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國際競爭力之比較對教育政策之啓示：以台灣爲例

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摘要

本研究探討教育相關變項是否與國際競爭力有關。資料是取自美國國家科學理事會及瑞士國際管理發展研究所之統計資料。結果顯出代表教育潛在變項之「每千人中研發人員數」單獨可解釋「競爭力」60%之變異量。本研究對教育政策有所啓示：以台灣爲例，台灣與瑞士皆爲天然資源稀少且國內市場狹小的小國家，其國際競爭力有賴人力資本，尤其是研發人員之創新。培養更多的研發人力爲教育可對競爭力有所貢獻之處。

關鍵詞：研發人力、理工教育、國際競爭力

Since 1989 the Institute for Management Development (IMD), Switzerland, has each year published indicators of the international competitiveness of economically important countries. It has attracted attention of policy makers worldwide. What can we learn from a comparison of international competitiveness?

International competition is a variety of inter-group competition. Johnson, Maruyama, Johnson, Nelson, and Skon (1981) distinguished inter-group competition from interpersonal competition because inter-group competition demands within group cooperation. To produce a product, all workforces in an enterprise have to cooperate with each other. The cooperation is either vertical or horizontal, or both. In their meta-analysis, Johnson, et al. (1981) found that there was no significant difference in achievement between cooperation without versus cooperation with inter-group competition (mean effect size = 0). And cooperation with inter-group competition promotes significantly higher achievement than do individualistic, no competitive efforts (mean effect size = .50, $SD = .37$, $t(19) = 6.04$, $p < .01$).

Qin, Johnson, and Johnson (1995) also discovered from their meta-analysis that mixed cooperation (in-group cooperation and inter-group competition) solved problems better than interpersonal competition (mean effect size = 0.39, $SD = 0.56$, $t(14) = 2.61$, $p < .05$).

The results of the meta-analysis carried out by Johnson, Johnson, and Maruyama (1983) indicate that cooperation with inter-group competition promotes greater interpersonal attraction among participants than does interpersonal competition (mean effect size = 0.75, $SD = 0.62$, $t(13) = 3.44$, $p < .01$).

The effect size of cooperation without competition is slightly higher than cooperation with inter-group competition but the difference is not significant (Johnson, et al., 1981; Qin, et al., 1995; Johnson et al., 1983). Because the economy of Taiwan is export- oriented, its products must compete with products from other countries in the world market. Therefore, international competition is inevitable for Taiwan. In schools, interpersonal competition might be muted, but cooperation with inter-group competition should be fostered. By the training of cooperation with inter-group competition, students can be assisted in forming the habit of following “play rule” in inter-group competitions.

Competitiveness is an important element in Social-Darwinian theory claiming that the dynamics of social evolution lie in the principle of “equal opportunity and fair competition.” If a society is full of competition, its total capabilities will be accelerated automatically, because during the process of competition, all the competitors will focus their attention on the improvement of their own competitive capabilities, and this is the process of the evolution in society.

The Organization for Economic Cooperation and Development (OECD) (1992, cited by Llewellyn, 1996) defines a nation’s competitiveness as: “the degree to which it can, under free and fair market conditions, produce goods and services which meet the test of international markets, while simultaneously maintaining and expanding the real incomes of its people over the longer term” (p. 237), and the World Economic Forum defines competitiveness as “the ability of a nation’s economy to make rapid and sustained gains in living standards” (Llewellyn, 1996: 89). These two definitions are compatible in that expanding real income is a necessary condition for making sustained gains in living standards. An expansion of real incomes depends on an increase in production and exportation of goods and services. There would thus be a strong relationship between a nation’s productivity and its competitiveness. It is evident that some countries grow economically at a faster rate than others. It can be hypothesized that the stronger competitiveness a country possesses, the faster its economic growth will be.

Llewellyn (1996) remarked that a healthy way to strengthen a country’s competitiveness is to "reduce its prices or costs per unit of output relative to those of its trading partners" or to create new products or improve the quality of its products to meet the demands of other countries.

