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Research Article

Toward consensus on a European GIS curriculum: the international post-graduate course on GIS

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Abstract. At the Department of Geoinformation of the Technical University of Vienna, a European Community funded project to develop an International Post-Graduate Course on GIS is underway. This intensive course is intended for participants with a variety of disciplinary backgrounds and experience who need a broad theoretical overview of GIS coupled with the necessary knowledge and skills to apply GIS in real situations. As curriculum design for GIS courses is normally carried out by a very small group of individuals, curricula generally reflect the specifics of the experience or disciplinary environment of these individuals. For this European project, a widely acceptable course curriculum was needed. This required the cooperation of experts from different disciplines, across many application areas and from different countries. A Delphi survey method combined with a meeting of a small number of GIS education specialists was used to achieve the necessary balance in the curriculum. The survey was used to determine the general content of the course and allowed the varied opinions of the group of European GIS experts to be merged towards a consensus. It resulted in the development of a list of important topics that need to be taught. Following completion of the survey, the GIS education experts met to review this list and discuss the concerns raised in the survey. These discussions led to the development of a Course Blueprint which describes the organisation of the course into 18 instructional units and outlines the objectives and contents that will be achieved in each of them.

1. Introduction

GIS education is finally maturing. GIS is now being taught by many universities throughout the world and in the full range of university departments, from planning to surveying, forestry and architecture (Goodchild and Kemp 1992). Many GIS specialties are developing and the opportunities for university level education are improving rapidly (Morgan and Fleury 1993).

It is clear, however, that a large group of potential GIS students cannot be accommodated in traditional university programmes. Many professionals who have been out of university for years are now finding it necessary to pursue some type of formal training while remaining on the job. Options for this group of students are many. These include conference workshops, training courses offered by software vendors and short courses prepared and presented as one-time opportunities by professional organisations and other groups with short term funding from various

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national and international agencies (Kemp 1993). While these courses do fill many niches, the need for ongoing formal post-graduate training is apparent.

To fill this void, the Department of Geoinformation at the Technical University of Vienna was awarded a three year, 300 000 ECU grant by the European Community (EC) to develop an International Post-Graduate Course on GIS (Kemp *et al.* 1993). The funding is provided under the COMETT (Community Action Program in Education and Training for Technology) programme. This EC programme has been designed to encourage cooperation between universities and industry in the development and provision of training in fields involving advanced technology. Initially, the project team at the Technical University was headed by Professor Dr Andrew Frank assisted by Dr Karen Kemp, Dr Irene Campari, Dr Werner Kuhn and Mrs Rebecca Winn. Partners in the project include universities and private enterprises in most European Community countries. Under the funding contract, the project team will, in cooperation with other European GIS experts, develop the curriculum outline, prepare teaching materials, present the course twice (Italy in 1994 and Spain in 1995) and, finally, revise and begin distribution of the package of teaching materials. The project will provide both immediate results in the form of graduates from the two subsidised sessions of the course, as well as long-term results in the form of a comprehensive set of teaching materials which will be available to assist universities and other organisations throughout Europe develop similar courses.

For this course, it was necessary to develop a GIS curriculum which does not reflect any specific disciplinary, national or application dependent viewpoint. Most GIS curricula have been based on designs determined by either a single person (the course instructor or a textbook author) or by a small group of individuals (see for example, Nyerges, 1989 and Unwin *et al.* 1990). For the *NCGIA Core Curriculum in GIS* (Goodchild and Kemp 1990), the project perhaps most comparable to this, a general course outline was made available for open review and discussion, but input came mostly from North Americans within the discipline of geography. A much broader focus was necessary for this pan-European course.

This paper describes the curriculum development phase of the project. Following a brief description of the course structure and philosophy, the method used to devise a truly European curriculum that fits the needs of post-graduate students is outlined. The paper concludes with a discussion and analysis of some of the results of this phase.

2. The international post-graduate course on GIS

Based on a consideration of both the needs of the marketplace and of the students who will attend the course, the goal of this course is to provide a comprehensive understanding of GIS technology and its application within the European context. The course is intended for university graduates who are currently employed in any field using spatial information and who would like to increase their knowledge of the use of GIS technology. Upon completion, participants will have a solid background on GIS architecture and functionality and an understanding of how GIS can be integrated into various administrative processes. It will be of particular value to people at the project supervisor and the technical and operational management levels. It is anticipated that a large proportion of the participants will come from medium sized private enterprises and government agencies. Upon successful fulfillment of all the requirements of the course, students will receive an internationally recognised diploma.

The International Post-Graduate Course on GIS builds on a successful national course offered during the period 1991 to 1993 at the Technical University of Vienna under the direction of Professor K. Kraus and Professor A. Frank. This course, taught in German and to be repeated in 1994–95, has similar goals but it is more disciplinary oriented with a focus towards surveying engineering. The success of the first offering of this national course demonstrated the need for such courses and showed what can be achieved.

Since the target students of the course are likely to be employed full-time, it was necessary to devise a structure for the course which both provides students with intensive instruction and causes limited disruption of their work duties. The resulting structure consists of a sequence of three two-week intensive classroom units together with a practical project unit to be completed by each student at his or her home. This set of four units will be presented over a period of one year and will provide over 200 hours of classroom and laboratory instruction plus more than 70 hours of practical experience. When compared to the model of the *NCGIA Core Curriculum in GIS* (Goodchild and Kemp 1990) which contains 75 one-hour lectures plus weekly laboratory sessions, our structure provides many more hours than a standard year long university course. Indeed given that a typical U.S. 'three-hour' one-semester university course offers about 40 lecture hours and perhaps 20 laboratory hours, this post-graduate course is equivalent to four to five university courses.

