Global Education in Manufacturing: Basic Framework, Industrial Survey and Possible Implementation

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Many new challenges and opportunities have arisen for Slovenia since May 2004 when it became a full member of the EU. On the one hand we have some successful economic players who can definitely gain from new opportunities, on the other hand some structural changes still have to be accomplished. One of the most demanding tasks is related to higher education and in particular to harmonization of EU and global educational systems. The paper presents the results of the international framework for a Master degree curriculum in manufacturing strategy and an example of the integration of competence in technology and business. A good example of meeting Bologna goals is to establish a system of easily recognisable and comparable educational degrees and to accelerate the employment of EU citizens as well as the competitiveness of the European higher educational system.

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Introduction

A few years ago Ridderstråle and Nordström published their best-seller *Funky Business* (2000) where they said:

> With the introduction of the plantation we moved from the hunting and gathering society into the agricultural one, and, with the coming of electricity, we entered the industrial era. Some call our world the knowledge society and others the brain one. The only certain thing is that the critical skills and answers of tomorrow will not be those of today. The future cannot be predicted – it has to be created. Either you see things happen or you make them happen.

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Managing Global Transitions 4 (3): 261–278

A similar observation considering the recent development within the industry has been written by Moseng and Rolstadås (2002):

> The industry has over the last decade undergone a significant change. It is no longer home-based; it operates in a global market. Digital business has become a strategy to survive. The extended enterprise is being implemented. Parts are made where conditions are most favourable. Non-core activities are outsourced. These service companies then become part of the supply chain that also spans suppliers and distributors. They all comprise an international co-operative network to provide manufactured goods and support services for a world market just in time, at low prices and with quality surpassing customer's expectations.

And also (Rolstadås 2004):

> In order to meet the challenge of the future way of business operation for the manufacturing industry, a new type of curriculum in manufacturing strategy is needed. For this reason the IMS project Global Education in Manufacturing (GEM) has been launched. The main objective of GEM is to develop a new curriculum covering both manufacturing technology and manufacturing business – a Master degree in Manufacturing Strategy.

At the first GEM information day within the annual professional conference of the former School of Management Koper, this new approach of education in manufacturing was presented (Dolinšek and Prodan 2003). Furthermore the tasks of SMK as a Slovenian partner, the products, expected benefits, and the first experiences obtained in the GEM project were discussed. However one of the main questions was whether it is possible that something developed within the GEM approach can also be successfully applied to the development of the education curricula in Slovenia. In relation to such a question Dolinšek (2002) concluded that:

> The very first question to which we need to find an answer in relation to such global education activities should certainly be: is such a global education system suitable for the Slovenian specialties with respect to the recent form of the educational system (five years of engineering study and three years of further scientific Master's degree study), and is this approach or

> are these curricula also appropriate for the specific needs of the Slovenian manufacturing industry?

Thinking about such a dilemma and about the necessary skills and knowledge of Slovenian engineers in relation to the GEM approach Dolinšek (2003) also stated that:

> In respect of the other NAS (Nearly Associated States) Slovenia has a relatively highly developed industry, which also largely contributes to the whole export from the country. To a large extent the main competitive advantage of this industry is based on professional skills and knowledge of engineers and the extensive investment of companies in the education of the workforce. We can establish that in that sense the needs for skills and knowledge of many Slovenian manufacturing companies are far ahead from what the academic institutions can provide. Therefore links and benefits, such as those provided through the GEM project, can be an excellent support for Slovenian educational institutions on their way to becoming part of the global education system.

On the basis of a response from the Slovenian industry (these tasks were completed within the GEM project) we also published the results (Dolinšek and Prodan 2004) and concluded that:

> One of the most important demands in developing the new curriculum is, therefore, firstly to define and understand the needs of the manufacturing industry for training and education on a global basis. The approach presented forms part of the international GEM project (Global Education in Manufacturing), a project in which Slovenia is also involved as a partner, and some experiences obtained in the GEM project and research into the needs in the education of the manufacturing strategies are also presented.

