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MECHATRONICS EDUCATION AND INTERNATIONAL STABILITY

THE DEVELOPMENT OF UNIVERSITY-LEVEL EDUCATION PROGRAMMES IN ADVANCED ENGINEERING IN KOSOVO

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Abstract: Emerging economies in the midst of fundamental restructuring of higher education can benefit from radical approaches to engineering education programme design. The authors present the case of the development of a Mechatronics Management curriculum in one of the new international universities in Kosovo in order to demonstrate that it is possible to develop higher-education programmes in advanced engineering, which have local economic context in an emerging economy. The authors illustrate how it is possible to use theories of engineering and technology professional competence to develop a coherent higher education programme which has the potential to deliver on aggressive economic and educational objectives.

Keywords: Education, Mechatronics, Economic Development

1. BACKGROUND AND CONTEXT

Emerging economies in marginalised territories have particular difficulties in building a sustainable, stable programme of social, economic and political activity over time. Rather than leaving local groups to their own devices, it is self evident that the international community can play a role in directly supporting initiatives in these territories. One of the most important strategic activities in which the international community must engage with people 'on the ground' is the development of educational infrastructures. As the global digital divide widens between the rich and poor, the need to support programmes specifically aimed at developing leading edge, high-technology-oriented educational programmes in disadvantaged regions provides one of the most significant opportunities for increasing socio-political and economic stability long term. This relationship between education and economic development is a subject of great interest to policy-makers, economists and educationalists and the linkages are well established (Cheong Cheng, Hung Ng, Kwok, Ching Mok (2002)).

The authors present an international educational project directed to one of the most troubles regions in the European zone, Kosovo. It demonstrates the tremendous and exciting educational work that can be achieved in such marginalised communities, where there is will and determination to do so. It also sets out a theoretical basis for the programme centred around recently developed competency frameworks. The paper then sets out, in broad terms, the design of the programme and finishes with a review of the particular difficulties encountered in launching a technology management course in Kosovo.

The key propositions of this paper are as follows:

P1: Is it possible to develop an advanced technology programme for higher education in an emerging economy which has, until quite recently, experienced high-levels of instability?

This gives rise to two other secondary propositions:

P2: If P1 is true, is it possible to develop such a programme so that it has both internationally recognised unique selling points

P2: If P1 is true can such a programme provide a basis for knowledge-based economic activities which have local economic context?

2. MECHATRONICS & ENGINEERING MANAGEMENT

Mechatronics consists of integration of mechanical engineering with electronics, computer systems, and advanced controls to design, construct, and operate products and processes. Mechatronics is one of the newest branches of engineering with far-reaching applications to any sector of society. Generally, a mechatronic system can be seen as a mechanism, which is driven by actuators that are controlled via microelectronics and software using feedback from one or more sensors. Mechatronics is therefore the title given to the sub-discipline of engineering which studies the integration of mechanical and electronic technologies to create 'intelligent' machines, systems and controllers. High levels of automation in manufacturing environments require designers with skills in mechanical sciences since machinery and robotic equipment is fundamentally of mechanical nature (Ashley (1997)). The actuation, monitoring and control of mechanical devices are, however, achieved by electrical and electronic means.

An example of a mechatronic system is the operation of the landing gear of an aircraft. When the system is activated, it is the actuator, driven by hydraulic forces, that moves the landing gear, consisting of struts and wheels, down into the correct position for landing. If the landing gear were under automatic control then various sensors (perhaps of altitude or wing-flap angle) would indicate to the controlling computer that the aircraft was about to land and the computer would activate the mechanical system. Summarizing: Mechatronics is an interdisciplinary field integrating Mechanical Engineering, Electronics, and Computer Science.

2.1 Mechatronics in Kosovo

A number of well-educated economically-disadvantaged so-called “second” and “third” world societies have recognised the potential of developing a knowledge economy from a low level of development. It is readily apparent that similar opportunities exist for Kosovo, once socio-economic and political stability has been achieved.

