IT EDUCATION AND UTILIZATION WITHIN THE UPCOMING SHARED MASTER OF SCIENCE IN CONSTRUCTION MANAGEMENT AND ENGINEERING IN THE NETHERLANDS

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ABSTRACT: In March 2004, the Task Force Sector Plan presented their final report to the State Secretary of Education, Culture and Science. In this report, the three universities of technology (3TU) proposed how they aim to create a single federation of Dutch universities of technology by combining their education and research programmes in order to enhance knowledge valorisation. In addition, five shared Master of Science (MSc.) programmes - not yet offered in The Netherlands but considered to be essential for the Dutch knowledge economy - were proposed, including the MSc. Construction Management and Engineering (CME) programme. The MSc. CME programme, realized at the three 3TU locations, consists of two blocks: (1) a general block and (2) a specialization block. The general block covers the topics that provide a sound basis for further specialization at one of the three locations of the 3TU. Within the general block – but moreover in the specialization block offered in Delft – contains a large amount of IT education and utilization. This paper will discuss the overall programme of MSc. CME programme and the development process of the MSc. CME specialization in Delft, with a special emphasis on the IT related subjects.

KEYWORDS: master programme, construction management, IT, education.

1 INTRODUCTION

In order to raise the Dutch "knowledge" economy from its mediocre position in innovation, in 2003 the Dutch Government established an Innovation Platform, headed by the Prime Minister with members from the Government, business enterprises and knowledge institutes. The task of the Innovation Platform is to propose strategic plans in order to reinforce the Dutch knowledge economy and to boost innovation by stimulating the co-operation of business enterprises and organizations in the public knowledge infrastructure (www.innovatieplatform.nl).

Apart from the installation of the Innovation Platform, a Science & Technology Sector Plan Task Force was formed consisting of Loek Hermans (chairman) and the three CEO's of the three universities of technology in the Netherlands - Delft University of Technology (TUDelft), Eindhoven University of Technology (TU/e) and the University of Twente (UT). In March 2004, the Task Force presented the Sector Plan "Power in Innovation" to the State Secretary of Education, Culture and Science. In the Sector Plan, the three universities of technology (3TU) indicate how they aim to create a single federation of the Dutch universities of technology by combining their educational and research programmes and enhancing their activities in the field of knowledge valorisation by 2010. With this comprehensive co-operation and co-ordination, the three universities of technology will combine forces for a dynamic and competitive position of the Dutch economy (Hermans 2004).

In September 2004, a 3TU Graduate School (GS) for the co-ordination of education, a 3TU Institute of Science & Technology for the co-ordination of research, and a 3TU Innovation Lab for the enhancement of knowledge valorisation were introduced by the 3TU federation (www.3tu.nl). The 3TU is the obvious party to ensure that the Dutch knowledge economy has sufficient technical and science graduates at its disposal. In the Sector Plan, five new shared MSc. programs - not yet offered in The Netherlands and considered to be essential for the Dutch knowledge economy - were proposed: (1) MSc. Embedded Systems, (2) MSc. Nanoscience and -technology, (3) MSc. Systems and Control, (4) MSc. Sustainable Energy Technology and (5) MSc. Construction Management and Engineering (CME). In the next three sections, the overall programme of the 3TU MSc. CME will be discussed with a special emphasis on IT utilization and education within the programme.

2 3TU MSC CME PROGRAMME

The CME MSc. programme, realized at the three locations of 3TU GS, is subdivided into two blocks: (1) a general block and (2) a specialization block. The general block covers the topics which provide a sound basis for

further specialization at one of the three locations of 3TU GS. On all three locations the general block consists of the following five course elements:

1. *Collaborative Design and Engineering*. This course deals with the social aspects of design and engineering processes as well as the technical and organisational aspects. During the course, students experience how creativity and working in teams have mutual influences and how the use of IT can affect supporting processes. The theoretical aspects of communication and information management in collaborative design and engineering are introduced. Important issues are the control over the design and engineering processes and the management of data exchange. Advanced IT tools and media for communication and on-line collaboration are discussed and practiced during the exercises, with a special attention to Electronic Document Management systems.
2. *Project Management*. This course deals with principles and techniques of project management. Project management is concerned with management techniques given a fixed project definition and a clear set of goals and requirements. This course aims at providing students with the insight, concepts and skills needed to understand the nature of leading, managing, co-ordinating and facilitating the actors in the project and the stakeholders concerned. Traditional IT tools supporting many project management functions related to the core management functions (objectives and constraints) scope, time, cost and quality and the facilitating functions (interactive and adaptable) information and communication, contracts and procurement, human resources and risk, are discussed and practiced during the exercises. In addition, there will be a special attention given to (visual) construction simulation tools based 4D and 5D CAD modelling and/or BuildingSmart technologies (http://www.buildingsmart.info/).
3. *Process Management*. This course deals with the principles and techniques of process management. Process management is presented complementary to project management. While project management is about realizing products and delivering products in a context of fixed goals and requirements, process management is about organizing and managing processes between actors and stakeholders, in order to (re)develop projects, goals and requirements amidst uncertain environmental policies. This course aims at providing students with the insight, concepts and skills needed to understand the nature of interaction between actors regarding the initiation and development of, and the decision-making on projects with uncertain and dynamic situations. A computer simulated environment will be offered to the students for practising and analyzing multi-actor behaviour, process management and arrangements (i.e. computer supported gaming).
4. *Legal and Governance Aspects*. This course deals with the legal aspects of the construction process, taking into account the institutional contexts of the actors involved in the construction process. During the course, students will gain insight into the possibilities and limitations posed by the Dutch, European and International legal systems, as well as into the fundamental positions and considerations of the public and private sector and their interactions during the construction process. This course will also pay some attention to the legal aspects of using IT in construction management and engineering processes.
5. *Integration and Orientation*. In the 'Integration' part of the course, students must show their ability to operate in a team and apply the expertise and skills (including IT expertise and skills) acquired so far in a real-life project setting (i.e. reflecting the practice of a design consultancy group).

The specialization blocks, differing for each of the three locations of the 3TU GS and match the local specializations consist of (1) obligatory courses, (2) elective courses and (3) a graduation project. The complete package of specialization courses together with the five general courses will lead students to the preparation of a graduation project. The specialization block in Delft will be discussed in more detail in section 7.

3 TOWARDS A COMMON ELECTRONIC LEARNING ENVIRONMENT FOR THE 3TU GS

While most 3TU MSc. development groups primarily focused on the development and organization of their curriculum, another group IT & Education and ELO-Groupware (IT&E) tried to sketch a realistic perspective for a future electronic learning environment for the 3TU GS. Because the 3TU MSc. groups were primarily focused on their curriculum, the ambitions with regard to an advanced IT-based instructional design (face-to-face, distance education, campus blend, etc.) were rather modest. Therefore, one of the problems of the IT&E group was that it was not very clear what was needed and when it was needed to facilitate the 3TU MSc. curricula. The danger of this situation is that the discussion narrows down to all kinds of interesting and nice working tools which from IT perspective cannot be managed.

Another problem of the IT&E group was the fact that the three locations of the 3TU GS already implemented different and rather traditional and closed virtual learning environments based on technology provided by Blackboard, WebCT, TeleTOP and Microsoft that are integrated with the internal IT infrastructures and information systems. The IT&E group denoted the importance to take first a step back and look at the problems from 3TU IT architecture. Starting point is the business processes, i.e. the education process starting from subscription till becoming an alumnus. Secondly, the information processes will be defined in terms of which functions are needed and considering the use of open specifications and standards (i.e. providing interoperability). With respect to the interoperability issues, it is important to broaden the discussion to look at the architecture as a digital learning and working environment (DLWE), and not solely as the classic virtual learning environment[1]. Finally, the technical

[1] Even if the 3TU will not achieve a common DLWE (both from a short or long term perspective), the open standard approach will guarantee a second best scenario ensuring that components can work together. The information process that

processes will be defined in terms of which tools are required, the client/server architecture, an integrated system or a combination of interoperable technical components etc. (stanleyportier.blogspot.com).

At the time writing of this paper, a common 3TU-DLWE is still a long term ambition. For the short time, a number of temporary and pragmatic technical solutions are provided by SURF, which is the higher education and research partnership organization for network services and IT in the Netherlands. SURF exploits a hybrid network (SURFnet6) and offers innovative services for security, authorization, middleware, identity management, groupware and video conferencing (www.surf.nl). In the next academic year (2007/2008), also Microsoft Sharepoint Portal technology (pilot) will become available for the exchange and central collection of learning sources of all kind.

