EduMapping the evolution of an academic GI curriculum – the case of Geomatics at Delft University

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ABSTRACT

This paper shows how EduMapping was used, in combination with Learning Outcomes, to describe the differences between versions of the Geomatics MSc programme at Delft University of Technology. With EduMapping labels, radar diagrams and centroid maps the changes in teaching content are visualized. The Learning Outcomes of each version were used experimentally to find out if the aimed for performance level of the students also changes. This experiment resulted in a change of level, but it is uncertain if it was caused by programme changes or by lack of conformity to the format rules.

INTRODUCTION

The MSc Geomatics programme[1] at Delft University of Technology is judged favourably by the students[2] and by its alumni. Also the staff-members involved in this MSc Geomatics programme are very motivated to educate the students at a very high level and to incorporate research activities into their teaching. So, it is not surprising that the latest visitations showed good marks for the programme, the facilities, and the quality of the education. The only thing is: throughout the last decades the number of registered students did not match the expectations and the potential. Despite a lot of marketing efforts, BSc students just didn't become aware of the existence of MSc Geomatics at Delft University of Technology.

To avoid threatening discontinuation of the programme, it was decided to shift Delft's MSc Geomatics programme from its current inter-faculty status to an independent programme, hosted by the Faculty of Architecture at Delft University of Technology. With regard to content, the MSc Geomatics programme will be of a more applied nature by a stronger focus on the built environment in order to make it more attractive for potential students. Besides, this update of the curriculum will increase the workability ("studiability") of the programme by a modular course setup. The new version of the programme (Verbree and Lemmens 2012) was developed during 2011 and early 2012. To help guard the quality of the curriculum during the update, EduMapping (Rip and Van Lammeren, 2010) was applied. This method includes a simple tool[3] to relate the components of the curriculum to a description of the GI domain: the Geographic Information Science & Technology Body of Knowledge (DiBiase *et al.* 2006), hereafter referred to as "GI-BoK".

EduMapping had been used in Delft to characterize the proposed (2011) and the final version (2012) of the programme. For this paper that was the opportunity to try answer the question: how does the EduMapping content characterization represent the three versions of the programme?

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[1] http://home.tudelft.nl/en/study/master-of-science/master-programmes/geomatics/

[2] The Geomatics programme at Delft University of Technology came out 3rd in the 2011 edition of the "Keuzegids Hoger Onderwijs" (N.N., 2011), listing the student's appreciation for academic master programmes in the field of earth sciences, geography and environmental sciences in the Netherlands.

[3] The EduMapping Toolkit: http://www.geo-informatie.nl/rip001/EduMapping/EduMapping.html

Assessment summary	ECTS size	share
GI subjects in BoK	45.0	38%
AM. Analytical Methods	6.2	5%
CF. Conceptual Foundations	4.9	4%
CV. Cartography and Visualization	2.8	2%
DA. Design Aspects	3.6	3%
DM. Data Modeling	4.5	4%
DN. Data Manipulation	3.4	3%
GC. Geocomputation	1.9	2%
GD. Geospatial Data	10.1	8%
GS. GI S&T and Society	4.3	4%
OI. Organizational & Institutional Aspects	3.4	3%
New GI subjects wrt mapping in May 2011	0.0	0%
Application of GI subjects in generic compo	75.0	63%
Non-GI subjects	0.0	0%
sum	120.0	100%

Figure 1. EduMapping label for Geomatics for the Built Environment 2012.

Changes in a teaching programme typically means: introduction of new subjects and / or expansion of the time spent to existing subjects and letting go of obsolete subjects, while the overall programme size remains unchanged. The values in the time/subject matrix, summarized in a label (Fig.1), make it easier to keep track of the consequences of the pruning and grafting process of programme change. In a compact way it shows how the study load of the programme is distributed across subject areas.

During preparation of this paper, a second question arose: how is the evolution of Geomatics reflected in the Learning Outcomes? That is important because they indicate the aimed-for capability level of the future graduates, so the impact of programme changes should be watched. The answers to the questions are relevant for GI curriculum managers and GI teaching programme directors.