Investment in R&D expenditures and personnel (scientists and engineers produced by the higher education institutions) are important factors for technological innovation, which can be indicated by granted patents. Technological catch-up relies heavily on technological activities. If the technologically advanced countries make further investments in R&D, then the technology gap and economic growth between them and countries following behind them would be persistent, or even enlarged. Patents are outputs of innovation while the expenditure and personnel of R&D are inputs to it. In a review of empirical literature, Fagerberg (1994) found that variables in technological innovation, such as R&D investment, patents, scientists and engineers etc. could have an impact on levels and growth of productivity.

The presence of universities with major programs in science and engineering, venture capital, technological and scientific employees in the local population, and a good quality of life are alleged as necessary preconditions of high technology development in particular places, such as in the cases of the production center of semiconductors and computers in Silicon Valley and that of communications equipment, computers and biomedical instruments in Range County (Scott & Storper, 1987).

Other variables which might contribute to international competitiveness are mentioned by Boltho (1996), such as improvements in infrastructure, raising the level of education and training of workforce, opening markets to foreign competition to invoke an imagined external threat, deregulating some aspects of economics, and sales and advertising campaigns.

The International Institute for Management Development (IMD) (2000) used 290 variables in comparing the competitiveness of 47 countries.　Among those variables, some can be classified as end product (outcome) elements of competitiveness, such as Gross Domestic Product (GDP) per capita and exports of goods, which might indicate the “real incomes” of a country’s people; life expectancy at birth, which represents the level of the standard of living; and patents granted to residents, and some as process (driving force) elements of competitiveness, which lead to a strengthening of competitive capability, such as connections to internet; total expenditure on R&D per capita; and total R&D personnel in business enterprises.　Among the 290 competitive variables in the IMD study, 139 were official statistics.　All the variables were categorized into eight factors: domestic economy, internationalization, government, finance, infrastructure, management, science & technology, and people.

The purposes of the present study are to investigate: (a) whether education related variables have a relationship with competitiveness, and if it so, by how much?　If education is related to international competitiveness, then education-related variables would have a significant association with competitiveness-related variables, (b) the nature of the causal relationship between process and product elements of international competitiveness; what proportion of variance in product elements can be accounted for by process elements of competitiveness?　According to the definition of competitiveness made by the OECD and the World Economic Forum, stronger competitiveness means higher incomes (to use GDP per capita as a proxy) and higher living standard (to use life expectancy at birth and private consumption expenditure per capita as proxies).　Higher private consumption expenditure per capita stands for stronger purchasing power.　These three variables are set as end product elements of competitiveness.

Method

The cross-sectional hard data (official statistics) from the database of the International Institute for Management Development (2000) were used.

The International Institute for Management Development (2000) includes an indicator of educational infrastructure relevant for producing engineers and scientists. The indicator "higher education enrollment of 1996" (net enrollment in tertiary education for persons 17-34 years old) has however 15 missing values and could not be used in the analysis.　Instead, a variable "ratio of total science and engineering degrees to the 24-year-old population: 1997 or most recent year" was adopted by the present author from the Appendix Table 5-18 of the database of the National Science Board (2000), which has only four missing values.

To test the hypotheses, Pearson's correlation, regression, as well as structural equation model (Jöreskog & Sörbom, 1993) were employed.　By the regression and structural equation model, the step-wise entrance of exogenous variables will be displayed, so that the phenomenon of multicollearity can be clarified.　When the coefficient of an exogenous variable is significant in the reduced model but turns to be not significant after a new exogenous variable enters the equation, it means that the effect of that variable is partialed-out by the new one.　And in the correlation matrix, one can find that the first-entered variable has a high correlation coefficient with the later-entered exogenous variable.

Results

The matrix of correlations in Table 1 indicates clearly that all the four education-related variables have significant correlation with GDP per capita, and they are interdependent with the exception of correlation between the "ratio of science and engineering degrees to the 24-year-old population in 1997" and the "pupil-teacher ratio in secondary education."

Table 1.　Correlations Between GDP and Education-Related Variables

	1. GDP per capita (N=47).	2. Total R&D personnel nationwide /1,000people (N=42).	3. Ratio of science & engineering degrees to the 24-year-old population in 1997 (N=43).	4. Secondary school enrollment/ relevant age group (N=43).	5. Pupil-teacher ratio in secondary education (N=45).
1	--	.79**	.68**	.63**	-.45**
2		--	.70**	.73**	-.47**
3			--	.59**	-.17
4				--	-.37*

* $p < .05$ ** $p < .01$

Table 1 shows that the variable "Total R&D personnel nationwide /1,000 people" has strongest relationship with the variable "GDP per capita".　In Table 2, the variable "R&D personnel per 1,000 people" accounts for 61.66% of the total variance in the dependent variable "GDP per capita".　As the other educational variables were added to the regression equation, no increments to the adjusted R^2 were observed. Consequently, the variable "R&D personnel per 1,000 people" was selected as a representative variable for education-related variable contributing to GDP per capita.