However, social and political stability does not, in itself, deliver prosperity or inculcate hope. Kosovan administration must carefully plan and set in place structures which will enable sustainable economic activity to emerge and flourish. Consequently, it is evident that there is a need to focus upon higher education as a pre-requisite for sustainable growth and stability, and, in particular, a focus upon emerging disciplines in the field of high technology is very important in developing a skill-bases for potential, future inward investment. Mechatronics provides a particularly appropriate discipline given a number of key opportunities and potentials in Kosovo:

1. Given the richness of geology in the region there is real potential for a well-developed mining industry using the latest automation systems, many of which utilise mechatronics systems

2. The principles of mechatronics are readily transferable to advanced manufacturing systems (a limited but none-the-less strong industrial base remains in the territory)

3. Mechatronics is an aspect of the knowledge economy which has received little attention in western universities, in spite of the enormous potential for products, services and entrepreneurial activity in this space.

The problem with mechatronics is that it is inherently interdisciplinary, combining both electronics, computing and mechanical engineering. Furthermore, a graduate of a mechatronics programme will require a set of skills and competencies that are more complex than traditional engineering programmes, in order to operate effectively in technology-driven initiatives in this space (Valenti (1996)). Thirdly, the lessons of countries such as the Republic of Ireland indicate that simply educating people in advanced technologies is not enough. An enterprise culture, along with strong management disciplines, is also necessary for emerging economies where existing opportunities may be few.

All this suggests a new type of degree programme, requiring a non-traditional approach to curriculum development in engineering and advanced technology. This in turn implies a new approach to the development of higher education inter-disciplinary programmes.

3. ENGINEERING MANAGEMENT EDUCATION & MECHATRONICS MANAGEMENT

Up to now, conventional engineering education throughout Europe, has been dominated by technical subjects, and has had little to offer in interdisciplinary academic training. Topics relating to economics, business management and jurisprudence have been considered voluntary exercises or professional post-formation needs rather than compulsory subjects. Vice versa, graduates from business schools, for example, have rarely had the chance to extend their knowledge in technical fields.

Fischer (2004) compared 138 Engineering Management Programs worldwide. His results are summarized in Figure 1. Figure 1 summarises the key subjects covered across these programmes. Firstly, it is apparent from the figure that the subject domain typically includes a combination of technical and non-technical subjects focussing upon general engineering. Secondly, figure 1 implies a high demand for graduates with non-technical skills from these programmes, as compared with the skill profiles of graduates. This further suggests an imbalance in the profiles of the programmes as against the demands of the organisations that employ the graduates of the programmes.

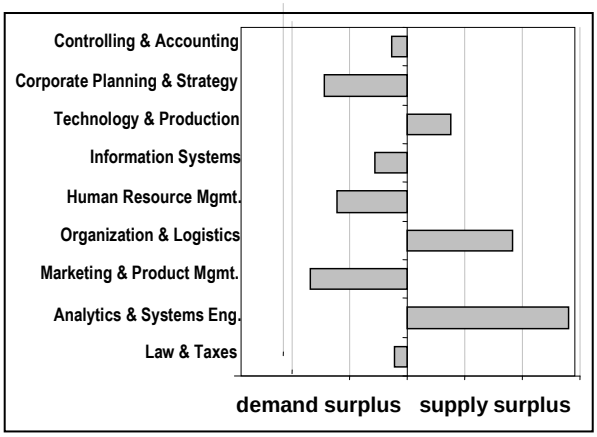

Figure 1. Summary of Results of Review of Engineering Management Programmes (adapted from Fischer (2004)).

Mechatronic managers possess the core skills of mechanical engineers and electrical engineers as well as management and business. Their knowledge enables them to solve a wide range of mechanical, electrical and software problems, allowing them to participate in and lead multidisciplinary design teams. Mechatronics managers have particular opportunities in Kosovo. For example, the rich geology of Kosovo means that mining, which makes significant use of mechatronics devices, has particular potential for mechatronics managers.

