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The IPSI BgD Transactions
Advanced Research

Trans-disciplinary Issues in General Science and Engineering

A publication of

IPSI Bgd Internet Research Society
New York, Frankfurt, Tokyo, Belgrade
July 2010 Volume 6 Number 2 (ISSN 1820-4511)

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Interview – Economist's Look to Creativity

Maskin, Eric

1. How you define inventivity and creativity?

Inventiveness/creativity in science is the ability to recognize a previously unseen connection between different ideas or phenomena.

2. What was the major catalyst which enabled the inventivity to happen in the case of invention that brought the Nobel Prize to you?

My work was in mechanism design, the branch of economics that studies how to design institutions for achieving social goals. What I did was to provide a criterion for determining which goals can be implemented by mechanisms and which cannot. I discovered this criterion by trying out lots of examples and then recognizing a pattern.

3. For small nations (like Montenegro or Serbia), what are the things to do to induce inventivity and creativity among young people?

I think the best way to encourage inventiveness in young people in Serbia and Montenegro is the way to encourage inventiveness anywhere else: make a significant investment in good schools.

About the Author

Eric Stark Maskin (born December 12, 1950) is an American economist and Nobel laureate recognized with Leonid Hurwicz and Roger Myerson "for having laid the foundations of mechanism design theory." He is the Albert O. Hirschman Professor of Social Science at the Institute for Advanced Study, and a visiting lecturer with the rank of Professor at Princeton University.

Human Carrying Capacities: a New Economics

Ord, Rob

Abstract— *This 'position' paper explores a methodology for changing how economists view the world. In biology, the 'carrying capacity' ('K') is the maximum sustainable population where deaths catch up to births, usually due to resource depletion, competition, and disease. If the global economy was to internalize the sum of our resources, its collapse, together with recent 'ecological surprises, may well be another early warning that the world at 7 billion people has surpassed K. Criteria for a new economic model are proposed, which, applied to accumulating debt and unemployment, support the early warning hypothesis. 'Depopulate, automate, and conserve' policies are proposed to be the best approach to this threat to the quality of human life.*

Index Terms— *Global economy, externality, overpopulation, carrying capacity ('K'), resource depletion.*

1. *INTRODUCTION*

Unable to explain current economic difficulties, former chairman of the Federal Reserve Alan Greenspan stated:

> "I made a mistake in presuming that the self-interest of organizations, specifically banks and others, was such that they were best capable of protecting their own shareholders and their equity in the firms".[1]

Thus, the "enlightened self interest" assumed by liberal economic philosophy from Adam Smith to Milton Friedman simply no longer fits the facts. No accurate economic 'big picture'[2] exists. This is mainly because economic theorists have always 'externalised' the biological limitations on an economy, especially overpopulation [3,4].

The legal philosopher Hart[5] first sought a 'big picture' of basic human needs, recognizing that legal theory needed to 'fit the facts'. He set out 'moral minima' for humans - including limited altruism and limited resources. Hart's methodology of first seeking an accurate "big picture" is noted here for economic theorists to consider – in terms of limited resources, over-population, and the "carrying capacity ('K', the maximum sustainable population) of states or regions.

2. *METHODOLOGY*

"Big picture" economic appreciation requires multidisciplinary research to obtain enough scientific information to propose a model. An economic theory must be able to reconcile unassailable basic limitations from physics, from biology and from its fellow social sciences. Old economic theory promoted large populations for both markets and large labour pools and externalized the ultimate consequences of these in terms of resources and pollution. But habitable territory and non-renewable resources (water, oil) are unassailable limitations - desert countries cannot support large populations. Meanwhile, past & present Western economic crises have largely involved 'debt' (a promise to pay for the value of a purchase) and 'redundancies' (unemployment), with little predictability.

In contrast, a 'big picture' economic model based on limited resources:

a. would treat human economic 'growth' like any other biological growth curve (i.e. Fig 1).

Fig. 1: Verhulst Logistic Growth

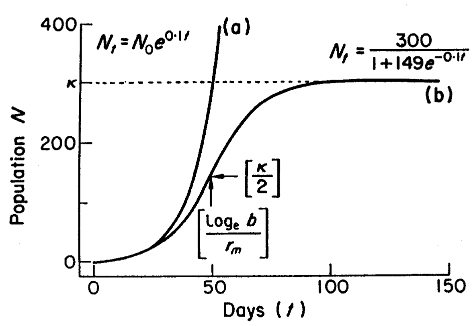
$$dN/dt = rN\,[(K - N)/K]$$

$$Nt = K / (1 + b\,e^{-rt})$$

$$b = (K - No)/No$$

$$\ln b = t'/r$$

Source: Lectures from Centre for Biological Control.



http://www.cnr.berkeley.edu/biocon/BC%20Class%20Notes/67-72%20Factors%20Growth.pdf

[1] Edmund L. Andrews, "Greenspan Concedes Error on Regulation" New York Times October 23, 2008 www.nytimes.com/2008/10/24/business/economy/24panel.html?n=Top/Reference/Times%20Topics/People/G/Greenspan,%20. in response to Congressman Henry Waxman, Chairman of the Oversight and Government Reform Committee that day.

[2] Colander, D., Föllmer, H., Haas, A., Goldberg, M., Juselius, K., Kirman, A. Lux1, T. & Sloth, B. "The Financial Crisis and the Systemic Failure of Academic Economics", opinion paper from a 'Modeling of Financial Markets'' 98th Dahlem Workshop, 2008.

[3] Ord, 2006.

[4] Diamond 2004.

[5] Hart HLA "Social Solidarity and the Enforcement of Morality", (1967) 56 University of Chicago Law Review, 9

In such models, K, the point at which births = deaths, defines the local carrying capacity.

b. would see 'redundancies' for what they are – literally humans 'excess to capacity';

c. would predict when debt could not be repaid (such as the subprime debt of 2008-9) because resources are no longer available

d. would take account of humans' highly evolved "social contracts":

- Labour in return for food and shelter;
- The 'rule of law' – protection in return for compliance.
- Responsibility in return for 'rights'.
- The acceptance of 'money' as a substitute for barter when supplying a good or a service.

e. would involve thinking from the bottom-up[4], starting from 'human resources' (real people or 'laborers') who are generally required to add value even with automation.

f. would involve thinking from the top-down[6]:

- With population-based resourcing, a country which retains non-renewable resources does not need to trade (as much) and is less vulnerable.
- With Hart's 'basic needs', a country which cannot supply its population with a basic need (food or shelter) will exceed its carrying capacity ('K') unless it can buy it.
- Trade involves borrowing to pay for the resource, while you supply your own resources and wait for payment. Is debt via money still appropriate?
- There is likely to be some economic predictor for a country approaching K.

3. ASSESSMENTS

Both Hart's model and population-based resourcing can be addressed in terms of bottom-up basic needs for shelter and consumables. Focusing on shelter and excluding people who have 'secured' their shelter[*], an economic overview which is compatible with biology can be proposed to explain the subprime crisis:

- Shelter is a basic need.
- Both emploee and employer are often in debt to the bank. If the bank cannot or will not lend more money, both employee and employer debt increases, because neither can service existing debt.
- Laborers' wages cannot pay off debt and buy resources, consumption drops and foreclosures commence.
- Employers who produce the resources do not sell as much and have to cut back on production and lay off staff.
- Redundant staff (as in the USA where up to 10% are expected to be unemployed by 2010) are surplus and unsupported in their community.
- It is intuitively evident that the community carrying capacity 'K' has fallen, victims must seek to 'make a living' elsewhere, or alternatively the state has to take over providing shelter to the unemployed.
- But the state itself has high debt and limited resources. Americans owe more than $10 trillion dollars for mortgages), and the US debt to China is $2.5 trillion as of early 2009.

An alternative hypothesis mooted for the economic downturn is a lack of trust in the monetary system. Most now agree that the subprime crisis was in essence a pyramid scheme, and pyramid schemes often continue until the 'resources' of the participants are exhausted. But resources are already limited, especially money. Interestingly, recent media reports the lack of money to lend has led to Europe considering barter, suggesting that money may be sidestepped.

Some commentators still believe that Western populations need to increase births and migration[6], to maintain production and consumption. While this is counterintuitive, the latter can only be tested when the critical parameters are internalized.

4. DISCUSSION

K can be assessed locally or globally, and has significant "quality of life" implications for an economy. Cohen[7] stated that "human carrying capacity cannot be defined independently of other regions if that nation trades with others and shares the global resources." Trade clearly allows rich countries to postpone locally or even

[*] Banks in a country lend to its individuals, and the shelter (i.e. housing) is provided. The laborer pays back the bank, and the bank services its debts. People who have paid in full for their shelter can then use their income to invest in banks by lending the banks their money, and a cycle ensues. But if the bank doesn't get paid as with the US subprime situation, the houses are abandoned or foreclosed and the debts passed on to the bank. If enough debts come to rest with the bank the bank's value collapses as shareholders realize that they are unlikely to get their investment back. At this stage prudent investors who had completely paid for their shelter and other assets lose their savings but are otherwise secure. The population of non-debtors will survive as they can work for consumables and they have their shelter. Up to 40% of 17 million (mostly older) British homeowners are debt free and have 1.4 trillion pounds in shelters ! The situation is similar in the US south, but only 17% in the US west are mortgage-free . These are the lucky ones.

6 Russell Shorto "No Babies?" *New York Times*, *Magazine* June 29 2008 http://www.nytimes.com/2008/06/29/magazine/29Birth-t.html?_r=3&pagewanted=all&oref=slogin&oref=slogin

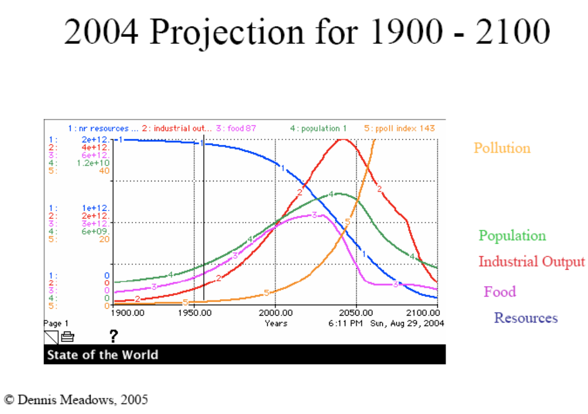
7 Cohen, JE, Population growth and Earth's human carrying capacity, Science 269, 341 (1995). http://www.biology.ualberta.ca/courses/biol468/uploads/w05/announcements/Topic%2001%20Population%20growth%20paper.pdf.

avoid the parameters contributing to K. The United States through debt servicing, for example, may have sufficient land, water and energy to prevent deaths from rising to match births for some time.

However, with costs for these basics escalating, the United States now finds itself with debt which must frequently be assumed by the taxpayer. There appears to be scope for a precursor to K, K', the load on a society due to debt, unemployment or rationing (of shelter, food, health care and education), which exceeds its ability to take on new births or immigration.

Such a point (K or K') is proposed to signal that local carrying capacity has been reached. Any economics based on K thus internalises resource depletion and pollution, migration and births.

Fig. 2: Meadows' Projections of Maximum Population (Ref. [9])



A K based model immediately puts economics in perspective. A population in excess of K will decrease (Fig 2). How it decreases is up to us. Apocalypse is the usual means, but the perspective allows fresh approaches to be considered. For example, an alternative to the economic "growth" model (of more labour for more products for more capital) becomes obvious: "depopulate, automate and conserve". One-child families appear to rapidly result in sustainable population levels[3]. (Fig. 3).

Fig. 3: Predicted result of 100 years of 1-child families on a per generation basis, assuming all are reproducing adults and exclusive of lag effects:

	25 y		50 y		75 y		100 y	
8 Billion	>	4 Billion	>	2 Billion	>	1 Billion	>	0.5 Billion
2010		2035		2060		2085		2110

[Even 2 billion humans may no longer present a significant threat to global weather, ecology, or supply, given technology & environmental awareness.]

Intuitively, a state whose citizens voluntarily undertook 100 years of one-child families would soon have adequate *per capita* shelter and resources, particularly with automation, to avoid the debt, unemployment and rationing issues of their grandparents. Is it just a coincidence that China and India, both of which undertook single child family policy, pulled themselves out of economic torpor so quickly?

Acknowledgments

IPSI staff, Prof. Veljko Milutinovic, Dennis Meadows, Don Alstad, and inspirational discussions of Martin Perl and Katsuhito Iwai at the April 2009 VIPSI conference.

References

[1] Edmund L. Andrews, "Greenspan Concedes Error on Regulation" New York Times October 23, 2008 www.nytimes.com/2008/10/24/business/economy/24panel.html?n=Top/Reference/Times%20Topics/People/G/Greenspan,%20. (in response to Congressman Henry Waxman, Chairman of the Oversight and Government Reform Committee that day).

[2] Colander, D., Föllmer, H., Haas, A., Goldberg, M., Juselius, K., Kirman, A. Lux1, T. & Sloth, B. "The Financial Crisis and the Systemic Failure of Academic Economics", opinion paper from a 'Modeling of Financial Markets'' 98th Dahlem Workshop, 2008.

[3] Ord, R "Numbers" (Baton Roca: Universal, 2006).

[4] 2. Diamond, J "Collapse: How Societies Choose or Fail to Survive". (Victoria, Australia: Penguin Group, 2005).

[5] Hart HLA, Concept of Law (Oxford: Clarendon Press, 1972), p189-195; Hart HLA "Social Solidarity and the Enforcement of Morality", (1967) 56 University of Chicago Law Review, 9.

[6] Cohen, JE, Population growth and Earth's human carrying capacity, Science 269, 341 (1995). http://www.biology.ualberta.ca/courses/biol468/uploads/w05/announcements/Topic%201%20Population%20growth%20paper.pdf.

[7] Russell Shorto "No Babies?" New York Times, Magasine June 29 2008 http://www.nytimes.com/2008/06/29/magazine/29Birth-t.html?_r=3&pagewanted=all&oref=slogin&oref=slogin

[8] [1]Alstad, D, Anderson A, Roe L, Noorbaloochi, S and C Bratteli, "Populus: Simulations of Population Biology" (U. Minnesota Dept. of Ecology, Evolution and Behavior.

[9] Meadows DH, Meadows DL, Randers J and Behrens WW, "The Limits to Growth: a Report to the Club of Rome's Project on the Predicament of Mankind" (London: Earth Island, 1972).

[10] Dasgupta P and K-G Miler, Poverty, Institutions, and the Environmental-Resource Base, WORLD BANK ENVIRONMENT PAPER NUMBER 9 13031 (Washington: The World Bank) March 1994. http://www-wds.worldbank.org/servlet/WDSContentServer/WDSP/IB/1994/03/01/000009265_3970702134014/Rendered/PDF/multi_page.pdf.

[11] Hopfenberg R, Human Carrying Capacity Is Determined by Food Availability, Population and Environment 25, No. 2, 109-117 (2003) http://panearth.org/panearth/CarryingCapacity.pdf.

[12] Jergen C, JM Van Den Berg and P Rietveld, Reconsidering the limits to world population: meta-analysis and meta-prediction, Bioscience 54(3), 195 (2004). http://goliath.ecnext.com/coms2/gi_0199-194132/Reconsidering-the-limits-to-world.html.

[13] Meyer PS and JH Ausubel, Carrying Capacity: A Model with Logistically Varying Limits, Technological Forecasting and Social Change 61(3):209{214, 1999. http://phe.rockefeller.edu/carrying_capacity/cc5.pdf).

[14] Shepherd, JJ and Lstojkov, The logistic population model with slowly varying carrying capacity, ANZIAM J 47 C492-C506 (2007) http://anziamj.austms.org.au/V47EMAC2005/Shepherd/Shepherd.pdf.

[15] David D. Zhang†, Peter Brecke, Harry F. Lee, Yuan-Qing He, and Jane Zhang, Global climate change, war, and population decline in recent human history, PNAS 104: 19214-19 (2007). http://www.pnas.org/content/104/49/19214.full.pdf.
[16] "Factors Affecting Population Growth, Notes, p 67-72, http://www.cnr.berkeley.edu/biocon/BC%20Class%20Notes/67-72%20Factors%20Growth.pdf.

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Knowledge Transfer with Intention to Improve Design While Reducing Operational

Maricic Tihomir, Karney W. Bryan, Pejovic Stanislav[1]

Abstract--All experts face the dilemma about where to draw the line between the effort of achieving a better design and when to implement a project. Although premature implementation often leads to expensive maintenance and operational problems, seeking perfection leads to costly and delayed projects. The challenge of making such decisions in complex energy systems is further complicated by extensive overlap of technologies, by the broad design experience and knowledge requirements, and by the ever-present social and economic dimensions. The question of how to achieve the best balance between design and operation is specifically considered for several well-known hydroelectric plants, (Grand Coulee, Niagara Falls, Richard B Russell, Iron Gates 2, Jenpeg, Bajina Basta, Zvornik) along with reflections on how this knowledge can better be transferred to less experienced designers. Any hydroelectric installation, as a rule, should be designed using several stages. At each stage, entire project documentation should be reviewed by independent reviewers selected and nominated by official authorities. The organized multidisciplinary transfer of experience is a priority task to be undertaken by the universities and electricity sector in Ontario and Canada. There is a clear need to plan, finance and implement various long-term initiatives; it is urgent that decisions to address this be made now.

Keywords: Design, Guidelines, Expert, Experience, Maintenance, Project stage, Rehabilitation, Runaway, Knowledge, Hydroelectric, Review, Small / large hydro plants, Transfer, Wasting money.

1 INTRODUCTION

Over the past decade, there have been several instances where the performance of new hydro developments was compromised by unsatisfactory operation of some component associated with the hydraulic design of the facility [44], [63], [50], and cases described in Sections 9 Illustrative Systems and 14 Bibliography. Frequently one of the main reasons is the lack of transfer of knowledge. Companies and experts keep their knowledge for themselves to be competitive in the market. In North America as well as most countries all over the world Universities have not been involved in the teaching of the design of electric plants. Particularly hydroelectric plants design is very difficult because there are no two identical sites in the World. Terrain configuration and geology are different, river data varies as well.

In addition the continuity of experience and expertise have been largely lost in Canada and most parts of the world due to the slow pace of implementation. Canada has had more than 100 years of experience in the electricity sector but individual areas have lost valuable knowledge that accrued during this period. However, poorly coordinated transfer of practical and theoretical experience appears to be root cause of this loss. The consequences are an unstable energy market and investment climate, accidents, inefficiency and troubleshooting (of the same problems), which have all shown up regularly in recent years, will continue to occur if appropriate steps are not taken. The organized multidisciplinary transfer of experience is a priority task to be undertaken by the universities and electricity sector in Ontario and Canada, even in most countries over the world; it is urgent that decisions to address this be made now. There is a clear need to plan, finance and implement various long-term initiatives [33].

One of the greatest tasks facing the electricity sector is the design of new, and the urgent rehabilitation of existing generating units. Yet there are too few engineers with extensive experience and too few project managers who know how to cultivate the right skills from the market place [59].