Profile of Geomatics for the Built Environment

The web pages of the 2-year 120 credits[4] programme describe it as follows (May 4, 2012):

"In the first year, you will take the Common Core courses as well as courses from the various Application Domains. The Common Core provides a strong foundation to all students by teaching the fundamentals of data gathering, processing, analysing, and visualisation. Covered topics include 'Positioning and Location Awareness', 'Geographical Information Systems and Geovisualisation', '3D Modelling of the Built Environment', 'Geo Datasets and Quality', 'Geo Databases Management Systems', 'GeoWeb Technology, 'Spatial Decision Support', and 'Geo-information Organisation and Legislation'.

The application domains are sets of interlinked courses meant to broaden and/or deepen the students' knowledge in one of the many Geomatics application fields: Urban Analysis, Asset/Facility Management, Water management, Hydrography, Remote Sensing and other geo-related fields. If you need to update your knowledge in Mathematics, Computer Science or basic geographical courses you can use a portion of the application domain credits to follow convergence courses."

"In the second year, students can choose to undertake the Geomatics Synthesis Project or follow additional courses from one of the Application Domains. The Synthesis Project allows you to combine knowledge from the core programme and apply it to a real-world project while gaining hands-on experience in project management. The MSc in Geomatics is concluded with an individual graduation project that takes about 9 months to complete."

[4] In Europe, a 'credit' represents a study load between 26 and 28 hours. In full: ECTS, European Credit Transfer and Accumulation System

The courses in the Common Core part take up 45 credits. This is the part that can be mapped to GI-BoK. The GI-component in the various application field courses or supporting convergence courses varies. It has not been mapped. Together, their study loads are 30 credits. The individual graduation project represents another 45 credits. It is important to note that only the Common Core part of the programme could be mapped to GI-BoK. The non-mappable 75 credits are booked as 'generic' GI.

METHOD

Use of EduMapping implies acceptance of a limited set of concepts to describe the contents of a teaching programme: the GI Body of Knowledge with its hierarchical structure of hundreds of Topics organized in some 70 Units across 10 Knowledge Areas. Use of EduMapping results in a matrix, showing amounts of study load (in credits) against subject areas. In the present version of the tool, a GI programme could be mapped to GI-BoK on the Units-level of detail. Edumappings of all three versions of the programme were made by Edward Verbree, programme manager of the present version of the Geomatics curriculum. The sets of Learning Outcomes of the 2010 version of the programme and the 2012 version were written by the teaching staff. For the proposal-version of 2011 no Learning Outcomes were formulated.

Edumappings comparison

The primary outcome of applying EduMapping is the label. It shows the distribution of study load in credits per content category. The four categories show: which share of the programme can be linked with GI-BoK Knowledge Areas, which share is clearly GI but not present in GI-BoK, which share is GI but cannot be linked to specific GI-subjects (hence: "generic"), and finally the share of the programme which is clearly not GI.

The first category, GI in BoK, provides most details. This invites further comparison. The quantitative nature of the edumappings allows a straightforward tabular comparison of the study load values per GI-BoK subject for the three versions. The 2011 version and the 2012 version of the programme were assessed on the level of GI-BoK-Units, but the 2010 version was assessed on the less detailed Knowledge Area level. This makes Knowledge Areas the preferred level of detail for comparing the three versions of the curriculum.

Please note that the assessment activity, required to produce the figures, is less straightforward. There clearly is an element of subjectivity involved, as was indicated in (Rip and Van Lammeren 2010). Sensitive parts of the process are the assignment of GI-BoK items to parts of the programme description, and also the quantification of their share of the whole.

The figures resulting from the assessments allow arithmetical processing and enable graphical presentation. Two types of visualization were created with Microsoft Excel: a Radar diagram and Scatter diagrams. For this purpose, the GI-in-BoK category in each label was taken to represent 100% of the programme. For that purpose the scores per Knowledge Area were recalculated to their part of 100%. This gives normalised shares for the dedication of study load to each of the Knowledge Areas.

The Radar diagram shows the 10 GI-in-BoK values by a polyline. Comparing different versions of the programme then means: check in which of the ten directions which polygon has higher or lower values. However, doing this for more than a few polylines soon becomes too complex.

To reduce the complexity of comparing more than a few polylines, their centroids can be calculated. The Scatter diagram was used to show the positions of the centroids of the three Geomatics versions in a two coordinate reference system. For this spatialization purpose, a little data processing was required: grouping, value addition per group and centroid calculation. This process was explained in (Rip and Van Lammeren 2010), and it is included in the EduMapping Toolkit.