4. DEVELOPING A KOSOVAN MECHATRONICS MANAGEMENT PROGRAMME

Typically, innovation in science, technology and engineering education has been somewhat constrained by well-established faculty structures present within European universities. It was recognised that the educational context provided by a completely new university in Kosovo (i.e. UBT) was ideal for reworking engineering education curricula along more interdisciplinary lines as is proposed by the recent developments in education research in this domain. The establishment of UBT as a completely new higher education institution in 2004 provided an excellent opportunity to work across traditional faculty boundaries, whilst ensuring the course is well anchored within a particular disciplinary domain. UBT represented a 'green-fields' site with a small but extremely motivated staff and student body. The development team recognised that a programme in mechatronics could therefore be designed and delivered along truly multi-disciplinary lines. This would enable the programme to be more grounded in the reality of mechatronics in its industrial setting.

5. CURRICULUM DESIGN: THEORETICAL APPROACH

Although the Kosovan economic situation would seem to be a long way from the western small-knowledge economy model, it was felt that a radical approach should be adopted in curriculum design. This radical approach needed firm foundations in recent education research.

This provided an opportunity to develop a green-fields approach to curriculum design. Whilst it is beyond the scope of this paper to unpack fully the various theoretical frameworks which were used to inform the final mechatronics programme, it is important to outline the three primary literatures incorporated into the theoretical approach:

1. Curriculum design (IS (2002), Computing Curricula (2001), SWEBOK (2000), SWECOE (2000)
2. Professional-isation of knowledge-work (Drohan (2005), IIvari (2002), SWEBOK (2000), SWECOE (2000), Iivari & Linger (1997) & (1999))
3. Professional competence (Devereux (2004), Carlile (2001), Down et. al. (1999))

5.1 Curriculum Design

Surprisingly, mechatronics has received comparatively little attention from engineering education researcherz. Since ten years ago concerns have arisen in the literature about how to best prepare under-graduate engineers to work with such technologies in organisational contexts. Academicians and engineering managers have identified several key areas for engineering educators to focus on, in particular in topics such as mechatronics and information technology. Serious criticisms of engineering curricula, especially in emerging areas such as mechatronics, gathered momentum in the mid-1990s. In 1995 research conducted by members of the American Society for Engineering Education (ASEE) indicated that engineering curricula were generally falling far short in terms of developing the professional competences engineering under-graduates required for the workplace (Masi (1995)). One of Masi (1995)'s key recommendations included 'together with business schools and industry, engineering schools should develop innovative programs for advanced degrees' (p. 44). This has not proved easy to achieve given historical demarcation between business and engineering faculties (for example). Valenti (1996) argued that mechatronics engineers require significant contextual preparation at undergraduate level. He further argues that many higher education institutes are struggling to meet the curriculum needs in this space, citing a variety of educational and administrative barriers. Similar insights were set out in Vest, Long & Anderson (1996)'s report of a national survey of the professional experiences of electrical engineering graduates conducted in the USA. In this study 'soft-skills' such as interpersonal communications rated very high in importance. What these, and subsequent, research articles clearly demonstrated was the need for a coherent theoretical approach to the development of engineering

education curricula which enabled undergraduates develop the necessary professional competences to perform there jobs on graduation. This challenge remains today.

The development team assessed the primary sources of guiding frameworks for science, technology and engineering education as follows: Institute of Electrical and Electronic Engineering (IEEE), Association of Computing Machinery (ACM), the British Computer society (BCS) and the International Federation of Automation and Control (IFAC). Also reviewed were the International Standards Organisation (ISO) publications. There was a singular lack of coherent frameworks which are based upon competencies associated with graduates of educational programmes in these fields.

5.2 Professional-isation of knowledge-work

Iivari (2002) developed a comprehensive framework for knowledge-work-oriented curricula. The authors adapted this work to provide underlying theory to inform the programme (see fig. 2). Drohan (2005) noted the need for educationalists in knowledge-work to provide a problem-centred approach in the delivery of these programme. Consequently, the authors focussed a great deal of attention on the design of two mechatronics laboratories.