The dilemma between smart design and less troubles is the question? At each stage, all project documentation should be reviewed by independent reviewers selected and nominated by official authorities. Reducing the amount of analyses, without justification, or worse yet, neglecting the design procedures puts the project at risk. Design, construction and operation of hydropower plants are complex tasks. A large number of details must be carefully considered, coordinated and executed in order that the projects achieve safe and economical operation.

What is the best way to protect consumers, taxpayers and investors (owners) wasting money? What is the best way to protect young inexperienced engineers and experts doing work not experienced and properly qualified to do[2]? A reply has been

[1] This work was supported in part by Ontario Power Generation and University of Toronto. Manuscript received March, 23th, 2009.

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[2] PEO (Professional Engineers Ontario) law of Ethics; link:

proposed in the "Conclusions and Recommendations" submitted to participants and posted on the Conference website [33]:

1. *More than 50% hydroelectric plants have trouble in operation.*
2. *Continuity of knowledge and experience has been lost.*
3. *Organized multidisciplinary transfer of experience is a priority task.*
4. *Action should be undertaken all projects, including short-changing, correctly to be designed and reviewed.*
5. *Taking short cuts can lead – and indeed has often led – to large-scale problems*

2 GOALS AND BEST PRACTICES

A. *Organizing multidisciplinary transfer of experience and knowledge - a major task that needs to be undertaken.*
B. *Creating experts to form future teams for designing hydroelectric plants with at least ten years of combined hands-on training in the classroom, design office and on-site.*
C. *Smart design - less troubles*
D. *Protecting inexperienced engineers and experts of doing work beyond qualifications[2].*
E. *Minimizing inefficiency and assist troubleshooting through lessons learned from past experience.*
F. *Protecting consumers and taxpayers.*
G. *Protecting environment.*
H. *Protecting owners' investments.*

3 PROJECT DEVELOPMENT

Any hydroelectric installation and other hydraulic projects[3], as a rule, should be designed using the following stages:

(i) Feasibility study,
(ii) General design,
(iii) Detailed design (after bidding),
(iv) Commissioning and running-in process,
(v) Trouble-shooting investigations, and
(vi) Reconstruction, redesign, adjustment or enlargement.

(vii) Review at each stage.

Ideally, all project documentation should be reviewed at each critical stage by independent reviewers selected and nominated by official authorities. Short-changing the analyses, without justification, or worse yet, neglecting any design stage or its associated review, puts the project at risk. At stake here is the economical and efficient functioning of the whole project; taking short cuts can lead – and indeed has often led [10] – to large-scale problems. The point here is that the design team, the project documentation, and the review process all play an interconnected role in anticipating and resolving difficulties before they are implemented in the field, and thus solving them when they are relatively simply addressed [8], [17], [19], [25]. At the same time reviewers as high experienced experts transfer their knowledge and experience to the designers and to the all present and responsible for the project proper and adequate review, construction and operation.

There is no a single hydroelectric project running through the commissioning and trial operation without troubles and troubleshooting; thus a higher degree of review and documentation through project stages could pinpoint problems earlier and more effectively than later [39], [45], [50], [61], [62], [63]. Furthermore, this process, while costing only a small premium, would decrease troubleshooting and maintenance costs over the project's life time.

Hydroelectric plant's equipment may have been designed in accordance with the highest standards and produced using the finest manufacturing practices, but this does not necessarily guarantee that equipment will operate properly when integrated in a system. Every hydropower project has unique design criteria. Unique characteristics of a particular installation can result in unknown and unexpected events during plant operation. For this reason, designs, reviews, construction, erection, start-up testing should be a carefully planned, step-by-step procedure that provides adequate projects, drawings, in short all documentation and data, for a thorough analysis of all operating conditions. All parts of the design should be reviewed to determine which items require analyses and to what extent. This is not only important for new designs that lack proven operating records, but similarly, when a system is expanded and up-rated, since these improvements must be predicted and verified with accuracy.

(viii) Construction and inspection is an extra (obvious) stage.

Although this is an obvious step, an experienced and qualified eye during the construction process duly documenting details would be of importance for future troubleshooting and maintenance activities, as well as to proactively deal with issues which may impact schedule and performance of the installation.

As an example, Canadian team of experts in Iranian company reviewing manufacturers drawings and booklet submitted reports [34], [35], [37] to protect the units from the water column separation as it was done designing pump storage plant successfully operating for decades [27], [12]. Owners' young inexperienced engineers having not

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http://www.peo.on.ca//publications/code_of_ethics.html

[3] Nuclear plants have, for instance, up to 25 pumping hydraulic systems of different types.

chance to be educated on the subject rejected to follow recommendations and the 2000 MW plant is running at risk. For the similar reason the reviewers rejected printing of the article [68] describing some phenomena not published in Western publications. New, longer article is under review [6].

4 STANDARDS, GUIDELINES, BOOKS,

Many important experiences and knowledge accumulated in last century are not yet introduced into the publications [8], [19], [18], [25], [21], [14] and many other standards, guidelines and recommendations such as IEC, ASMA, ASCE, IEEE, EPRI, IEA, USBR,[4] etc. The young experts therefore have nowhere to read and learn about phenomena very important for the safety of electric plants. In addition the Design of Hydro and Wind Electric Plants is thought at the University of Toronto for the first time in Winter 2009; so far this is the first time that the Design of Hydroelectric Plants is presented to the students in North America.

5 COMPUTERS' APPLICATION

These problems are perhaps further magnified by the use of computers and readily available programs. Overall, the practice of professional engineering has become increasingly reliant on computers, and engineers use many programs that incorporate technical principles for design and simulation. Ultimately these programs are used as tools for baseline installations and in some cases their applicability can be seriously questioned. Invariably, such programs are based upon assumptions, limitations, interpretations and judgments on engineering criteria that were made by or on behalf of an engineer when the program was first developed. Therefore, it is often difficult to determine, simply by using a program or studying its manual, the inherent assumptions, coding algorithms employed and their limitations. When using computer programs to assist in this work, engineers should not only be aware of the engineering principles and incorporated assumptions but must independently verify the results and are thus responsible for the interpretation and correct application of the analyses the programs provide [7].

Engineers are responsible for verifying that results obtained by using software are accurate and acceptable. Given the increasing flexibility of computer software, the engineer should ensure that professional engineering verification of the software's performance exists. In the absence of such verification, the engineer should establish and conduct suitable tests to determine whether the software performs what it is required to do and at the required level of accuracy.

Clearly, the engineer must be alert to the possibility that errors may exist in design software and, as for any design data or design aid, must perform independent checks to ensure the validity of such design assistance. It is not acceptable professional practice to assume that computer output is accurate unless the user has independently verified both the program and the output. Briefly, the engineer must ensure that the program is appropriate for the application, that it is accurate when used properly (as established by validation tests), and that it is correctly used by properly trained personnel. Most importantly, remember the old adage in engineering that an engineer should never base a really important decision on a single calculation (or invalidated computer output). Alternative and independent computations must be made to validate the original results. Reviews should be done to reduce the probability of troubles and incidents

It is the manager's responsibility to ensure that this is done consistently. Ontario professional engineering (PEO) Ethics and Law enforce managers and professionals [71] to verify the computer programs and results of calculations.

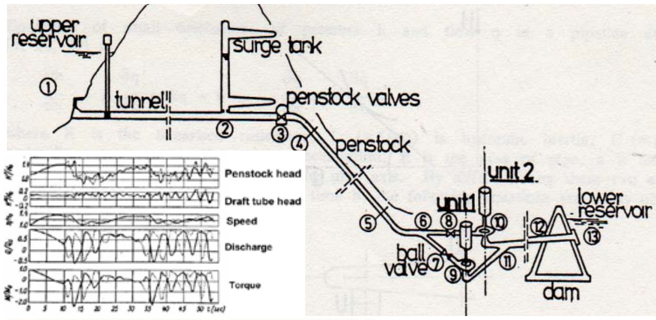
As an important, typical example for computer applications and difficulties with understanding the fluid flow in the hydroelectric and all other hydraulic systems[3] is the analysis of the computed results. Outputs are numbers, tables and diagrams but users have to understand, analyze, and make decisions. Our software [75], [76], [77], [78], [79], and other commercial software we have used [74], [80] as most other programs do, are printing results but analyses and decisions must be made by users.

For instance in the case Figure 1 the water column separation in the draft tube and pressure jump up to 10 bar when separated water columns rejoined has not been noticed by designers and manufacturers. As the system runs into the "S" form instability the results of calculation and measurements are unpredictable and unrepeatable.

6 HYDRAULIC TRANSIENTS

Transients in hydraulic networks and infrastructure can become critical constraints during design and operation. Vibrations produce the highest pressures in the waterways and associated conduits. They cause critical stresses in the overall hydraulic, civil, and mechanical structure and therefore cannot be neglected during design. This aspect is independent of the size of the conduits or hydraulic machinery and is thus recommended for all installations including mini and small hydro. Many books have been published on modeling and calculations of hydraulic transients ([24] and many other books and

[4] IEC - International Electrotechnical Commission, ASME – American Society for Mechanical Engineering, ASCE American Society for Civil Engineering - , IEEE - Institute of Electrical and Electronics Engineers, , EPRI - Electric Power Research Institute, IEA – International Energy Agency



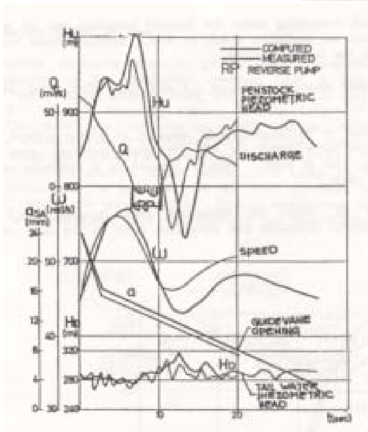


Figure 1 Bajina Basta pumped-storage plant; two pump-turbines each 315 MW output and pump discharge 51 m^3/s at speed 428.6 rpm; head 600 m. Low specific speed unstable "S" form four-quadrant curves are the source of severe transients even at one unit load rejection. Penstock pressure prevented to exceed designing pressure but water column separation in the draft tube and pressure jump up to 10 bar when separated water columns rejoined has not been noticed by designers and manufacturers.

articles) and vibrations (few books [15], [22] and many articles) but only two guidelines for transient and vibration analysis, [8], [19] based on the books [12], [17], [20]. [5] Transient analysis of hydraulic auxiliary systems in hydro, thermal and nuclear plants has been analyzed in [19] based on the book [16] and related research project. It is important to repeat that these books do not cover phenomena casing dangerous hydraulic accidents if not prevented. Some of those are scanned in Section 9 Illustrative Systems. The costs associated with cavitation, transient conditions, vibrations and stress analysis for mini, small and big hydroelectric plants are often quite comparable in absolute terms; however, the relative cost as a fraction of the total investment is obviously much greater. Bigger plants usually entail such costs less than one percent of the total whereas smaller installations may well see these costs as being nearly equal to overall initial expenses.

The pressures stemming from private sector design and accounting are certainly now upon us in a big way. The result is a rapid movement to minimal staff or no site staff. Extensive use of numerical simulation for the performance of hydraulic machinery is remarkable these days, but a shortage of qualified specialists and engineers is often aggravated as a result. New staff, whose number will have to grow again in the light of initiatives, will rely on the new guidelines and upon up-to-date standards and technical literature.

Small hydro power plants often suffer from the same problems as the large ones. The analyses of transient regimes are actually more complicated, due to complex boundary conditions. Despite this, there is a general tendency to decrease the design costs and to simplify analysis.

Thus, in general, the smaller the hydroelectric plant, the higher the risk of having troubles as the result of reduced project costs. Saving money by reducing reviewing costs further increases the risk.

7 RISK AND RUNAWAY PROTECTION

In designing a hydraulic machine unit, the runaway operating condition has to be considered. The balance between safety and costs for manufacturing components and maintenance must be recognized and allowed for. Excluding very small size units, all generator / motors are at risk at full runaway [63].

Some books [14], [21] and articles [61], [55], [63] discuss the issue.

Units must withstand the full runaway speed for a short time, as stipulated in the delivery specifications of the order. According to the experience hydro plants actual runaway occurs only very seldom.

Another alternative is economically preferable, since the probability of runaway occurrence is small enough that the damage and repair costs are less than the savings obtained by eliminating the costly protective devices[6].

In the example [61], [63] the client's designers identified the dangerous phenomenon of the unstable "S" form pump-turbine characteristics and water column separation. The manufacturer verified the instability and the control system were altered to prevent catastrophic runaway and pressure surges in the long penstock (Figure 1). But, in another case hydraulic resonance accident occurred operating in trial operation in the unstable "S" zone [32].

8 VIBRATION SEVERITY

Excited forces in the hydro generator unit include those from hydraulic, mechanical and electrical sources. The test value is compared with standard or permitted values. Some nations and organizations suggest standards based upon the test material. When the unit vibration satisfies these standards, normal operation and safety are usually ensured. Two books, [15], [22], are the highest level scientific,

[5] Research projects at the University of Belgrade supported by electricity sector

[6] Contrary to practice with thermal turbo generators, the hydro turbo set in general has to withstand the runaway speed of its turbine. This is a multiple (1.4 to 3.3) of the rated speed, depending on the design. The first safety precaution is the speed governor of the set (if any at all). At least each set has an emergency shutdown device for the case a certain overspeed (about 1.3 of the rated one) is surpassed.

theoretical, and practical site and laboratory analyses of hydraulic and hydraulic machines vibrations; knowledge crucial for high level hydraulic design. The phenomenon that hydraulic resonance sometimes occurring when increasing submergence and sometimes when decreasing submergence is explained in the articles [3] and [56]. Model test results confirmed the odd phenomenon for hydraulic waterways resonance excited by the draft tube vortex core [35].

At the present time international vibration standards do not exist. Some important draft tube phenomena [2], [3] are not yet included into standards, guides and books.

8.1 Vibration and hydro unit lifetime

Hydro units should provide a service life of at least 4 years and/or 25000 hours before requiring a general overhaul. The average service life before requiring a major rehabilitation should be not less than 30 years. Actual lifetime will depend upon the maintenance performed and mode of operation (e.g. a unit start may be considered equivalent to 8-15 operating hours; a runaway event could be much higher depending on the duration of the event).

Investigations on many units have shown that vibrations experienced by hydro units increase with operating hours. This is caused by gradual erosion and corrosion of the unit and its bearings (generator supports, spider, bearing inserts, etc.), and also by abrasive and cavitation destruction of the runner and associated turbine components, which disturbs runner balance. As the result vibration of the unit reaches boundary "trip values", and the unit must be removed from service and overhauled. Several methods and formulae for the calculation (estimation) of average lifetime between overhauls [4], [15], [22], [38], [64] are based on measured vibration of the unit.

The vibration standards should take into account vibration severity as the main source of crack's propagation. Severity of vibrations directly influences the rate of crack propagation which in turn correlates to increased maintenance requirements and operational risk [31].

8.2 Reliability

The value of energy produced depends on the mode of production. Of course, the goal is to achieve high rate of production with low cost of operation and maintenance for as long as possible. On the other hand, life of the unit is dependent upon the operating conditions. There are some ranges and conditions which reduce the life of the unit. Characteristics of these zones are higher levels of vibrations, cavitation, and flow speed.

It is well known that oscillations of the unit are indicators for operating qualities (cavitation characteristic of turbine, resonance in any component). During unit commissioning the characteristics of oscillation may be used to determine the degree of success for the installation or overhaul. Finally, this data may be used to determine the best technical / economical operating strategy for the unit [3], [4], [15], [64].

Every unit problem may be predicted [4], [15], [22] [53]. Proper investigation and analyses of the results provide information. Developing systems for diagnosing potential problems is the most effective method for increasing reliability and maximizing time between overhauls.

The guidelines for determination of vibration conditions have been developed based upon numerous experiments [10], [15], [22]. There have also been some international attempts for standardization of allowable vibration [15].

8.3 Fatigue

Fatigue is the progressive and localised structural damage that occurs when a material is subjected to cyclic or fluctuating strains at nominal stresses that lead to structural failure. The maximum values of stress that result in fatigue failure are often significantly less than the ultimate tensile stress, and also below the yield stress of the material [41], [50], [65].

The problems associated with cavitation erosion, transient states and vibrations may arise in operational installations, sometimes after several years of seemingly normal operation. These problems usually relate to emergency or catastrophic cases, damage to the plant due to breakdown of equipment, excessive vibrations or other similar situations.

Figure 5 and Figure 6 show the consequences of excess vibrations and fatigue.

8.4 Protection

To determine the root cause of the problem and develop an effective remedy, a very detailed and precise study must be undertaken at all designed stages as specified in paragraph Section 3 Project Development.

9 Illustrative Systems

9.1 Layout and Methodology

To illustrate the possible causes and origins of specific systems, several cases studies are introduced. Many others cited in the Sections 13 References, 14 Bibliography[7], and 12 Appendix.

The goal is to simply illustrate the range of issues and challenges that so quickly arise in practice, and is not intended to apportion fault or blame on any party or developer because the experts dilemma

[7] The bibliography at the end lists general references containing material describing some of many accidents, incidents and troubleshooting.

always present has been: smart design/low costs of investments and expensive maintenance/short life span or the best expensive design and construction versus low maintenance costs and long lifespan. Rather, it is presented to advocate a renewal of collaborative ties and a sharing of expertise across the field. In all cases, the role of the design process, its connection to operation, and the specific role of hydraulics (and particularly transients) will be illustrated, and comments are made about the possible value and role of the review process. Space limitations prohibit doing justice to the details of these designs.

9.2 Grand Coulee Hydroelectric Plant

Grand Coulee is a typical example of smart design. Peak energy has been needed and the new 700 MW units have been built. There was no space. Therefore turbulent 90^0 bending inflow into the intake structure and outflow into the tailrace has been the "only acceptable and reasonable solution." High maintenance costs, expensive plant deliver clean "cheap" peak hydro energy into the electrical grid (Figure 2).

Figure 2 Grand Coulee hydroelectric Plant

9.3 Sir Adam Back Hydroelectric Plant

Sir Adam Back. (Figure 3) has similar inflow hydraulic conditions into the turbines on the right side of the dam as the previous Grand Coulee case but more severe inflow having twice 90^0 bending of the water stream once into the inflow canal and then into the turbine intakes. Really an "S" type bending is known as the source of increased turbulence. Saved investments yet increased maintenance costs. Post factum comparison of investments, maintenance costs and energy losses could give data for future analyses.

Figure 3 Sir Adam Back 2 (Satellite photo)

9.4 Richard B. Rustle Pump-Turbines

Figure 4 shows Richard B. Rustle Plant with four turbines and four insufficiently submerged pump-turbines. Based on the available data describing troubles (identified sources listed in the figure) a bid was submitted. The final solution is unknown as the bid failed.

