

## **Possibilities and challenges for system dynamics research and education in Europe.**

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### **Abstract**

In October 1993, a group of 7 academic institutions submitted to the ERASMUS Office of the European Union (EU) in Brussels an application to establish an Inter-University Cooperation Program (ICP), i.e. a student exchange program, in system dynamics. This initiative is coordinated by the De-partment of Information Science, University of Bergen, Norway. A first response is expected by the end May 1994 and the final decision will be known in July. The program will be implemented during the academic year 1994 - 95.

When the ICP is established, it will receive a grant to support a number of students visiting host institutions abroad in order to receive a formal training in the theory and practice of system dynamics. The program will also support the exchange of faculty and system dynamics curriculum development.

The system dynamics method has proven particularly useful in social sciences and in public and pri-vate management. A large number of enterprises currently apply system dynamics in their design of policies and in management training. The system dynamics method is taught and applied in prominent management schools, schools of social science and technological institutes in Europe, America, Asia and Australia. Although originating and partly dominated by American Universities (MIT in particular), there is a large numbers of courses in theory, applications, and software development taught in Europe. It is our purpose with this programme, by joining forces, to emphasize this European tradition of the field.

This paper describes some possibilities and challenges that arise from this program. It also indicates how we could initiate a research program in Europe, possibly an ESPRIT-program, based upon system dynamics.



## **Possibilities and Challenges for System Dynamics Research and Education in Europe.**

### **Introduction**

In October 1993, a group of 7 academic institutions submitted to the ERASMUS Office of the European Union (EU) in Brussels an application to establish an Inter-University Cooperation Program (ICP), i.e. a student exchange program, in system dynamics. This initiative is coordinated by the Department of Information Science, University of Bergen, Norway. A first response is expected by the end May 1994 and the final decision will be known in July. The program will be implemented during the academic year 1994 - 95.

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### **The purpose of the ERASMUS program**

The purpose of this ICP is to establish a high-quality, Pan-European education in system dynamics, defined as a simulation-based method by which we investigate, understand, learn about, and manage complex, dynamic systems in a variety of domains. The education will cover theory, method, models, and techniques. It will emphasize the essence of system dynamics and its applicability to both a number of fields and across these fields.

Although there are a number of courses currently offered at European universities, there are only a few academic programs that provide a full graduate education in the system dynamics. Therefore, the program will include a two-year International Master of Philosophy (M.Ph.) Program in System Dynamics and support education at Ph. D. level.

The current undergraduate education in this discipline is often not sufficiently comprehensive. Consequently, the program is also designed to facilitate advanced undergraduate studies in the field. It is mandatory that students be given the opportunity to visit institutions that complement the system dynamics education offered by their home institutions.

Although a large body of modern theories, methods, and techniques are being developed to solve complex problems, there is evidently a major role to be played by system dynamics. It is important that we identify that role, that research supports that role, and that education and practice emphasizes

that role. To act competitively within the scientific community of Europeans, we will have to identify the role and market the significance of system dynamics more aggressively. To do so, a research program (e.g. SPRINT, ESPRIT) must be established to supplement the ERASMUS program. Experience has shown that two such programs often mutually fertilize each other. An initiative to a Pan-European research programme will be launched within 1994.

### **Current and future ERASMUS partners**

The seven partners that finally joined forces October '93 are: University of Bergen, Norway, Universidad de Sevilla, Spain, Universidade Nova de Lisboa, Portugal, The Technical University of Denmark, University of Sunderland, England, The Technical University of Mikkeli, Finland, Stord College of Education, Norway. These are among 20 candidate institutions also representing Great Britain, Germany, Holland, Italy, France, and Sweden. Several of them were already in the process of preparing a statement of endorsement when we reached the time limit last year. This indicated a willingness, at least on the part of the system dynamicists, to participate in the exchange. The fact is that several of these initiatives were procrastinated by politics and bureaucracy.

The history of system dynamics taken into consideration, it comes as no surprise that current and potential partners can be classified as typically belonging to the social sciences, including business, or to natural sciences, including engineering. Moreover, most of the system dynamics education is linked to applications ranging from financing or organizational and social learning to environmental studies or electrical, mechanical, and biological engineering.