At the GEM workshop organized within the international IMS Forum 2004, where we presented our efforts and results in introducing GEM curricula into the Slovenian educational practice, it was also stated that (Dolinšek, Starcic, and Kopac 2004):

> Many new challenges will arise for Slovenia as a full member of the EU from May 2004, and also many opportunities. On the one hand we have some successful economic players who

> can definitely gain from new opportunities, but on the other hand some structural changes still have to be accomplished. Among them, one of the most demanding tasks is related to the higher educational system which has to be harmonized with the EU and global educational systems. The paper discusses the above mentioned problems and puts particular emphasis on the needs of the Slovenian industry, particularly those related to the competencies, as a contrast to the discipline-based education practice mainly offered by Slovenian universities. Links and benefits, such as those provided through the GEM project, can be an excellent support for Slovenian educational institutions on their way to becoming part of the global education system.

The actions that followed were focused on the implementation of GEM curricula in relation to the changes of educational programmes due to the Bologna declaration and the Slovenian law on higher education (Slovenian GEM industrial workshop), the last achievements of the GEM project, the possibilities of introducing GEM results into the Slovenian universities, and also on the GEM industrial training model.

Competences Needed in Modern Manufacturing

In the most general sense, manufacturing is central to the existence or survival of a business, and the manufacturing industry is a key industry. The activity of manufacturing is much more than machining metals or etching wafers: a manufacturing enterprise is an extended social enterprise. Within the manufacturing industry, challenging activities influencing competitiveness are therefore connected to radical new ways of operating (digital business) and to new products (extended products).

Digital business involves an advanced use of the information and communication technology in every link of the supply chain to simultaneously reduce costs and lead times and to increase profit. Interesting problems are connected to e-commerce within the manufacturing systems design and production management, and e-commerce within the design and product development. In this context, manufacturing should not be understood in the traditional sense but as a new way of working as a digital business with extended products. Extended products mean taking a lifetime product support perspective and thus including all services to support the product in addition to the manufacturing of the product itself.

This will require that intelligence is embedded in the product. It includes both tangible and intangible products and services. The main challenge is within the support services for the product. Digital business significantly accelerates the flow of information within the extended enterprise. The creation of extended products through digital business is illustrated in figure 1.

In manufacturing companies the required knowledge, skills and engineering competence are provided by mechanical engineers, industrial engineers and electrical, electronic and computer engineers. Their basic education is discipline oriented, focused on mechanics, operation research, cybernetics, electronics, etc. To a limited extent this education reflects the real needs of the industry that faces problems of an integrative nature across the traditional disciplines such as:

- working with digital tools for communication;
- working in a multicultural environment;
- working in interdisciplinary, multi-skill teams;
- sharing of tasks on a global and around-the-clock basis;
- working in a virtual environment.

The existing curricula for Masters in manufacturing are directed more towards manufacturing engineers rather than the manufacturing strategy. They have often tended to emphasize theory over the process and have failed to meet the needs of the manufacturing enterprises operating as future extended and virtual enterprises.

A curriculum in Manufacturing Strategy will be designed for a Masters programme. It will be based on traditional engineering bachelor degrees. However, it will deviate from the traditional education by focusing on tomorrow's industrial situation, requiring enterprise architects and products architects. The future education in Manufacturing Strategy must build the industrial competence by providing a learning atmosphere in the company (a co-operation between academia and industry).

The competence areas have been divided into three main areas (for a detailed overview of all topics see Dolinšek and Prodan 2003):

- technological competence (Product related topics, Production related topics, Business operation related topics),
- humanistic competence (Individual related topics, Company related topics),