Table 2.　Coefficients From the Regression of GDP Per Capita on Education-related Variables

	Model 1	Model 2	Model 3	Model 4	Model 5
R&D personnel	.79**		.67**	.54**	.46*
S & E degrees		.62**	.15	.18	.22
Enrollment				.13	.07
Pupil-teacher ratio					-.18
F values	F (1,40) = 66.93**	F (1,41) = 25.45**	F (2,37) = 28.23**	F (3,33) = 16.18**	F (4,31) = 12.21**
Adjusted R^2	.6166	.3679	.5827	.5585	.5616

Note.

R&D personnel = Total R&D personnel nationwide / 1,000 people;

S&E degrees = Ratio of science and engineering degrees to the 24-year-old population in 1997;

Enrollment = Secondary school enrollment / Relevant age group;

Pupil-teacher ratio = Pupil-teacher ratio in secondary education

* $p < .05$ ** $p < .01$

In order to test the causal relationship between process and product elements of international competitiveness, different models of LISREL were tried and displayed in Table 3 Because of multicollinearity, it is necessary that variables be introduced step by step to show the effect of each process element on the product elements of international competitiveness.

The parameter specifications used by Jöreskog & Sörbom (1993) were applied, but with minor amendment in the present study. Instead of $\lambda_{ij}^{(X)}$ and $\lambda_{ij}^{(Y)}$, λij was employed to stand for the standardized effect of a latent variable on an observed variable. In doing so, the serial number of the first latent endogenous variable must follow that of the last latent exogenous variable, and the serial number of the first observed endogenous variable has to come after that of the last observed exogenous variable.

International competitiveness is a latent variable (an abstract construct) and must be indicated by measurable and observable variables. It was indicated by three observed variables: life expectancy at birth, GDP per capita, and private consumption expenditure per capita.

In Table 3, the number of the subscript of a Roman alphabet letter denotes the serial number of an observed variable. The number of the subscript of Greek alphabet letter denotes the serial number of a latent variable. δ and ε represent the error term of an observed independent (X) and dependent variable (Y) respectively. Because of length restriction of the article, the error terms in Table 3 were omitted. They were all not significant. The outer number of the subscript λ is the serial number of a latent variable, and the inner number is that of its indicator. The non-significance of error term and the significance of λ term of an observed variable indicates that the observed variable is suitable to be the proxy of that latent variable, e.g. the significances of λ_{22}, λ_{32}, λ_{42} in Model 1 mean that the observed variables Y_2 (Life expectancy at birth), Y_3 (Private consumption expenditure per capita), and Y_4 (GDP per capita) are appropriate to be used as the indicators for the latent dependent variable η_2 (competitiveness).

Table 3.　Different Structural Equation Models Demonstrating Effects of Determinants of Competitiveness