Its methodology is often taught as part of its practice. This may be one of the reasons why the scientific foundation for the field, such as rigorous definitions for powerful concepts like feedback loop polarity dominance, has developed relatively slowly over the last decades. As a consequence, the same is more or less true for the development of appropriate software although that has picked up speed lately. One of the goals that we could set for the ERASMUS program is a strengthening of our education with respect to our common methodology, facilitated through the advanced use of computers.

More importantly, though, is the cross-fertilization that can take place across a number of areas of application. Typically, a system dynamicist is expected to interact with a variety of specialists and distill and formalize the essence of this interaction in a multidisciplinary model. Also, the experience gained from problem analyses and policy composition in one area should be generalized and carried over to other areas of concern. The ERASMUS program provides students who utilize system dynamics, to gain this inter- and multidisciplinary experience in institutions across Europe that all recognize system dynamics as a common foundation. This should benefit, not only the student and her/his home institution, but also the host institution.

We have experienced reluctance when we invite institutions to join our ERASMUS ICP, a reluctance that originates from the fact that professors consider their teaching not as system dynamics per se – rather its application. If we excluded all of them, we would probably be left with no program. There is no need to operate under a designated system dynamics program. Provided the underlying methodology is system dynamics, this methodology is being emphasized and taught intermittently, and software is being made available for the purpose of modeling, simulation and analysis, you should be a part of this ERASMUS ICP.

In fact, in view of the international M.Ph. degree we will offer as part of the ERASMUS ICP, we would welcome the partnership of institutions that employ individual professors who are recognized system dynamicists, even though they may currently not be teaching system dynamics. In that case, the institution can take advantage of our ICP, send students abroad to complete the course require-

ments, while granting the local professor the opportunity to act as thesis advisor upon the return of the student -- in collaboration with the host institution, say, the University of Bergen, that grants the degree.

**ERASMUS Resources**

The University of Bergen, has sponsored the preparation of this ICP application, covered the associated traveling expenses, and is expected to grant a 5 months scholarship designated to the development and composition of a M.Ph curriculum.

Through the ERASMUS program, the community of system dynamicists will gain access to monetary resources that can increase student as well as teacher mobility. The program will cover expenses associated with one meeting per year among the partners. This meeting will be lead by the coordinating institution, but can be hosted by any of the partners. There will be held a supplementary meeting every year in connection with the International System Dynamics Conference.

The exchange program can vary in size and diversity from one year to the next, depending upon the number of partners and their programs such as compatibility, duration etc. Typically, the European Union will offer grants to cover 60% of the estimated demand for exchanges of students and teachers.

For the academic year 1994-95, we have applied for the support of an estimated 27 students to be exchanged for a period of 3 (an ICP minimum) - 5 months. We expect this program will be scaled down by the Union to 16 students. This modification will grant us the opportunity to select among applicants those most eligible and to modify the mix of visits granted. We will use this opportunity to prioritize a good geographic distribution and long-term visits. Some grants may be doubled, for instance, to cover a 6 - 10 months period required to complete courses associated with a M.Ph. or a Ph.D. program. The exchange program for which we have applied support, is reflected by the matrix, portrayed Exhibit 1 (note that these are estimates).

	<i>Bergen</i>	<i>Lyngby</i>	<i>Sevilla</i>	<i>Lisboa</i>	<i>Sunderl.</i>	<i>Mikkeli</i>	<i>Stord</i>
Bergen, Norway			1 (5)	2 (5)	1(5)		
Lyngby, Denmark			2 (4)				
Sevilla, Spain	1 (5)	2 (5)					
Lisboa, Portugal	2 (5)		1 (5)		1 (5)	2 (5)	2 (5)
Sunderland, England				1 (3)		2 (3)	
Mikkeli, Finland				2 (3)	2 (3)		
Stord, Norway				2 (3)	1 (3)		

Exhibit 1: The student exchange matrix (number of exchanges and duration of stay (in months)).

Each row in this matrix indicates the host institution, and each column the corresponding home institution. The numbers in each cell indicate the number of students to be exchanged and (in parenthesis) the expected duration of their stay (in months). The variety in volume and duration, is a reflection of discrepancies between the number of students that each institution expect to send out and receive. It also reflects academic programs and expected language barriers.