3. Developing the curriculum

The first phase in the project necessarily required the development of the course curriculum. Since the project involves partners from many different disciplines, work environments and countries, it was necessary to devise a curriculum development method that allows many different viewpoints to be combined into a comprehensive but cohesive whole. The challenge, of course, is to avoid a 'design by committee' result. The project plan for this development phase included an initial Delphi-style survey to elicit the list of course topics that should be included, followed by a small meeting of GIS experts to convert the survey findings into a pedagogically sound course blueprint.

It is widely agreed that developing a curriculum should be more than simply identifying the subject matter that is to be taught. Jenkins describes curriculum development as 'an interaction between aims and objectives, methods of assessment, teaching methods and content' (Jenkins 1991, p. 104). Often, educationalists insist that curriculum development must begin with the statement of objectives, 'what one expects students to know or do as a result of a particular course' (Jenkins 1991, p. 105). However, since the lecture method of instruction, though widely criticised by educationalists, remains the predominant method in post-secondary education, a subject centered approach to curriculum development is the familiar route. This tension between the tendency to concentrate on defining content and a recognition of the benefits of working from clearly stated educational objectives can be seen in the process described here. While the result here has tended towards the subject centered approach, the following description of the development process does outline the efforts made to address these other issues including defining objectives, methods of assessment and teaching methods.

3.1. *The Delphi method*

The Delphi method of consensus building was developed in the early 1950s by The Rand Corporation in the U.S.A. (Linstone and Turoff 1975). While it has been primarily used as a tool to assist decision-makers formulate development or regulatory plans that will be acceptable to conflicting interest groups, it has been frequently used in curriculum development projects (see for example, Billingsley 1984, Judd 1972). The basic philosophy of the Delphi approach requires panelists to reconsider their personal viewpoints in light of those of others. Where there are differences, panelists are required to express their opposition in a manner which allows it to be examined rationally. Through several iterations, panelists reconsider and revise until, ideally, panelists' opinions merge towards a consensus solution.

A simplification of the Delphi approach was adopted for this project. In this case the problem is not so much conflicting opinions about what should be included in a GIS course, but a need to reduce the large list of potential topics that might be included to one that is manageable and yet sufficiently complete for the intended students. Our Delphi survey consisted of three rounds. The first round contained a set of open-ended questions which asked participants to briefly express what they thought were the most important topics that needed to be included in the course. A compilation of these responses produced the structured second round which asked participants to rate each item according to whether, in their opinions, it was important or not within the context of this course. The final round summarised the findings of the second round and gave participants a final opportunity to comment on the resulting list of topics. The following sections discuss these rounds in detail.

3.2. *Round one—eliciting course topics*

Recognising that a course on GIS must address both the transfer of theoretical knowledge and the acquisition of practical skills, the first round of the survey made a sharp distinction between skills and knowledge. Knowledge was defined as the general theoretical notions that develop as a result of instruction or experience while skills referred to technical abilities. Following a short section designed to elicit information on the background and experience in GIS education of the respondents, the survey asked them to list what they considered to be the three most important skills and the three most important knowledge areas that should be addressed in the course, and up to eight specific topics that should be included. The questionnaire was structured with large open blocks of space to allow considerable freedom in the form of responses.

The round one survey was distributed by post in late November 1992 to 62 people representing a broad cross-section of GIS practitioners and academics from 19 European and four other countries. Here the Baltic countries are counted as part of Europe. These countries represented in the survey are Austria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Lithuania, Norway, Portugal, Switzerland, Spain, The Netherlands, Turkey, U.K., Australia, Canada, Russia and U.S.A. Panelists were selected who had either:

(*a*) a demonstrated interest in GIS education (i.e., academics, vendor and government GIS trainers),
(*b*) positions supervising major GIS or LIS operations (i.e., heads of federal or state cadastral information divisions), or
(*c*) senior positions in large GIS software companies.

Missing from this list are people who represent the target students of this course. While it would have been useful to have included some real GIS users in the survey group, it was difficult to identify a few specific individuals who could give us discerning evaluation of their own needs and experiences. Clearly this is an area of inquiry that has yet to be explored. However, by including people who are in supervisory positions over such users, we hope to have captured the relevant information.

Forty-nine of the original surveys were returned, resulting in a response rate of 79 per cent. Table 1 summarises the response rates of all three rounds to date with a breakdown according to the work environment of respondents where *a* indicates respondents in academic institutions, *c* indicates those working with consulting companies, software vendors or other commercial enterprises and *g* indicates those working for the government.

As anticipated, the completed questionnaires provided a plethora of suggested topics with every questionnaire suggesting something new and many respondents expressing similar ideas using very different words. Compilation of this round of the survey required merging these diverse responses into organised lists of skills and knowledge areas which could be evaluated by the complete panel of participants in the next round. Clearly, this required careful rewording and combining of ideas and a conscious attempt to prevent our own preconceptions and prejudices about the course content from affecting the outcome. However, at this point, an attempt was made to assert some educational theory by ensuring that skills were stated using active verbs—a method commonly used to assist in the formulation of educational objectives (Gronlund 1985). As much of the original wording and content as possible was retained with the result that some items in the combined lists of topics were somewhat vague and others clearly redundant.

Items were grouped into themes to provide some organisation to the random lists and to assist in their evaluation in the next round. The final lists from the results of the first round of the survey contained 252 items grouped into 15 categories. These are shown in table 2.