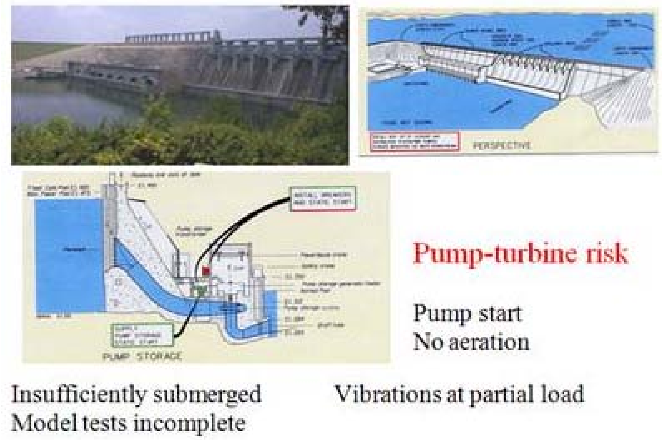


Figure 4 Four turbines each 78 MW.
and four pump-turbines each 76 MW

9.5 *Iron Gates 2 / Jenpeg*

Figure 5 and Figure 6 show the consequences of excess vibrations and fatigue. Figure 5 portrays sixteen bulb Iron Gates 2 turbines each rated at 28 MW. Large vibrations at high heads starting at the rated head have been measured. To reduce investments, the turbine specific speed (type of the turbine) is not properly selected increasing vibrations [46], [50]. After 20 years of operation, shaft failure occurred (Figure 6), and frequently runner blades cracks have had to be repaired.

Jenpeg Hydroelectric plant has identical units but no data available.

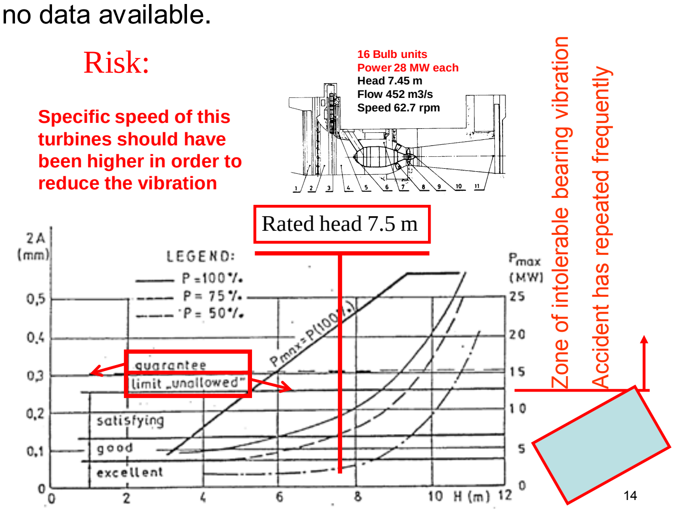


Figure 5 Sixteen units each 28 MW

A detailed technical, technological and economic analysis should take place prior to redesign, reconstruction and adjustment, considering the balance between manufacturing and maintenance costs [31].

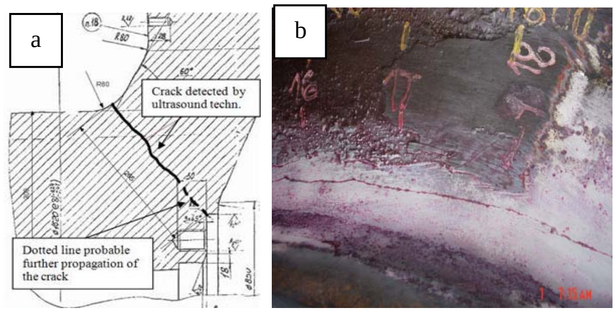


Figure 6 a Horizontal shaft crack; b Shaft to flange transition radius; damaged protective coating and shaft material crack along the perimeter

9.6 Masjed-e-Soleyman hydroelectric plant

In this example [62] the client's designers identified the dangerous phenomenon of water column separation, as described at the end of Section 3Project Development.

The Masjed-e-Soleyman plant is a big 2000 MW underground structure with eight equal turbines having long tailrace tunnels (Figure 7). An air injection system designed to prevent the rejoining of the separated water columns in the draft tubes occurring in most transient regimes. The submergence must have been increased at no additional costs to prevent reverse waterhammer [30], [34], [35], [36], [39], [45], [62]. A better organized design, reviews and involvement of experienced expert could have made the project at lower risk and costs.

Powerplant designed by inadequately trained and inexperienced engineers has been put in danger by water column separation in the turbine draft tube. Insufficiently submerged to prevent water column separation in trial operation excessive pressure surges measured; air injection system added to mitigate pressure peaks [30], [34], [35], [36], [37], [39], [45]. Complete excessive transient analyses should have been done [17], [8], [25] and the system appropriately protected. At partial loads vibrations are present as well [3].

The panel of experts nominated to solve the problem verified during commissioning and trial operation also has not protected adequately the system and controversial articles were published [30], [45], [62], [63], [68], [6].

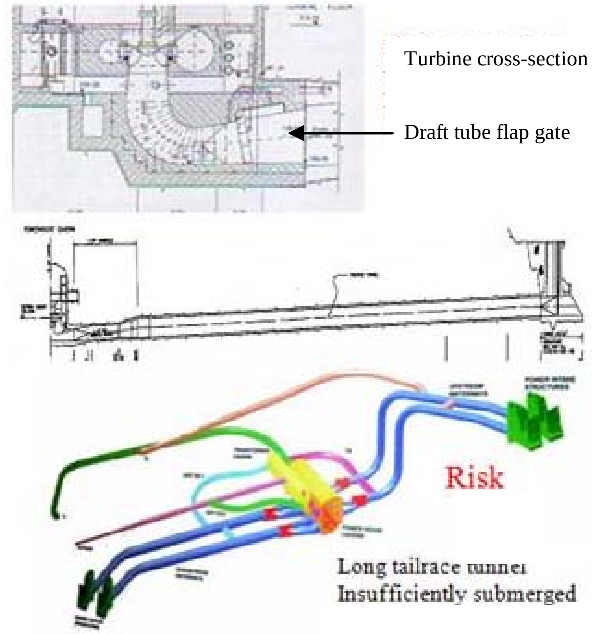


Figure 7 Power plant under construction; eight unit each 250 MW

9.7 Hydroelectric plant Zvornik

A 22 MW generating unit was operating during the night with an output of 8 MW. Because of the governor failure the guide-vanes opened very quickly and the power output increased; oscillations between 20 and 25 MW registered, and then roaring sounds were heard from the turbine. Emergency shut-off button pressed. A banging noise was heard; water was leaking out through the turbine head cover. One of the runner blades was broken at the root (Figure 8) [5].

A year later in another plant a turbine having the identical runner had catastrophic accident as well.

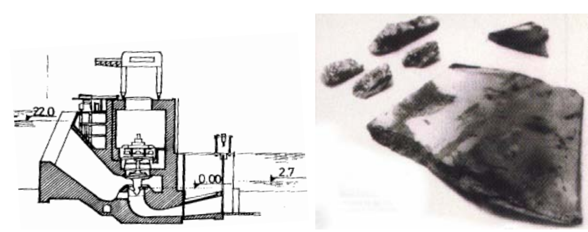


Figure 8 Hydroelectric plant Zvornik Runner Blade Broken in the Accident

9.8 Hydroelectric plant under construction

The next example is a small 20 MW plant (Figure 9) under construction which could be at risk. Based on figures and data originally posted on internet the cause might be high head, big diameter, bulb unit sensitivity to vibrations and/or bend disturbing the inflow into the turbine. We are lead to believe that designers have verified and corrected all issues, highlighting again the value and role of a review process.

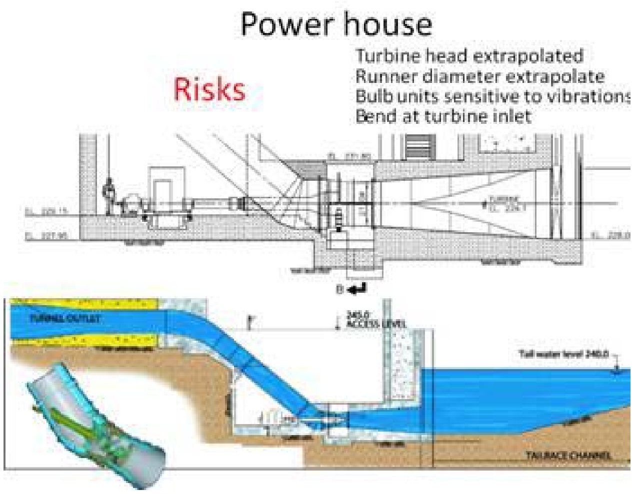


Figure 9 Small powerplant under construction: two units each 10 MW. Hydraulic constraints must be verified.

9.9 *At the end of Illustrative Systems*

As has been illustrated from the above case examples, troubleshooting of both large and small hydro installations will almost certainly occur in the field and would thus require experts to provide solutions. Many of these problems, particularly for mini-hydro, are due to incompatible approaches to the design as opposed to large installations. Such a process is thus encouraged for smaller installations, perhaps with the aid of codes or guidelines for standard, contemporary or replicable design.

10 *ACTION AT THE UNIVERSITY OF TORONTO*

10.1 *Case studies*

The Division of Environmental Engineering and Energy Systems at the University of Toronto has decided to support editing and writing a book tentatively titled *The Current State of Technology in Hydraulic Machinery and Cases in Hydraulic Plants Design, Construction, Maintenance and Operation* to provide important examples to project team members and reviewers.

All interested to collaborate and coauthor are invited to join the team. We are very excited about the idea of including a section on "Smart Designing – Less Troubles" as a key component of this endeavour and within the near future.

10.2 *Cooperation in preparing the new ASME Guide*

Cooperation with ASME (American Society of Mechanical Engineers) Hydro Power Technical Committee is editing and reviewing The Guide to Hydropower Mechanical Design, planned for 2009 [8], [25].

10.3 *New courses*

New courses related to the Electric Plant Design at graduate and undergraduate level are scheduled to start for the first time in the next years.

Courses already started:

1. Design of Hydro and Wind Electric Plants (S. Pejovic: Winter 2008 – graduate, B.W. Karney and S. Pejovic: 2009 undergraduate students),
2. Energy Transformation Systems (S. Pejovic: Winter 2006).

11 *CONCLUSIONS*

The growth of both electricity demand and subsequent production and supply, and particularly the related interest in hydropower, is of world wide scope and significance. It is a growth and interest that shows no sign of decreasing or letting up [26], [28], [40], [70].

And yet there is also no doubt that hydropower plant design, construction and operation are complex tasks. Such an undertaking requires, among other things, competent environmental and hydrological assessments, careful planning and design, visionary financing, long-sighted political planning, demanding construction and supervision, painstaking commissioning and trouble shooting, and meticulous operation and control. Tens of thousands of details must be accurate, well conceived and executed, and carefully coordinated for a project to achieve safe and economical operation that can be judged a social, technical and environmental success. Yet, when only a few of these myriad details are overlooked, under-estimated or improperly linked to each other, great complications can quickly arise. It has not been uncommon to have major investments in hydro projects to under-perform and forced to run at much lower than design loads due to failures in the review process, particularly associated with the poorly understood issues of system hydraulics. The purpose of this paper is to review such issues and bring them strongly to the attention of the larger energy community.

For large-scale projects, even minor performance improvements deserve consideration during development and testing. Similarly, when a system is expanded and up-rated, since most of the investment is justified by the performance improvements alone, these improvements must be predicted and verified with accuracy. The effectiveness of incentives for performance achievement has many examples to date.

Yet small developers are seldom as well equipped, financed or experienced as those working on larger units. As a result, they are exposed to face greater risks and complications. Special standards to provide comprehensive rules and guidelines for smaller units and new developers would largely alleviate some of the inherent, yet avoidable risk.

The issues and concerns associated with developing special manuals for hydroelectric plants, particularly smaller plants, should be effectively engaged and controlled by a public committee or task force, including possible solutions. The main purpose of reviews is to protect consumers, taxpayers, environment, and owners from unqualified designers, manufacturers, managers and other complications and thus to avert avoidable risks and expenses during operation [25].

12 APPENDIX

It is impossible in a limited lengths paper to include all important and relevant details about the cases studies. To begin to provide reference resources, the authors are collecting together a set of examples and case studies on the following web site: (to be determined).

This site includes more details about the examples presented here, and also information about additional cases. Comments on this collection are welcomed.

13 REFERENCES

Periodicals:

[1] Denys A., Plunkett T., *Ozark-Webbers Falls Turbine Repairs*, Waterpower '65 pp 1570-1578.

[2] Lee T. S., Pejovic S., Air Influence on Similarity of Hydraulic Transients and Vibrations, Transaction of the ASME, Journal of Fluids Engineering, Vol. 118, December 1996, pp. 706-709.

[3] Pejovic S., *Understanding the Effects of Draft Tube Vortex Core Resonance,* Hydro Review Worldwide, HCI Publications, September 2000, p. 28-33.

[4] Pejovic S., Gajic A., *Profit Management and Control in Transient and Steady Operation of Hydroelectric Plants*, No. 29-30, Serbian Scientific Society, Belgrade 2001-2002, pp. 5-20. <Profit Management NDS 2002>

[5] Pejovic S., Krsmanovic Lj., Gajic A., Obradovic D., *Kaplan Turbine Incidents and Reverse Waterhammer,* Water Power and Dam Construction, 1980, pp. 36-40<Water Power 1980>

Periodicals (Unpublished):

[6] *Pejovic S. Karney W.B. Zhang Q., Colombo A.F., Maricic T., Reverse Waterhammer in Draft Tube*

Books:

[7] Andrews G.C., Kemper J.D., *Canadian Professional Engineering Practice and Ethics*, Harcourt, 1999.

[8] ASME HPTC, PEJOVIC S., Co-Author, *The Guide to Hydropower Mechanical Design,* ASME Hydro Power Technical Committee, HCI Publications, 1996.

[9] *Guidelines for Analysis of Regulation of Hydroelectric Power Plants*, Russian, Moskva 1977.

[10] *Guide on How to Develop a Small Hydropower Plant*, European Small Hydropower Association – ESHA 2004, http://www.esha.be/

[11] *Guidelines for Hydroelectric Francis Turbine Upgrading by Runner Replacement*, IEA Technical Report, CD, 2001.

[12] Krsmanovic Lj., Pejovic S., Gajic A., Djonin K., *Examination of the Mechanical Equipment in Hydro Power Plants in Order to Increase Its Operating Life (in Serbo-Croatian),* Belgrade, 1985, pp. 62.

[13] Krivtchenko G. I., Arshenevsky N. N., Kvyatkovskaya E. V., Klabukov V. M. (1975). Hydraulic Transients in Hydroelectric Power Plants, (in Russian), Moskva.

[14] Kovalev, N.N., *Hydroturbines, Design and Construction,* Translated from Russian, Israel Program for Scientific Translation, Jerusalem, 1965.

[15] Ohashi, H., 1991, Editor, *Vibration and Oscillation of Hydraulic Machinery*, Avebury Technical.

[16] Pejovic S., *Guidelines to Hydraulic Transient Analysis and Measurement on Pumping Auxiliary Systems of Hydro- and Thermal Powerplants (in Serbo-Croatian),* Faculty of Mechanical Engineering, Belgrade, 1990, pp. 88.

[17] Pejovic, S., *"Guidelines to Hydraulic Transients Calculations in Hydro Power Installations",* (in Serbian), Beograd, 1984.

[18] Pejovic, S., A.P. Boldy, *Guidelines to Hydraulic Transient Analysis of Pumping Systems*, P&B Press, 1992.

[19] Pejovic, S., A.P. Boldy, D. Obradovic, *Guidelines to Hydraulic Transient Analysis,* Gower Technical Press Limited, Aldershot, Hampshire GU11 3HR United Kingdom, 1987.

[20] Pejovic S., Krsmanovic Lj., *Measurement and Analysis of Vibrations of Hydro Power Plants (in Serbo-Croatian),* Masinski Fakultet, Beograd, 1984, pp. 87.

[21] Raabe J., *Hydro Power: The Design, Use and Function of Hydro-mechanical, Hydraulic and Electrical Equipment,* VDI-Verlag, 1985.

[22] Vladislavlev, L.A., 1972, *Machine Vibration of Hydroelectric Plant*, (in Russian), Moskva.

[23] US Army Corps of Engineers Construction Engineering Research Laboratories, Water Hammer and Mass Oscillation (WHAMO), 1998, http://www.cecer.army.mil/usmt/whamo/whamo.htm

[24] Wylie E. B., Streeter V. L., *Fluid Transients in Systems*, Prentice Hall, 1993.

Books (Unpublished):

[25] ASME HPTC, Pejovic S., Maricic T., Karney B.W., *The Guide to Hydropower Mechanical Design,* ASME Hydro Power Technical Committee, HCI Publications, New edition plan*ned 2009.*

Technical Reports:

[26] BC Hydro and Power Authority, "*Inventory of Undeveloped Opportunities at Potential Micro Hydro Sites in British Columbia*", E5967, March 2000, [Online]. Available. http://www.bchydro.com/rx_files/environment/environment1837.pdf

[27] Design Criteria of the Tailrace Tunnel to Prevent Water Column Separation, Toshiba, 1976, Report.

[28] Energy Information Administration, "*International Energy Outlook 2007"*, DOE/EIA-0484(2007), May 2007 [Online]. Available: http://www.eia.doe.gov/oiaf/ieo/

[29] Karney B., Pejovic S., Colombo A., *UofT - Supply Mix Submission* – OPA, August 18 2005, http://www.powerauthority.on.ca/

[30] Brekke H., Jacob T., Leyland B., Pejovic S*., Masjed-E-Soleyman Transient Problems upon Load Rejection,* Panel of Experts Mission of November 18 To 25, 2003, Report.

[31] Maricic T. ., "*Unit 2 Overhaul Report,"* Internal unpublished report of OPG, July 2007.

[32] Martin C.S., Post Accident Report, Frequency, Resonance, and Hydraulic Transients Analysis, BHRA Pumped Storage Installation, the Tata Power Company Ltd. January 1996, Report.

[33] Pejovic S*., Hydro Power Technology, Prospect of Hydro Small and Big as a Renewable Energy Resource in Canada and Abroad*, IEEE Electrical Power Conference, Montreal, Report, 2007. http://www.ieee.ca/epc07/IEEE_EPC2007_Panel_Session_HydroPowerTechnology.pdf.

[34] Pejovic S., *Masjed-E-Soleyman Water column separation and rejoining. An approximate analysis of water column separation*, Hydro Québec International, RSW International, Teheran, Report, 1998.

[35] Pejovic S., *Mesjad-E-Soleyman Analysis of Draft Tube Flap Gate,* Hydro Québec International, RSW International, Teheran, Report, 1998.
[36] Pejovic S. Karney W.B., Zhang Q., *Masjed-E-Soleyman Hydraulic Transients. Water Column Separation in the Draft Tube*, Draft Tube Surges, Iran Water & Power Resources Development Co./ Lahmeyer International Gmbh, Panel of Experts Mission of November, Report, 2004.
[37] Pejovic S., Samadzadeh B., Supervised by Khris R., 1998*, Masjed e Soleyman Stability Analysis,* Report, Hydro Québec International, RSW International, Teheran, Report, 1998.
[38] Pejovic S., in cooperation with Electronic Design, *Hydropower plant Profit On-Line Management and Control*, 1996, pp. 4. <Click here for more information>
[39] Pejovic S. Karney W.B. and Zhang Q*., Masjed-E-Soleyman Hydraulic Transients. Water Column Separation in the Draft Tube, Draft Tube Surges,* Panel of Experts Mission of November, Report, 2004.