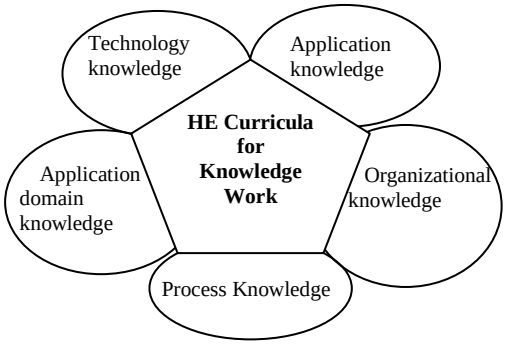

Figure 2. Higher Education Curricula for Knowledge Work (Adapted from Iivari (2002)).

The first laboratory was based upon a 'real-life' manufacturing environment to place mechatronics problem in some real-life context. Problem solving education also benefits from a 'playful' competitive setting which involves both team-oriented activities and multi-disciplinary activities. Consequently, the authors designed a robot-soccer laboratory.

In assessing theory of the professionalisation of knowledge-work as it applied to the design of the programme, it became apparent there was a need to include professional competence theory.

5.3 Professional competence

Professional competence theory provide to be of particular importance to the development of this programme, included Devereux (2004) in which she studies professional competence amongst ICT graduates in industry. In setting out her framework of information technology professional competence Devereux (2004) draws upon several literatures, including education, IT, Management and Engineering. Devereux described the following key dimensions of educational competence for information technology and systems professionals:

1. Technical Competence: the individual has sufficient subject knowledge and can plan and organise so as to achieve maximum results
2. Administrative Competence: the individual has a range of business knowledge, can follow rules, procedures and guidelines set out by the organisation and can perform to the expected standards set out by the organisation
3. Ethical Competence: The individual has moral standards which guide them in their decision making activities in the work environment
4. Productive Competence: The individual is efficient and capable of producing desirable results. Productive competence particularly focuses upon the capability of the professional to continuously develop their knowledge and skills.
5. Personal competence: The individual can manage time, possesses necessary 'people skills', time management, communications and conflict management skills to operate effectively in the working environment:

In terms of *technical competences*, the fundamental courses provide essential knowledge of mechatronics through related disciplines. The main focus is on natural science so that a solid foundation is scheduled for basic knowledge. This includes Mathematics, Physics, Chemistry, Engineering mechanics, Materials, Computer Science, Information Technology, Electrical Engineering and Electronics. From the Business side fundamentals are given on Economics, Accounting and Statistics. This will address both Administrative and Technical competences. It also demonstrates an attempt to address the broader definition of 'technical competence' set out in the competency framework.

What Carlile (2000) calls '*administrative' competence* has been demonstrated by Devereux (2004) to be central to professional competence in the work-place. This includes what is commonly referred to as "knowledge of the business" and an ability to follow correct standards and procedures. Standards are critical in professional work, especially in science, engineering and technology fields. Standards here refer to technical specifications, evaluation and approval of documentation (e.g. associated with work practices) (Schmidt (2000)). In Devereux (2004)'s study, business knowledge proved extremely important to professional competence, independent of the level of technical content within the job. Consequently, the programme development team focussed much attention upon developing curricula which would enable a mechatronics graduate to be conversant with business issues, and

appreciate these in the context of the implementation of mechatronics technologies.

According to Hersh (2000) the ever increasing advance in technologies has required a deeper and deeper consideration of ethics in engineering and the sciences. Professional ethics is receiving increasing attention amongst science and technology researchers, as well as in the education and business literature (c.f. Hersh & Stapleton (2004), Devereux (2004), Badiou (2001), Shaw (1996)). For this programme ethics deals with making decisions and judgements applied in an engineering and technology deployment context and will incorporate both ethical standards and a concern for other stakeholders such as technology users. The programme development team have incorporated ***ethics*** as a mandatory subject for the curriculum. Very few engineering and technology undergraduate programmes in the western hemisphere incorporate ethics as a major subject so that this is a relatively new approach. The programme development team have also incorporated a more advanced ethics syllabus into the programme as an elective in the final year.