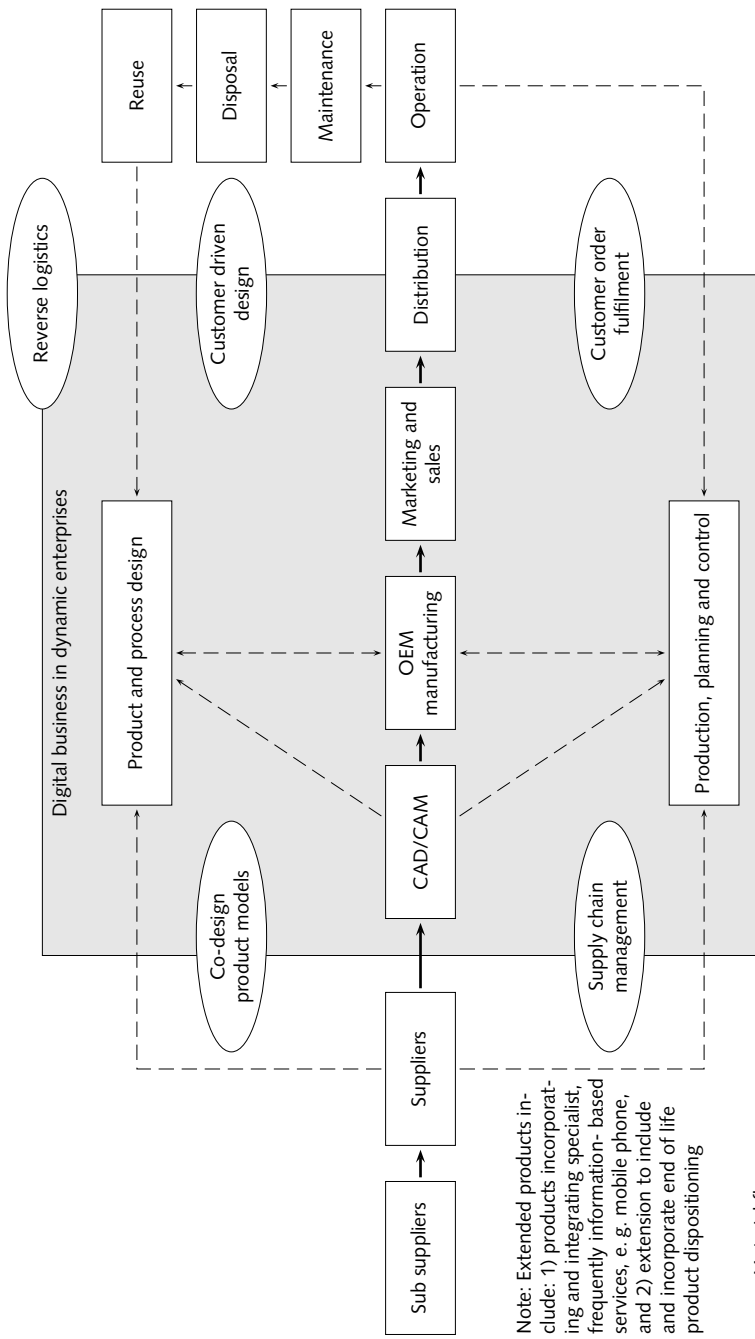

FIGURE 1 The concept of digital business and extended products (GEM-NAS 2002)

- business competence (Business and economic related topics, Management related topics).

The companies were asked to rate on scale 1–5 the importance of the topics today, and in five years time. They were also asked about the needs for future education and training.

SURVEY METHODOLOGY

The survey was undertaken in the manufacturing industry worldwide in order to get the industry point of view on education for the development of an international curriculum. The questionnaire was developed and conducted by SINTEF Industrial Management, Norway. The construction of the questionnaire was focused on measuring current needs and practices in the industry as well as getting an idea about future development.

The questionnaire was divided into two parts; the first part covered the general demographical information to be used as classification variables for the analysis, and the second part covered the competence areas. Within each competence area the companies were asked to rate the importance of different pre-selected topics for their job performance today, within five years, and also rate the need for further education and training (scale 1–5, from no importance to high importance).

The survey was accessible on the internet to a contact person in each country. In addition a paper version was sent to the contact persons. The questionnaire was in some cases translated in order to meet language problems in different countries. There were three different ways of sending the questionnaire to the companies. If the internet-version was used, the contact person forwarded the mail containing the link to the questionnaire to the companies after entering contact information. After the companies had entered their information into the scheme the results were transferred directly to the database. The two other ways of data collection were to send the paper copy by mail to the companies or to interview persons at the companies either by personal interviews or by telephone. In both cases the filled in questionnaires were handled by the national contact person, who entered the information into the electronic scheme and sent them directly to the database.

Research was conducted from September to December 2002, and 21 countries responded to the questionnaire (17 from EU, USA, Australia, Japan and Korea). Within the sample of 556 companies, 20 respondents were from Slovenia. The companies were divided into three groups refer-

TABLE 1 Importance of different competences (%)

	Slovenian research	GEM research
Management-related topics	14.65	14.47
Business & Economic-related topics	13.55	14.11
Company-related topics	14.65	14.22
Individual-related topics	14.65	13.83
Business operation-related topics	13.55	14.11
Production-related topics	13.92	14.50
Product-related topics	15.02	14.75

ring to size in number of employees; with group 1 having 1–250 employees, group 2 having 251-1000 employees and group 3 consisting of companies with more than 1000 employees. All statistical analysis was performed using the program SPSS, version 11; descriptive statistical analyses were applied and correlation analysis was based on relation to region and company size.