Papers Presented at Conferences:

[40] Ahsan Q., Alam M.T., *Electrical Power Crisis in Bangladesh: Impacts of the Optimal Use of Energy Limited Hydro Unit on the System Reliability and Production Cost*, IEEE Electrical Power Conference CD Montreal 2007.
[41] Angehrn, R., Eckert R., 1990, *Service Life of Horizontal Shafts in Low Head Turbines under Corrosion* Fatigue, IAHR 15th Symposium, Belgrade.
[42] Gajic A., Pejovic S., Ivljanin B., *Reverse Waterhammer - Case Studies,* Proceedings of the International Conference on CSHS03, Belgrade, 2003.
[43] Gajic a., Predic Z., Muskatirovic J., Pejovic S., Manzalovic P., *Investigation of Cracks on the Kaplan Turbine Stay Vanes*, IAHR Symposium, Belgrade, 1990, pp. A4 1-12.
[44] Gordon J., *Hydro Hydraulics - a Disappearing Art?* IEEE Electrical Power Conference CD Montreal 2007.
[45] Kiani A., Brekke H., Leyland B., Jacob T., Pejovic S., *Transient problems upon load rejection Masjed-e Soleyman case study*, Hydro 2004, Porto, Portugal.
[46] Karney B., Gajic A., Pejovic S., *Case Studies – Our Experience in Hydraulic Transients and Vibrations*, Proceedings of the International Conference on CSHS03, Belgrade, 2003.
[47] Kumar G., Karney B., *Electricity Usage in Water Distribution Networks,* IEEE Electrical Power Conference CD Montreal 2007.
[48] Kumar A., Verma H.K., *"Standards and Guidelines for Small Hydropower Development:* The Indian Initiative", presented at the Himalayan Small Hydropower Summit, Dehradun, India, October 2006.
[49] Lautier P., O'Neil, C., Deschênes C., Ndjana H.J.N., Fraser R., Leclerc M., *Variable Speed Operation of a New Very Low Head Hydro Turbine with Low Environmental Impact,* IEEE Electrical Power Conference CD Montreal 2007.
[50] Maricic T., Haber D., Pejovic S., *Standardization as Prevention of Fatigue Cracking of Hydraulic Turbine-Generator Shaft*, IEEE Electrical Power Conference CD Montreal 2007.
[51] Murray H., 1980, *Hydraulic Topics in Development of High Head Pump-Turbine and Investigation on Related Problems in Japan*, General Lecture, 9th IAHR Symposium on Hydraulic Machines and cavitation, Tokyo, Japan.
[52] Obradovic D., Pejovic S., Gajic A., *Analysis of Earthquake Effects upon Hydraulic Structures,* 5th International Conference on Pressure Surges, Hannover, 1986, pp. 35-41.
[53] Pejovic S., *Profit Management and Control of Hydropower and Pump Plants,* Proceeding of the International Joint Power Generation Conference, Denver, Colorado, 1997, pp. 539-545.
[54] Pejovic S., *Similarity in Hydraulic Vibrations of Power Plants*, Joint ASCE/ASME Mechanics, Fluids Engineering, and Biomechanics Conference, San Diego, USA 1989, American Society of Mechanical Engineers, Paper 89-FE-4, pp. 5.
[55] Pejovic S., *Pressure Surges and Vibrations in Hydropower Plants - Experiences in Yugoslavia*, The Current State of Technology in Hydraulic Machinery, Gower Technical ,1989, pp. 177-204.
[56] Pejovic S., *Troubleshooting of Turbine Vortex Core Resonance and Air Introduction into the Draft Tube*, IAHR Symposium, Lausanne, Switzerland, 2002.
[57] Pejovic S., Gajic A., Obradovic D., *Auto-Oscillation of the Intake Wheel Gate*, IAHR Symposium, Trondheim, 1988, pp. 443-450.
[58] Pejovic S., Gajic A., Obradovic D., *Reverse Water Hammer in Kaplan Turbines*, IAHR Symposium, Tokyo, 1980, pp. 489-499.
[59] Pejovic, S., Karney, B.W. Colombo, A.; *Supply Mix*, Ontario Power Authority Volume 5 - Submissions and Presentations Received website http://www.powerauthority.on.ca/Storage/18/1388_Pejovic-Karney_text.pdf
[60] Pejovic S., Krsmanovic Lj., Gajic A., Obradovic D., *Resonance in the Piping System of a Power Plant During Filling-in*, IAHR Symposium, Amsterdam, 1982, pp. 43; 1-10.
[61] Pejovic S., Krsmanovic Lj., Jemcov R., Crnkovic P*., Unstable Operation of High-Head Reversible Pump-Turbines,* IAHR 8th Symposium, Leningrad, 1976, pp. 238-295.
[62] Pejovic S., Karney B., Zhang Q., *Water Column Separation in Long Tailrace Tunnel*, Hydroturbo, Brno 2004.
[63] Pejovic S., Karney B., Zhang Q., Kumar G., *Smaller Hydro, Higher Risk,* IEEE Electrical Power Conference CD Montreal 2007.
[64] Pejovic S., Vukosavic D., *Vibrations and Economy of Hydropower plant Operation,* IAHR Work Group on the Behaviour of Hydraulic Machinery under Steady Oscillatory Conditions, Milano, 1991, Paper 1, pp. 11.
[65] Sallaberger M., Haas M., Michaud C., Maricic T., 2005, *Advanced Design of Francis Runner for Refurbishment Projects*, Waterpower Conference CD.
[66] Time V.A., 1960, *Reverse Water Hammer in the Kaplan Turbine Drat Tube*, (in Russian), Electricheskie Stancii, No 3, 1960.
[67] Zmudj A.E., Litkovskii J.A., Rubek N.N., 1960, *Reverse Waterhammer in Hydroelectric Plants* (in Russian), gidroelectromashinostroenije, No 2, 1960.

Conferences papers rejected by reviewers:

[68] Pejovic S., Karney B., Maricic T., Zhang Q.F., Colombo A., Draft Tube Reverse Waterhammer – "S" Form Instability and Site Measurement, Rejected by reviewers

Standards:

[69] *IEEE Standard for Hydraulic Turbine and Generator Integrally Forged Shaft Couplings and Shaft Runout Tolerances, 2001*, IEEE Std 810-1987 (R2001).
[70] EPRI Norms: *"Hydro Life Extension Modernization Guidelines*; Volume 2, Hydromechanical Equipment, TR-112350-V2, Final Report August 2000.
[71] *The Use of Computer Software Tools by Professional Engineers and the Development of Computer Software Affecting Public Safety and Welfare*, Association of Professional Engineers of Ontario (PEO) 1993 [Online]. Available: http://www.peo.on.ca
[72] *Terms of Reference (TOR) for Pre-Qualification for Installation/Construction Companies of Pico/Micro/Mini-hydropower Projects*, Alternative Energy Promotion Centre, Mini-Grid Support Programme, The Energy Sector Assistance Programme, March 2007, http://www.aepcnepal.org/rc/tender/Pq_installer_March28_2007.doc

Computer programs:

[73] Fitzgerald R., Van Blaricum V.L., *WHAMO* (Water Hammer and Mass Oscillation computer program)

http://www.cecer.army.mil/usmt/whamo/whamodownload.htm

[74] Gordon J.L., *Hydrohelp* (A series of excel programs developed for pre-feasibility assessment of hydroelectric sites), www.hydrohelp.ca

[75] Obradovic D., (Pejovic S.) *HUDCST / HELEK* (Computer programs for transient analysis in piping and hydroelectric systems)

[76] McInnis., D.A., Karney B.W., Axworthy D.H. *TransAm* (Computer program for calculations of pipe networks, distribution hydroelectric and pump systems)

[77] Pejovic S., *ReverseWH* (Computer Program for Calculations of Potential Danger in Hydro Power Plants with Kaplan and Bulb Systems due to Reversible Water Hammer and Rotor jumping,).

[78] Pejovic S., *RigidWH* (8. Computer Program for Calculation of Transient Processes in Hydro Power Plants with a Double Regulation based on the Rigid Water Column Theory).

[79] Pejovic S., (Obradovic D,) *VIBR,* (Computer program for hydraulic vibration and stability analysis of hydroelectric plants, pumping systems, elastic tubes (internal or external artificial systems of pulsatile human blood systems) and high pressure oil hydraulic components based on graph theory),

[80] Wood .J., Funk J.E., *SURGE2000* (Computer program for Water Hammer calculations): http://fluidhammer.com/Software.htm

Oral presentations at IEEE Electrical Power Conference Montreal 2007

[81] Breimer E.R., Kostic M., *Compact Electrical System for Small Hydro,* IEEE Electrical Power Conference CD Montreal 2007.

[82] *Hunt S., Transient System Response of a Hydro Scheme with an Air Pocket,* IEEE Electrical Power Conference CD Montreal 2007.

[83] Vansant C. **"***Minimizing Risk during the Process of Hydroelectric Project Design.*"

14 BIBLIOGRAPHY

1. *The Current State of Technology in Hydraulic Machinery*, International Editorial Committee Book Series on Hydraulic Machinery, Gower Technical, 1989.
2. *International Congress on Cases and Accidents in Fluid Systems*, São Paulo, Brazil, 1989.
3. Pejovic S., Personal websites at the University of Toronto and Belgrade, http://individual.utoronto.ca/StanPejovic/ and http://myelab.net/~cane/
4. *Proceedings of the International Conference on CSHS03*, Belgrade, 2003.

15 BIOGRAPHIES

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Understanding Creativity

Viktor Dörfler, Zoltán Baracskai, and Jolán Velencei

Abstract— We have never seen creativity. More precisely, we have never seen the creative process; what we have seen is the creative individual (ex ante) and the outcome of creativity (ex post). Therefore we try to understand creativity by examining creative individuals and their creations. In this paper we only consider the creation of new knowledge. We draw on a wide variety of backgrounds. We wander into the area of cognitive psychology to investigate who is talented for creativity. We also draw on arts, history and philosophy of science, stories of mystics, some great novels and essays we have read as well as our experience in both working with creatives and creating new knowledge. Based on this shaky foundation we will describe creativity as illumination, through jokes, as a quest for harmony, as being kissed by the muse.

Index Terms— creativity, intuition, tacit knowledge, talent, harmony

FOR this paper we derive the concept of creativity from creation; i.e. creating something that did not exist before. In our previous work (e.g. [1]) we have distinguished between the creation of *ideas* and creation of *values*. First an idea, new knowledge, is created, and then this idea can be used to create a new value. If only the first happens the creative idea will remain unknown; to spread, the idea needs to be carried by a value. Thus the creation of idea is typically associated with creativity and the creation of value with innovation; but we will refrain from using the term innovation due to its widespread overuse and misuse. A similar distinction has been outlined by Csíkszentmihályi [2]; he distinguishes between personal *creativity* (with no capital letter) and *Creativity* (with capital C), which, apart from the personal creativity, also includes the knowledge domain and the field represented by the gatekeepers. Similar to Gardner [3], we use the latter two as the context for personal creativity; but in the present paper we exclusively focus on the creative accomplishment of individuals. The reason for this is that we believe that any new knowledge can exclusively originate in the mind of a person. Using Einstein's [4: 8-9] words:

"It is clear that all the valuable things, material, spiritual, and moral, which we receive from society can be traced back through countless generations to certain creative individuals. The use of fire, the cultivation of edible plants, the steam engine – each was discovered by one man. Only the individual can think, and thereby create new values for society – nay, even set up new moral standards to which the life of the community conforms. Without creative, independently thinking and judging personalities the upward development of society is as unthinkable as the development of the individual personality without the nourishing soil of the community."

By doing this, we do not want to diminish the importance of the trans-personal dimension of knowledge, however it is not the topic of this present paper (we have addressed this topic in our research on knowledge sharing, see e.g. [5]). For this paper it is sufficient to note that if new knowledge is created in such a knowledge-sharing process, all the participants will 'possess' the new knowledge subsequently, although their personal pictures on the created new knowledge may substantially differ.

We sometimes contrast artists and scientists, meaning that the artists are those who create while scientists do what Kuhn [6] describes as normal science. But if you look at scientists such as Einstein (e.g. [4]) or Poincaré (see e.g. [7]) we see a world much more like that of the artists than the world of normal science. We may try contrasting artists with engineers, and thus dividing scientists into scientists-as-artists and scientists-as-engineers. But then we look at development engineers creating all those engineering beauties (see for instance [8, 9, 10]) and we have to give up this contrast as well. Perhaps the best counter-example to both these contrasts is the maverick inventor Nikola Tesla. He is sometimes classified as engineer, sometimes as scientists; he certainly considered himself as both [11]. And we seem to owe to him most of our present technology, at least, in part. He is definitely never regarded as artist. But, as Hong [12, 13] showed, his thinking is as that of the greatest artists. So, for the moment, we suggest

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Manuscript received July 2009.

contrasting arts and crafts – when one is creating something new, we talk about arts, when (s)he does else, it is crafts.

Trying to understand the essential aspects of creativity we start from the creative individual and explore what (s)he has to be talented for. Along the way we explain the concept of illumination in terms of cognitive psychology. Then we describe various aspect of creativity. Namely, we examine how jokes work; we explore the need for freedom and its consequence, responsibility; we circle around the role of love and beauty to bring nearer what it means to be kissed by the muse. In the conclusion we return to the creative individual just to attempt to beg the teachers of the creatives not to educate their gifted pupils so that would not destroy their gift!

1 WHO CAN BE CREATIVE?

Of course only creative people can be creative – but if the answer was so simple, we would not be asking the question. Most would agree that Dali and Buñuel are creative individuals. But you probably would not ask them for a creative way of performing your eye surgery.[1] What therefore are they missing? The answer is the knowledge in eye surgery. So even the most creative person can only be creative in the domain in which (s)he is knowledgeable. To figure out how much one should know, we need to understand what this 'how much' can mean. For the present discussion we will express the levels of knowledge in terms of cognitive schemata. Using this picture we will also offer a representation of creativity.

Cognitive schemata are by definition the fundamental building blocks of knowledge [14: 84]:

"Cognitive schemata are units meaningful in themselves with independent meanings. They direct perception and thinking actively, while also being modified themselves, depending on the discovered information. Cognitive schemata have very complex inner structures, various pieces of information are organized in them by different relations. The various schemata are organized in a complex way in our brains; in the course of their activities they pass on information to each other and also modify each other continuously."

The complex way in which our schemata are organized we call an ill-structured multileveled hierarchy. This means that, apart from the elementary schemata, we also have meta-schemata, i.e. schemata that consist of other schemata. In this sense they are at a higher level in the hierarchy. However, this hierarchy being ill-structured allows that these schemata may overlap. Similarly, a particular schema A may be in terms of one relation higher in the hierarchy than a particular schema B but in a different relation their position may be reversed. When we complete a task, take a decision or solve a problem, several schemata become organized into an ad-hoc structure. [15: 47-51] If working on the task, the decision, or the problem results in a deeper understanding, a meta-schema is formed, which usually dissolves some of the incorporated schemata though it can re-create them on other occasions. This is how a good mathematician, who 'has forgotten' how to do integrals, can 'learn' it in very short time without any additional input.

The newly formed meta-schema often goes beyond the constituting schemata. This means that on such occasions new knowledge is created. The more schemata we have in a particular domain, the higher the complexity of our schemata (higher level meta-schemata), the 'greater', more complex, and more surprising the newly created knowledge can be. The formation of meta-schemata happens in almost zero time, as if in a flash of 'recognition', and may be accompanied by (sometimes very strong) emotions and feelings. We usually call it illumination.

We can distinguish four levels of knowledge in terms of cognitive schemata: (1) the novice may have a few lots of ten schemata, (2) the advance beginner several hundred, (3) the expert several thousand, and (4) the master some tens of thousands schemata. In our work on knowledge levels [16] we also distinguished a fifth level, the grandmaster, but the grandmaster has the same number of schemata as the master. The difference however is that (s)he also has a super-schema, i.e. a single cognitive schema that is a meta-level of all the schemata in the discipline. This we usually call wisdom. As we do not engage in the relationship of wisdom and creativity in this paper (see e.g. [17] for some views), the four levels are sufficient. It is easy to guess that the master can create more complex new ideas than the expert, who, in turn, will be more creative than the advanced beginner. Yet this is often true but not always. Sometimes the advanced beginner may be more creative than the expert. We will now explain how this is possible.

Illumination, in which the meta-schema is born, is a leap into a more complex knowledge level. Often this will mean that in the creative insight, for example, the expert gets a sneak-peak into the master-level knowledge. This will only happen if the person is talented sufficiently for the next level. Thus, if we have an ad-

[1] It is an allusion to a scene from their film "An Andalusian Dog" when a cloud passes in front of the moon.

vanced beginner who is talented for the expert level and an expert who is not talented for the master level, it happens that the advanced beginner is more creative. The only problem is that we do not know yet what the talent – or gift – is. We can speak of a talent for a particular discipline when the commonsense knowledge of the gifted is structured in a similar way to the knowledge in that discipline. As a secondary school mathematics teacher beautifully said about a pupil gifted in mathematics: *"It is as if he already had all the mathematical structures in his mind and all I had to do was to attach the appropriate labels."*

But does the gift for the discipline always infer also gift at being creative in that discipline? This question is hard to answer. We have never seen a master who was not creative in her/his discipline, at least in some period(s) of her/his life. But it seems that something else is needed in addition. Creativity is only one of the many types of cognitive processes, and it seems that people are not equally talented in the various types. Although without much evidence, we suggest that the creative person needs to be double-gifted: once for the discipline and once for creativity. And this only works at a reasonably high level of knowledge. A novice, regardless of her/his talent, will almost certainly come up with creative ideas that are simply wrong. The advanced beginner's creative ideas will, almost always, be trivial to the master – or wrong. Moreover even at expert level, the ideas are unlikely to be "great"; it is still often either "OK, so what" for the master or "wrong". And even if the germ of the idea is a germ of a great idea, the expert can rarely pitch it in a way that it would be well received. Usually these ideas are further elaborated only when the expert reaches the master level and becomes able to see the full picture.

The person's knowledge, in itself, cannot account for creativity. The whole personality of the person is involved in it. Gardner [3] examined creativity from a cognitive viewpoint and found numerous factors that may in themselves (or in some combinations) indicate creativity. For instance, a multicultural background seems to go along with creativity, and creative individuals usually also seek to experience different cultural settings. It is not clear, however, whether there is a causal relationship here. Even a more or less comprehensive list of the relevant factors would exceed the length of this paper, so probably it is better to indicate only that the whole personality is involved.

We will take another path trying to understand something about those cognitive processes that we call creativity. Namely, we will try to understand how *jokes* work.

2 Creativity as Jokes

Several years ago, starting from Boulding's [18] levels of system complexity, we tried to establish what the specifically human features are in order to understand the nature of the human-level system. Then we found that telling jokes is a uniquely human specialty. Telling and understanding jokes is a very complex process; it requires meta-cognition, abstract thinking, and historic memory. Essentially, it is the same as creativity. To understand this better, we will first have a look at how jokes are, if they are, different from logic.