With reference to the Teaching Staff Mobility Programme, we have applied for the support of an estimated 9 teachers to be exchanged for a period of 2 (an ICP minimum) - 4 months each over the academic year 1994-95. Due to a large number of uncertainties at the time of application, it was not possible to claim replacement costs this time. We expect this program will be scaled down by the Union to 4 teachers. This modification will grant us the opportunity to mix an optimal selection of exchanges. The current mix reflects similarities in academic orientation.

System Dynamics is typically taught by a very small number, often one or two, members of the faculty at each university. In many cases, teachers are specialized in areas taught elsewhere than at their home institution. This creates a need for teacher rotation in the ICP programme. The aim is to obtain a better utilization of teachers and, at the same time, to facilitate an educational enrichment of the field, e.g. to exchange educational experiences, methods, models, techniques, and tools. Typically, this will allow a pure system dynamicist to teach an application of particular interest to him, or an applied scientist to concentrate his/her teaching on a pure subject matter of significance to his/her application of the field.

During their visit, the teachers exchanged are expected to contribute by an amount of teaching corresponding to their regular workload at their home institution, though possibly in another form and typically in seminars as graduate level advisors. Such advisory roles can be initiated during visits and extended in the form of distance learning upon their return. This will significantly improve the utilization of relatively scarce and scattered teaching resources in the field.

Guest seminars are usually rather advanced, aimed at graduate level, and open to host faculty. They will serve to broaden the perspective on education, including curriculum development, and on research within the field. The broadening of perspective will benefit the host university and its staff and create the foundation for new ways to teach System Dynamics and for the initiation of joint, student-based research projects. The personal contact established between guest teacher and host students will benefit the students and most certainly enhance purposeful student mobility.

When we take advantage of the Teaching Staff Mobility Program, we will seek to prioritize a good geographic distribution and visits that will generate new curricula and material for graduate level education in system dynamics and its variety of application. The exchange program for which we have applied support, is reflected by the matrix, portrayed Exhibit 2 (note that this is an estimate).

	<i>Bergen</i>	<i>Lyngby</i>	<i>Sevilla</i>	<i>Lisboa</i>	<i>Sunderl.</i>	<i>Mikkeli</i>	<i>Stord</i>
Bergen, Norway			1 (4)	1 (4)	1(4)		
Lyngby, Denmark	1 (2)		1 (2)				
Sevilla, Spain	1 (4)	1 (2)					
Lisboa, Portugal						1 (4)	1 (4)
Sunderland, England							
Mikkeli, Finland							
Stord, Norway							

Exhibit 2: The teacher exchange matrix (number of exchanges and duration of stay (in months))

**Academic prerequisites, recognition, and compatibility**

As described, there is a limited number of students that can be exchanged within each ICP. Moreover, the host institutions can define academic requirements that must be satisfied by the students they receive. The home institution has an important responsibility when they prepare students for studies abroad. They must inform about the requirements that they should meet so that s/he arrive with realistic expectations. To ensure that our students have a minimum of academic experience, we will require them to have completed successfully three years of university education before joining the program.

Most universities, already participating in European exchange programs, have approved the generalized use of ECTS-credits. Each host institution in our current ICP will grant full recognition for study abroad periods. To guarantee the attractiveness of this ICP, we will take measures to ensure that all partners fully recognize a well-defined subset of the courses included in this program.

**Joint development of new curricula and JITOL.**

For decades, curricula have been developed on an individually basis. We must expect that there exists a large body of books, manuscripts, models (including generic structures), case studies (including source material), assignments, ideas etc. that can be exchanged across the field.

Moreover, the computers allows us to store, exchange, and present this material electronically. The investment in producing educational programs electronically is relatively large, though extremely effective and efficient. The costs are drastically falling as a consequence of the new structure of operating systems that allow for a seamless production across a variety of software platforms. If we can inspire more people to store their teaching experience electronically, it will benefit our community greatly and allows us to adapt and to re-use that material in a variety of educational contexts.

More importantly, we can utilize that material for distance education. In a national as well as a Pan-European educational perspective, we must expect the demand for this kind of education to increase dramatically as a result of the costs associated with a traditional form of education. It significantly extends our student body to a large number of professional practitioners who require on the job training in the form of an apprenticeship. Moreover, it allows us to reach students in Eastern Europe who otherwise would currently not be able to participate for economic reasons.