SURVEY RESULTS

Survey results show that the industry considered all competences almost equally important (see table 1). The most important competences are product related (in GEM and also in the Slovenian research).

A comparison of results obtained in all IMS regions and in Slovenian companies is shown in table 2. We can see that there are some similarities between the results.

If we analyse which competences are important today and try to find out which will be important within 5 years we can conclude that:

- topics which are important today also need education in the future;
- less important topics today (remanufacturing of products, simulation in production, sustainable manufacturing, simulation in business operations, multicultural skills, e-learning . . .) seem to be more important in the future;
- all proposed topics need a focus in a new curriculum.

The GEM framework identifies seven core knowledge areas within any new manufacturing curriculum all of which reflect the current and future needs of the manufacturing industry. Table 3 shows an overview of the knowledge areas.

A skeletal framework is illustrated in figure 2. The framework has a

TABLE 2 Today's importance of competences in industry (mean values)

	Slovenian research[1]	GEM research[2]
Management-related topics		
Finance	3.9	3.6
Innovation management	3.3	3.7
Change management	3.8	3.6
Management information	4.0	3.6
Benchmarking/Performance	3.7	3.5
Productivity improvement	3.9	4.0
Entrepreneurship	3.3	3.4
Strategic Planning	4.1	3.8
Health, Environment	3.9	3.7
Legal aspects and Intellectual	3.4	3.6
Business & Economic-related topics		
Marketing & Sales	4.2	3.8
E-commerce	2.1	3.0
Procurement & Contract management	4.1	3.7
Cost engineering/Cost management	4.2	3.9
Branding	3.6	3.7
Company-related topics		
Organizational aspects	3.7	3.8
Knowledge management	3.4	3.7
E-learning	2.8	3.2
Interdisciplinary team (building)	3.3	3.4
Multicultural strategy	2.8	3.2
Corporate social responsibility	3.0	3.5
Company culture	3.3	3.6
Company image and branding	3.8	3.9

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number of elements. Students will enter a particular programme with a bachelor's degree and may or may not be induced into the programme or university through a series of induction, bridging or capstone courses or workshops. The details of these activities are solely the responsibility of the university concerned. A number of courses will then be available to students. Universities do not offer courses in advance. On the contrary,

TABLE 2 *(continued)*

	Slovenian research[1]	GEM research[2]
Individual-related topics		
Creativity	4.0	4.0
Interpersonal communication skills	3.8	4.2
Multicultural skills	2.9	3.4
Teamwork capabilities	3.9	4.3
Motivation	4.0	4.2
Business operation-related topics		
Enterprise modelling	2.7	3.3
Extended enterprise design	2.9	3.2
Extended enterprise operation	3.1	3.1
E-work	2.7	3.2
Project management	3.5	3.9
Logistics and Supply chain management	4.1	3.6
Simulation in business operation	2.5	3.0
End-of-life management	2.4	3.2
Quality management	4.1	4.2
Production-related topics		
Intelligent manufacturing	2.5	3.5
Manufacturing technology	4.0	4.1
Material flow	3.5	3.8
Manufacturing systems	3.6	3.8
Simulation in production	2.5	3.3
Cleaner production	3.3	3.4
Sustainable manufacturing	2.8	3.3
Product-related topics		
Product development in general	4.1	4.0
Extended product development	3.7	3.6
Simulation in product development	2.5	3.5
Clean products	3.4	3.3
Remanufacturable products	1.6	3.0

1. $N = 20$ 2. $N = 556$ Source: Dolinšek and Prodan 2004.

they will develop courses on the basis of their core competencies on campus. However, the GEM framework will be available to help educators in identifying and specifying courses of interest.