When we present our ideas, even the most creative ones, we must do this in a logical way, at least if we want to have them accepted. It could be argued that there may be more appropriate ways of presenting creative ideas, for instance by means of metaphors, symbols, poetry, or pictures. (Cf Hong's [19] idea on picture-based reasoning.) The whole idea of academic publications is based on logical presentations [20: 110]:

"Logic is the way of scientists, or other people, who have to present their ideas. Even if a scientific breakthrough came out through hunch or chance it must be presented as if it were the result of logic. Otherwise ideas cannot be accepted."

But logic, in this sense, is definitely not how we tell jokes. This corresponds to the ever hopeless attempt to explain a joke to those who did not understand it. In a similar vein, everyone who ever experienced a creative leap knows that there is no such thing as *method* for being creative or a logical way to produce the creative outcome. (See e.g. [21: 7-9].) The ideas cannot be *produced* but they can be *reproduced* by means of logic. Therefore Simon, at least for most of his life, believed (e.g. [22]) that it was possible to build a General Problem Solver (GPS). Descartesheld a similar idea [23: 92]:

"Descartes, René (1596-1650), great mathematician and philosopher, planned to give a universal method to solve problems but he left unfinished his Rules for the Direction of the Mind."

Descartes and Simon could not do it. The reason is, we believe, that it cannot be done. It seems that creative thinking does not obey rules, cannot be put into an algorithm, and is desperately anti-methodical in Feyerabend's [24] sense. There are no common elements in different creations [25: 281]:

"… the events and results that constitute science have no common structure; there are no elements that occur in every scientific investigation but are missing elsewhere… Successful research does not obey general standards; it

relies now on one trick, now on another, and the moves that advance it are not always known to the movers… scientists will get a feeling for the richness of the historical process they want to transform, they will be encouraged to leave behind childish things such as logical rules and epistemological principles and to start thinking in more complex ways – and this is all we can do because of the nature of the material. A 'theory' of knowledge that intends to do more loses touch with reality."

De Bono calls this non-algorithmic part of thinking, which is responsible for our achievement in seeing things differently, "lateral thinking"[2] [27] and sometimes "parallel thinking" [28], to contrast it to vertical (or convergent) thinking. In good jokes there is a convergent/vertical way of thinking along which the joke-teller takes us. This convergent line, the mainstream, would lead to the obvious conclusion. This is the essence of convergent thinking; there is a single outcome which the thinking converges towards. Then, unexpectedly, the joke-teller leaps out from the convergent mainstream of thinking, into a lateral branch. The elements considered are rearranged to form a new order, and thus to make new sense when we get to the punch line. If there were to be no new order it would not be a joke, it would be something senseless. Nobody would laugh. We laugh because we understand that there is another way of thinking according to which the punch line is perfectly logical. It makes sense – but we would not have thought of it. (Cf also with [29].)

This is the way of thinking needed to create something new. There are two important characteristics. Firstly, the lateral detour is a discontinuity [27: 88]:

"A discontinuity is a change which does not arise as part of the natural development of a situation. Thus, a sudden kink on a graph suggests that the basic situation has changed, that some new factor has come in. A discontinuity also implies that the new factor does not arise from within the situation but from outside. In its extreme sense, discontinuity implies that the factor is not connected at all with the situation under consideration… The word discontinuity is often applied when a connection cannot be seen."

Secondly, the lateral thinking is logical but only with hindsight. While we swim in the mainstream, the lateral runway cannot be seen; yet once we arrive at the end of the runway and we look back, it can be seen as another mainstream (ibid):

"In hindsight every single insight solution must be obvious. And usually it is the very obviousness of the solution that makes it so infuriating."

However, listing numerous examples, Gladwell [30] warns that we have no evidence that the *ex post* explanation has anything to do with the way how the intuition got to the novelty. We completely agree with this but, fortunately, the role of explanation is not to describe how one arrived at the creative result but to check whether the creative outcome makes sense.

Therefore, creativity is about seeing things differently, but not in *any* different way! In other words it must be in a way that makes sense, except that no one has seen it before. Hadamard [31] investigated how new results are born in the domain of mathematics, which is usually thought of as being completely logical. His investigation confirmed both of the previous characteristics, i.e. that a previous deep knowledge is essential, and that the novelty is born in a flash of intuition. According to Hadamard, the first phase is the conscious hard work of trying to solve some problem. Then follows a forgetting phase, which may mean a continuation of the work unconsciously. Next comes the sudden insight accompanied by a sense of certainty. This is followed by another conscious phase of putting on paper and proving (in mathematics!) the result.

We now have a reasonably solid explanation why there can be no methods for being creative: The creative jump cannot be seen ex ante, only ex post. An algorithm cannot go into a place that cannot be seen. Only imagination can. Only intuition. Not a machine, only a human.

In his various books de Bono brilliantly describes this non-algorithmic, anti-methodical nature of creativity and then, quite surprisingly, he gives a series of methods for lateral thinking: the "PO" [32], the "Six Thinking Hats" [33], the "Aims, Goals and Objectives" (AGO), the "Consider All Factors" (CAF), the "Other People's Views" (OPV), the "Alternatives, Possibilities and Choices" (APC), the "First Important Priorities" (FIP), the "Consequence and Sequel" (C&S), the "Plus, Minus and Interesting" (PMI). [20: 63-150] Is this not infuriating? Why would someone who obviously understands the essence of creativity offer methods for it? We have found the answer for this well *beyond* the scope of science:

[2] The term lateral thinking is used here in de Bono's original sense (to make a contrast to convergent thinking, as described above). Unfortunately the same term is also used to indicate the techniques developed to stimulate thinking outside the box (many of them also by de Bono); but while these may stimulate intuiting by means of diverting attention from the 'usual', they are by no means intuiting or part of it. [cf 26: C2]

Coelho[3] went to the desert to find his guardian angel and he had a series of steps to perform. One of these is called the ritual that destroys rituals. The explanation is that the magus gradually becomes the slave of his own rituals; therefore occasionally, he has to undergo a process of purification to get rid of them. The purpose of the ritual that destroys rituals is to help him to step out. De Bono's methods can be understood in the same way. He created methods to help stepping out of our rituals. Methods that destroy methods.

This leads us to the next aspect of creativity; the creative must be free to create. Few would dispute this statement – but being free is not as simple as it sounds.

3 Creativity as Freedom and Responsibility

Freedom is the opposite of slavery. Of course, one may argue that there is no slavery in the world today but there are other views as well; e.g. Marcuse [34: 36] asserts that:

"The slaves of developed industrial civilization are sublimated slaves, but they are slaves, for slavery is determined neither by obedience nor by hardness of labor but by the status of being a mere instrument, and the reduction of man to the state of a thing."

Freedom can be fully understood only if examined in relation to the complete personality. [35: viii] Fromm (ibid: 26) distinguishes two kinds of freedom: the negative, or *"freedom from"* as well as the positive or *"freedom to"*. We are free from the bonds of the pre-individualistic society; but we are also left without the safety it guaranteed; we are left in isolation. There are two responses to this situation; either we seek new dependences and submissions or we advance to a realization of positive freedom based on uniqueness and individuality. Which way to chose is answered by Szondi's [36] fate-analysis.

According to Szondi we have several possible fates for ourselves. These are determined by our genome and instincts (ontogenetic and philogenetic heritage) on the one hand, and by our socio-cultural environment on the other. Nobody can choose a fate that (s)he has not seen or does not have built-in. The (positively) free person can choose from the available ones; but the others live a constraint-fate. Therefore we also call the positively free people *"self-strong"*, the others are *"self-weak"* or *"fate-ill"* people. Szondi claims that only people who can choose their destiny can be happy. So who can be free? According to Szondi the answer lies in the children's room. The children's room is not necessarily a separate room but a place where the child can express herself/himself. To have a children's room makes the difference between being raised for freedom instead of obedience. The famous Hungarian architect Imre Makovecz said in an interview that he only accepts an apprentice who could look up to her/his father (dominant parent) instead of fearing him. If one was trained for obedience, it takes hard work to make one free [34: 44]:

"… it must first enable its slaves to learn and see and think before they know what is going on and what they themselves can do to change it. And, to the degree to which the slaves have been preconditioned to exist as slaves and be content in that role, their liberation necessarily appears to come from without and from above. They must be 'forced to be free', to 'see objects as they are, and sometimes as they ought to appear', they must be shown the 'good road' they are in search of."

We argue that only free people can be creative. They need both negative freedom, so that being creative is allowed by the authorities, and also positive freedom, which means that they can handle their own creativity [35: 208]:

"We are proud that we are not subject to any external authority, that we are free to express our thoughts and feelings… The right to express our thoughts, however, means something only if we are able to have thoughts of our own: freedom from external authority is a lasting gain only if the inner psychological conditions are such that we are able to establish our own individuality."

Why would one remain a slave if one can be free? Presumably this is because freedom has its price – a high price. First, freedom always goes together with responsibility. If one is told what to do or how to make one's choices – one is not responsible. But if one is free to choose from existing solutions or to create a new one then one is responsible for one's choices and creations [25: 284]:

"… an absence of «objective» standards does not mean less work; it means that scientists have to check all ingredients of their trade and not only those which philosophers and establishment scientists regard as characteristically scientific. Scientists can thus no longer say: we already have the correct methods and standards of research – all we need to do is to apply them. For according to the view of science that was defended by Mach, Boltzmann, Einstein and Bohr, and which I restated in AM,[4] scientists are not only responsible for the correct application of standards they have imported from elsewhere, they are re-

[3] Coelho, Paulo (1995) The Valkyries, Harper Collins, London.

[4] The acronym reads "Against Method" which is another book of the author.

sponsible for the standards themselves."

Second, being free is scary. Being a slave is secure, as it is known. Of course, for the one who is free, being a slave sounds scary – but actually it is pretty simple to realize that slavery is secure. This makes the tie between freedom and creativity even more obvious: creating something that did not exist before is a leap into the unknown. We need to give up the known and secure for the unknown and dangerous. What incredible intellectual courage Einstein must have needed to give up the only two certain things that make the foundation of physics, the time and the space!? (quoted by [37: 66]):

"It was as if the ground had been pulled out from under one, with no firm foundation to be seen anywhere, upon which one could have built."

This is what it takes to be creative. And then, you have your intellectual child, your creative result and you are responsible also for how it affects the lives of others. If you make a medicine, that is great. But if one starts killing people with it? The same creative accomplishment can be used to build a power plant and to make a bomb…

4 CREATIVITY AS LOVE AND BEAUTY

Creation is often described by creatives as an act of love. This is in perfect harmony with being responsible for what you create. You also love it. The one does not exist with the other; the Hungarian poet Tibor Déry said: *"To love is to take responsibility."* It seems promising to explore the conception of love in order to heighten our understanding of creativity.

Fromm [38], investigating the role of love in our lives, explained that essentially love is a capability of a person, not something that happens to her/him (ibid: 36):

"Love is not primarily a relationship to a specific person; it is an attitude, an orientation of character which determines the relatedness of a person to the world as a whole, not towards one 'object' of love."

Fromm identifies five objects of love and five types of love accordingly: brotherly love, motherly love, erotic love, self-love and love of God. The following categorization largely follows Fromm's description but Lewis's [39] inquiry is also considered. The different types of love have different essential characteristics; thus, understanding the types of love will help understand the essence of love. This will, at the end, lead us to understand what the muse is.

Philos, the brotherly love, is the most essential type of love; the other types do not exist without it. Philos is our sense of responsibility and care, our curiosity to know about other people and our respect towards others. It is the capacity to love. It is love between equals, which does not imply that we are the *same* but that we are *one*. The culmination of Philos is the friendship in its greatest and noblest sense. Philos is not exclusive; moreover, two is not even the best number for it. Using Lewis' [39: 74] example, if ***A***, ***B***, and ***C*** are friends, and ***A*** dies ***C*** does not only lose ***A*** but also ***A***'s part in ***B***; e.g. how ***B*** used to laugh on ***A***'s jokes. Self-love also belongs to Philos. Self-love emerges from emotional maturity: we cannot love others without loving ourselves, and thus self-love actually defines the brotherly love: *"love thy neighbour as thyself"*.

Eros, the erotic love, is much more than sexuality; sexuality, *Venus*, belongs to physiological needs. Though all kinds of love make us become one with other people, the total union is Eros. This is a complete fusion with another person. As we are not capable of total fusion with all other people, the erotic love is exclusive; a union with a single other person. The phenomenon of oneness and individuality that we can see on a personal plain is repeated in erotic love – one loves all the people but loves someone in a special, individual way. Eros, like Philos, is love of equals. Eros without Philos is only passion.

Storge, the motherly love, seems to be somehow a mixture of the previous ones; it is unconditional as Philos, exclusive as Eros and non-equal as Agape (see next). However, Storge is not examined in this paper.

If love governs us towards unity with other people, than *Agape*, the love of God, governs us to embrace the whole of nature, the whole universe. In purest form it can be observed in saints who go among people to help them and hermits who leave the world of people to be united with the general force of life. Another pure type is the inspired enthusiasm of a person doing… well, doing anything. What is characteristic for all three versions, is that the person experiencing Agape is consumed by it. The last version of Agape is the same as the flow experience of Csíkszentmihályi [40] and the peak-experience of Maslow [41]. We need to describe this Agapean inspiration that is so typical to creatives [42: 101]:

"The term peak experiences is a generalization for the best moments of the human being, for the happiest moments of life, for experiences of ecstasy, rapture, bliss, of the greatest joy. I found that such experiences came from profound aesthetic experiences such as creative ecstasies, moments of mature love, perfect sexual experiences, parental love, experiences of natural childbirth, and many oth-

ers. I use the one term – peak experiences – as a kind of generalized and abstract concept because I discovered that all of these ecstatic experiences had some characteristics in common. Indeed, I found that it was possible to make a generalized, abstract schema or model which could describe their common characteristics. The word enables me to speak of all or any of these experiences in the same moment."

Csíkszentmihályi (ibid: 71) portrayed the flow experience in activities (such as work) as a state in which:

"Concentration is so intense that there is no attention left over to think about anything irrelevant, or to worry about problems."

Now we can understand the well-known phrase of *being kissed by the muse*. The inspired state of flow requires Agape but Agape is not readily available; it is easier to get dissolved in it if accompanied by Eros. After all, it was Eros who was characterized by the strongest sense of unity. The inspiration is brought by the Muse, who is actually a form of love herself/himself: Muse=Eros+Agape.

The flow state is the perfect state; more precisely one of the two perfect states. Besides the peak experience, which corresponds to creativity, Maslow in his journals [43] also describes the *plateau experience*, which corresponds to wisdom. We do not investigate the conception of wisdom in the present paper, but it is interesting to note that the two are related. (See [17] for more details.) The flow state also means establishing a complete harmony with ourselves, with our discipline, with the world, and with the whole universe. The flow state is harmony realized in the mind of a person. When in such state, we also search for harmony, and the creative idea is also the embodiment of harmony. Or indeed it is beauty, as harmony and beauty is just an aspect of harmony. So creativity is also often perceived as the achievement of harmony or beauty.

The conceptualization of harmony can be traced back as far as to the ancient Greece, and probably further. It is notable that Heraclitus, whose writings seem to be the earliest written discussions of harmony in the Western philosophical tradition, derives the conceptualization of harmony from music. [44] It is notable because music appears to be the very source in which we experience harmony as a dynamic phenomenon. [45] As creativity brings about a new harmony, we certainly need a dynamic picture of harmony. There are various characteristics of harmony, the proper discussion of which is beyond the scope of this paper. However, it is worth noting that harmony is frequently regarded as an essential intrinsic feature of the nature and, as such, it transcends the objective-subjective dichotomy. (Cf [46]) It is often related to truth [47] in the sense that something is true as it is harmonious (although we prefer to avoid the true-false dichotomy as we believe that there are many possible truths), it is also understood as transcendence [48]. All of these features are essential to perceive creativity as the creation of a new harmony.

When James Clark Maxwell invented his famous four differential equations describing the electromagnetic fields, in the first version he included all the facts he knew, all experimental results. But he was not satisfied. He argued that the equations are not beautiful. He added a new component to make them more beautiful, although there was absolutely nothing that would require that new component. However, years later, the new component (today we call it the *magnetic shift*) was proven to be right. Maxwell sensed the lack of harmony and he also sensed where the deeper harmony laid. We still use the second form of Maxwell's equations today. Leonardo is often quoted as recognizing that a machine did not work as it was not beautiful. Because of its lack of harmony. For all creation, whether belonging to arts, science, or engineering, delivers a new harmony that was not seen before. Using the words of Heraclitus (quoted by [44]): *"The hidden harmony is better than the obvious."*

CONCLUSIONS

In this paper we have managed to cover only a few aspects of creativity, though important ones. We talked about knowledge, in which the creative should achieve high levels before becoming able to achieve significant creative results. In relation to this, we examined what it means to be 'gifted' and saw that the creative needs to be talented in the *discipline* as well as in *creativity*. This led us to query the creative thinking process, and we have found that it should be lateral, the same way as in jokes. We have realized that to be able to think laterally, the creative needs to be free; but this also means that (s)he has to take responsibility. Responsibility, in turn, leads us into the area of love and understanding of how the Muse works; that (s)he is Eros and Agape together. Finally we identified the inspired state, when the creative is 'kissed by the Muse', with the concept of harmony and beauty and so, due to that, the creative process with the quest for harmony/beauty.

We know a few other things about creatives and their creations. We know, for instance, that the creatives are often not the most pleasant people to work with. There is no single typical personality that we have seen in all creatives.

Some are lonely wolves and others have active social lives. They often have many friends but they can never fit into the anxious world of mediocrity, it is not rare that they lead a louche life. If one examined life stories of great creatives, one would find that many, if not most, of them had problems in school. Based on the discussion above we come nearer to understanding why. Our schools do not support looking at things differently (lateral thinking), they are about control rather than freedom. If harmony or beauty are mentioned at all, it will be in the 'less important' classes which are typically not even graded. And it is quite rightly so, because we can only mark what we can unambiguously check against a predefined set of expectations. We teach pupils, and even our students, that there is a single right answer or, at least, that they can get to the right result by applying certain existing tools/methods. In our Western schools only the convergent thinking is nurtured; creativity is in the best case tolerated and most often persecuted. The only type of teaching-learning that does not work against creativity, at least the only one we know of, is the master-apprentice relationship in the Polanyian [49] sense.

We conclude with words of John W. Gardner (quoted by [50: 313]):

"When Alexander the Great visited Diogenes and asked whether he could do anything for the famed teacher, Diogenes replied: 'Only stand out of my light.' Perhaps someday we shall know how to heighten creativity. Until then, one of the best things we can do for creative men and women is to stand out of their light."

References

[1] Z. Baracskai, V. Dörfler, and J. Velencei, "Business Creativity: An Evolutionary Approach."

[2] M. Csíkszentmihályi, *Creativity: Flow and the Psychology of Discovery and Invention*, New York, NY: HarperCollins, 1997.

[3] H. Gardner, *Creating Minds: An Anatomy of Creativity Seen through the Lives of Freud, Einstein, Picasso, Stravinsky, Eliot, Graham, and Gandhi*, New York, NY: Basic Books, 1993.