Scatter diagrams were also made of the centroid coordinates for the individual modules of each version of the programme, altogether about 40 of them.

Comparison by means of Learning Outcomes

Nowadays, in the European Higher Education Area, Learning Outcomes (LO) are essential to describe qualifications to be obtained at third level institutions. LO's are defined as a statement of what a learner is expected to know, understand, and/or be able to demonstrate after completion of a process of learning. The standardized format of a set of LO's starts with the phrase "On successful completion of this module, students should be able to:", followed by descriptive triplets of the form: active verb – object – context for each LO (Kennedy 2007). It is recommended to formulate four to six LO's for a teaching module. In each LO, only one action verb should be used. A guide to help which verb to choose can be the non-exhaustive lists of verbs for each of the six stages of Bloom's taxonomy (fig. 2). These 6 stages represent performance levels, for which learners could acquire the ability. Bloom also defined performance levels for the affective domain and the psychomotor domain, but here only the cognitive domain is relevant.

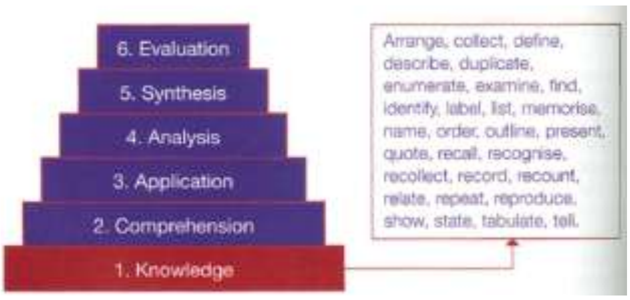

Figure 2. The first stage of Bloom's Taxonomy, with suitable active verbs (Kennedy, 2007).

For the Delft Geomatics MSc programme, LO's were available for the 2010 and the 2012 version of the programme. They were experimentally processed as follows. For each LO it was determined to which performance level the action verb belonged. In a number of cases, the LO contained more than one action verb, in which case the one belonging to the highest performance level was chosen to represent the LO. The other two components of the LO, the object and the context, were not taken into consideration. The performance level for a group of LO's (ideally 5 LO's per module) was calculated by simply averaging the set of values. This approach produced performance values for the individual modules. For the programmes, the values for their individual modules were also averaged.

It appeared, that the LO format rules have not been followed very closely when making LO's for the Geomatics 2010 version. For some 2010-modules, this required a more than average amount of interpretation by the authors to decide which active verb(s) might give a fair representation of the teaching intention of those modules. Then the number of the appropriate Bloom-stage was taken to represent the performance level for that LO.

RESULTS

EduMapping products

Three types of results were available from the collected EduMapping excel sheets.

1. Labels. The values in the labels of the three versions are shown in Table 1.

2. Radar diagrams. The visualisations of the In-BoK categories (columns ‘c’ in Table 1) are in Figure 3.
3. Centroid coordinates. They were also calculated for the c-columns in Table 1.Their values are shown in scatter plots in Figures 4 and 5.
   Figure 4 shows the centroids of the Knowledge Area scores for the EduMappings of the three programme versions in a two-dimensional space (explained in Rip & Van Lammeren 2010). The horizontal axis (x) reaches from all time spent on Society & Organisation subjects (left) to all time spent on Concept/Methods/Tools subjects. The vertical axis (y) reaches from all time spent on Physical Reality (top) to all time spent on Presentation (bottom). The resulting centroid coordinates were: x:6.03, y:8.87 for 2010; x:0.65, y:11.76 for 2011; 7.93,10.33 for 2012.
   Figure 5 combines the centroid representing a version of the whole programme with the centroids representing the individual modules of the programme. It shows the centroid clouds for the three Geomatics editions.

Table 1. Values in the labels resulting from EduMappings made by E.Verbree. The values in the columns marked ‘c’ were used for visualisation in radar diagrams and for calculation of the centroid coordinates.