The community of system dynamicists, highly experienced as they are with computers, hold a competitive advantage in this field of education. In the context of a European research program, JITOL (Just In Time Open Learning), the Department of Information Science, University of Bergen, in collaboration with Stord College of Education, develops a concept for distance education in system dynamics. Our experience indicate that we will be able to extend our education across Europe utilizing electronic networks, and we plan to do so, in the context of our M.Ph. program within ERASMUS.

Due to the uncertainty associated with the ERASMUS ICP in system dynamics, our application, submitted last year, did not contain a claim to cover expenses in connection with joint development of new curricula. In view of the above, we clearly need such funding and should plan to outline a program for joint curriculum development to be included in the application for this year. As pointed out, the University of Bergen is expected to grant a 5 months fellowship for this purpose.

### **M.Ph. and Ph.D programs**

The Norwegian government has proposed that 10 - 12 international Master Programs be established. The University of Bergen has responded by proposing, among other, a program in system dynamics. This program will serve three purposes: It will constitute our contribution to the ERASMUS ICP in system dynamics. Moreover, a limited number of students from development countries, having completed their undergraduate education elsewhere, will be admitted and granted financial support. This is a part of the reorganization of the Norwegian assistance to development countries. Finally, as a part of an initiative to improve conditions in Eastern Europe, we will also accept a small number of students from these countries. The official language will be English.

Graduate studies at Norwegian universities have a minimum duration of two years. The course requirement in a Master Program will typically be completed within 3/4 - 1 year. The remaining time will be spent on a thesis.

The fact that two years are required to complete a Master Degree, corresponds poorly with the fact that ERASMUS supports a student for only one year. Consequently, the ERASMUS student can spend a maximum of one year in Bergen and return to complete her/his course requirements and thesis at home. This indicates the need for distance education in the form of JITOL and the need for local thesis advisors, as suggested above. Obviously, all graduate courses that are listed in our ERASMUS ICP catalog will be accepted as a part of a Master Degree, although overlaps will be taken into account.

The graduate program in Bergen will consist of 3-4 courses, each corresponding to 1/4 of a year's study:

- (1) There will be one course on advanced fundamentals and the practice of system dynamics. This course will require a steep learning curve and, in addition to the lectures, it will be based upon a number of work-shops and assignments.
- (2) We will probably also offer an advanced follow-up in the form of a seminar of distinguished lecturers that address advanced topics in system dynamics.
- (3) Stord College of Education will offer a course in simulation-based interactive learning environments.
- (4) We will follow up with a course in the design and implementation of system dynamics based simulators for management education.

International Master Program graduates are not automatically eligible for Ph.D. studies. To be so, their theses must require at least 1.5 year's work. If that is the case, if the thesis satisfies our quality requirements, and if the candidate has a complete undergraduate education corresponding to 4.5 years' studies, then the department will consider an application to be accepted in the Ph.D. program at the School of Social Sciences.

### **Tasks to be addressed.**

To make ERASMUS work, we must devote our attention to the development of a coherent set of courses offered by the partners. Moreover, we must publish a catalogue of our joint program and outline recommended paths through this program. Moreover, we must identify weaknesses in the program and seek to eliminate those weaknesses through course adjustments and curriculum development.

We must seriously address the problem associated with language barriers. There is reason to hope that we can converge on a curriculum that encompass no more than 2 - 3 languages, where English will be the dominating one. These problems can be alleviated through language training, usually of-



ferred at the home or the host institutions. Graduate studies will, in part, be offered in the form of individualized training or seminars. Consequently, the language problem will be less dominant.

We must recruit new partners and overcome recruitment problems caused by university politics and bureaucracy. The four main arguments used by administrators against ICP participation are these:

1. System dynamics is not one of our major fields, at most a promising method that some members of our faculty insist on pursuing. Our program of relevance to system dynamics is also modest, and we do not want to assign more weight to that program or commit ourselves to system dynamics by joining this ICP.

In this case, much will depend on the position and the strategy of the individual system dynamicist. The best ways to support an individual professor, is to;

- create an infrastructure of educational and research facilities that act as guide-lights;
- publish and exchange information, so as to make the field visible and well recognized;
- develop a diversified, adaptable, and coherent curriculum for the field with a set of public domain examples; and
- position the field within the context of the home institution.

This context is not only the area of application characterizing each institution. It is just as much the scientific tradition held by that institution. In our review of European, educational programs, it was evident that system dynamics is often neglected in traditional institutions as a consequence of its reputation as systems engineering rather than science. Moreover, the unique position system dynamics has as a vehicle for learning has traditionally not been appreciated or recognized.