Managing Global Transitions

TABLE 3 GEM knowledge areas (Rolstadås 2004)

Knowledge area	Description
A Development of extended products	The development of a combination of a physical product and associated services/enhancements that improve marketability.
B Digital business along the supply chain	Information on how a business can use e-commerce and related technologies and processes to develop, expand or enhance its business activities along the facilities and functions involved in producing and delivering a product or service.
C End of life planning and operation	Techniques on how to develop methodologies and tools to support the end-of-life routing/processing decision based on economic, environmental and societal criteria.
D Business operation and competitive strategy	Explanation of how organizations function and interact with competitors and their market place, and deliver performance over time.
E Intelligent manufacturing processes	Elaboration of techniques applicable for handling complex production working in an uncertain, changing environment, with special emphasis on artificial intelligence and machine learning approaches.
F Intelligent manufacturing systems design	Tools on how to model the skills and knowledge of manufacturing experts so that intelligent equipment and machines can produce products with little or no human intervention.
G Enterprise and product modelling and simulation	Information on how to develop and use computational representations of the structure, activities, processes, information, resources, people, behaviour, goals and constraints.

Industrial Training

The GEM curriculum is developed for a Masters degree to be delivered at universities. To implement this, the GEM Alliance has been formed.

In addition, GEM Europe has the ambition to deliver appropriate training to people working in industry. Such students will, however, differ from campus students:

- the student will pursue his/her studies while working;
- students can only be away from work for short periods, normally not more than one week at a time;
- training will have to be delivered at the place and at a time the student decides;
- the student will not directly select an extensive programme, but would rather build a training from smaller components;
- the company of the student may be supporting such training both financially and morally.

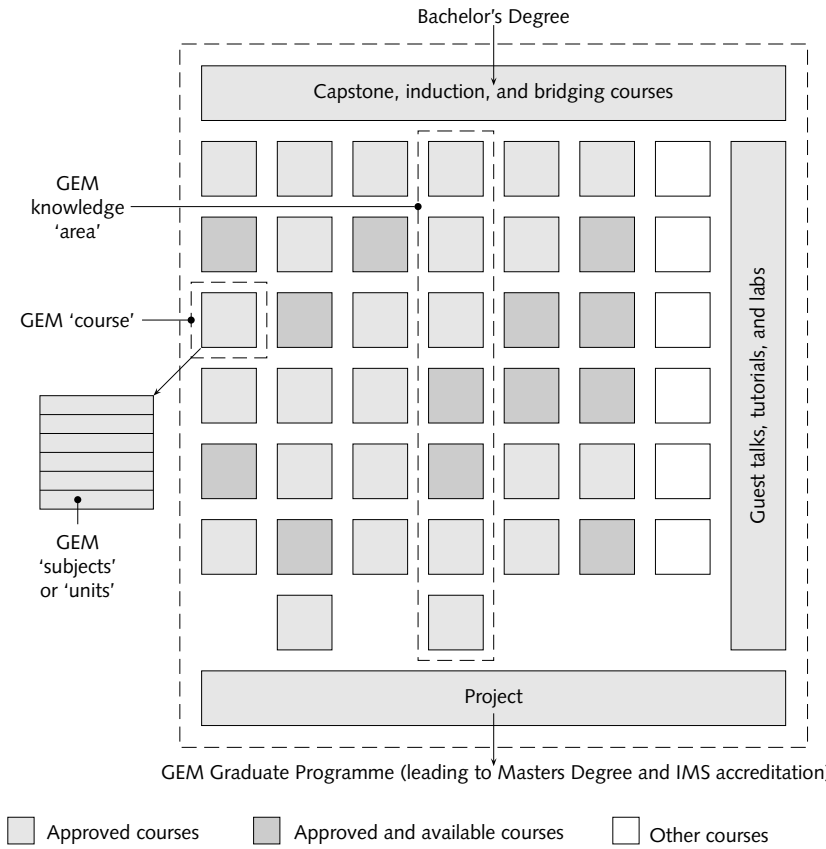

FIGURE 2 The GEM framework skeleton (Rolstadås 2004)

These differences create a need for a different learning approach:

- the training has to be modular so that the student can 'take small steps' towards a full training;
- the student will have access to real life problems and examples from own company;
- training will have to be based on blended learning.

Blended learning is an approach that has proven successful in other cases. This means that the students meet as a class in plenary sessions for a limited number of times, and that they work individually or in small groups by learning over the internet using a learning portal (virtual sessions). Learning over the internet has been tested through the GEM demonstrator which gave a positive feedback on the approach. An

important issue, though, is an interactive supervision with a moderator or a teacher. This has proved to be one of the most critical success factors in e-learning. Unfortunately, it is a factor that is overlooked in many of existing e-learning offers in the market where the focus is often on the portal's learning management system.