	Geomatics 2010			**Geomatics 2011 (concept for 2012)**			**Geomatics 2012 – for the built environment**		
	a. ECTS	b. share	c. In-BoK =100	a. ECTS	b. share	c. In-BoK =100	a. ECTS	b. share	c. In-BoK =100
GI in BoK	**47.0**	**39%**		**51.0**	**43%**		**45.0**	**37.5%**	
AM	*7.0*	*6%*	14.9%	*5.5*	*5%*	10.8%	*6.2*	*5%*	13.7%
CF	*3.0*	*3%*	6.4%	*2.0*	*2%*	3.9%	*4.9*	*4%*	10.9%
CV	*3.0*	*3%*	6.4%	*5.0*	*4%*	9.8%	*2.8*	*2%*	6.3%
DA	*2.5*	*2%*	5.3%	*2.0*	*2%*	3.9%	*3.6*	*3%*	8.0%
DM	*4.5*	*4%*	9.6%	*11.0*	*9%*	21.6%	*4.5*	*4%*	10.0%
DN	*3.0*	*3%*	6.4%	*0.0*	*0%*	0.0%	*3.4*	*3%*	7.5%
GC	*3.0*	*3%*	6.4%	*2.5*	*2%*	4.9%	*1.9*	*2%*	4.2%
GD	*11.0*	*9%*	23.4%	*12.0*	*10%*	23.5%	*10.1*	*8%*	22.3%
GS	*6.0*	*5%*	12.8%	*3.0*	*3%*	5.9%	*4.3*	*4%*	9.5%
OI	*4.0*	*3%*	8.5%	*8.0*	*7%*	15.7%	*3.4*	*3%*	7.6%
GI Not in BoK	**10.0**	**8%**		**6.0**	**5%**		**0.0**	**0%**	
Generic	**56.0**	**47%**		**60.0**	**50%**		**75.0**	**62.5%**	
Not GI	**7.0**	**6%**		**3.0**	**3%**		**0.0**	**0%**	
sum	120	100%	100%	120	100%	100%	120	100%	100%

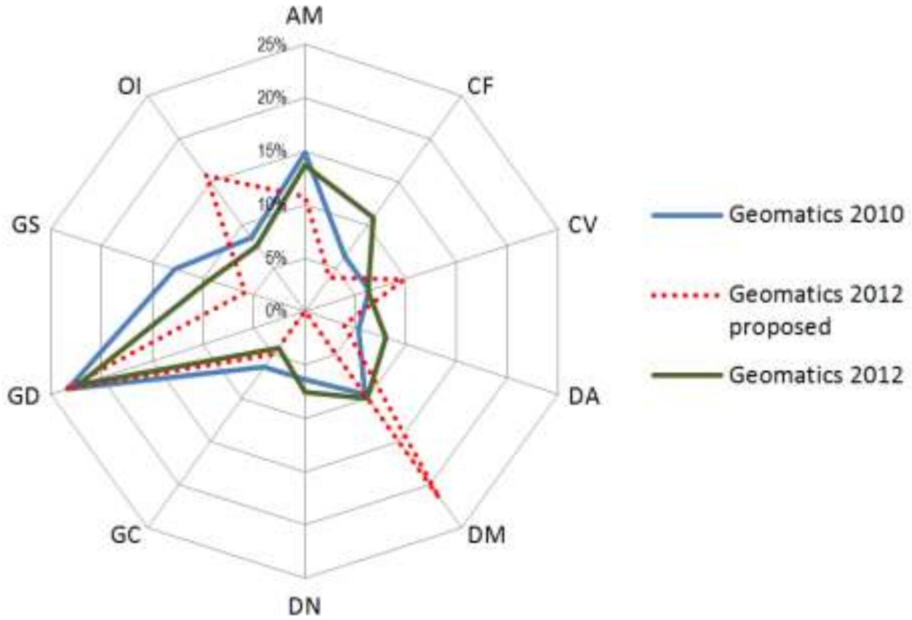

Figure 3. Three overlaid Radar diagram polylines representing the three versions of the Geomatics programme, as mapped on 10 GI-BoK Knowledge Areas by E.Verbree.