[4] A. Einstein, *The World As I See It*, New York, NY: Kensington Publishing, 1956.

[5] Z. Baracskai, V. Dörfler, and J. Velencei, "Knowledge Restaurants at the End of the Paradigm."

[6] T. S. Kuhn, *The Structure of Scientific Revolutions*, 3rd ed., Chicago, IL: The University of Chicago Press, 1962.

[7] W. Heisenberg, *Physics and Philosophy: The Revolution in Modern Science*, London: Penguin Books, 1962.

[8] M. J. Flynn, *Computer Architecture: Pipelined and Parallel Processor Design*, Boston, MA: Jones & Bartlett publishers, 1995.

[9] V. Milutinović, *Surviving the Design of a 200 MHz RISC Microprocessor: Lessons Learned*, Los Alamitos, California: IEEE CS Press, 1996.

[10] V. Milutinović, *Surviving the Design of a 16 MPs Multiprocessor System: Lessons Learned*, Los Alamitos, California: IEEE CS Press, 1997.

[11] N. Tesla, *My Inventions: The Autobiography of Nikola Tesla*, Milton Keynes: Filiquarian Publishing, 1919.

[12] F. Hong, "Tesla Composed Like Mozart," *Celebration of the 150th anniversary of the birth of Nikola Tesla*, http://www.med.wayne.edu/physiology/facultyprofile/hong/PDF%20files/Tesla_Composed_Like_Mozart.pdf, 2006].

[13] F. Hong, "The enigma of human creativity: Hidden messages from Nikola Tesla's Moji Pronalasci," *Naš Tesla (Our Tesla), Technical Science Monograph No. 18*, R. J. Halaši, I. P. Ćosić and T. J. Halaši, eds., pp. 127-176, Novi Sad, Serbia: University of Novi Sad Faculty of Technical Science, and Society for the Promotion of Science Novi Sad, 2006.

[14] L. Mérő, *Ways of Thinking: The Limits of Rational Thought and Artificial Intelligence*, New Jersey, NJ: World Scientific, 1990.

[15] Z. Baracskai, *A profi vezető nem használ szakácskönyvet*, Nyíregyháza, Hungary: "Szabolcs-Szatmár-Bereg megyei Könyvtárak" Egyesülés, 1999.

[16] V. Dörfler, Z. Baracskai, and J. Velencei, "Knowledge Levels: 3-D Model of the Levels of Expertise," in The Sixty-eighth Annual Meeting of the Academy of Management, Chicago, IL, 2009.

[17] A. Craft, H. Gardner, and G. Claxton, *Creativity, Wisdom, and Trusteeship: Exploring the Role of Education*, Thousand Oaks, CA: Corwin Press, 2008.

[18] K. E. Boulding, "General Systems Theory: The Skeleton of Science," *Management Science,* vol. 2, no. 3, pp. 197-208, 1956.

[19] F. Hong, "A survival guide to cope with information explosion in the 21st century: picture-based vs. rule-based learning," *21st Webzine,* vol. 3, no. 4, 1998.

[20] E. de Bono, *Teach Your Child How to Think*, London: Penguin Books, 1993.

[21] K. R. Popper, *The Logic of Scientific Discovery*, 2nd ed., London: Routledge, 1968.

[22] A. Newell, and H. A. Simon, *Human Problem Solving*, Englewood Cliffs, NJ: Prentice Hall, 1972.

[23] G. Pólya, *How to Solve It: A New Aspect of Mathematical Method*, 2nd ed., London: Penguin Books, 1957.

[24] P. K. Feyerabend, *Against Method*, 3rd ed., London: Verso, 1993.

[25] P. K. Feyerabend, *Farewell to Reason*, New York, NY: Verso, 1987.

[26] E. Sadler-Smith, and E. Shefy, “Developing Intuition: 'Becoming Smarter by Thinking Less',” *Academy of Management Proceedings*, pp. C1-C6, 2004.

[27] E. de Bono, *Lateral Thinking for Management: A Handbook*, London: McGraw-Hill, 1971.

[28] E. de Bono, *Parallel Thinking: From Socratic to De Bono Thinking*, London: Viking, Penguin Group, 1994.

[29] A. Koestler, *The Act of Creation*, Danube ed., London: Pan Books, 1971.

[30] M. Gladwell, *Blink: The Power of Thinking without Thinking*, London: Penguin Books, 2005.

[31] J. Hadamard, *The Psychology of Invention in the Mathematical Field*, New York, NY: Dover Publications, 1954.

[32] E. de Bono, *Po: Beyond Yes and No*, London: Penguin Books, 1973.

[33] E. de Bono, *Six Thinking Hats*, London: Penguin Books, 1990.

[34] H. Marcuse, *One-Dimensional Man: Studies in the Ideology of Advanced Industrial Society*, 2nd ed., London: Routledge, 1964.

[35] E. Fromm, *The Fear of Freedom*, London: Routledge, 1942.

[36] L. Szondi, *Ember és sors: Három tanulmány*, Budapest, Hungary: Kossuth Könyvkiadó, 1954.

[37] F. Capra, *The Turning Point: Science, Society, and the Rising Culture*, London: Flamingo, 1982.

[38] E. Fromm, *The Art of Loving*, London: Harper Collins, 1957.

[39] C. S. Lewis, *The Four Loves*, London: Harper Collins, 1960.

[40] M. Csíkszentmihályi, *Flow: The Psychology of Optimal Experience*, 2nd ed., London: Rider, 2002.

[41] A. H. Maslow, *Religions, Values, and Peak-Experiences*, New York, NY: Penguin, 1970.

[42] A. H. Maslow, *The Farther Reaches of Human Nature*, London: Penguin Compass, 1971.

[43] Author ed.^eds., “The Journals of Abraham Maslow,” abridged ed., Lexington, MA: Lewis Publishing, 1982, p.^pp. Pages.

[44] C. Y. Cheng, “On Harmony as Transformation: Paradigms for the I Ching,” *Journal of Chinese Philosophy,* vol. 16, no. 2, pp. 125-158, 1989.

[45] G. Bateson, *Mind and Nature: A Necessary Unity*, New York, NY: Bantam Books, 1980.

[46] M. Polanyi, *Personal Knowledge: Towards a Post-Critical Philosophy*, London: Routledge, 1962.

[47] G. Rudebusch, “Harmony as Truth: A Greek View,” *Journal of Chinese Philosophy,* vol. 16, no. 2, pp. 159-175, 1989.

[48] S. W. Laycock, “Harmony as Transcendence: A Phenomenological View,” *Journal of Chinese Philosophy,* vol. 16, no. 2, pp. 177-201, 1989.

[49] M. Polanyi, “The Republic of Science: Its Political and Economic Theory,” *Minerva,* vol. 1, pp. 54-74, 1962.

[50] B. Cramond, "Developing Creative Thinking," *Methods and Materials for Teaching the Gifted*, F. A. Karnes and S. M. Bean, eds., pp. 313-351: Prufrock Press Inc., 2005.

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The Dynamics of Knowledge Spillover for Functionality Development in Japanese Acoustic Equipment Industry

Shibata, Yosuke; Saiki, Tomoko

The purpose of this study is to demonstrate how Knowledge Spillover affects functionality development by an analysis of trends in the number of patent applications as proxy of technologies. We group acoustic equipment technologies, a speaker as a product, in Japan into two groups using International Patent Classification (IPC). We group Transducers as Basic Technology, and Components, Circuits and Diaphragms as Complementary Technology.

The result shows that, in the process of functionality development of a speaker, Basic Technology is first developed in order to have products working by focusing on structural technologies, and then Technological Knowledge is spilled over from Basic Technology to functional technologies indicated as Complementary Technology, especially Material Technologies.

Keywords: Innovation; Knowledge Spillover; Technology Knowledge

1. INTRODUCTION

It is important for companies to continuously produce valuable new technologies and, by assimilation of new skills, to create inventions and ideas which show their innovation capability. The Research and Development (R&D) efforts of companies, which lead to innovations, are essential for a company's growth and also for the growth of society itself.

A plethora of papers has been published discussing the usefulness of Knowledge Spillover as one of the foremost factors in encouraging the development of technological innovation. As Griliches (1979)[1] has mentioned, the level of productivity achieved by one firm or industry depends not only on its own R&D efforts but also on the general knowledge accessible by it, which includes Knowledge spilled over from other companies and industries.

In previous studies, patent data has been recognized as a useful indicator in quantitatively evaluating technological innovation (Griliches, 1990)[2]. A relation between Innovation and Knowledge Spillover is discussed by using patent data in many papers.

In this study, we use patent data to analyze the relation between innovation and Knowledge Spillover among the technologies used in the manufacture of a product, and examine how Knowledge Spillover affects functionary development. We make use of the International Patent Classification (IPC) to group the technologies used in the creation of a product into Basic Technology and Complementary Technology. The purpose of this study is to propose a new scope of Knowledge Spillover between these technologies.

2. KNOWLEDGE SPILLOVER

2.1 In relation to Knowledge Spillover

We find three main points of view in previous papers in relation to Knowledge Spillover.

The first point is technological affinity. It is comparatively easy to obtain Knowledge from other companies which are working with similar technological systems, because it is assumed that these companies possess similar technological facilities and experiences. Companies working with similar technologies should be able to raise R&D productivity by referring to other companies' R&D result. (Jaffe, 1986[3]: Lee, 2006[4])

The second point concerns geographical distance between companies. Geographical distances relate to the ease of communication with other companies. Companies, which are located in a region close to one another, can easily make contact, so they have the advantage of prompt information exchanges. (Jaffe, Trajtenberg and Henderson, 1993[5]: Tappeiner, Hauser, and Walde, 2008[6])

The third feature is cultural differences. It is relatively easy for companies to cooperate with another company which shares a similar culture concerning management principles, business structure and language. A mutual understanding of culture could be the key for promotion of Knowledge Spillover.

In this paper, we focus on the technological affinity in analyzing Knowledge Spillover.

2.2 The new scope of Knowledge Spillover

Many previous papers have mainly discussed the Knowledge Spillover at the level of countries, industries, or companies. For instance, how the spillover effect among different foreign countries

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affects domestic productivity has been discussed (Branstetter, 2001[7]; Eaton and Kortum, 1999[8]; Keller, 2002[9]). The importance of Knowledge Spillover between industries has also been discussed (Scherer, 1984[10]: Griliches and Lichtenberg, 1984[11]: Goto and Suzuki, 1989[12]). Additionally, the importance of control of industrial characteristics has been reported (Bernstein and Nadiri, 1988[13]: Bernstein, 1997[14]: Terero, 2001[15]).

Geroski (1995)[16] has reported that Knowledge Spillover effect depends on the maturity of technologies. Therefore, when Knowledge Spillover is discussed, industrial characteristics and technological characteristics should be taken into consideration. Recent papers have focused on this point and discussed the existence of the Knowledge Spillover effect between different technologies. Ohmura and Watanabe (2006)[17] analyzed the Technology Spillover effect in fine ceramics. Nakagawa and Watanabe (2007)[18] also analyzed the Technology Spillover effect in the nonferrous metal industry, and they have introduced two dimensional models (inter-technology spillover and intra-technology spillover) to analyze Technology Spillover more specifically (2008)[19].

We discuss the Knowledge Spillover effect among components of a product possessing different technological characteristics. We use IPC to group the technologies and analyze the technological characteristics of the components.

The IPC is used for the classification of inventions of patents and patent applications according to the different areas of technology to which they pertain. We divide the different technologies used in the manufacture of the components in a product into the groups “Basic Technology” and “Complementary Technology”, by the IPC in patent applications.

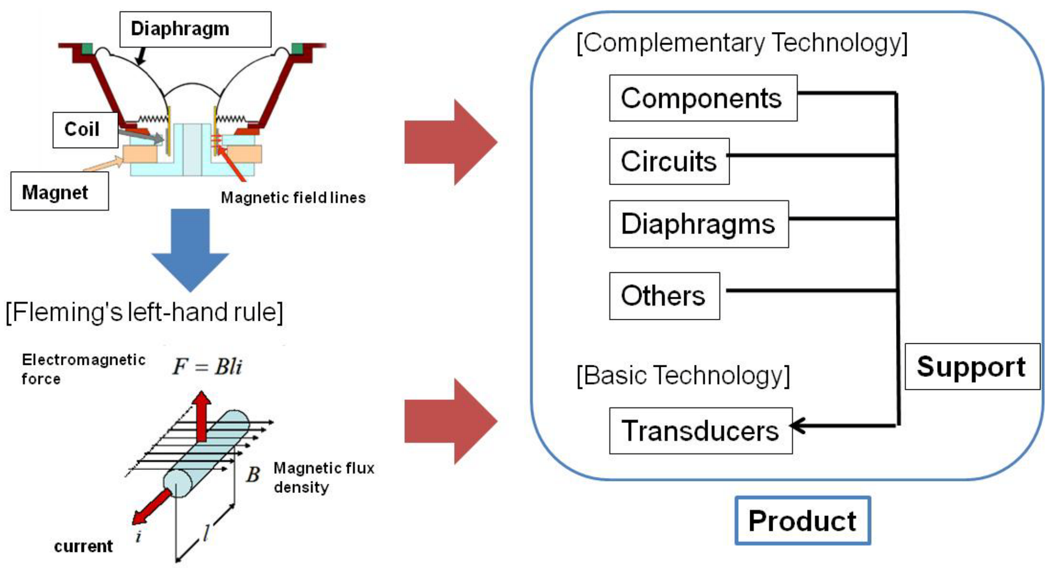

Fig.1 Technological Compositions of a Speaker [Cross-section diagram of a speaker composed of Dynamo-electric converter]

We define “Basic Technology” as a technology which uses the fundamental physical laws as the core technology of a product and “Complementary Technology” as a technology which supports Basic Technology to produce an efficient product.

3. Acoustic Industry in Japan

We focus on the electro-acoustic industry as the place to analyze Knowledge Spillover effect among technologically different components. We select a speaker as the product, a main product in the industry.

Today, many products, especially Information Technology (IT) and digital equipments contain a small-sized speaker, for example, Headphone, Earphone, Cellular phone, Portable music player, Laptop PC, PDA (personal digital assistant), and Flat-screen television. The dissemination of these IT and digital equipments has accelerated the expansion of the market in speakers since the late 1990s.

The Basic Technology used in a speaker consists primarily of the dynamo-electrical system, which is based on Fleming’s rules. The dynamo-electrical system has been used in a speaker for over 30 years. It can thus be said that the Basic Technology of a speaker has remained the same.

The Dynamo-electric Transducer is the most popular Transducer model, and its mechanism is based on Fleming’s left hand rule as the fundamental physical discipline. The process of changing electrical signals to structural vibration follows this rule. Passing a current through a coil generates electromagnetic force(Coil) in response to the magnetic field lines (Magnet), and thus electromagnetic force is used for generating structural vibrations (Diaphragm).

These three compositions (Coil, Magnet and Diaphragm) are essential in the Basic Technology.

Figure 1 shows the three technological components of the Basic Technology of a speaker.

Japanese companies occupy a large share of the market in speakers in the world. Japanese companies also contribute nearly 70% to the number of patent applications relating to speakers in the world as Figure 2.

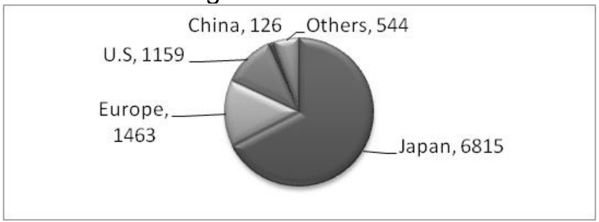

Fig. 2 Share of the number of patent applications relating to a speaker which were filed 1995~2004
Sources: the Japan Patent Office (JPO) website

Figure 3 shows the trend in the number of patent applications relating to a speaker which were filed to the Japan Patent Office (JPO). It demonstrates that the number of patent applications began to increase rapidly in the late 1990s. Obviously, innovations in speaker technologies occurred at that period.

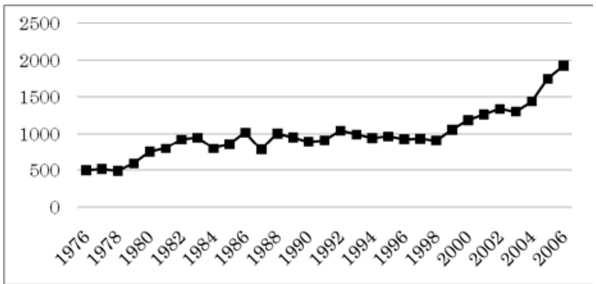

Fig.3 The trend in the number of patent applications relating to a speaker

4. *HYPOTHESIS*

In the late 1990s, demands in the market have changed from the relatively large-sized speakers of the 1980s to small-sized speakers. Development of IT and dissemination of digital equipments, for example, cellular phones and portable music players, are considered as reasons for the demands concerning the decrease in size of speakers.

The requirements for miniaturizing speakers and improvement of the acoustic characteristics of speakers are contradictory. The key components to satisfy the two requirements simultaneously are diaphragms, as they exist in the widest part of all devices and also control the acoustic characteristics of a speaker. The ability of diaphragms depends on its materials.

Therefore, speaker companies no longer could rely on papers to make diaphragms as they had in the 1980s, but had to develop materials with suitable characteristics which could be used as diaphragms in smaller-sized speakers.

The main characteristics needed for materials in diaphragms are as follows.

1, Light Weight; The weight of materials influences the sound range of a speaker. If the weight of the materials is high, the transmission efficiency decreases, and therefore the highest value of the sound limit of a speaker decreases.

2, High Rigidity; The rigidity of materials influences the sound quality of a speaker. If the rigidity of materials is low, structural vibration is divided in the high frequency area. In such a case, different parts of the diaphragms vibrate randomly, and this divided structural vibration leads to the aggravation of the sound quality.

3, High Internal friction; Vibration energy has to be absorbed in the inner diaphragms in order to stop vibrations. If the internal frictions are low, vibrations do not stop smoothly and continue for a long time worsening the sound quality. The internal friction also influences the sound quality.

In the 1980s, R&D was concerned with the field of structural technologies such as the manufacture of a transducer or mechanical parts rather than with the material of diaphragms, which was made from a paper having light weight and high rigidity, and being considered the best material at that time. Then, in the late 1990s, R&D concentrated in the field of functional technologies, that is, in developing other materials for diaphragms in order to satisfy the demands of miniaturization of speakers.

In a mature market, essential structural technologies for the product have already been developed to a certain level. Therefore, technological improvements relating to the functionality of the product to satisfy a new customer's needs is required in the next stage.

Based on such an historical analysis as above, we consider that the functionalities of a speaker have been developed in two stages of Knowledge Spillover.

In the first stage, Basic Technology is developed in order to have products working by focusing on structural technologies. After the structural technologies have already been developed to a certain level, at the next stage, the functionality of a product is developed, and in this process Knowledge Spillover occurs in the transition from Basic Technology to functional technologies indicated as Complementary Technology.

In the second stage, the Knowledge should thus be able to pass from Basic Technology to Complementary Technologies, and between Complementary Technologies. Collaboration among the functional technologies comprising the Complementary Technology is required to satisfy the new demands of the customer.