Productive competence refers to the ability to 'learn-to-learn' and the thinking skills central to knowledge-based roles. The preparatory course also, uniquely, incorporates 'Creativity and Learning Skills' to provide a basis for developing productive competences as set out in the programme's competency framework. This competence is closely related to the 'knowledge' competence (sic) (in Technical Competence in this framework). Much of the research on higher education learning has focussed upon delivery methods, especially criticising didactic forms of delivery. Consequently, this programme has emphasised practice-based learning and problem-centred learning.

Devereux (2004)'s research indicated that personal competence extremely importance in knowledge-work. She particularly noted the importance of conflict management and time-management skills. In addressing the first competency set the mechatronics programme team believed that a focus upon inter-personal communications would be adequate. However, other programmes specifically deal with conflict management and this may prove to be a weakness of the current programme, especially given the position of mechatronics at the intersection of multiple disciplines. As with numerous other programmes the issue of team working is primarily addressed through the delivery modes designed into the programme. The course is also preceded by courses in business communications in order to instil in students, at the earliest possible date, the importance of communication skills.

The final year BSc. Thesis proves candidates ability to describe a special but usually very narrow field of interest with deepen study. Through the integration of enterprise studies and related management knowledge in the program, it is envisaged that participating students will have the necessary skills and know-how to operate the work for their thesis into business start-ups, and then directly supporting the economic growth aspirations of their region.

4. SUMMARY

The proposed program provides broad-based bachelor-level education in the basic principles of electrical, mechanical and computer engineering as well as business and information systems. It fills a major gap in current mechatronics programmes by focussing, in a balanced way, upon both technical and non-technical aspects of mechatronics management. In particular, the focus upon enterprise, systems engineering and mechatronics, as well as the provision of a broad foundation in science, ensures that graduates will be sought after by a wide variety of prospective recruiters. Furthermore, graduates will have the necessary acumen to start-up their own companies which is a critical issue for the development of the emerging Kosovan economy.

This program is consequently one of the first trials worldwide to educate " Mechatronic Managers" and is certainly the first to base such a programme in an emerging, post-communist economy .

The essential ingredients set out above are unique for the proposed program of study in a number of ways. Firstly, they are dedicated to the special interests of participants in their real-life work context. Secondly, the foundation program provides a wide range of key competencies from computing and engineering to soft skills and management in a single engineering degree. And reflect the theoretical foundations set out earlier in this paper.

Usually Mechatronics programs are pieced together from a combination of lectures from existing engineering programs and they can be considered therefore as an incomplete mosaic. In this programme the authors had the opportunity (and challenge) of designing an entire mechatronics degree program from the start in a green-fields site in an emerging economy. The program is particularly dedicated to realities of small and medium enterprises in small (developing) countries without ignoring the requirements of large engineering employers. The difficulties involved in balancing all these goals in a single objective, and creating a single coherent programme should not be underestimated. The main goal of this program is to educate engineering managers in the field of mechatronics with specific emphasis upon new companies so that the graduate can start-up, expand and manage effectively a small or medium-sized companies.

6. CONCLUSION

The bachelor's degree in mechatronics briefly outlined here takes advantage of the university of business and technology as a relatively green-fields site in which inter-disciplinary curricula of this sort are ideally suitable. IT also recognises the unique circumstances in Kosovo, including the aspiration of

the Kosovan administration to move towards a knowledge-economy. The programme design has been completed and will be offered to students in September 2006. It is currently being promoted in the region.

Proposition 1 asked if it is possible to develop an advanced technology programme for higher education in an emerging economy where recent instability has been high. The findings suggest that it is possible.

Proposition 2 asked if is it possible to develop such a programme so that it has internationally recognised unique selling points. This has also been found to be true. The programme outlined here takes advantage of the unique situation of the University of Business and Technology as well as the unique opportunity to develop the first mechatronics management programme in the Balkan region. However, in order to ensure this uniqueness, a series of tradeoffs were necessary in the curriculum design. Imn order for these trade-offs to be well reasoned, the design team required a complex theoretical framework by which to inform curriculum design decisions. This proved to be a non-trivial exercise.