It is suggested that GEM Europe adopts a blended learning approach as follows:

- two plenary sessions; one at the beginning and one at the end;
- a number of virtual sessions in between; each session to be carried out within a given time window;
- plenary sessions to provide learning through the interaction between students and by an extensive use of industrial experts;
- virtual sessions to include various activities such as readings, video lectures, slide-shows, assignments and tests;
- optional project assignments going over the whole learning period, to be executed in small groups and to be based on real life problems in the students' companies.

A STRATEGY FOR INDUSTRIAL TRAINING

For the GEM Europe partners a possible strategy for implementing industrial training could be based on the following items:

- interested partners will form an, alliance or some other form of partnership, to be regulated through a memorandum of understanding or an agreement;
- the partners operate a common training programme so that learning objectives and skills attained are the same across all partners;
- training to be offered at two levels:
  1. engineer update level and
  2. executive level;
- training to be offered on an annual basis;
- exchange of students, courses and teachers.

What follows is a brief introduction to an implementation model for each of the two levels.

TRAINING AT THE ENGINEER UPDATE LEVEL

Training at an engineer update level could be named GEM Manufacturing International Update. A possible delivery model is shown in figure 3.

It is assumed that similar programmes following the same model with the same objectives are offered annually by each partner in their own country. The schedule should be synchronized in order to allow a student exchange.

Each of the two plenary sessions is offered by each participating partner. Lectures may be in the local language. The first will focus on knowledge area B and the second will be devoted to presentation and discussion of the project assignments. Students may be exchanged, i. e. a single student may choose to follow a plenary in a country different from the host university.

The student will have to select four virtual sessions. Each partner will normally offer at least one virtual module of 2 ECTS. There may be several modules in each knowledge area, allowing the student to select which one to follow. However, at the end all knowledge areas will have to be covered to obtain a certificate.

Each partner delivering a virtual module will be responsible for handling all students that follow this module.

The student is enrolled at one university (Host University). Credits earned at other partnering universities will have to be acknowledged by the host university that will issue the final certificate upon completion.

The student should be able to take single modules and gradually build up a full curriculum for the certificate. There will be separate course fees for each of the plenary and virtual modules as well as the project assignment. These are payable to the host university which in turn will reimburse the other partners depending on which modules the student follows. There will be an administrative overhead for the host university.

TRAINING AT THE EXECUTIVE LEVEL

Training at the executive level could be named GEM Manufacturing Executive International Forum. A possible delivery model is shown in figure 4. There will be one fixed programme with fixed locations and a virtual session per year. Locations will rotate amongst the partners. The whole training is delivered in English.

Both plenary sessions will focus on knowledge area D. The education will be highly interactive, drawing upon international experts from the manufacturing industry and with the universities in a facilitating role.

The student will follow all four virtual sessions. Each session will be offered by one of the partners. The training in virtual sessions will follow the same approach as the engineer update level.