Therefore, the hypothesis is set up like as follows.

[Hypothesis]

In the technological development in the Acoustic Industry, 1, There is Spillover of Technological Knowledge in the development of functional technologies

2, There are two kinds of Technological Knowledge Spillover in the development of functional technologies; a) Spillover from Basic Technology to Complementary Technology and b) Spillover from one Complementary Technology to another Complementary Technology.

5. *ANALYZING MODEL*

Griliches (1984)[20] has suggested by empirical analysis a quite strong relationship between R&D and the number of patents and concluded that patent statistics could be a useful economic indicator in illuminating the process of innovation. We use the number of patent applications as an indicator of innovation, and the number of patent applications given the specific IPC or FI(File Index) as Basic Technology or Complementary Technology as an indicator of Technological Knowledge of Basic Technology or Complementary Technology, respectively.

In this study, we use FI(File Index) to group technologies. FI developed by the JPO is a more specific patent classification than IPC. FI is given to patent applications by the JPO as well as IPC.

We use as proxy variables of Innovation and Technological Knowledge the following.
[The process of innovation]
The trend in number of patent applications relating to a speaker
[Technological Knowledge]
The number of patent applications grouped as either Basic Technology or Complementary Technology by using IPC or FI.

Patent applications are filed for inventions and IPC are given by the JPO according to the inventions in the patent applications. Inventions are defined as technological ideas in patent applications. The number of patent applications published with specified IPC correspond to the volume of technological ideas disclosed in patent applications of the technology fields of the given IPC. Patent applications filed and published depend on inventions disclosed in patent applications as technological ideas in both the groups of Basic Technology and Complementary Technology. Basic Technology and individual Complementary Technology are defined independently by IPC or FI.

The number of patent applications relating to a speaker (P) in the innovation process of a speaker and Technological Knowledge of Basic Technology and Complementary Technology are described as in equation (1-1):.

$$P=A'+\alpha' T'_{basic}+\sum_n \beta'_n T'_{comp(n)} \qquad (1-1)$$

where, "A'" indicates a constant value. T'_{basic} indicates Technological Knowledge of Basic Technology, and it is measured by the number of patent applications given "IPC of Basic Technology". $T'_{comp(n)}$ indicates Technological Knowledge of Complementary Technology, and it is measured by the number of paten applications given "individual IPC of Complementary Technology". "n" indicates the number of Complementary Technology. α' and β' are coefficient values, respectively.

In case of the existence of Knowledge Spillover, the equation (1-1) can be rewritten as the equation(2-1)

$$P=A+\alpha T_{basic}+\sum_n \beta_n T_{comp(n)} + \sum_m \gamma_m K_{spill(m)} \qquad (2-1)$$

where, "A" is the same as in the equation(1). T_{basic} indicates Technological Knowledge of Basic Technology, and it is measured by the number of patent applications given "IPC of Basic Technology without IPCs of Complementary Technology". $T_{comp(n)}$ indicates Technological Knowledge of Complementary Technology, and it is measured by the number of patent applications given "individual IPC of Complementary Technology without IPCs of other Complementary Technology". $K_{spill(m)}$ indicates Technological Knowledge Spillover between technologies, and it is measured by the number of patent applications given "both IPCs of Basic Technology and Complementary Technology or two or more IPC(s) of Complementary Technology". "m" indicates the number of combinations of Complementary Technology. α, β and γ are coefficient values, respectively.

T'_{basic} and $T'_{comp(n)}$ is expressed like as follows.

$$T'_{basic}=T_{basic}+K_{spill\ (basic\text{-}comp)}$$
$$T'_{comp(n)}=T_{comp(n)}+K_{spill\ (basic\text{-}comp)}+K_{spill\ (comp\text{-}comp)}$$

where $K_{spill(x\text{-}y)}$ is defined as Technology Knowledge Spillover between x technology and y technology.

We group the technologies of a speaker by IPC or FI into one Basic Technology (transducers) and Three Complementary Technologies(Comp1, Comp2, Comp3), that is, four technological segments; Basics, Mechanics, Electronics, and Materials. The three Complementary Technologies correspond to components, circuits, and diaphragms, respectively. Then, "n" can be considered equal to 3, "m" is equal to 11 according to the combinations of Complementary Technology. (1-1) and (2-1) are rewritten as (1-2) and (2-2)., respectively.

$$P=A'+\alpha' T'_{basic}+\beta'_1 T'_{comp1}+\beta'_2 T'_{comp2}+\beta'_3 T'_{comp3} \qquad (1-2)$$

$$P=A+\alpha T_{basic}+\beta_1 T_{comp1}+\beta_2 T_{comp2}+\beta_3 T_{comp3}$$

$+\gamma_1 K_{spill(basic\text{-}comp1)} + \gamma_2 K_{spill(basic\text{-}comp2)}$
$+\gamma_3 K_{spill(basic\text{-}comp3)} + \gamma_4 K_{spill(comp1\text{-}comp2)}$
$+\gamma_5 K_{spill(comp1\text{-}comp3)} + \gamma_6 K_{spill(comp2\text{-}comp3)}$
$+\gamma_7 K_{spill(basic\text{-}comp1\text{-}comp2)} + \gamma_8 K_{spill(basic\text{-}comp1\text{-}comp3)}$
$+\gamma_9 K_{spill(basic\text{-}comp2\text{-}comp3)} + \gamma_{10} K_{spill(comp1\text{-}comp2\text{-}comp3)}$
$+\gamma_{11} K_{spill(basic\text{-}comp1\text{-}comp2\text{-}comp3)}$

(2-2)

Comp1 is termed “Mechanics: mech”. Comp2 is termed “Electronics: ele”. Comp3 is called “Materials: mat”. The equations are then rewritten as (1-3) and (2-3), respectively

$P=A'+\alpha' T'_{basic}+\beta'_1 T'_{mec}+\beta'_2 T'_{ele}+\beta'_3 T'_{mat}$
(1-3)

$P=A+\alpha T_{basic}+\beta_1 T_{mech}+\beta_2 T_{ele}+\beta_3 T_{mat}$
$+\gamma_1 K_{(basic\text{-}mech)}+\gamma_2 K_{(basic\text{-}ele)}+\gamma_3 K_{(basic\text{-}mat)}$
$+\gamma_4 K_{(mech\text{-}ele)}+\gamma_5 K_{(mech\text{-}mat)}+\gamma_6 K_{(ele\text{-}mat)}$
$+\gamma_7 K_{(basic\text{-}mech\text{-}ele)}+\gamma_8 K_{(basic\text{-}mech\text{-}mat)}$
$+\gamma_9 K_{(basic\text{-}ele\text{-}mat)}+\gamma_{10} K_{(mech\text{-}ele\text{-}mat)}$
$+\gamma_{11} K_{(basic\text{-}mech\text{-}ele\text{-}mat)}$

(2-3)

6. *Definition about composition of Speaker by IPC*

Electro acoustic Equipment such as a microphone, a recorder, and a speaker are classified by IPC as [H04R]. We select technologies related to a speaker from those technologies using FI (Figure 4).

1, As Basic Technology, we chose two types of transducers. These are defined by IPC as Transducers of moving-coil type (H04R9) and Piezo-electric transducers (H04R17) in the main group level of IPC.

2, As Complementary Technologies, there are three main devices which support the work of a transducer in a speaker; namely, the Component (H04R1), Circuit (H04R3), and Diaphragm (H04R7).

2.1, Mechanics; We classify technologies which belong to (H04R1) as “Mechanics”, The technologies which belong to this IPC , H04R1, are parts of speakers and are composed of three different components; Components of structural detail, Components of Frequency characteristics, and Components of human interface.

2.2, Electronics; We classify technologies which belong to (H04R3) as “Electronics”. The technologies which belong to H04R3 of IPC include circuits according to the definition of IPC.

2.3, Materials; We classify technologies which belong to (H04R7) as “Materials”. The technologies include materials for diaphragms, methods for settlement of parts and structure of diaphragms.

Figure 5 shows the trend in the number of patent applications of individual Technology Knowledge.

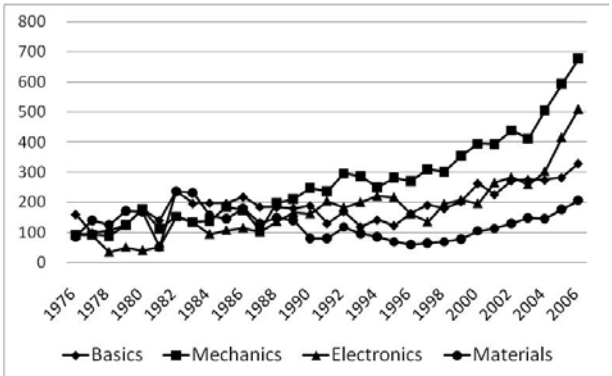

Fig.5 The trend of the number of patent applications in each Technology Knowledge

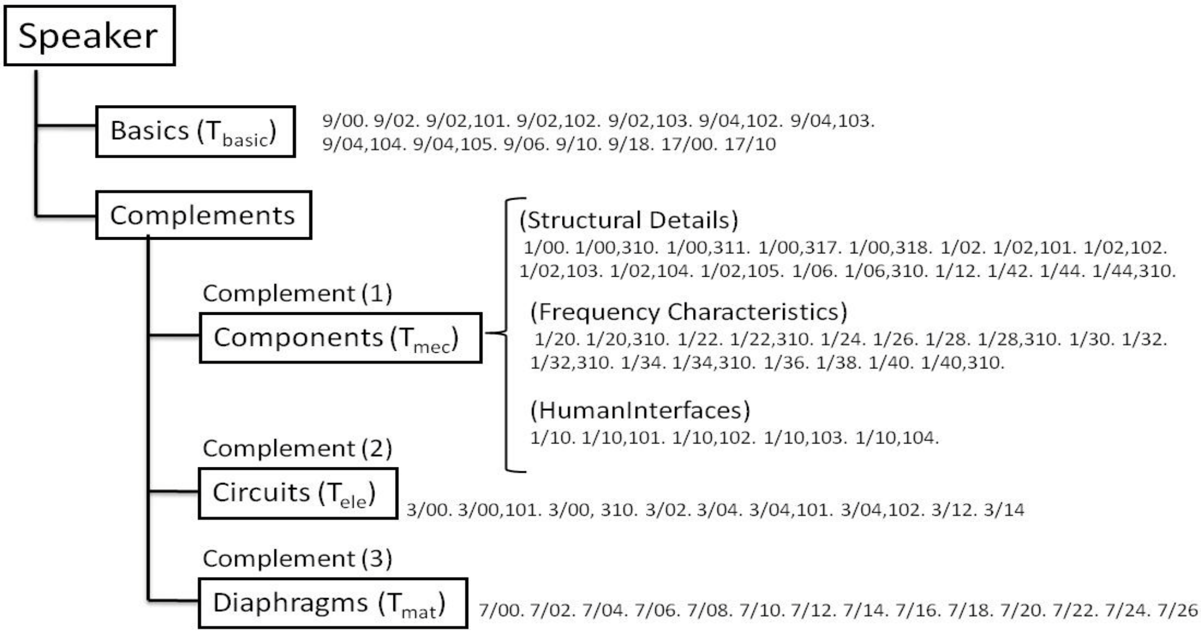

Fig.4 Composition of IPC relating to speaker technologies (H04R)

7. *Entropy about Technology Knowledge*

We analyzed the diversification rate in the number of patent applications of these four Technology Knowledge, by calculation of Entropy.

The value of Entropy is computed by the following equation:

$$E=-\Sigma_i S_i \log_2 S_i$$

where E; Entropy, S_i; Share of Technology Knowledge (i=1~n). Entropy can have a value from 0 to 2.

As the variable of Entropy, following four elements is substituted in this formula. S_1~S_4 indicates the share of the number of patent applications relating to "Basics": S_1, "Mechanics" :S_2, "Electronics": S_3, and "Materials": S_4, respectively.

Figure 6 demonstrates the trend of Entropy values and shows that there are two waves. During the first wave (1980~1989), by referring to Figure 5, it is considered that an increase of the number of patent applications in Mechanics and Electronics contributes to the increase of Entropy. During the second wave (1996~2006), an increase of the number of patent applications in Materials contributes to the increase of Entropy.

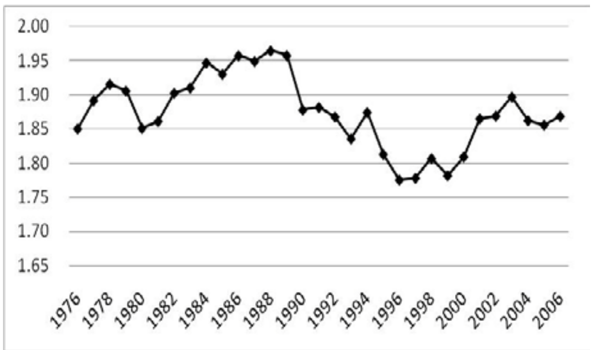

Fig.6 Entropy of four Technology Knowledge

Therefore, comparison between the trends of the number of patent applications of these two periods was made to analyze how technological compositions changed

8. *Result*

A result by the multiple regression analysis of the equations (1-3) and (2-3) in the two periods is as follows. To ensure degrees of freedom, we divide the data in one year into the data in four terms of the year. As to the equation (2-3), the quantities of $K_{(basic\text{-}mech\text{-}ele)}$, $K_{(basic\text{-}ele\text{-}mat)}$, $K_{(mech\text{-}ele\text{-}mat)}$, $K_{(basic\text{-}mech\text{-}ele\text{-}mat)}$ measured by the number of patent applications are less than 1% of the value of T_{basic} (number of patent applications of Basic Technology), and so we can eliminate these proxies.

The result of the analysis follows after eliminating the proxies with low t-values.

[1st wave; 1980 to 1989]

(1-3)

$$P=53.95+1.05T_{basic}+1.12T_{mec}+1.22T_{ele}+1.04T_{mat}$$

(3.85) (3.81) (3.15) (3.54) (4.18)

adj R^2; 0.80 DW; 1.41

(2-3)

$$P=48.51+1.47T_{basic}+1.45T_{mec}+1.18T_{ele}+1.28T_{mat}+0.73K_{(basic\text{-}mat)}$$

(3.90) (5.32) (4.25) (3.70) (5.00)

(2.07)

adj R^2; 0.85 DW; 1.72

[2nd wave; 1996 to 2006]

(1-3)

$$P=74.64+0.48T_{basic}+1.07T_{mec}+0.90T_{ele}+1.50T_{mat}$$

(5.27) (1.36) (3.81) (3.21) (2.69)

adj R^2; 0.94 DW; 1.97

(2-3)

$$P=33.27+1.04T_{basic}+1.57T_{mec}+1.02T_{ele}+3.05T_{mat}+0.70K_{(basic\text{-}mech)}+0.66K_{(mech\text{-}ele)}+2.11K_{(mech\text{-}mat)}$$

(2.64) (2.81) (6.25) (3.86) (4.77)

(2.83) (2.47) (2.56)

adj R^2; 0.96 DW; 2.48

The results reveals that the equation (2-3), which includes the Spillover of Technological Knowledge, can account for the process better than the equation(1-3) by comparison of the values of adj R^2.

In the first wave, Basic Technology is demonstrated to have mainly contributed to the increase of "P". Only Spillover of Technology Knowledge between Basic Technology and Materials is revealed to be statistically significant.

In the second wave, Technological Knowledge of Materials is demonstrated to have contributed the most to the increase of "P". The contribution of Technological Knowledge of Materials significantly increased comparing that in the first stage. On the other hand, the contribution of Basic Technology decreased.

The Knowledge Spillover between Basics and Mechanics, Mechanics and Electronics, and Mechanics and Materials is revealed to be statistically significant in this period.

Hypothesis 1 and 2 are verified.

9. *DISCUSSION*

On the basis of intensive empirical observation on patent statistics, it could be concluded that Technology Knowledge Spillover leads to the functional development of a speaker in the electrical acoustic industry. It is shown that there were two stages in the functional development of speaker technologies. The Knowledge Spillover could account for the development and there is Knowledge Spillover from Basic Technology to Complementary Technology.; especially, Knowledge Spillover from Basic Technology to Materials, and between Complementary Technologies; especially, Knowledge Spillover between Mechanics and Materials.

It could be considered that, in the process of the functional development of a speaker, the Knowledge is spilled over from Basic Technology to Material technologies, and then the Knowledge of Material technologies is spilled over to Mechanical technologies. As previously mentioned, the demands of miniaturization and improving the sound characteristics of a speaker are structurally contradictory. The key to satisfy both of the demands is the invention of a new material. In the acoustic industry, it can be said that Material technologies have an important role in leading the flow of Knowledge Spillover, and thus improving the functionality of speakers. It also can be said that by this flow of Knowledge, the development of the functionality of materials was accelerated.

In future works, an analysis of this technology spillover effect from the aspect of physics should be helpful.