4 THE SITUATION AT THE DELFT LOCATION OF THE 3TU GS

In the early phase of the development process of the programme, it was observed that the situation at the Delft Location of the 3TU GS was complex, due to the involvement of three faculties (i.e. Faculty of Civil Engineering and Geosciences, Faculty of Architecture and Faculty of Technology, Policy and Management). An internal deliberation in Delft in April 2006 resulted in a common agreement that the section Design and Construction Processes at the Faculty of Civil Engineering and Geosciences (CiTG) taking the lead in the development process of the programme and to represent the Delft University of Technology (TUDelft) in the 3TU GS. In order to provide answers on the questions about the necessity and feasibility of such specific MSc. CME programme for the faculty CiTG in terms of finance, students and philosophy, a feasibility study has been carried out. A trend analysis was part of this feasibility study. In next section the results of this trend analysis is discussed.

5 TREND ANALYSIS OF THE (DUTCH) CONSTRUCTION INDUSTRY

The current state of the (Dutch) construction industry can be characterised as very fragmented and traditional. Until recently there were no incentives to change. However, the increased pressure from society and government persuaded the construction industry to change towards a more innovative and competitive branch of industry. Particularly this is the case in where a parliamentary inquiry (2002-2003) revealed some large-scale irregular pricing practices in the construction industry of the Netherlands. Apparently, the fundamental obstacle to change is prompted by its governing culture and the system of norms and values that slows down or prevents innovation. The large number of clients and suppliers in the construction industry form an obstacle for the systematic mobilisation of clients and suppliers. The impenetrability of the market structure in the construction industry is another reason for limited innovation. Transactions in the construction industry are predominantly based on the lowest price. Inadequate competition and low transparency frustrates the proper interaction between supply and demand, verifiable trade and the proper appreciation of innovations.

In November 2003, the ministers of Housing and the Environment, Economic Affairs and Infrastructure jointly presented "Future perspective for the construction industry". The main goal of this document was to initiate, to encourage and to facilitate change in the Dutch construction industry in order to (1) restore thrust among stakeholders in both demand and supply side, (2) to improve relations between government and industry (3) to stimulate improved relations within the industry and (4) to stimulate the necessary system and process innovations. A national Steering Board (Regieraad Bouw) was installed to supervise the change (www.regieraadbouw.nl). The necessary funds for research and development became available through the national research and innovation programme for the Dutch construction industry PSI*Bouw* (Process and System Innovation in Buildings, www.psib.nl). During the last three years, the construction industry together with the academic institutes has invested a great deal of effort (and finance) in providing PSI*Bouw* the necessary impulse for translating the demands from the society and government into a list of "ambitions" for the necessary transition of the BC industry (Table 1).

Table 1. Desired transition of the Dutch construction industry (also known as the PSIBouw 8-liner).

From	TO
Supply-oriented work	Demand-oriented work
Capacity and effort-oriented work	Result-oriented work
Fragmented work	Integrated work
Fixed price at inception	Value versus price at the end
Risk management prior to the process	Risk management during the process
Focus on the control of costs	Focus on production of benefits
Building for a few parties	Building for all stakeholders
Settling everything at inception	Dynamic steering
Payment for promises	Payment for deliveries

PSI*Bouw* has been divided into five clusters: (1) "Construction Practices", (2) "Solutions", (3) "Conditions", (4) "Instrumentation" and (5) "Knowledge". The backbone of PSI*Bouw* is formed by the clusters "Construction Practices" and "Solutions". The cluster "Construction Practices" identifies the new ideas and monitors the trends within the construction industry and asks cluster "Solutions" to provide practical and working solutions. The clusters "Conditions" and "Instrumentation" can be seen as the scientific clusters that absorb the scientific questions that arise in the two backbone clusters. Cluster "Knowledge" establishes a set of competence criteria for future workers in the Dutch construction industry on which the curricula of universities and higher education can be built (PSI*Bouw* 2006).

is required to support a student's learning process should not be hindered by technical barriers. Even if the underlying systems are different, the front-end interface for the end-user may still be one coherent environment.