Model 1	Model 2	Model 3	Model 4	Model 5
X_1=RDPERSON	X_1=RDPERSON	X_1=RDPERSON	X_1=RDPERSON	X_1=RDPERSON
Y_2=LIFE	X_2=RDEXPEND	X_2=RDEXPEND	X_2=RDEXPEND	X_2=RDEXPEND
Y_3=GDP	Y_3=LIFE	X_3=COMPUTER	X_3=COMPUTER	X_3=COMPUTER
Y_4=CONSUMPT	Y_4=GDP	X_4=HANDY	X_4=HANDY	X_4=HANDY
ξ_1=Educat	Y_5=CONSUMPT	Y_5=LIFE	X_5=ADVERTIS	X_5=ADVERTIS
η_2=Compet	ξ_1=Techinno	Y_6=GDP	Y_6=LIFE	Y_6=PATENT
λ_{22}=0.80*	η_2=Compet	Y_7=CONSUMPT	Y_7=GDP	Y_7=LIFE
λ_{32}=1.00*	$\delta\varepsilon_{23}$=-0.06	ξ_1=Techinno	Y_8=CONSUMPT	Y_8=GDP
λ_{42}=0.97*	λ_{11}=0.85*	ξ_2=Techinfr	ξ_1=Techinno	Y_9=CONSUMPT
ζ_2=0.40	λ_{21}=0.96*	η_3=Compet	ξ_2=Techinfr	ξ_1=Techinno
γ_{21}=0.77*	λ_{32}=0.80*	λ_{11}=0.88*	ξ_3=Market	ξ_2=Techinfr
$\chi_{(1,N=42)}$=0.002,	λ_{42}=1.00	λ_{21}=0.93*	η_4=Compet	ξ_3=Market
p=0.96	λ_{52}=0.97*	λ_{32}=0.96*	λ_{11}=0.88*	η_4=Patents
GFI=1.00	ζ_2=0.17	λ_{42}=0.83*	λ_{21}=0.93*	η_5=Compet
RMR=0.00	γ_{21}=0.91*	λ_{53}=0.82*	λ_{32}=0.94*	λ_{11}=0.88*
R^2=0.60	$\chi_{(3,n=42)}$=3.69	λ_{63}=0.99*	λ_{42}=0.81*	λ_{21}=0.95*
	p=0.30	λ_{73}=0.96*	λ_{53}=1.00	λ_{32}=0.93*
	GFI=1.00	ζ_3=0.07	λ_{64}=0.82*	λ_{42}=0.80*
	RMR=0.0085	ϕ_{12}=0.89*	λ_{74}=0.99*	λ_{53}=1.00
	R^2=0.830	γ_{31}=0.21	λ_{64}=0.97*	λ_{64}=1.00
		γ_{32}=0.78*	ζ_4=0.03	λ_{75}=0.82*
		$\chi_{(10,n=42)}$=3.61,	ϕ_{12}=0.91*	λ_{65}=0.99*
		p=0.96	ϕ_{13}=0.83*	λ_{95}=0.96*
		GFI=1.00	ϕ_{23}=0.91*	ζ_4=0.26
		RMR=0.031	γ_{41}=0.04	ζ_5=0.02
		R^2=0.93	γ_{42}=0.64	ϕ_{12}=0.91*
			γ_{43}=0.33	ϕ_{13}=0.81*
			$\chi_{(14,n=42)}$=4.66	ϕ_{23}=0.92*
			p=0.99	β_{54}=0.01

Table 3. (continued)

Model 1	Model 2	Model 3	Model 4	Model 5
			GFI=1.00	γ_{41}=0.82*
			RMR=0.028	γ_{54}=0.01
			R^2=0.97	γ_{52}=0.55
				γ_{53}=0.47*
				$\chi_{(19,n=42)}$=14.2
				p=0.77
				GFI=1.00
				RMR=0.026
				R^2=0.98

Note.

RDPERSON= Total R&D personnel nationwide / 1,000 people

RDEXPEND= Total expenditure on R&D per capita

COMPUTER= Number of computers / 1,000 people

HANDY= Cellular mobile telephone subscribers / 1,000 people

ADVERTIS= Advertising expenditure per capita

PATENT= Number of patents in force / 100,000 inhabitants

LIFE= Life expectancy at birth　　GDP= GDP per capita

CONSUMPT= Private consumption expenditure per capita

Techinno= Technology innovation activities　　Techinfr=Technology infrastructure

Market=Market activity　　Patents=Granted Patents　　Compet=Competitiveness

* $p < .05$

In Model 1 of Table 3, "R&D personnel per 1,000 people" was selected as an indicator for education. $\gamma_{21} = 0.77$* in Model 1 indicates that education makes a significant contribution to competitiveness. γ_{21} is the standardized regression coefficient of ξ_1 on η_2. The outer number of the subscript γ is the serial number of the independent latent variable, and the inner number is that of the dependent latent variable.

R^2= .60 designates that education alone can explain 60% of the variances in competitiveness. This result supports the hypothesis that the education-related variable "R&D personnel per 1,000 people" does have a significant association with competitiveness-related variables.

