocessor technology. A corollary to the Japanese system of life-long employment is that there are no restrictive labour practices on the part of the unions and that undertakings and workers consent to a considerable retraining effort with a view to redeployment and mastering new technological requirements. Thus most of this retraining is done internally and by equipment suppliers.[13] However, many other institutions are active in this area, as there is a high demand for technicians and highly skilled workers familiar with the new technology. A characteristic feature of this training is that specially designed kits and home computers are widely used. In particular, the kits have the advantage that trainees learn to understand the hardware and both assembler and machine code languages. Home computers are employed mainly to teach software development. Another special feature of the Japanese training scheme is the spread of microcomputer clubs, which are supported by the larger manufacturers and schools. The largest club had a membership of 20,000 in 1978.[14]

It can thus be confirmed that in general some form of further training or retraining in microprocessor technology can be found in various countries. However, it is still very far from systematic. The main weaknesses of training packages at present on the market have been identified as follows. The hardware often comes in fully assembled form so that trainees cannot learn from assembly tasks because the insertion techniques using components generally employed in industry are not applied; moreover, it cannot be expanded and adapted to keep pace with technical advances, is too compact and too complex to operate, does not contain fault-simulation devices, is often expensive and cannot be copied. The software supplied is not accessible, does not contain learning aids and programming assistance, and cannot be copied. Accompanying documentation generally neglects to define target groups and required educational attainment, is not attuned to the knowledge of skilled workers, does not take account of required technical skills, often neglects pedagogic principles, does not contain fault-finding instructions, usually puts emphasis on programming, contains no guidance for instructors and gives no building plan of the installation. Thus the value of such systems to the trainee is frequently doubtful.

When it comes to the integration of microprocessor technology into approved training regulations and training programmes and the establishment of generally applied training requirements and standards the picture is even bleaker. Despite exhortations from governments, employers' organisations and trade unions the nettle is grasped only hesitantly.

For instance, it is now recognised in the Federal Republic of Germany that following the emergence of microelectronics it is urgent to determine the new training requirements for skilled workers in the electrotechnical trades, to develop appropriate training methods and teaching aids and to revise existing training regulations. At the same time instructors should be given an opportunity for further training. In order to achieve this objective the Essen Vocational Training Promotion Centre in co-operation with the Federal Institute for Vocational Training Research has launched a curriculum research project on the incorporation of microprocessor technology in training for the electrical/electronics trades.[15] The Federal Ministries for Education and Science and for Research and Technology and the Federal Employment Institution are funding the project with DM 3.8 million. The curriculum, which takes the form of modules of 120 hours of instruction, will be addressed to teachers and instructors, young trainees and adults and is to be tested throughout the Federal Republic in 20 industry-run centres for initial training and 10 centres for the retraining of adults. In 1980 there were about 130,000 trainees in 23 electronics/electrotechnical trades in the Federal Republic who were potentially directly concerned by this project. Thirty undertakings of different types and sizes have been selected to participate directly in it, and are expected to supply the necessary information and data. Their instructors will benefit from the further training course to be designed and will test the teaching aids developed by the project. All other interested undertakings–and there had been a remarkable response from about 130 firms by the end of March 1981–will benefit regularly from an information service which will diffuse the project results. The basic training kit which is being developed should not cost more than DM 1,000. In this way it is hoped to enable undertakings to update their methods and to include microelectronics skills in initial and further training for the various electrical/electronics trades before the long procedure of revising official training regulations and curricula is completed. These regulations and curricula date back about eight years and do not take microelectronics sufficiently into account.

It is interesting to note that this very well planned and thorough research project was launched only at the beginning of 1981 although the extensive industrial application of microprocessor technology had already started in 1975 and shortcomings in microelectronics training had been diagnosed three to five years earlier. The project is expected to be completed in the first quarter of 1985, after which legislative measures will be needed to integrate the findings into existing training regulations.

Similar long delays in adjusting the training regulations and programmes for skilled worker and technician training and further training of instructors may be found in other countries, with the sole exception of Japan, which is definitely moving fast in this area. Canada and the United Kingdom are typical and well documented cases in this respect. Their apprenticeship programmes with emphasis on time-serving are generally out of tune with this new technology.[16]

There is general agreement among training specialists that the key problem is the multiplier effect of instructor training, i.e. to enable instructors in industry to impart the new skills. There is pressure on them at plant level from management and trainees to teach microelectronics.

Instructors of the older generation are suddenly confronted with the new technology and find that their trainees are frequently better informed than themselves through hobby journals and clubs. Many instructors are not used to the necessary group work methods. They encounter problems in exercising authority and urgently need further technical and pedagogic training.