At the time of writing, almost 50 research projects have been started in PSI*Bouw*, and a number of these have already been completed. The IT related research and development projects have been positioned in cluster "Instrumentation". This cluster is seen as an "enabler" for the other clusters and thus only provides the "instruments" for the concepts and methodologies that are developed somewhere else. From this the following key areas for IT research and development have been derived (PSI*Bouw* 2005 and 2006):

- Improvement of (development and application of) IT applications in the areas of logistical supporting instruments, such as document control, workflow management, supply chain management, systems which have at their basis univocal construction appointment schemes. PSI*Bouw* have also recognised this problem and tries to embed the IT developments within cluster Instrumentation in the current PAIS activities. PAIS stands for Platform for coordination of technical information structure in which five Dutch initiatives in the field of construction appointment schemes cooperate (www.paisbouw.nl).
- Support for professional clients in the choice for how their projects can be offered to the market under the best conditions. For each project, a professional client (also known as public client) has to make an assessment of how that project can be brought on the market under the best conditions. Many factors can play a role here such as own expertise, expertise suppliers, desired influence, level of difficulty, desired innovation, desired cooperation etc. Assessment models can support the professional client in its choice.
- Development of demand specifications with which projects can be managed and controlled based on value creation instead of lowest cost. Well formulating the demands by means of performance requirements, constraints and desired functionalities is important if the client wants to manage and control projects based on value creation instead of lowest realisation cost.
- Develop of appraisal and selection methodologies for several unlike solutions on the basis of factors and criteria such as past performances, sustainability versus life-cycle, value versus quality, involvement stakeholders and management of risks. An example project in this key area is PIPS. PIPS stands for Performance Information Procurement System which is an integrated working method developed by the Arizona State University (US) in which has been combined: (1) selection method of suppliers based on past performances and (2) the identification, measurement and allocation of project risks. The PIPS project most important objective of research is to investigate whether this integrated working method can be applied in the Dutch construction industry.
- Development of benchmarking instruments with which suppliers can be stimulated to improve their processes in the supply chain, with as a result that they will perform and serve the client better in the future. An example project in this key area has been initiated by the Dutch Association for House Owners. The project aims to develop an instrument with which construction errors in new residential houses can be monitored and benchmarked against earlier monitoring results from other housing projects (Dado 2006).

The project ProClient has been initiated by TNO Building in cooperation with the three technical universities in the Netherlands to investigate and provide a roadmap for the future IT research activities during and after the PSI*Bouw* period. The project has been granted by PSI*Bouw* and is expected to start in June 2006. This project has as most important objective to provide insight the (non-) possibilities of IT for the improvement of the communication between client/user and supplier, including the insight in the targeting mechanisms for process and system innovation in general (Dado and Beheshti 2006).

Now that the Dutch construction industry has taken up a position towards addressing the consequences of increased pressure from the society and the government, this places heavy demands on the competence of the industry - a new type of competence that is not the same as it used to be. Therefore the construction industry must change. These types of changes require a change in "decision, doing and acting" within the industry. In addition, it also means that there is a change in the needs of skills and knowledge for future construction managers. This change in the needs of skills and knowledge for future construction managers is also (although in a slightly different context) recognized by a number of branch organizations in The Netherlands, such as the Dutch Construction and Infrastructure Federation (Bouwend Nederland) and the Economic Institute for the Construction Industry (Economisch Instituut voor de Bouwnijverheid - EIB). In general they mention the following drivers for this change:

- The increase of the complexity of the projects and the underlying construction processes;
- The increasing possibilities of information and communication technologies;
- Increased focus on construction process management;
- The increase of the responsibility and the liability in design, life-cycle maintenance and finance;
- The increase of the level of participation of clients during construction processes and the increased focus on transparency during the negotiation phase;
- The increase of working in (international) consortia;
- Increased focus on human resource management.

A prognosis of the labour market of the construction industry for the period 2005-2010 predicts only a small increase (approximately 1% per year) of the overall employment in the construction industry. However, an increase of 3.2% of the employability of construction managers with an academic background is expected. This employability will increase by the accelerated outflow of elderly construction managers till 2020. In addition, it is expected that gross production and the added value of the construction industry will increase while the overall employment remain more or less equal, indicating an increase of the complexity of the management tasks in the near future (Dado and Veenstra 2005). In the next section, the profile of the construction manager of the future in terms of general and scientific personal and domain-specific requirements will be discussed.