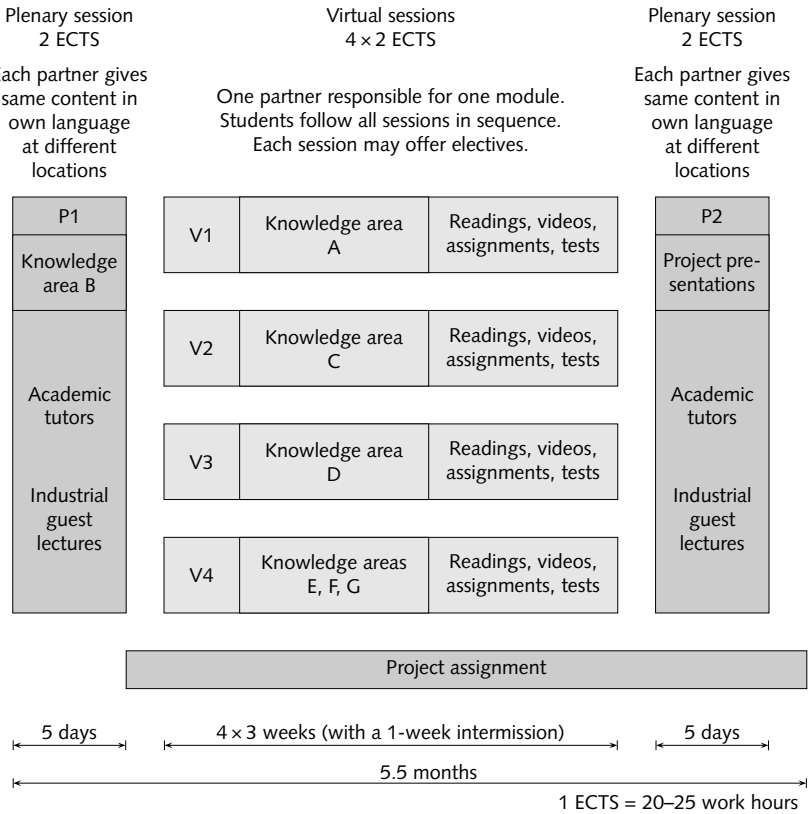

FIGURE 3 Model for training at the engineer update level

The student is enrolled at one university (Host University). Credits earned at other partnering universities will have to be acknowledged by the host university that will issue the final certificate upon completion.

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Conclusions

The main objectives of GEM were to define and understand the needs of the manufacturing industry for training and education in manufacturing strategy on a global basis to comply with the concept of digital business, extended products and entrepreneurship. On the basis of the

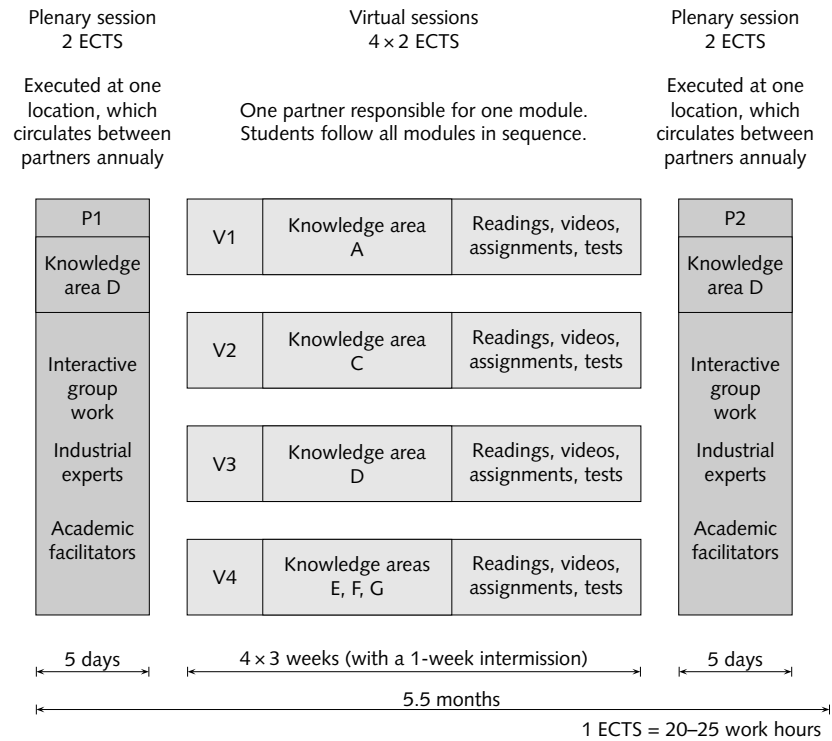

FIGURE 4 Model for training at the executive level

survey among all IMS regions compared by Slovenian companies we can conclude that there are similarities between the results. If we compare those results with the importance of competence in five years we can see that:

- topics which are important today also need education in the future;
- less important topics today (remanufacturing of products, simulation in production, sustainable manufacturing, simulation in business operations, multicultural skills, e-learning, etc.) seem to be more important in the future;
- all proposed topics need a focus in a new curriculum;
- concerning technological competence product development in general, the product related manufacturing technology and quality management are considered as most important topics;
- among the humanistic competences, teamwork capabilities and image and branding seem to be the most important;

- within the business competences, cost management and productivity improvement are considered as the most important topics.

Slovenia has a relatively highly developed industry that needs professional skills and knowledge of engineers not only in the field of engineering but also in the business field. We know that the need for skills and knowledge of many Slovenian manufacturing companies is far ahead from what the academic institutions can provide; a co-operation between industry and academia is therefore necessary. The GEM project is based on industry needs and can thereforebe an excellent example of how to prepare new curricula.

Acknowledgments

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