Finally, an open comments question at the end of the survey form provided respondents an opportunity to give general insight into their own personal approaches to GIS curriculum development. Perhaps the most useful comment at this point was one by Dr Robert Maher, Manager of Education and Training Services for the Ontario Ministry of Natural Resources in Canada. He suggested that rather than using the now traditional three level structure common in courses of this sort (i.e., the structure promoted by the three volumes of the NCGIA Core Curriculum—Introduction, Theoretical Issues and Applications Issues), the domains of the course should be spatial (including spatial problem solving, language of spatial relations and processes, GIS tools, georeferencing, geographical communication, integrated technologies), information systems (systems analysis, GIS design, dbms,

Table 1. Summary of response rates.

		# mailed				# received				
	Date	*a*	*c*	*g*	total	*a*	*c*	*g*	total	% return
Round one	November 1992	38	8	16	62	27	7	15	49	79
Round two	March 1993	38	8	16	62	23	7	11	41	66
Round three	May 1993	27	8	15	50	14	2	6	22	44

a = academic, *c* = commercial, *g* = government

Table 2. Summary of results from the first round.

	Themes	# of items
Skills	Using GIS	8
	Knowledge of theory	11
	Operational skills	21
	Working with data	8
	System planning skills	18
	System management skills	14
Knowledge	Nature of spatial data	26
	Spatial analysis	17
	Data issues	32
	Related technologies	12
	Technology aspects	20
	Application areas	24
	Management and implementation	28
	Cartography and visualisation	9
	History and trends	4
Total number of items		252

user interfaces) and institutional (organisational design, socio-economic impact). Such an approach was used with success in the Surveying Engineering Department at the University of Maine and has influenced the new curriculum at the Technical University of Vienna. As well, many respondents stressed the need for students to be encouraged to become self-learners so that they could continue their GIS education without formal courses.

3.3. *Round two—evaluating responses*

The second questionnaire was based on the list of topics developed from Round one. To help ensure that all survey participants understood the context of the survey, this second questionnaire began with a clear statement of the objectives of the proposed course (which had been slightly reworded in a response to comments received in the first round). The definitions of skills and knowledge were also refined—skills were defined as those activities which a graduate from the course should *be able to do*, while knowledge was used to describe those topics a graduate should *know about*.

Respondents were asked to review each item in the lists from Round one and indicate how important they felt it was within the context of the proposed course. Items were rated on a simple three-level scale (important, somewhat important and not important). While this limited scale provided only a crude evaluation of each item's value, it was used so that respondents would not find the work of assessing the long list of items too onerous. An additional level of evaluation was produced by asking respondents to identify the ten most important skills and the ten most important knowledge areas amongst those items they had indicated as important. As well, recognising that there was considerable redundancy in the lists, respondents were asked to indicate which items they felt were redundant.

This survey was distributed by fax in early March 1993 to the same set of 62 people as the first round, including those who did not respond the first time since there had been some problems with the postal service distribution initially. As a result, the second round garnered three new respondents while losing 11 of the Round one respondents. A final return of 41 or 66 per cent was achieved. The breakdown of respondent types is shown in table 1 above.

Quantitative analysis of responses. Given the structured response forms used in the second round, it was possible to begin the analysis with a quantitative summary. The percentage of responses in each of the three categories (important, somewhat important and not important) were calculated and the category represented by the median response noted. These summaries were calculated for each of the subgroups (academic, commercial and government) as well as for the whole group of respondents. Since it was clear that the presence of similar items would tend to dilute the weighting put on individual concepts, we analysed the redundancies by constructing cluster diagrams showing how individual items were related. Some examples of these diagrams are shown in figure 1. The number in each circle indicates the item number used in the second round of the survey. These numbers along with their associated descriptions are listed in table 3. These diagrams clearly illustrated which items were seen to be central and which ones were associated with these central items.

Analysis of Round two results. A number of interesting aspects emerged from the analysis of the second round of the questionnaire. While we had anticipated considerable difference of opinions about which items would be important, there was, in fact, considerable similarity, particularly when the opinions of the academic, government and commercial sectors are considered as separate groups. Interestingly, our participants from the government sector generally stressed the need for students to learn practical aspects such as performing needs analysis, operating a commercial GIS, writing macros and selecting appropriate systems for a specific application. The

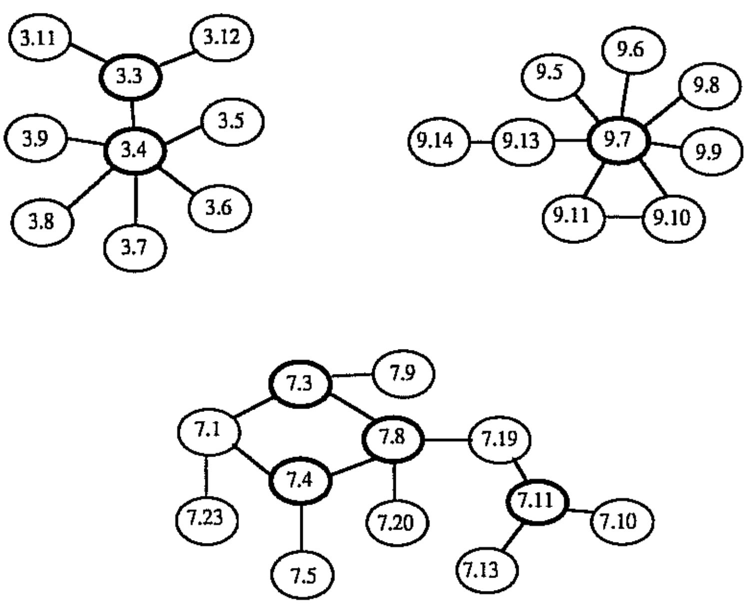

Figure 1. Example cluster diagrams from the analysis of Round two responses. Items in dark circles are central themes. Numbers refer to items described in table 3.