Current European research programs, however, clearly aim for tangible end-products that concretely contribute to the competitive advantage of the European Union. Moreover, European industry is beginning to recognize the significance of organizational learning. Therefore, we believe that system dynamics faces an historic opportunity in Europe.

2. The ICP on system dynamics currently may not seem to consist of the most significant institutions in business or engineering. Consequently, what will be the quality of the education offered in these institutions?

To counteract this attitude, it is very important that we recruit a number of well recognized institutions within the fields of social sciences (business) and engineering. We are of the opinion that we have not renounced quality to ensure a sufficient number of partners in our ICP. In the future, we will require that the partners satisfy a set of criteria that guarantee the quality of our program. The strategy will be to grow modestly by including a few well-recognized institutions rather a number of institutions that gain from the ICP more than they contribute.

3. We already do take part in a few ICP's of relevance to our major fields and for the sake of maintaining the quality and concentration of our international exchange programs, we prefer to be very selective in our choice of partners.

This is one of the major reasons for e.g. business schools dealing mainly with other business schools, thereby reducing the potential for cross-fertilization. System dynamics is a vehicle for inter- and multi-disciplinary studies and should be actively applied to break barriers so as to enable the educational institutions to address more readily real problems that, by Nature require this kind of approach.

Inflexible academic programs aimed at a particular profession, typically do not host system dynamics. More importantly, there is little room for options. The course requirements are often narrowly defined, and exams from abroad are seldom recognized.

The educational system in Europe is changing. Some universities are actively pursuing a program of internationalization, such as ERASMUS. Others join more reluctantly. The net effect is the development of a system of mutually recognized academic programs that allow students to compose their individual programs. This process has a great momentum and, when utilized carefully, it will allow students to incorporate major portions of an education in system dynamics in their own programs.

From the students' point of view, the benefits from including system dynamics in their education must not be compensated by an uncertainty associated with the academic credits earned from the program. The education will be made more attractive by the fact that we will offer a graduate degree in system dynamics. Thus, some students will be able to earn a double degree, say in business or engineering and in system dynamics.

4. We are not willing to waive tuition.

In a few European countries, a large number of academic institutions, particularly those of high reputation, are privately funded, and require their students to pay tuition. Because the ERASMUS program does not cover tuition, this has two effects: Very often these institutions are reluctant to accept (non-paying) exchange students. To the extent that they are willing to waive tuition, they would prefer partners that require tuition to be paid by their own students as well.

The University of Bergen has, for several decades, operated under exchange agreements with a number of American universities, including a small-scale program in system dynamics. Provided the exchange is well-balanced, our partners have waived tuition in all of these cases. As long as the benefits from joining an ICP, therefore, is greater than the cost of waiving additional income from foreign students, we believe this problem will find its solution within the framework of the European Union.

Having listed these four arguments, we believe that most of them will be attenuated by an increase in the quality, diversity, and size of our ICP. Currently, we face a boot-strapping process. We must succeed through successful examples. We will seek to make the M.Ph. program, to be offered by the University of Bergen, such an example that should inspire other institutions to follow up and collaborate so as to make this a Pan-European graduate program in system dynamics.

#### **Initiating an ESPRIT research proposal**

In our ERASMUS-contacts with system dynamicists all over Europe, we were left with an impression that, although they could not take part in an ERASMUS ICP at this point of time, they would like to participate in a joint research program. It is very difficult to obtain funding for such a program from the European Union. At least, we will have to outline a program with a clear vision that we all share and explicitly state operational goals that we all contribute to and against which our contribution can be measured.

It is also unlikely that we will be granted support for a program that focus on methodology alone, i.e. a program in system dynamics. The program statement must demonstrate a willingness to contribute to the productivity at large of the European Union. We believe that it is possible to identify a common denominator for the demands of the European Union and current research in system dynamics. Moreover, we think that system dynamics can represent an important contribution to the methods required to solve some of the most serious problems facing the Union. These are, typically, vaguely described, nonlinear, dynamic problems, characterized by a variety of lags and by uncertainty.

An initiative may arise from Scandinavia. The Department of Information Science, University of Bergen, and the School of Technology Management, Chalmers University of Technology, Sweden, currently debates a research program in collaboration with the industry that will focus on "Building

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