6 THE PROFILE OF THE CONSTRUCTION MANAGER OF THE FUTURE

The lists provided in this section are based on the trend analysis made in the previous section and complemented with the results of subject-specific interviews with specialists in the field of CME and a graduate student survey conducted by the Faculty CiTG in 2005.

Regarding the general and scientific personal requirements of the construction manager of the future, he or she should have the following qualifications:

- A thorough scientific attitude. In his or her scientific attitude he or she does not restrict himself or herself to the specific boundaries of the CME domain and is able to cross these boundaries;
- The ability to reflect on the complete scope of matters and issues in the domain: is able to form an opinion and contribute to discussions;
- As an academic, the manager understands the potential benefits of research and is able to understand and incorporate the results of research;
- Understands the importance of oral and written communication skills, in particular in English, and can make effective use of these;
- Has the habit to reflect upon his or her own work and continuously uses relevant information to improve his or her competences;
- Is able to operate (or lead) multi-disciplinary and multicultural teams [Schaefer, 2005].

Regarding the domain-specific requirements of the construction manager of the future, he or she should have the following qualifications:

- Is able to work from different disciplinary viewpoints and levels, including the ability to recognize and to work with the interconnections that exist between levels;
- Has a life-cycle mindset: is able to make decisions which guarantee future values and benefits;
- Has a demand- and client-oriented mindset: is able to help clients to specify their needs and to translate these into products with most benefit for both client and supplier;
- Understands the fundamental difference between process- and project management and is able to apply the underlying techniques and methodologies in projects;
- Understands the concepts of dynamic control at strategic, tactic and operational levels in the different life-cycle stages of projects;
- Is able to recognise and to control uncertain factors (i.e. risk management), with a special attention for process aspects and (not individual) safety aspects;
- Understands the concepts for optimal design/composition of plans and projects, incorporating technical, financial, economical and social viewpoints;
- Is able to recognize the relevant legal aspects during construction processes and is able to analyze these in the context of public and private institutional frameworks;
- Understands the concepts of financial engineering including project financing and financial accounting and is able to recognize the associated risks;
- Is able to make a well-considered judgement of the applicability of IT instruments at individual, project and company levels [Dado and Veenstra 2005, Schaefer et al. 2006].

The lists regarding general, scientific personal and domain-specific requirements was the starting point for the development of MSc CME specialization at the Delft location of the 3TU GS, that will be discussed in the next section.

7 THE MSC CME SPECIALIZATION AT THE DELFT LOCATION OF THE 3TU GS

As mentioned in section 4, the section Design and Construction Processes at the Faculty CiTG leads in the development process of the MSc. CME programme in Delft. The mission of this section is the scientific clarification and practical promotion of the theme “process and system innovation in buildings”. This goal will be achieved by creating a link between innovation and the scientific research providing a significant contribution to both science and the society. This contribution will be realised by the “Living Building Concept” (LBC) as developed within the section. The LBC is an extensive theoretical framework of concepts wherein the value plays an equally significant role as the cost of a construction work. This approach will have widespread consequences for the relationships between stakeholders, the methods of tendering construction works, the assignment of tasks as well as the sharing of responsibilities and risks (De Ridder 2005). The introduction and adoption of advanced information and communication technologies in the construction industry is seen as one of the key enablers for this change. Many of these concepts are (or will be) integrated with the obligatory and elective courses and are the research subjects of the graduation projects which are conducted under the supervision of staff members of the involved section. In this respect, the participation of Faculty of Technology, Policy and Management (TPM) becomes of crucial importance, because of their wide experience in both education and research in several of the areas that are covered by the LBC. The Faculty of TPM aims to use internationally oriented teaching and research to make a significant contribution towards providing sustainable solutions to complex (social) problems which involves analyzing the structure and operation of technical multi-actor systems as well as the development of intervention strategies, practices, and instruments for designing and improving systems of this kind.

Based on the findings in the sections 5 and 6, the specific research profile of the section Design and Construction Processes at the faculty CiTG and the available expertise at the Delft location of the 3TU GS, a MSc CME programme[2] has been developed (see Table 2).

[2] Note that the whole CME programme has been benchmarked against similar CME programmes offered outside the Netherlands including programmes offered by the university of Loughborough and University of Reading (United Kingdom), Universitat Stuttgart (Germany) and Purdue University (United States).