Table 3. Items in the Rond two survey shown in figure 1. Analysis of the cluster diagrams shows that items in bold print are central themes.

Item	Description
	Operational skills
3·3	**Operate a single commercial software package**
3·4	**Operate several commercial software packages**
3·5	Enter data into a GIS
3·6	Operate a digitizer, scanner and plotter
3·7	Use digital images for analysis of thematic information
3·8	Perform data transformations
3·9	Write macros
3·11	Given a particular GIS, navigate through its data schema
3·12	Make queries
	Nature of spatial data
7·1	Essence of spatio-temporal phenomena
7·3	**Language of spatial relations and processes**
7·4	**Modelling geographical reality**
7·5	Representation of geographical knowledge
7·8	**Spatial entities, relations and attributes**
7·9	Spatial processes
7·10	Mapping spatial data into the GIS data model
7·11	**Data models and structures for spatial data**
7·13	Field versus object views and raster versus vector representations
7·19	Spatial concepts as implemented in GIS
7·20	Links between geometric and attribute data
7·23	Spatio-temporal data models
	Data issues
9·5	Data acquisition (graphical and textual)
9·6	Data input and verification
9·7	**Data capture technologies**
9·8	Digitizing
9·9	Scanning
9·10	Data conversion
9·11	Advanced data conversion techniques
9·13	Advantages and disadvantages of different data capture methods
9·14	Integrating data from different models and sources

academics were only moderate advocates of these aspects and the commercial sector were, surprisingly, the least supportive of the inclusion of such practical education.

There was also a distinct division between those who think that land registration and cadastral aspects should be essential elements of the curriculum and those who think these aspects are only somewhat important. This separation was clearly representative of the different application and academic orientations of our participants. In the revised list for the third round questionnaire, this contradiction was addressed by including land registration and cadastrals as part of the range of source data issues, and land information systems as an important application area to study.

Revisions for Round three. Given the quantitative information described above and tempering it with a consideration of the strength with which each median represented the opinions of all respondents as well as of each subgroup, each individual item was reviewed to determine whether it should be rejected, considered as part of another item or revised. Only seven items were rejected due to strong 'not important' ratings, but many more were eliminated through consideration of redundancies. Items rated as not important included:

— fractals,
— adapt GIS methodology to special cultural and local situations,
— conduct a complete real-world GIS project,
— explain the specific problems of post-communist countries,
— figure out how any established GIS works in 1 day,
— operate several commercial software packages,
— start sales negotiations on systems and data.

Items which were seen to be related were combined where possible. Central items within categories received particular attention. As well, there was considerable redundancy between items in the Skills section and items in the Knowledge sections (particularly between the System planning skills and the Management and implementation knowledge). Thus, in the final list, the Skills section was reduced to a single group and included only items which can be thought to be practical skills, eliminating those skills which are merely a demonstration of the acquisition of knowledge. As well, we felt it was necessary to divide the skills into a set which included those new skills which should be acquired during this course and a set which included those skills students of the course could be expected to already possess when they begin the course, but which might need some upgrading. Such already acquired skills ('skills needing refreshing') include:

— use graphics to communicate information,
— know where to find more information,
— continue learning on his/her own,
— work comfortably with a computer,
— organise team projects,
— demonstrate basic presentation skills.

Clearly, this decision to restate a large portion of the developing course content as knowledge rather than as active learning outcomes (skills) moved the survey results firmly away from an objective-oriented approach to curriculum development towards the subject-centered one. This is the direction in which the iterative process of the Delphi survey led. As will be seen, later phases of the development process attempted to at least partially balance this move.

The result of this revision was the elimination of 33 per cent of the second round items giving a new set of 168 items grouped into 11 categories. Items were grouped within the categories according to whether they received a median rating of 'important' or 'less important'. Table 4 summarises the results of Round two.

3.4. *Round three—confirming consensus*

The Round three survey contained a summary of the Round two analysis and the list of items outlined in table 4 below. Respondents were asked to examine each of the deleted items to determine whether they agreed or disagreed that the item should be deleted. If they disagreed, respondents were asked to write a short comment describing the grounds for their disagreement. Then, respondents were asked to

Table 4. Summary of Round two results.

Themes	# of items Important	Less important
Nature of spatial information	13	3
Data issues	10	2
Database issues	3	2
Spatial analysis	5	8
Technology aspects	3	15
Related technology	—	12
Application areas	3	12
Management and implementation aspects	2	25
Cartographic and visualisation aspects	2	4
History and trends	—	3
Skills to be acquired	13	18
Existing skills needing refreshing	10	
*Total items	168	
Deleted items	82	

*Total items plus deleted items do not sum to the original total of 252 since some items were combined in the revised list.

review the list of retained items and, again, comment on any whose final rating they disagreed with. There was no structured response form for this round.

The final round was distributed by fax in May 1993 to only those people who had responded to either or both of the previous rounds. This reduced our third round distribution to 50 and only 22 of those (44 per cent) responded. Respondents in general seemed satisfied with the revised lists though each one identified three or four items which he or she felt had been rated incorrectly (i.e., less important when it should be important or vice versa).

Analysis of Round three results. Although each respondent commented on only three or four items each, there was still sufficient indication that further refinement of the lists was possible. In particular, some items which had been downgraded by the rule of the majority in the second round, apparently became more important when considered in the context of the final set of items. Items which four or more final round respondents felt should be upgraded in importance are:

— Digital terrain models,
— Data upgrading methods,
— Metadata,
— Database design methodologies,
— Various types of spatial analysis,
— Basic steps in the completion of a small application.