Proposition 3 asked if this programme can underpin knowledge-based economic activities in a local economic context. This was shown to be probably true. It required a coherent framework by which to inform decisions, particularly in assessing what competencies are needed in knowledge-work. The inclusion of enterprise studies, creativity, problem centred learning etc. as well as the balancing between the various professional competencies developed in the programme, indicate that this proposition is also likely to be true. At the time of writing it is felt that this proposition is only partially validated. We shall only know if knowledge-based activities are genuinely demonstrated as a result of the programme when the first graduate sets up her mechatronics engineering business in Kosovo.

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REFERENCES

Ashley, S. (1997). 'Principles of Mechatronics', *Mechanical Engineering*, May (feature article) http://www.memagazine.org/backissues/may97/features/mechtron/mechtron.html

Badiou, A. (2001). *Ethics: An Essay in the Understanding of Evil*, Verso: London.

Carlile, O. (2000). *Incompetent Teachers in Irish Voluntary Secondary Schools: Principles' Asessments, Attitudes and Reactions*, Ph.D. Thesis, University of Hull.

Cheong Cheng, Yin, Hung Ng, Kwok, Ching Mok, Magdalena Mo (2002). "Economic considerations in education policy making: a simplified framework" *Intntl. Jour. of Educational Mgt.* 16, 1, pp.18 - 39

Computing Curricula (2001). *The Joint Task Force on Computing Curricula*, IEEE Comp. Soc/ACM.

Devereux, N. (2004). *Information Technology Professional Competence: An Empirical Study of Irish Higher Education*, M.Sc. Thesis, WIT, Ireland.

Down, C., Martin, E., Hager, P. and Bricknell, L. (1999). 'Graduate Attributes, key competence and judgements, exploring the links', *Proc. Of HERDSA Annual International conference*, Melbourne

Fischer, G. (2004): *Industry and Participant Requirements for Engineering Management*. PhD Thesis; VUT, Vienna

Stapleton, L. & Hersh, M. (2004). 'Technology Development and Ethical Decision Making: Identity Factors and Social Construction', *Proceedings of International Multitrack Conference of Advances in Control Systems*, Tech. Univ. of Vienna, Elsevier.

Iivari, J. & Linger, H. (1997). 'What is knowledge work?", Burnstein, F, Linger, H. & Smith, H. (eds.), Proc. Of t*he International conference of Information Systems Development*, Melbourne pp. 131-144.

Iivari, J. and Linger, H. (1999). Knowledge Work as Collaborative Work: A Situated Activity Theory View, *Proceedings of the 32nd Hawaii Inter-national Conference on System Sciences.*

Jones, O. & Tilley, F. (2003). Competitive Advantage in SMEs: Organising for Innovation and Change, J. Wiley: NY.

Iivari (2002). Towards A Distinctive Body of Knowledge for Information Systems Experts: A Knowledge Work Perspective, IEEE.

IS (2002). *Model Curriculum Guidelines for Undergraduate Degree Programmes in Information Systems*, AIS.

Masi, C.G. (1995). 'Re-engineering Engineering Education', IEEE Spectrum, **32(9)**, pp. 44-48.

Shaw, W. (1996). Business Ethics, Wiley: NY.

Schmidt, M. (2000). *Implementing the IEEE Software Engineering Standards*, SAMS Publishing.

SWEBOK (2000). "SWEBOK: Guide for the software engineering body of knowledge", IEEE Computer Society: MA.

SWECOE (2000). "SWECOE: Code of ethics and professional practice", IEEE Computer Society: MA.

Valenti, M. (1996). Teaching tommorrow's engineers', Mechanical Engineering, 118/7 (July), pp. 64-70.

Vest, D., Long, M., Anderson, T. (1996). **'**Electrical engineers' perceptions of communication training and their recommendations for curricular change: Results of a national survey', *IEEE Trans. on Professional Communication*, **39(1)** pp. 38-43.