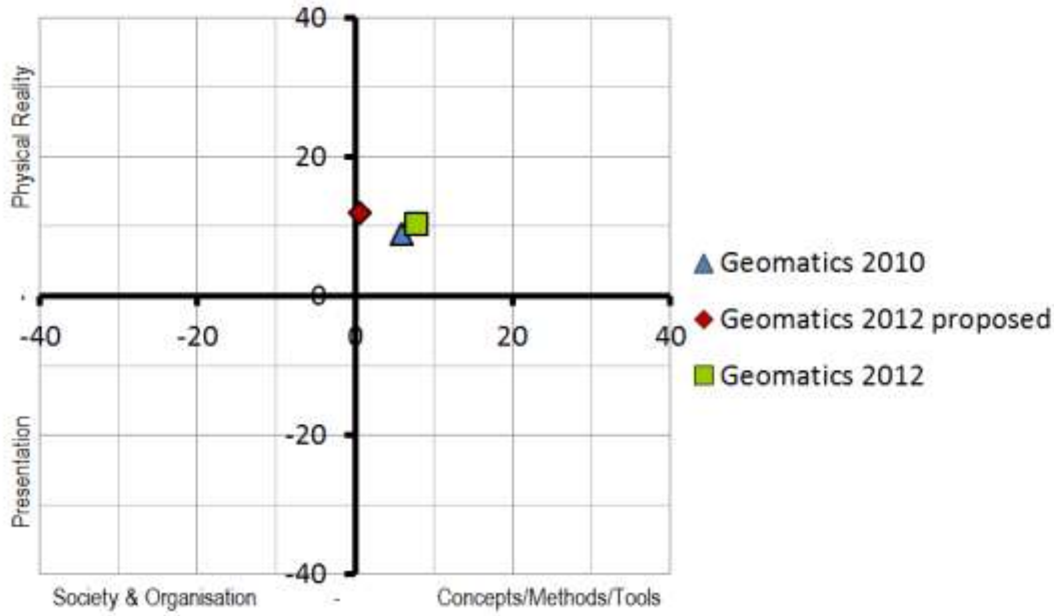

Figure 4. The centroids of the Knowledge Area scores for the three EduMappings in a two-dimensional space.

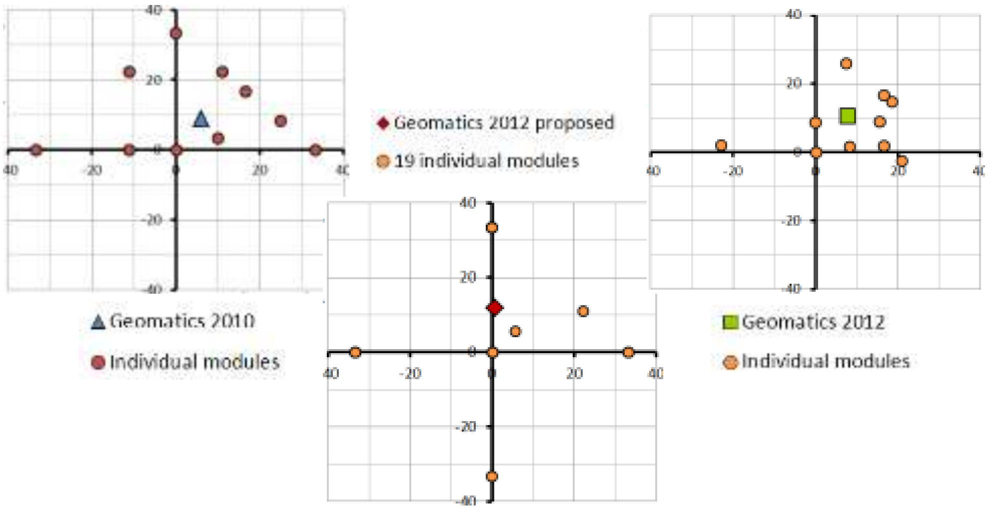

Figure 5. The clouds of centroids for the individual modules of the 3 Geomatics programmes

Learning Outcomes

Lists with LO's were available for the 2010 version and the 2012 version of Geomatics (Verbree and Lemmens 2012).

The analysis of the learning Outcomes per unit in the core programme resulted in the following average values for the performance levels of students that successfully completed the units.