It is possible that some of these issues had been lost in the rewording of other items, or that items which most people felt in the second round were not of major importance attained such a low average rating that they were pushed completely off the lists. However, these problems are not major and we concluded that this last round gave us sufficient information for a final revision and overall confirmation of the final list of topics and skills.

3.5. *Value of the Delphi survey*

The Delphi survey has had several favourable results. While the final list of topics may compare favourably with those developed by many GIS educators without the assistance of similar information, having completed the process has given us a solid foundation upon which we can confidently design our course. Since we have had the opportunity to tap the experience of a great variety of European GIS experts, it seems likely that our list of topics is more comprehensive than any developed within a single discipline or country. This gives us a truly justifiable basis for contending that our course is indeed international.

However, some concern was voiced that a list of topics does not make a curriculum. Indeed, our Delphi survey was not able, nor was it designed, to provide us with a pedagogically-sound structured curriculum containing the clear statement of educational goals, objectives and derived tasks favoured in the curriculum development literature (Gold *et al.* 1991, Gronlund 1985). The survey produced simply a list of topics. No guidance is provided about the appropriate manner of instruction for each topic, nor about the proper sequence. To address this issue, our curriculum development plan included one additional phase—the expert meeting. The results of this meeting are in the next section.

One particularly insightful comment on the results of the survey provided a note of restraint that demanded consideration during the final phases of curriculum development. Dr C. Peter Keller of the University of Victoria, Canada, observed that:

There exists the risk when conducting a survey like yours that you will capture responses that reflect past and present thinking, but that do not reflect visionary contributions. GISs in the past have evolved as tools for inventory and routine information query in industry and government. This reflects in our mode of thinking. Some initiatives are struggling with the use of GIS for SDSS [Spatial Decision Support Systems] and analysis—and here visionary industry and government are running into problems of out-of-date data, lack of understanding of spatial analysis, and lack of ability to effectively communicate the message. Your group may want to give this some thought. To what degree ought your course prepare the next generation of GISers, not produce clones of the last generation (Keller 1993, personal communication).

3.6. *Expert meeting*

Following the completion of the third round of the survey, a two-day meeting of a group of 13 people involved in GIS education was convened in Vienna in June 1993. The group consisted partly of survey respondents and partly of people who were not involved in the survey. This combination allowed both fresh insight and continuity. Participants came from Germany, Spain, Greece, France, U.K., The Netherlands, Italy and Austria. While most participants were from universities, there were also some from government land information and regional planning agencies as well as from the U.N. training agency, UNITAR.

At the meeting, participants considered many of the more difficult issues in curriculum design. Following presentations about various approaches to GIS education for working professionals and a full analysis of the Delphi results, the group was charged with addressing a number of issues, including:

(*a*) identification of detailed objectives and a discussion of how each objective can best be achieved,
(*b*) consideration of the depth of coverage each topic should receive given the objectives and the survey results,
(*c*) evaluation of various methods of instruction for different topics given the objectives,
(*d*) development of a detailed syllabus for the course,
(*e*) an outline of the required practical exercises, and
(f) a plan for evaluation of the course.

While all of these objectives were not achieved in the two days, the meeting did make considerable progress which would not have been possible without the groundwork prepared by the Delphi survey. Using a mixture of full group and small group sessions, the participants developed an outline for the organisation of the important themes brought out by the Delphi survey into 18 lecture units to be taught in the three two-week classroom sessions of the course. With mixed success, the group identified objectives for these 18 units and arranged all the Delphi survey topics within this framework. Whenever possible they also outlined practical exercises and considered which teaching methods would be best for achieving the objectives of each unit.

There were two aspects to our efforts at the meeting that proved difficult to resolve. The group recognised the central role the practical project will play as the means for ensuring that the students have the opportunity to review and implement the theory they learn in the classroom. However, it became clear that in addition to the logical development of concepts, the sequencing of topics needs to account for the fact that students must know certain things before they can be asked to:

(*a*) identify and plan the theme and structure of their practical projects in the time between the first and second classroom sessions, and
(*b*) carry out their practical projects in the time between the second and final sessions.

Since the students will be expected to present the results of their practical project during the final classroom session, units in this part cannot contain anything that will be necessary for the successful completion of useful and interesting projects. As well, the group concluded that the first classroom part should end with a practical unit on needs analysis and feasibility studies for GIS and the second part with a unit on methodologies for system design and selection.

This essential organisational requirement determined by the placement of the practical project led to some difficulty in determining the content of the last classroom part. Considerable discussion at the meeting revolved around the development of a logical organisational framework for the assorted items that must be placed at the end of the course. In fact, by the conclusion of the meeting, this aspect of the course curriculum was still unsettled and was left to the course developers to resolve.

In spite of these few unrealised objectives, the expert meeting was a refreshing and extremely useful exercise. Participants were enthusiastic about the process and were pleasantly surprised at the ease with which we were able to incorporate the range of cultural, language and disciplinary backgrounds. The meeting provided an excellent opportunity for us to review the Delphi survey results with other GIS

Table 5. Outline of units for the International Post-Graduate Course on GIS, July 1993.

Part one—Spatial information for GIS	
0.	Introduction to course
1.	Spatial concepts and the representation of spatial knowledge
2.	Determining and representing location
3.	Modelling reality in an information system
4.	Spatial concepts as implemented in GIS
5.	Data sources for GIS
6.	Traditions and use of GIS
7.	Needs analysis and feasibility studies for GIS
Assignment of the practical project	
Part two—Information systems for GIS	
8.	Technical aspects of information systems
9.	Special information system requirements of GIS
10.	Database issues
11.	Technical aspects of digital spatial data
12.	Spatial analysis
13.	Methodologies for system design and selection
Presentation of project proposals	
Part three—Practical project	
Part four—Using GIS in the organisation	
14.	Communicating spatial information
15.	Economics of geographical information
16.	Project management
17.	Implementing GIS in an organisation
18.	GIS in society
Presentation of projects	

education experts and helped us develop a pedagogical framework into which these results could be placed. In fact, the meeting was so productive that shortly after the conclusion of the meeting, the results of the Delphi survey plus the discussions from the meeting were crystallised into a complete Course Blueprint which forms the basis of the next phase of the project—materials development.