In Model 2, “Total expenditure on R&D per capita” was combined with “R&D personnel per 1,000 people” to form indicators for the latent variable “Technological innovation activities”. The latent variable “Technology innovation activities” explained 83% of variances in competitiveness. $\gamma_{21} = 0.91^*$ denotes that “Technology innovation activities” is a significant determinant of competitiveness. In order to improve fitness of model, the error term $\delta\varepsilon_{23} = -0.06$ was generated by a statement: “set the errors between RDEXPEND and LIFE correlate” in the LISREL 8 program, as the Maximum Modification Index located at this term. After modification, the fitness of the model improved.

In Model 3, the latent variable “Technology infrastructure” was indicated by observed variables “Number of computers/1,000 people” and “Cellular mobile telephone subscribers/1,000 people”. In Model 4, the latent variable “Market activity” was indicated by the observed variable “Advertising expenditure per capita”. In Model 3 and Model 4, the latent variables “technology infrastructure” and “market activity” were introduced stepwise. They both brought about increment of R^2.

“Granted patents” was inserted to Model 5 as an intervening variable between innovative activity and competitiveness.

The non-significance of γ_{31} (the effect of technology innovation activities on competitiveness) in Model 3 was due to multicollinearity. The effect of technology innovation activities on competitiveness was originally significant in Model 1, but after stronger latent variable (Technology infrastructure) was introduced, its effect was partialed out. Similar cases are the non-significances of γ_{41}, γ_{42}, γ_{43} in Model 4 and γ_{52} and γ_{54} in Model 5. $\gamma_{41} = 0.82^*$ means technology innovation activities have significant influence on number of granted patents. $\gamma_{54} = 0.01$, $\gamma_{52} = 0.55$, $\gamma_{53} = 0.47^*$ mean that “Market activity” has a significant effect on competitiveness, but the effect of “Technology infrastructure” and “Granted patents/1,000 people” on competitiveness is partialed-out by the stronger latent independent variable “Market activity”.

ϕ_{ij} marks the covariance of two independent latent variables. ζ is the error term of a latent dependent variable. ζ_5 = 0.02 in model 5 hints that R^2 = 1- .02 = .98. It indicates that the three latent independent variables (ξ_2, ξ_3, and η_4)can explain 98% of variances of the dependent variable “Competitiveness” (ξ_5).

Have the results of the present study any implication for the educational policy makers of small countries such as Taiwan?

The situation of Taiwan is analogous to that of Switzerland. They are both small countries with scarce resources and limited domestic market. Their competitiveness hangs on human capital, especially on innovations by R&D personnel. To cultivate more and more creative R&D personnel is the contribution education can make to competitiveness. From Table 4, it can be seen that R&D personnel per 1,000 people in Switzerland is about 1.5 times as many as in Taiwan. The overall rank of competitiveness of Switzerland improved from ninth in 1996 to fifth in 2000, and the R&D personnel per 1,000 people in Switzerland ranked second in 2000. To catch-up to the level of Switzerland in this respect would be a reasonable goal for the educational policy of Taiwan, if it seeks to improve its international competitiveness.

Discussion

Among education-related variables which may have relationship with international competitiveness, “R&D personnel per 1,000 people” is the variable most suitable to be chosen as the indicator for the latent variable “Education,” because it has stronger correlation with GDP per capita than other variables, such as “Ratio of science and engineer degrees to the 24-year-old population,” “Ratio of secondary school enrollment to the relevant age group,” or “Pupil-teacher ratio in secondary education.” “R&D personnel per 1,000 people” standing alone, can explain 60% of variance in international competitiveness, which was represented by three observed variables: "Life expectancy at birth," "GDP per capita," and "Private consumption expenditure per capita."

Table 4.　Comparison of the Competitiveness Related Indicators Between Taiwan, Switzerland, and the Best countries

Variable	Value of Taiwan	Rank of Taiwan	Value of Switzerland	Rank of Switzerland	Value of best country
GDP per capita	$13,111	25	$36,071	2	$44,424(Luxembourg).
Private consumption expenditure per capita	$7,973	26	$18,260	5	$21,953(USA).
Number of computers/1,000 people	260.1	23	408.3	10	538.9(USA).
Cellular mobile telephone subscribers/1,000 people	493.60	10	441.65	13	679.10(Finland).
Advertising expenditure per capita	151.1	19	346.53	13	419.41(USA).
Total expenditure on R&D per capita	$242.80	20	1142.3	1	1143.2(Switzerland).
Total R&D personnel /1,000people	4.662	14	7.11	2	7.401(Sweden).
Number of patents in force/100,000 in habitants	686.8	7	1342.2	1	1342.2(Switzerland).
Life expectancy at birth	73.7	31	79.1	5	80.3(JAPAN).