Table 2. Overview of the intended student performance level for Geomatics 2010 and 2012 versions, based on the available Learning Outcomes

Core programme MSc Geomatics 2010 – 29 ECTS		Core programme MSc Geomatics 2012 – 45 ECTS	
GM1050. GIS Principles and Applications	4.2	GM.1 Sensing Technologies for the Built Env.	1.0
GM1080. Geo Database Management Systems	1.5	GM.2 GIS and Cartography	4.8
GM1090. Introduction Geomatics	2.0	GM.3 Positioning and Location Awareness	4.2
GM1210. Location Based Services	3.8	GM.4 3D Modelling of the Built Environment	5.6
GM1240. Imaging Remote Sensing	2.7	GM.5 Spatial Decision Support for Planning and Crisis Management	4.4
CIE4521. Multivariate Data Analysis	2.3	GM.6 Geo Database Management Systems	4.3
CIE4522. Satellite Navigation	2.5	GM.7 Geo Web, Sensor Networks and 3D-Geo Visualisation Technology	3.8
GE4662. Org. and Legal Aspects of Geo-Inf.	6.0	GM.8 Geo Datasets and Quality	3.8
		GM.9 Geo-information Org. and Legislation	5.2
Overall average performance level (scale 1-6): 3.1		**Overall average performance level (scale 1-6): 4.1**	
Remarks: For 9 modules there were 15 content descriptions, interpreted as 25 LO's. The LO-format was not used in 5 descriptions.		Remarks: Nr. of active verbs: 79 in 40 LO's. Maximum was 4 verbs in one LO. Most verbs were in vocabulary offered by Kennedy (2007).	

FINDINGS

The objective of this paper is to show the usefulness of the EduMapping method for concise description of GI teaching programmes and, in spite of that compactness, be able to compare their contents. The focus here is on showing a few steps in the evolution of the Geomatics MSc programme at Delft University of Technology. The findings from the two views on the programme versions are described below.

Edumappings

The comparison of labels in Table 1 shows many figures. Looking at the four horizontal main categories, it is clear that the study load of the GI-in-BoK category stays under 40% of the programme. In the 2011-proposal its share was 43%, an increase that apparently did not survive discussion. A second remark is, that in the 2012 edition of Geomatics no time is spent to GI subjects that are Not-in-BoK, or to subjects that are not GI. However, the textual description of the programme on the website shows that supportive courses could be taken in for instance mathematics or computer science. And that part of the Common Core is a module on GeoWeb Technology, which is not a lengthy item in GI-BoK. The programme allows students to follow an individually profiled sequence of modules. The use of EduMapping requires specific choices, otherwise links to BoK-items cannot be made. So the focus on the Common Core part is in fact too narrow to show the full spectre of the programme. Nevertheless, the GI-in-BoK category shows a nice subdivision of how the study load touches on all Knowledge Areas, and how it differs between the versions of the programme.

Figure 3, the Radar diagram, shows superimposed polylines for the GI-in-BoK category of each programme version. More pregnant than in Table 1 it shows the proposed changes in 2011 for the Knowledge Areas Data Modelling (DM), Data Manipulation (DN) and Organizational and Institutional Aspects (OI).

Figure 4 shows the centroid positions for the three Geomatics versions. On this aggregation level, the 2012 version is pretty close to the 2010 version. The 2011 version was a little more data oriented and had a considerably stronger orientation towards Society and Organisation.

Figure 5 shows all three versions in separate plots, with the centroid positions representing their individual modules. The point cloud provides more context. It shows for instance that Geomatics 2010 had three modules in the left half of the plot, whereas Geomatics 2012 only has one. This explains why in Fig.4 the 2012 centroid position is a little more to the right than the 2010 centroid.

Learning Outcomes

At first sight, Table 2 shows that Geomatics 2012 aims for a 25% higher overall average performance level by its graduates. This generates questions: For which subjects? and: Is it plausible?

To answer the first question a comparison of the EduMapping labels of the Geomatics versions is helpful, because it shows how much of the study load is directed at which GI-BoK subject. There, the different module names and the different number of modules play no role.

To answer the second question it is relevant to look at the Learning Outcomes themselves. In this case it appears that especially of the Geomatics 2010 LO's many were not LO format compliant. In the non-compliant cases, the active verbs were chosen by the authors, based on the provided sentences. The teaching staff might have chosen other active verbs, having in mind how they would examine and test the student's progress. Therefore, the calculated performance level values for Geomatics 2010 cannot be trusted. The change from value 3.1 to value 4.1 is not entirely credible, due to the quality of the 2010 Learning Outcomes.