3.7. *Course Blueprint*

The Course Blueprint contains a description of each of the 18 units to be taught in the course. Objectives are outlined for each of the units and topics to be covered in each are indicated. Table 5 lists the 18 unit topics. The detailed Course Blueprint is included in Appendix A. While this Blueprint provides the basic structure for the course, we recognise that the individual contributions of each unit writer and the students' evaluations of the initial course presentations will necessarily lead to further modification.

Finally, an opportunity to confirm the convergence of opinions we sought to achieve in our curriculum development process appeared in the form of two responses to the Round three survey that were not received until after the completion of the Course Blueprint. We were pleased to confirm that the concerns noted by these respondents regarding the ratings of items at the end of Round two had already been incorporated into the Course Blueprint as a result of their being addressed either by other respondents in Round three or during the discussions at the expert meeting.

4. Conclusion

While some educationalists voiced initial doubts that our Delphi survey could produce a solid foundation for the development of an effective GIS course, we argue that the Course Blueprint is proof to the contrary. By concluding the Delphi survey effort with an expert meeting, we were able to crystallise the many issues raised into a comprehensive course concept. Likewise, without the Delphi survey, our expert meeting would not have been able to gather sufficient momentum to generate the course framework and unit objectives that it did. Of course, the curriculum development process will not conclude with this phase. Evaluation of the materials both through review processes and in the classroom will follow. Adjustments of the content and structure of the final realisation of the course can be expected.

The curriculum design method described in this paper achieved our intended goals. The Course Blueprint reflects a broad view from the combined knowledge and experience of the GIS experts. The process discussed shows how it is possible to move from an unorganised list of topics to a pedagogically sound, realistically structured course outline. A few differences between different subsets of the participating experts are acknowledged, but in general agreement amongst opinions was very strong and consensus was reached easily.

Acknowledgments

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Appendix A. The Course Blueprint of the International Post-Graduate Course on GIS, July 1993

Course goals

Upon completion of this course, students will have a comprehensive understanding of GIS technology and its application within the European context. Participants will gain a solid background on GIS architecture and functionality and an understanding of how GIS can be integrated into various administrative processes. Methods for determining the needs for GIS and for planning, selecting and implementing systems for organizations will be explored. Instruction is provided through a mixture of lectures, paper exercises and computer practicals. Students will acquire hands-on experience with a commercial GIS programme. Interaction with an international group of instructors and participants in an intensive learning environment provides a stimulating educational experience. Students who successfully complete all four parts of the course will receive a formal certificate from the Technical University of Vienna.

This course is intended for professionals who are currently employed in any field using spatial information and who would like to increase their knowledge of the use of GIS technology. It will be of particular value to those at the project supervisor and the junior and operational management levels. It is anticipated that a large proportion of the participants will come from medium sized private enterprises and government agencies.

Within the course, several application areas will be reviewed, including: suitability analysis, facility siting, natural resource management, facilities management, land information systems, urban planning and management, network applications, marketing, topographical analysis, map-making, scientific and research applications and simulations and mathematical models. As well, some skills which entering students should already possess may benefit from reinforcement during the course. These include: know where to find more information, continue learning on his/her own, work comfortably with a computer, interact with other professionals, organize team projects, break a problem into smaller parts for solution, describe project management methodologies, educate others in his/her organization, demonstrate basic presentation skills and use graphics to communicate information.

Part one—Spatial information for GIS

Spatial information is both raw material and product of GIS. A good understanding of the nature of this spatial information is critical for the success of GIS applications. The transformation of data about entities, physical processes and human activities distributed on the surface of the earth into a form suitable for digital storage and analysis is the focus of the first part. Here, we examine the various types and sources of spatial information, its special characteristics and its limitations. Methods of digital data collection, including surveying, photogrammetry, digitizing and scanning, and the characteristics of paper maps as a data source are explored. As well, we consider how the many types of spatial information are used in various agencies to solve spatial problems and to help manage spatially distributed resources and facilities. Students learn to use a simple GIS and are introduced to the operation of a selected commercial GIS program.

Unit 0. Introduction to course

This short, introductory unit outlines the contents, structure and objectives of the course. Members of the course organizing team are introduced. Learning materials are distributed. The timetable and student responsibilities are discussed and clarified. Students are introduced and each describes what he or she expects to achieve from this course.

1. *Spatial concepts and the representation of spatial knowledge*

This unit considers the different ways in which space and spatial information are understood and used by various scientific and administrative disciplines and cultures. At the end of this unit, students will recognize their own particular spatial concepts and be able to examine these with respect to other approaches. Topics include: concepts of spatial information, spatial and spatio-temporal phenomena, spatial processes, human cognition of space, representation of spatial knowledge, integrated GIS approach.

2. *Determining and representing location*

In this unit various systems for expressing the location of phenomena on the surface of the Earth including the use of both local and absolute coordinates are presented. At the end of this unit, students will be able to summarise various methods for describing location and to explain the function and construction of map projections. They will be able to discuss the issues of accuracy, transformations and distortion with respect to projections. Topics include: georeferencing, coordinate systems, map projections, determining location, coordinate transformations, geocoding, GIS without coordinates.