Appendix

[A list of IPC or FI relating to a speaker]

[H04R1/00]Details of transducers
[H04R1/00,310･]Speaker
[H04R1/00,311･･]Waterproof structure
[H04R1/00,317･･]by using bone conduction
[H04R1/00,318･･]support board or suspender
[H04R1/02･]Casings; Cabinets; Mountings therein
[H04R1/02,101･･]Speaker cabinets
[H04R1/02,102 ･ ･]Speaker cases applied to specific thing
[H04R1/02,103 ･ ･ ･]for using with other equipments
[H04R1/02,104･･]front panel of speaker
[H04R1/02,105･･]Attachment tools for speaker
[H04R1/06 ･]Arranging circuit leads; Relieving strain on circuit leads
[H04R1/06,310･･]Speaker
[H04R1/10･]Earpieces; Attachments therefor
[H04R1/10,101･･]Headphone and appendage
[H04R1/10,102･･･]Pad
[H04R1/10,103･･･]Attachment tool
[H04R1/10,104･･]Earphone and appendage
[H01R1/12 ･]Sanitary or hygienic devices for mouthpieces or earpieces
[H04R1/20･]Arrangements for obtaining desired frequency or directional characteristics
[H04R1/20,310･･]Speaker
[H04R1/22 ･ ･]for obtaining desired frequency characteristic only
[H04R1/22,310･･･]Speaker
[H04R1/24 ･ ･ ･]Structural combinations of separate transducers or of parts of the same transducer and responsive respectively to two or more frequency ranges
[H04R1/26･･･]Spatial arrangement of separate transducers responsive to two or more frequency ranges
[H04R1/28 ･ ･ ･]Transducer mountings or enclosures designed for specific frequency response; Transducer enclosures modified by provision of mechanical or acoustic impedances,
[H04R1/28,310････]Speaker
[H04R1/30･･･]Combinations of transducers with horns
[H04R1/32 ･ ･]for obtaining desired directional characteristic only
[H04R1/32,310･･･]Speaker
[H04R1/34･･･]by using a single transducer with sound reflecting, diffracting, directing or guiding means
[H04R1/34,310････]Speaker
[H04R1/36････]by using a single aperture of dimensions not greater than the shortest operating wavelength
[H04R1/38････]in which sound waves act upon both sides of a diaphragm and incorporating acoustic phase-shifting means
[H04R1/40･･･]by combining a number of identical transducers
[H04R1/40,310････]Speaker
[H01R1/42 ･]Combinations of transducers with fluid-pressure or other non-electrical amplifying means
[H01R1/44･]Special adaptations for subaqueous use
[H01R1/44,310･･]Speaker
[H04R3/00]Circuits for transducers
[H04R3/00,101･]Protection circuit
[H04R3/00,310･]Speaker
[H04R3/02･]for preventing acoustic reaction
[H04R3/04･]for correcting frequency response
[H04R3/04,101･･]by using a negative feedback circuit
[H04R3/04,102･･]for transducers of moving-coil, piezo-electric transducers, and other transducers
[H04R3/12･]for distributing signals to two or more loud-speakers
[H04R3/14･･]Cross-over networks
[H04R7/00]Diaphragms for electromechanical transducers; Cones
[H04R7/02･]characterized by the construction
[H04R7/04･･]Plane diaphragms
[H04R7/06･･･]comprising a plurality of sections or layers
[H04R7/08････]comprising superposed layers separated by air or other fluid
[H04R7/10････]comprising superposed layers in contact
[H04R7/12･･]Non-planar diaphragms or cones
[H04R7/14･･･]corrugated, pleated, or ribbed
[H04R7/16 ･]Mounting or tensioning of diaphragms or cones
[H04R7/18･･]at the periphery

[H04R7/20・・・]Securing diaphragm or cone resiliently to support by flexible material, springs, cords, or strands
[H04R7/22・・・]Clamping rim of diaphragm or cone against seating
[H04R7/24・・]Tensioning by means acting directly on free portion of diaphragm or cone
[H04R7/26・]Damping by means acting directly on free portion of diaphragm or cone
[H04R9/00]Transducers of moving-coil, moving-strip, or moving-wire type
[H04R9/02・]Details
[H04R9/02,101・・]Frame; appendage
[H04R9/02,102・・]Magnetic circuit
[H04R9/02,103・・]Damper
[H04R9/04 ・・]Construction, mounting, or centering of coil
[H04R9/04,102・・・]Coil
[H04R9/04,103 ・・・]Lead wire; Connection between coil and lead wire
[H04R9/04,104・・・]Bobbin
[H04R9/04,105 ・・・・]Bobbin and other components
[H04R9/06・]Loud-speakers
[H04R9/10・]Telephone receivers
[H04R9/18・]Resonant transducers, i.e. adapted to produce maximum output at a predetermined frequency
[H04R17/00]Piezo-electric transducers; Electrostrictive transducers
[H04R17/10・]Resonant transducers

(where「・」means the technological ladder.)

REFERENCES

[1] Z. Griliches, Issues in Assessing the Contribution of R&D to Productivity Growth, Bell Journal of Economics, 10, 92 (1979)
[2] Z. Griliches, Patent Statistics as Economic Indicators: A survey, Journal of Economic Literature, 28, 1661 (1990)
[3] A. Jaffe, Technological Opportunity and Spillovers of R&D: Evidence from firm’s patents, profits and market value. American Economic Review 76, 984 (1986)
[4] G. Lee, The effectiveness of international knowledge spillover channels, European Economic Review, 50, 2075 (2006)
[5] A. Jaffe and M. Trajtenberg and R. Henderson, Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations, Quarterly Journal of Economics, 108, 577 (1993)
[6] G. Tappeiner, C. Hauser, and J. Walde, Regional Knowledge Spillovers: Fact or Artifact, Research Policy, 37, 861 (2008)
[7] L. Branstetter, Are Knowledge Spillovers International or International Inscope?: Microeconometric Evidence from the U.S. and Japan, Journal of International Economics, 53, 53 (2001)
[8] J. Eaton and S. Kortum, International Technology diffusion: theory and Measurement, International Economic Review, 40, 537 (1999)
[9] W. Keller, Geographic Localization of International Technology Diffusion, American Economic Review, 92, 120 (2002)
[10] F. Scherer, Using Linked Patent and R&D Data to Measure Interindustry Technology Flow, A, Griliches, R&D patents and productivity, University of Chicago Press, 417 (1984)
[11] Z. Griliches and F. Lichtenberg, Interindustry Technology Flows and Productivity Growth: A Reexiamination, Review of Economics and Statistics, 66, 324 (1984)
[12] A. Goto and K. Suzuki, R&D Capital, Rate of Return on R&D Investment, and Spillover of R&D in Japanese Manufacturing Industries, Review of Economics and Statistics, 71, 555 (1989)
[13] J. Bernstein and M. Nadiri, Interindustry R&D Spillovers, Rates of Return, and Production in High-Tech Industries, American Economic Review, 78, 429 (1988)
[14] J. Bernstein, Interindustry R&D Spillover for Electrical and Electric Products: The Canadian Case, Economic Systems Research, 9, 111 (1997)
[15] M. Terero, Analyzing the Spillover Mechanism on the Semiconductor Industry in the Silicon Valley and Route 123, Econometric Society World Congress 2000 Contributed Papers from Econometric Society, 90 (2001)
[16] P. Geroski, Markets for Technology: Knowledge, Innovation, and Appropriability, Stoneman, Handbook of the Economic Innovation and technological Change, Blackwell, 90 (1995)
[17] A. Ohmura and C. Watanabe, Cross-Products Technology Spillover in inducing a self-propagating dynamism for the shift to a service oriented economy: Lessons from high-performance fine ceramics, Journal of Service Research, 6, 2, 145 (2006)
[18] M. Nakagawa and C. Watanabe, Moving beyond organizational inertia as a survival strategy for resources-based industry in a service-oriented economy: lessons from cross-sector technology spillover in the nonferrous metal industry, Journal of Service research, 7, 1, 7 (2007)
[19] M. Nakagawa and C. Watanabe, A Driver for Materials Technology Innovation: Changes in Technology Spillover Structure in Japan’s Nonferrous Metal Industry, New Directions of Technology Management, 1 , 25 (2008)
[20] A.Pakes and Z. Griliches, Patents and R&D at the Firm level: A First Look, Z. Griliches, R&D patents and Productivity, University of Chicago Press, 55 (1984)

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Using Data Driven Decision Making in Higher Education: A Pilot Case Study with Implications for Technology Policy

Wright, Diane Ph.D.

Abstract – In today's American system of education, large amounts of data are being collected at every level, kindergarten through college (K-20). In years past, this data were simply collected and used for basic accounting, or reporting purposes as opposed to driving important decisions to facilitate meaningful change. While this scenario has changed dramatically in the K-12 education sector, postsecondary education is still playing "catch-up," in many ways, in terms of navigating the intricacies of data-driven decision making. This pilot case study of data-driven decision making in a selected College of Education reflects the results of the implementation of data-driven decision making strategies in response to the re-accreditation process. Using a convenience sample and a semi-structured interview protocol, the researcher recommends a hybrid technology policy model as most effective in terms of using technology to monitoring and make data-driven decisions regarding student performance. Future research will be conducted to determine the extent to which the pilot case study results can be generalized to other higher education settings.

Purpose

The purpose of this pilot case study was to determine how data-driven decision making is being implemented in a selected U.S. Colleges of Education. In addition, this case study was conducted to determine if and how the data collected at the College level links with the K-12 education sector, and to what extent; as well as to determine what infrastructure improvements are needed. Finally, the researcher sought to assess the attitudes of college level administrators in terms of the concepts of centralized vs. decentralized data-driven decision making infrastructure design and utility, their related experiences and characterization as well as their perception of the extent to which they are able to influence College/Unit level data-driven decision making? The research questions were as follows:

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1. What types of data are typically collected at the College of Education/Unit level to make data-driven decisions in the U.S.?
2. In what categories do these data-driven decisions generally fall?
3. How is data collected at the college level in the selected U.S. College of Education used to make data-driven decisions?
4. How is data-driven decision making being implemented in U.S. Colleges of Education?
5. How does the data collected in U.S. Colleges of Education and used for purposes of data-driven decision making link with U.S. K-12 education?
6. What improvements need to be made in terms of data-driven decision making infrastructures U.S. K-20 systems?
7. What do U.S. College of Education level administrators think about the concepts of centralized vs. decentralized data-driven decision making infrastructures in terms of their design and utility? Related experiences? Characterization?
8. What influence do U.S. College of Education Administrators have with regard to data-driven decision making?

Significance

It is well documented that educational leaders who engage in data driven decision making at the K-12 levels of education position themselves not only to be able to respond responsibly to accountability requirements, but also to reap the benefits of the more efficient use of resources (McClintock & Snider, 2008). Fewer empirical studies to date have been reported in terms of the experiences with data-driven decision making at the postsecondary levels of education. And, despite a few domestic and international best practice examples, higher education still finds itself, at best, trying to navigate through the intricacies of data-driven decision making (Briggs, 2006).

Literature Review

Within the context of K-12 education, one aspect of data driven decision making is characterized by the ability to create change based on feedback from standardized testing (Grigg et al., 2005). This standardized testing component, though also evident at the postsecondary level in the form of GREs, LSATs, GMATs, etc. is very seldom used to create change based on student performance results perhaps with the exception of some basic skills competency examinations. According to Bernhardt (1998), Holcomb (1999), Johnson (2002) & Love (2002), student achievement data is the paramount driving force behind data-driven decision making at the K-12 level. Such measures can consist of attendance rates and drop-out rates, as well as standardized test scores.

In the realm of U.S. higher education, however, data-driven decision making is a relatively new term. Only since the early 1980s has it gained in emphasis at the postsecondary level. The latter is particularly true relative to assessment. “Assessment” comprises a set of systematic methods for collecting valid and reliable evidence of what students know and can do at various stages in their academic careers. Those who need to determine accountability need this information to drive their decision-making (Ewell, 2006). In higher education, however, even today assessment results are rarely discussed in the related literature in terms of their use in the decision making process (Bers, 2008) in any depth. Adding to the challenges of assessment for purposes of decision making at the postsecondary level is the lack of faculty enthusiasm not to mention overall student discontent with assessment. More recently, the issue of assessment appears to be resurfacing, with technology at its center.

Despite an awareness of the importance of technology in being able to engage in data driven decision making, however, many problems exist in terms of viable infrasstructures to support data driven decision making. Collaboration across sector is particularly an issue (Means, 2000, 2001; Wedman, 2001).

Specifically, Nicaise & Barnes (1996) and Perkins (1992) note that technology is not being used to its full potential in the decision making processes of education. Hutchings & Shulman (1999) also note that the use of information (data) generated for increased learning should be an area of focus. But, data-driven decision making is minimally supported by faculty and staff (Lazerson, Wagener, & Shumanis, 2000).

In enacting a data-driven decision making system, it is extremely important to discern exactly where this data is being stored and how this data is being used, if at all. According to Voorhees (2008), an institution that has a storehouse of organized and central data is best suited to engage in data-driven decision making (Voorhees, 2008). However, what about specific academic colleges/units? The predominance of information held by centralized institutional research offices is very generalized by nature, and used to generate reports for a multitude of external stakeholders. What about discipline specific information that is needed to influence major change at the college/unit level?

In a study reported by George et al. (2008) students at a small private liberal arts college in Alberta, Canada where asked to complete a five day time diary and 71-item questionnaire to access predictors of academic success. In this study, the findings yielded predictors of academic success beyond what was found in the current literature. What if the specific academic colleges/units, conducted a survey to assess predictors of academic success within their own unique subsystem? Or, better yet, used the data already being collected at the college/unit level to drive decisions regarding strategies that could be put in place to increase student learning? Current technology resources make the latter much more feasible than may have been the case in years past.

Centralized systems may not to be very effective for large academic units (Stocum & Rooney, 1997). In a related management practice, universities have experimented with decentralized fiscal management, i.e., responsibility center management (RCM). RCM allows units to have more of a say in their own unique planning and creates a greater sense of accountability for outcomes (Whalen, 1991). In addition, RCM provides individual units the flexibility to move funds around, as needed.

Methodology

A researcher developed semi-structured interview protocol was developed to examine how technology was used to make data-driven decisions within a selected college during the re-accreditation process at the college level and what types of decisions were involved. The research questions were used as the basic framework in the development of the protocol. The semi-structured interview protocol was piloted in a 4-year public institution's College of Education not included in this study. Semi-structured interviews were held with the college's Director of Evaluation, the Director of Technology, the Director of Student Field Placements, and a department chair who had also served as the Chair of the college's re-accreditation process. A document analysis was also conducted of the selected College's of Technology Plan, as well relevant committee meeting minutes and other relevant documents, as appropriate.

Data Analysis

Qualitative methods were used to analyze the data collected. Relevant text and documents were content analyzed. Themes were created based on a triangulation of interview results, document analysis, and a review of the literature.

Findings

Findings reveal that at the selected pilot College of Education, an initiative has been taken to place data-driven decision making at the center of its comprehensive technology plan. This plan represent a collaboration of efforts among the University's (Central) Information Resources and Management Division (IRM) and the College of Education's (Decentralized) Educational Technology Support (ETS) team. A clearly defined objective of this technology plan was to facilitate the collection of data to make better and more-informed decisions, specifically regarding enrollment management within the college.

In this pilot study, it was also found that the impetus of its implementation of data-driven decision making infrastructure was its re-accreditation process or an external driver. More importantly, however, findings revealed that the selected institution's success is the integration of several data-bases accessible to college administrators at all times. With the integration of several data-bases, multiple sources of data can be accessed to generate a number of reports. Decentralized units are able to query the data they need on an "as needed" basis resulting in more informed decision making.

Summary/Conclusions/Recommendations

From this pilot study, one can draw several conclusions. First, the more databases available, the more information will be available that can be accessed by the user. Second, the balance between centralized and decentralized data-driven decision making is beneficial as it allows individual units to access exactly the information that they need to make meaningful change decisions. In addition, the extent to which data-driven decision making is a common topic and moved from being talked about to practice among both administrative staff and faculty is critical. It was also found that one of the primary ways data-driven decision making can be used is in the collection of student performance data to make sure that programs are producing quality products (e.g., teachers, educational leaders, etc.). Finally, based on the pilot study results, two key themes emerged relating to the use of technology in making data-driven decisions: (1) integrated systems of data-bases, and (2) commitment to data-driven decision making.

Integrated System of Data-Bases

This pilot study of a U.S. College of Education demonstrates the advantages of having access to a highly integrated system of data-bases. It was determined that such highly integrated systems create a very efficient balance between centralized and decentralized data-driven decision making practices.

Commitment to Data-Driven Decision Making

Many factors were determined to be present that could explain the pilot study college's commitment to data-driven decision making. In a state university system undergoing a drastic governance reorganization over the last five years and more recently in the midst of severe budget cuts, the pilot study College's system of universities are responsible for answering a growing number of calls for accountability. In fact, its most recent governance legislation was titled, K-20 Accountability.

Data-driven decision making represents both a tool and a method for generating solutions and responding to these calls. Particularly in the case of the pilot college, not only was it required to provide a high number of quality graduates in an identified state workforce shortage area, but, the pilot college served a large number of part-time students who worked as full-time professionals and thus was compelled to must make sure that it's course content was highly practitioner based; i.e., that its students could translate classroom experience to the workplace immediately.

Future studies should focus on the extent to which one is able to generalize the pilot study findings, and why organizations/entities are highly committed to data-driven decision making, while others may not be as far along. Factors such as governance structures, budgetary constraints, accreditation status, relationship with the local community and schools, and types of student enrollment are also factors that will need to be considered. Yet another question might be where the idea of data driven decision making typically gets its initial impetus first, i.e., as a result of the accreditation/re-accreditation process or system-wide calls for accountability. The results of this pilot study provide a baseline for such future research.

References

[1] Angelo, T. A. (2003). Developing the scholarship of assessment: Guidelines and Pathways. In S. E. Van Kollenburg (Ed.), *A collection of papers on self- study and institutional improvement (*pp. 11-15*).* Chicago, IL: Higher Learning Commission.

[2] Bernhardt, V. (1998). Data analysis for comprehensive schoolwide improvement. Larchmont, NY: Eye on Education.

[3] Bers, Trudy H. (2008). The role of institutional assessment in assessing student learning outcomes. *New Directions for Higher Education, 141,* 31-39.

[4] Biggs, L. (2006) Data-driven decision making: It's a catch-up game. Campus Technology. http://campustechnology.com/articles/41085 5/ retrieved August 8,2008.

[5] Ewell, P. T. (2006). Making the grade: How boards can ensure academic quality. Washington, D.C.: Association of Governing Boards of Colleges and Universities.

[6] George, D., Dixon, S., Stansal, E., Gelb, S. L., & Pheri, T. (2008). Time diary and questionnaire assessment of factors associated with academic and personal success among university undergraduates. *Journal of American College Health*, *56(6),*706-715.

[7] Grigg, J., Halverson, R., Prichett, R., & Thomas, C. (2005). The new instructional leadership: Creating data-driven instructional systems in schools. Madison, Wisconsin: University of Wisconsin, Wisconsin Center for Education Research. (WCER Working Paper No. 2005-9).

[8] Holcomb, E. (1999). Getting excited about data: How to combine people, passion, and roof. Thousand Oaks, CA: Corwin Press.

[9] Hutchings, P. & Shulman, L. S. (1999). The scholarship of teaching: New elaborations, new developments. *Change, 31(5),* 10-15*.*

[10] Johnson, R. S. (2002). Using data to close the achievement gap: How to measure equity in our schools. Thousand Oaks, CA: Corwin Press.

[11] Lazerson, M., Wagner, U. & Shumanis, N. (2000). What makes a revolution? Teaching and learning in higher education, 1980-2000. *Change, 32(3),*13-19*.*

[12] Love, N. (2002). Using data/getting results: A practical guide for school improvement in mathematics and science. Norwood, MA: Christopher-Gordon.

[13] Means, B. (2000, 2001). Technology use in tomorrow's schools. *Educational Leadership*, 57-61.

[14] McClintock, P. J., & Snider, K. J. G. (2008). Driving decision making with data. *New Directions for Institutional Research, 137,* 15-40*.*

[15] Nicaise, M., and Barnes, D. (1996). The union of technology, constructivism, and teacher education. *Journal of Teacher Education, 47(3),* 205-212*.*

[16] Perkins, D. (1992). Technology meets constructivism: Do they make a marriage? In T. M. Duffy & D. H. Jonassen (Eds.), Constructivism and the technology of instruction (pp. 45-55). Hillsdale, NJ: Erlbaum.

[17] Stocum, D. L., & Rooney, P. M. (1997). Responding to resource constraints: A departmentally based system of responsibility center management. *Change, 29(5),* 50-57*.*

[18] Voorhees, R. A. (2008). Institutional research's role in strategic planning. *New Directions for Higher Education, 141,* 77-85*.*

[19] Wedman, J. (2001). Knowledge innovation for technology in education (KITE). A successful catalyst grant application to U.S. Department of Education's Preparing Tomorrow's Teachers to use Technology Program. Columbia, Missouri: University of Missouri.

[20] Whalen, E. (1991). Responsibility center budgeting: An approach to decentralized management for institutions of higher education. Bloomington, IN: Indiana University Press.

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