As technology moves faster, further specialised training of adult workers or retraining inevitably gains in importance, since industry can no longer rely on the replacement of one generation of workers by another or on redundancy measures. Although there has been some concern that older trainees might be less able to keep pace with developments and industry is therefore hesitant to train them in the emerging technologies, this has been revealed as a fallacy, since there is by now abundant evidence that what counts most is motivation and ability to learn. Formal educational attainments are of much less significance in view of new teaching methods which are able to overcome any barriers to adult learning that might exist. This has been confirmed even in retraining courses for electrical and electronics occupations, which are considered to be exceptionally demanding. Thus, even workers with low educational attainments can acquire complex skills through individual self-paced programmed instruction. This applies also to programming skills for which there is an increasing demand in the microelectronics world as software development is lagging behind. Programmers need clear thinking, good observation, spatial skills, and the ability to make sense of abstract patterns and designs. It was found that about 5 per cent of shop-floor workers are suitable for training as programmers.[17]

The inertia of vocational schools

The inertia of institutionalised training in vocational schools without a direct link with industry has often been denounced as a major obstacle to rapid adaptation of the workforce.[18] The main reason is, of course, that most vocational teachers rapidly lose touch with the technical realities of industry after their training and are given little opportunity to refresh their contacts. In general, despite the fact that they should form a vital link with industry, their further training is neglected. It has been estimated that updating their knowledge in microelectronics would require 200 to 500 hours of further training depending on the background knowledge of the individual. Although they rarely get the opportunity to acquire this,[19] there are exceptional cases in which vocational schools live up to expectations, but this is usually thanks to the initiative of some interested teachers and local industries acting as pioneers or catalysts.

Such an initiative has, for instance, been taken in the vocational schools in the Stuttgart area in the Federal Republic of Germany; as a result, related theoretical instruction of about 15 hours is planned to familiarise metal trades trainees with microcomputers and their application in the control of machine tools.[20] The intention is that this related instruction should complement a special training programme for skilled workers operating numerically controlled machine tools offered by many undertakings as an addition to the official curriculum for trainees in metal forming. A difficulty appears to be that training requirements are very much in flux owing to current technological change, and the future profile of the special complementary training programme remains uncertain. However, it is considered that knowledge of microprocessor technology and of programming tasks is the key element. Moreover, such training should include about 40 hours of practical exercises in dialoguing with a microcomputer in an elementary computer language. Experience in various schools has shown that in this way trainees acquire a sound knowledge and understanding of microcomputer structures.

Another exception to the rule that modern technology bypasses vocational schools is the Electrical Trades and Watchmaking School of Geneva, a full-time school with a high reputation which, in its four-year programmes for mechanics/electronicians and radio and television electronicians and six-year programmes for technicians, started teaching microelectronics as soon as this technology was introduced in Swiss industry. It was, in fact, so advanced that its first graduates in the field had problems in finding suitable jobs. The factors that explain this progressive approach are (i) a dynamic teaching staff; (ii) flexible curricula; (iii) close collaboration with local industry, which is very competitive in the high-technology range and has traditionally depended on this school for the recruitment of skilled personnel and supports it; and (iv) a predilection among the carefully selected trainees for the technologies of the future.

This goes to show that in favourable conditions and with adequate support vocational schools may overcome their inertia, but it remains a rare occurrence.

Living with the training gap

A review of the above observations and factors influencing training systems leaves no doubt that as technology leaps ahead, the training gap is bound to persist because of the inevitable delays in the measures taken to close it and to remedy the worst shortcomings. This is small comfort to young people entering careers in the metal trades. It is a predicament for industry and the education and training establishments. What could the training systems do to give trainees the best possible preparation for the future? It would seem that the principle of imparting broad basic and systematic training aiming at versatility and flexibility without sacrificing a sound grounding in essential practical skills, followed by specialised training which may be updated at any time during a career, remains as valid as ever. If anything, the speed of technological change will enhance the importance of further training. This approach constitutes the only realistic protection against the obsolescence of specialised skills.[21] It has been pointed out that overemphasis on theory in training is liable to cause frustration. Thus a balance must be found.[22] Nevertheless, ability to learn and adapt, abstract and logical thinking (as opposed to manipulative skills), mathematical and planning skills, comprehension of systems, creativity, ability to communicate and to work in a team and ability to decide become increasingly important; a strong motivation of individuals for continued learning is perhaps the most essential asset for coping successfully with microelectronics technology.[23]

Training and education systems have fostered the above principle only incompletely and to varying degrees–if they have not neglected it entirely–at a high cost to the workers and society. A new educational crisis may be upon us because the systems have so far been incapable of reducing "computer illiteracy". They are frequently hampered in their endeavours to reform by vested interests in the existing organisation and standards or lack of adequate training standards and means. The performance of training systems themselves is inextricably linked with the achievements of primary and secondary education. It seems that training is far too often forced to build on shaky or inadequate general knowledge, e.g. poor mathematical and language skills. Moreover, instruction on data processing and computers percolates only slowly into schools, aggravating the problem of acceptance of new technologies. The resistance to change generally encountered is thus likely to have deeper roots than can be uncovered in this context. It may well be a sign of the sclerosis that some believe they detect in certain industrial societies.[24]

This article has not set out to evaluate and rank the achievements of various national training systems. They are too differently perceived and internally too bitterly disputed. Moreover, the best industrial training is of roughly equivalent standard in most highly industrialised countries. On the other hand, it is perhaps no accident that the countries which have the most resolutely tackled modern requirements and given themselves the institutions, curricula, standards, methods and resources to meet them have usually done comparatively well in international economic competition, with corresponding benefits in standards of living. This naturally raises the question of governments', employers' and unions' policies, attitudes and roles in this field. These policies interact and can be decisive factors or strong hindrances in bridging the training gap. However, these interactions in various countries are of a complex nature and must be left to further study.

Notes

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