3. *Modelling reality in an information system*

This unit introduces the basic concepts of information systems as a means of storing and retrieving attributes about real entities. At the end of this unit, students will be able to outline the characteristics of common database management systems and to perform simple data modelling and query exercises on attribute data. Topics include: historical development of database management systems, information systems as a logical model, data models and their use, accessing data.

4. *Spatial concepts as implemented in GIS*

This unit describes how the spatial concepts discussed earlier are expressed in GIS. At the end of this unit, students will be able to describe the basic data models and structures used in GIS and to explain how they affect the use of data stored in spatial databases. Topics include: data models and structures for spatial data, cartographic models, rasters, topological models, typical applications for each type of model, typical spatial operations using each type of model, spatial reasoning.

5. *Data sources for GIS*

This unit examines the various sources of data used in GIS. At the end of this unit, students will be able to describe the differences in the characteristics of data obtained from various data sources and to outline the processes required to collect data for a spatial database from various sources. They will also be able to assess the suitability, cost, accessibility and quality of existing datasets. Topics include: different types of spatial data and their characteristics, data sources for GIS, maps, data capture technologies, land registration and cadastres, photogrammetry, remote sensing and digital imagery, data conversion, data editing, data quality, combination, integration and compatibility of various technologies, integrating data from different models, sources and scales.

6. *Traditions and use of GIS*

This unit introduces students to the typical uses of GIS and the range of applications in which it can be used. At the end of this unit, students will be able to outline the historical development of GIS technology and to contrast the various technological approaches to the digital handling of spatial data. Topics include: overview of GIS applications, GIS roots, typical uses of GIS.

7. *Needs analysis and feasibility studies for GIS*

This unit provides a review of the concepts presented in this part of the course as well as an introduction to a methodology for needs analysis and feasibility studies. At the end of this unit, students will be able to describe the development cycle for a GIS and to explain the purpose of a GIS needs analysis. They will be capable of outlining a procedure for performing an analysis in a specific organization. In the period between this and the next part, students will use this methodology to assist them in the preparation of their project proposals. Topics include: the development cycle, resources and requirements for a GIS implementation, spatial information products, methology for conducting a needs analysis, feasibility studies, case study.

Assignment of the practical project

Part two—Information systems for GIS

The second part concentrates on GIS as a special type of digital information system. Here we consider how spatial databases are constructed and managed and how spatial data is manipulated for analytical and management purposes. GIS architecture and data structures as well as the processes and hardware for input and output are examined. Participants gain extensive experience on a commercial GIS of their choice and are taught techniques for continuing self instruction. At the end of this part, the class critically reviews each student's proposal for the practical project to be completed in the next part of the course.

8. *Technical aspects of information systems*

This unit provides an introduction to computer based information systems in general. At the end of this unit, students will be able to describe the basic components of information systems and their physical limitations and to demonstrate knowledge of the relevant elementary principles of computer science. Topics include: computer hardware, computer software, operating systems (DOS, Mac, UNIX, NT), computer programming, software engineering, system architecture, computer networks and communication, cost and performance characteristics of computer components.

9. *Special information system requirements of GIS*

This unit examines the special characteristics of GIS as information systems by considering hardware and user interface aspects. At the end of this unit, students will be able to describe the basic functions of the hardware and software components of a GIS. Topics include: GIS as a type of information system, special demands of GIS, hardware strengths and weaknesses, commercial GI systems capabilities and limitations, user interface design.

10. *Database issues*

This unit considers in considerable detail, relevant aspects of database management systems. At the end of this unit, students will be able to describe selected technological characteristics of database management systems and to explain the role of metadata and how it may be stored. Topics include: database concepts, database management systems in general, database management systems for GIS, data modelling, metadata, transaction and update management, distributed databases, database technology alternatives, expert systems and knowledge bases.

11. *Technical aspects of digital spatial data*

This unit examines technical issues related to the management and use of spatial data given currently available systems. At the end of this unit, students will be able to describe the characteristics of some specialized spatial data models and to explain the technical aspects of data quality as they apply to data capture, storage and representation. Topics include: basic concepts from geometry for the modelling of spatial data, treatment of geometric data, specialized data models, data quality issues, data standards and data exchange.

12. *Spatial analysis*

This unit examines various spatial analysis techniques in order that students will understand how GIS applications may incorporate these important functions. At the end of this unit, students will be able to choose between several different spatial analysis tools with respect to the phenomena and processes they are analyzing. Topics include: GIS functionality for spatial analysis, raster analysis and 'map algebra', digital map overlay, network analysis, areal analysis, surface interpolation, spatial statistics, error analysis and propagation, basic algorithms of geographical data processing.

13. *Methodologies for system design and selection*

This unit provides the basis for the completion of the practical project during the time between this and the next classroom part of the course. At the end of this unit, students will be able to outline a methodology for evaluating and choosing between different GIS for a specific project. Topics include: basic steps in the completion of a small application, designing a GIS implementation, specifying a GIS, selecting a GIS, pilot projects, database design methodologies, planning for update and maintenance.

Presentation of project proposals

Part three—Practical project

Building upon the knowledge and experience gained in the first two parts of the course, the third part allows students to expand this knowledge through practical application. Each student individually completes a practical GIS project using the data and facilities available at or near his or her workplace. Project themes may range from the development of a small set of data and analytical operations addressing a particular problem, to the analysis of the needs for GIS within an organization, to the drafting of a detailed plan for the introduction of GIS into a particular agency. In most cases, students' projects will be of immediate value to the agencies and companies which employ them. Students will be guided through their projects with the assistance of GIS experts in their own countries.