CONCLUSIONS AND RECOMMENDATIONS

The preceding chapters of this paper showed how a GI curriculum could be characterized by making EduMapping assessments and by using the Learning Outcomes. In the opinion of the authors this approach is useful for programme management and to provide GI programme information to prospective students, GI employers and professional GI organizations.

However, remarks must be made about a number of limitations to the application of these methods.

Assessor subjectivity

The subjectivity in selecting a GI-BoK item and a time share to represent an aspect of a course or programme is unavoidable. Also, LO writing is prone to subjectivity. In this case, the edumappings were done by the person now carrying responsibility as programme director. The advantage here is in the fact that this person has also been involved with two earlier versions of the MSc programme, which implies a certain continuity and experience in linking teaching content to GI-BoK.

If this is better than a collection of edumappings made by different persons might be the subject of another paper. Asking individual members of staff to make edumappings for modules they teach would introduce the impact of personal differences in interpretation, skill (familiarity with GI-BoK) and attitude (patience to assign study loads to parts of an existing programme).

The authors see the following strategies to deal with subjectivity:

- EduMapping assessments and LO formulation should be done by the person closest to the actual teaching. This would cause the transfer of as much of the teacher's experience and plans as possible into the results.
- If GI-BoK could be compared to a language, than it would be best for the international GI community to learn that language, teach it, and use it to set up GI courses from the start. This would reduce the need to translate to and from GI-BoK.
  At this place, it seems good to point at the fact that the most detailed level of GI-BoK, the Topics, consists of LO-like sentences, more than 1600 in total. In GI-BoK they are referred to as "formal educational objectives" (DiBiase et al. 2006, p.30). They are surprisingly similar to the Kennedy's LO's: they also start with an active verb. The GI-BoK Topics offer a wealth of LO-like sentences for each of the GI-BoK Knowledge Areas.
- Use subjectivity by asking less involved colleagues, or even colleagues from abroad, to make an EduMapping assessment of the same course and formulate LO's for it. Then discuss the resulting differences. These discussions might bring out different opinions on the focus of the curriculum, hidden implicit assumptions or local terminology. That should lead to adaptation of the course description.

GI-BoK imperfections

At the AGILE[5] conference 2012 in Avignon, France, one of the authors of this paper did a short poll about GI-BoK during a presentation with about 100 people present. It appeared that 80-90% was aware of GI-BoK, about 50% was familiar with it, and about 10% liked it. It seems justified to criticise GI-BoK for a diversity of reasons (usability, content, up-to-dateness). Reinhardt (2011) did so. However, this should not lead to dismissal of that work. It has been a point of departure for the Geospatial Technology Competence Model published by the United States Ministry of Labor (DOLETA 2010). It also was the basis for on-going "foundational research" (Ahearn *et al.* 2012).

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[5] AGILE: Association of GIS Laboratories in Europe. Membership in 2012: 89 in 23 countries.

This research is funded by the American National Science Foundation. The objective is to develop a successor "GIS&T BoK2" with a web 3.0 character. The GI Body of Knowledge does have a future! In this situation, the recommendation of the authors is to make do with the paper version of GI-BoK, for now. Build up experience and familiarity and in this way prepare for BoK2.

Context

The concept of EHEA, the European Higher Education Area, ensures that teaching in Europe will become more coherent between countries. The European Qualification Framework is a translator to connect teaching levels in one country to those in another country by means of Learning Outcomes. Of course a disciplinary reference is also needed. GI-BoK could be just that for GI Education. EduMapping can help to convert existing programme and course descriptions to GI-BoK referenced descriptions. In that way a "common ground" could be created for all actors in the GI education field.

In the Netherlands, an important actor is CROHO, the central register for third level education, agency of the Ministry for Education. If an already accredited programme like Geomatics wants to update or refocus, CROHO asks NVAO, the national accreditation organisation, to check if the intended changes stay within bounds. This visitation of the Geomatics for the Built Environment programme will take place before the end of 2012. The authors expect that the EduMapping results will help to satisfy the visitation committee that the change in identity of the programme does not require re-accreditation.

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