Table 2. Structure of the MSc. CME programme in Delft[3].

1.1	Legal and Governance Aspects	Choice 2/5: 1. Economics 2. Building Design and Construction Informatics 3. Probalistic Design 4. Functional Design in Civil Engineering 5. System Dynamics
1.2	Process Management	Project Management
2.1	Collaborative Design and Engineering	1. Plan and project evaluation 2. Operations Research 3. Philosophy, Technology, Assessment and Ethics 4. Risk Management
2.2	Integration and Orientation	
3.1	1. Dynamic Control of Projects 2. Financial Engineering	International Management/Cross Cultural Management
3.2	Preparing Graduation Project	Elective Courses (choice from list, incl. Knowledge Management and Advanced System Design)
4.1+4.2	Graduation project (30 EC)	
	general courses (see section 2)	obligatory courses / elective courses (or choice)

The following courses of the MSc CME specialization block contain IT related subjects:

- *Building Design and Construction Informatics.* This course is an introductory course of theories, methods and techniques regarding the application of information and communication technologies, to improve the quality, efficiency and effectivity of design and construction processes. The main emphasis of the course is on information modelling and product data technology for the building and construction industry. The goal of the exercises is to familiarise the students with the basic skills of building information modelling using UML (Unified Modelling Language) as well as building feature modelling using ArchiCAD.
- *Knowledge Management* (accompanying previous course in the list). The main emphasis of this course is on information management and knowledge technology for the building and construction industry. The goal of this course is to provide students with the fundamental knowledge and skills of IT tools in building and construction, including basic skills of process modelling using SADT techniques (IDEF0) as well as knowledge modelling using a real-life case.
- *System Dynamics*. This course deals with dynamic non-linear feedback systems on a high level of aggregation in order to develop hypotheses and conceptual models for complex (civil engineering) systems. A computer supported gaming and simulation environment for advanced simulation of non-linear problem-solving will be offered to the students.
- *Advanced System Design*. In this course students (individual or as a group of two students) design, develop and implement a system for mainly a (building and civil) engineering problem. The emphasis of this exercise is on system development methods and techniques and the use of IT solutions. The goal of the exercise is to familiarise the students with practical aspects of system development, enabling them to employ IT-enabled tools whenever required for the purpose of their graduation project or during their professional work.

8 CONCLUSIONS

The current state of the (Dutch) construction industry can be characterised as very fragmented and traditional that has no incentives to change. This places heavy demands on the competence of the industry - a new type of competence that is not the same as it used to be. Therefore the construction industry must change. There is also an increased pressure from the society and the government on the Dutch construction industry to change towards a more innovative and competitive branch of industry as well improving the image of the industry. These types of changes require a change in "decision, doing and acting" within the industry. The fundamental obstacle to change is prompted by its governing culture and the system of norms and values that slows down or prevents innovation. The large number of clients and suppliers in the construction industry form an obstacle for the systematic mobilisation of clients and suppliers. The impenetrability of the market structure in the construction industry is another reason for limited innovation. Transactions in the construction industry are predominantly based on the lowest price. Inadequate competition and low transparency frustrates the proper interaction between supply and demand, verifiable trade and the proper appreciation of innovations.

These inevitable changes in the working of the industry also points to the need for different skills and knowledge for future construction managers. These changes in the needs, skills and knowledge for future construction managers are also recognized by a number of branch organizations in The Netherlands. The opportunity to tackle this problem was provided after the final report of the Task Force Sector Plan presented to the State Secretary of Education, Culture and Science. This led to a proposal that the three universities of technology (3TU) aim at creating a single federation of Dutch universities of technology by combining their education and research programmes in order to enhance knowledge valorisation. Amongst others the 3TU federation proposed a new MSc programme for Construction Management Engineering that will be realized at the three locations of the 3TU. The MSc CME consists of two blocks: (1) a general block and (2) a specialization block. The general block covers the topics that provide a sound basis for further specialization at one of the three locations of the 3TU. Within the general block – but moreover in the specialization block offered in Delft – contains a large amount of IT education and utilization. This paper discussed the overall programme of MSc. CME programme and the development process of the MSc. CME specialization in Delft, with a special emphasis on the IT related subjects.

[3] Two-year programme, divided in 8 blocks.

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