Part four—Using GIS in the organization

GIS often involves a complete change in the manner in which an organization is structured and functions, particularly when it comes to the use and management of the enterprise's spatial information resources. By examining various case studies, the final part of the course considers organization-level issues related to the use of GIS. Since GIS is useful only if the outputs from it are effectively communicated, cartographic and graphic design aspects for the presentation of spatial data are reviewed. Students study the necessary steps in the process of system development, from needs analysis, through the request for proposals to the pilot study, final implementation and management plan. Questions of organizational politics, the economics of maintaining spatial databases and sharing data across organizational and international boundaries are also considered. Issues particular to specific application areas are highlighted. The presentations of students' projects provide additional opportunities to examine implementation issues.

14. *Communicating spatial information*

Results from GIS may be both tabular and graphic. It is important to understand how this information can best be communicated to the final users. At the end of this unit students will be able to use the basic principles of cartography and graphic design to produce output from a GIS that provides clear and accurate representations of the data. Students will also be able to describe various techniques for visualizing spatial information and to explain the basic principles of colour perception and how three dimensional information is represented in two dimensions. Topics include: visualization and the representation of GIS data, elements of cartographic design, theory of semiology of graphics, graphic design, computer graphics, cartographic generalization in the context of GIS, cartographic representation of GIS data, communicating information with a GIS, verbal communication, presenting lists and reports.

15. *Economics of geographic information*

This unit examines the economic aspects of the implementation and use of a GIS in an organization. At the conclusion of this unit, students will be able to explain the potential financial benefits and costs of introducing a GIS. Topics include: concept of corporate data, cost benefit analysis, copyright and ownership of data, marketing spatial data, the European geo-information market and its actors, case study.

16. *Project management*

This unit examines various issues related to the management of a GIS project. At the end of this unit students should be able to list several important management aspects that need to be considered when planning the implementation of a GIS in an organization. Topics include: financial management, data acquisition, data administration, geographical information inventory management, training and education, using and understanding technical documentation, case study.

17. *Implementing GIS in an organization*

This unit examines some of the organizational impacts resulting from the introduction of GIS into an organization. At the end of this unit, students will be able to describe these impacts and to design a plan for implementing a GIS such that negative impacts on the organization are minimized and the benefits (financial and otherwise) are maximized. Topics include: organizational context of GIS, advantages and disadvantages of using GIS, problems and implications involved in adopting GIS, socio-economic impact of GIS on institutions, strategies and tactics for implementing GIS, promoting GIS within an organization, managing a multiparticipant project.

18. *GIS in society*

This unit considers several general but important organization-level aspects, including legal and ethical issues, the future of GIS technology and research and development needs. At the end of this unit, students will be able to discuss the present and future role of geographical information and GIS in organizations. Topics include: driving forces behind the expansion of GIS, law and geographical information, ethics of geographical information, international GIS projects, future of GIS, research and development activities and needs.

Presentation of projects

Appendix B: Delphi survey respondants and GIS education meeting participants

Education meeting participants

Irene Campari, Technical University Vienna, Austria
Marco Cavagnoli, CSI Piemonte, Italy
Petra Cremers, Rijkshogeschool Groningen, The Netherlands
Andrew Frank, Technical University of Vienna, Austria
Bruce Gittings, University of Edinburgh, United Kingdom
Steve Gold, UNITAR, Switzerland
Helmut Gran, Landesvermessungsamt Rheinland-Pfalz, Germany
Michael Gould, Universidad Complutense de Madrid, Spain
Marinos Kavouras, National Technical University of Athens, Greece
Karen Kemp, Technical University of Vienna, Austria
Serge Motet, Institut Geographique National, France
Gerhard Muggenhuber, Bundesamt für Eich- und Vermessungswesen, Austria
Fred J. Toppen, University of Utrecht, The Netherlands

Survey respondents

Emin Bank, Turkey
Darius Bartlett, Ireland
Yvan Bédard, Canada
Flavio Bonfatti, Italy
M. J. D. Brand, Northern Ireland
Heinz Brüggemann, Germany
Marien de Bakker, The Netherlands
Carlos Jose dos Santos Cardaso, Portugal
Manfred Ehlers, Germany
Manfred M. Fischer, Austria
David Forrest, United Kingdom
Dieter Fritsch, Germany
Michael Goodchild, U.S.A.
Michael D. Gould, Spain
John Herring, U.S.A.
Ernst Höflinger, Austria
Ole Jacobi, Denmark
Wolfgang Kainz, The Netherlands
Johannes Kanonier, Austria
Rimantas Kaulakys, Lithuania
Marinos Kavouras, Greece
C. Peter Keller, Ireland
Gintautas Kmieliauskas, Lithuania
Milan Konecny, Czech Republic
Andreas Kotsonis, Cyprus
Menno-Jan Kraak, The Netherlands
Zenonas Kumetaitis, Lithuania
Robert Laurini, France
David J. Maguire, United Kingdom
Robert Maher, Canada
Serge Motet, France
Byron Nakos, Greece
Richard G. Newell, United Kingdom
John O'Callaghan, Australia
Helge Onsrud, Norway
Harlan J. Onsrud, U.S.A.
F. J. Ormeling, The Netherlands
Sandra Piscedda, Italy
Mark Pork, Estonia
David Rhind, United Kingdom
Massimo Rumor, Italy
Tapani Sarjakoski, Finland
Stratis Stamouras, Greece
Josef Strobl, Austria
Hayati Tastan, Turkey
Vladimir Tikunov, Russia
Maurizio Trevisani, Italy
Lysandros K. Tsoulos, Greece
Richard Wright, U.S.A.