Data source: From "*The world competitiveness yearbook"* by International Institute for Management and Development, 2002, Lausanne, Switzerland: IMD.

The significant correlation between the "Ratio of secondary school enrollment to the relevant age group" and GDP per capita found in the present study confirms the result of Mankiw, Romer, & Weil's (1992) study which demonstrated that adding human capital, with the "Ratio of secondary school enrollment to the relevant age group" as a proxy, to the exogenous variables (saving and population growth) of regression equation led to a significant increment of .2 in R^2.

A direct way to expand the number of R&D personnel is to increase the scale of doctoral programs in Science and Engineering.　The National Science Board (2000: Chapter 4) describes the worldwide effort to expand doctoral programs in science and engineering.　The major Asian countries, China, India, Japan, South Korea, and

Taiwan, awarded science and engineering degrees in an average annual increment of 12% from 1993 to 1997. In Western countries, by individual country, the USA has the highest number of doctoral degrees in Science and Engineering fields in 1997. But the combined doctoral Science and Engineering degrees of the three largest European countries (the UK, Germany, and France) recently surpassed that of the USA. Endeavors in strengthening and expanding doctoral education in science and engineering are to develop the capacity for high quality research leading to technological innovation and to build up the knowledge-based economy, and in the end to gain strength in competitiveness.

If Taiwan seeks to improve its international competitiveness, to catch-up to the level of R&D personnel per 1,000 people of Switzerland would be a reasonable goal for the educational policy of Taiwan. However, it is easier for Mainland China to enlarge the number of R&D personnel than Taiwan. Under the leadership of the central government, Mainland has put various long-term and home-based projects into force, such as “The 863 Research Project”, and “The Hundred, Thousand and Ten Thousand Talent Plan” to train scientist and engineers at home and attract oversees Chinese scientist and engineers from abroad (Cao, 1996). In contrast, education in pluralistic Taiwan has been facing a value-conflicting controversy in emphasizing the education of scientists and engineers on the one hand, and pay attention to social sciences and humanities on the other. Since the 1990s, the Council for Economic Planning and Development has been criticized for manipulating the enrollment of higher education through manpower projection and planning in gearing for the nation’s economic development. In the final report on the educational reform, it is declared: “any quantitative planning for the expansion of higher education is inevitably self-assertive” (Educational Reform Evaluation Committee, 1996: 68). As a consequence, every higher education institution may put forward proposals to establish up to five new departments or graduate schools to the Ministry of Education for approval. But after a few years of boost, the Ministry of Education could not afford to it and regulated that the burden of finance and personnel of newly established department or graduate school lie with the university self. Therefore, it would be more difficult than before to establish new departments of science and engineering to nurture R&D Personnel. Although the number of graduates with a PH. D. in science and technology has increased yearly since 1987/88, it decreased from 103,300 in 2000/01 to 101,700 in 2001/02, and the proportion of such graduates to the total number of graduates with a PH. D. decreased from 80% in 1994/95 to 69.5% in 2001/02 (Council for Economic Planning and Development, 2002: Table 22). Whether the result of the present study can be used as argument to promote the cultivation of R&D personnel will challenge the intelligence of educational policy makers.

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Implication of Comparison of International Competitiveness for Educational Policymaking: The Case of Taiwan*

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Abstract

This study investigates whether education-related variables have a relationship with international competitiveness. Analyzing data-bases statistics from the National Science Board and the International Institute for Management Development, the present study shows that: “R&D personnel per 1,000 people,” which represents the latent variable “education,” standing alone, can explain 60% of variance in competitiveness. The result of the present study has implication for educational policymaking. The situation of Taiwan, as an example, is analogous to that of Switzerland. They are small countries with scarce resources and limited domestic market. Their international competitiveness hangs on human capital, especially on innovations by R&D personnel. To cultivate more and more creative R&D personnel is the contribution education can make to competitiveness.

Keywords: international competitiveness; R&D personnel; education of science and engineering

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