Competence Dimensions in a Bologna-oriented GIS Education

Uwe SCHULZE, Detlef KANWISCHER & Christoph REUDENBACH

Abstract

As part of the Bologna Reform, competence-oriented restructuring of the curricular content within the field of Geographic Information Science and Technology in higher education in Germany is becoming an essential educational enterprise. In this context, an engaging discussion and systematic study of the professional and personal competences involved in GIS education is inevitable. However, it is largely unclear which and how professional and personal competences need to be incorporated into a competence-based GIS&T curriculum. This shortfall in geoinformation education in Germany needs to be addressed and invites further research. This paper identifies the dimensions of GIS competences that are crucial for a successful GIS education that enables students to master and work with and within Geographic Information Systems.

1 Introduction

As early as the 1990s, GIS education in tertiary education in the U.S., Canada and some European countries (UK, Austria) started to be accompanied by a systematic, technology-related curricula development (KEMP & GOODCHILD 1992, MARBLE 1998, DIBIASE 2006, JOHNSON 2006). In contrast, a similar development within GIS training in higher education in Germany is still a desideratum. Basic curriculum questions have remained largely unanswered up to the present (PEYKE 1996, BILL 1996, 2005).

The current debate about the development of a competence-based GIS curriculum in higher education in Germany is mainly influenced by the competency-based design of educational processes in the course of the Bologna Reform. Within this process the major goal is to connect subject-related knowledge and generic competences among students in order to activate basic action competences to foster multiple problem- and application-oriented solutions using GIS.

Geographic information systems serve as methodological tools to answer spatial problems and questions thus, their solutions-oriented application requires both a broad range of domain expertise as well as additional skills. However, this integrated perspective is not yet fully a part of the German debate on GIS competences; a debate that is predominately based on Sui’s paradigm of teaching and learning about or with GIS. This fact is not surprising, since in Germany there is lack of research in the empirical capture of competences in the higher education sector in general. In this context ZLATKIN-TROITSCHANSKAIA & KUHN (2010, p. 15) state: “As central as the issue of competence assessment has become as part of TIMSS and PISA on primary level, it is still neglected so far in higher education.”

Against this background, our paper focuses on the theory-based identification of core competences within the field of GIS education as a basis for an empirical assessment. First, we

This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution license (http://creativecommons.org/licenses/by/3.0/).
will present an outline of the current competence debate in higher education in Germany. Based on this outline we will analyse current international and national curriculum documents that determine content-related competence structures for GIS training and education. Finally, we will discuss the operationalization of core competences in terms of modelling and measurement of competences in higher education.

2 Defining ‘Competences’ in Higher Education in Germany

The question of an applicable definition of ‘competence’ turns out to be a never ending story. Due to a vast number of different terminological and conceptual approaches DELEMARE LE DEIST & WINTERTON (2005, p. 29) regard competence as a ‘Fuzzy Concept’ and claim “that it is impossible to identify or impute a coherent theory or to arrive at a definition capable of accommodating and reconciling all the different ways that the term [competence] is used”. Within the international competence debate DELEMARE LE DEIST & WINTERTON recognize three traditional approaches: behavioural approach (USA); functional approach (UK); multi-dimensional and holistic approach (France, Germany, Austria).

Within the German education system the competence concept was established in the 1970s in the form of the concept of key qualifications (DEUTSCHER BILDUNGSRAT 1974, MERTENS 1974). The so-called ‘competence-based turn’ (ARNOLD & SCHÜSSLER 2001, p. 54) of the 1990s marks the change from a mere subject orientation within learning fields (input orientation) towards an action competence approach (output orientation). Today there are four major elements that belong to the concept of key competences in higher education: personal competence, social competence, cognitive competence and methodological competence (cf. HEIERLE 2006).

In addition to the holistic and problem-oriented definition of ‘Kompetenz’ by WEINERT (2001), the current design of the competence concept in higher education in Germany is dominated by different strategic documents within the framework of the Bologna Reform: The Qualifications Framework of 2005 and the European Qualifications Framework for Lifelong Learning (EQF) of 2008 frame a legally binding character for the development of study courses in Germany. Devised on the basis of the TUNING-Project and the Dublin Descriptors of the Joint Quality Initiative, the nationally effective Qualifications Framework defines the learning outcomes for the degree programs Bachelor, Master and PhD and describes related competences and skills a graduate should have by the end of his or her studies.

On the other hand, the EQF “is a common European reference framework which links countries’ qualifications systems together” (EUROPEAN COMMISSION 2008, p. 3). The EQF classifies eight referencing levels of vocational and academic education and training, and describes knowledge, skills and competences (abbreviated as KSC throughout the text) in the sense of learning outcomes. In the EQF: “‘competence’ means the proven ability to use knowledge, skills and personal, social and/ or methodological abilities, in work or study situations and in professional and personal development. In the context of the European Qualifications Framework, competence is described in terms of responsibility and autonomy” (EUROPEAN COMMISSION 2008, p. 11).

Another document, which is currently being discussed in a draft version, is the German Qualifications Framework for Lifelong Learning (GQF). This document uses the EQF as a
reference tool to relate the national qualification systems to the European level. In accordance with the EQF, the GQF defines ‘competence’ also as: “the ability and readiness to use knowledge, skills and personal, social and methodological competences in work or study situations and for professional and personal development (AK DQR 2009, p. 14)”. However, the following sentence has been added: “Competence is understood in this sense as action skills (ib.)” The mere adoption of responsibility and autonomy, as addressed in the EQF, is in this case specifically extended by the aspect of ‘self-acting’. This multidimensional and holistic approach put forth in the GQF is also reflected in the structure and description of Kompetenz within this document. In contrast to the EQF, the GQF is based on a four-tier distinction of (1) subject related knowledge, (2) skills (both are summarized as ‘professional competence’), (3) social competence and (4) self-competence (summarized as ‘personal competence’). This explicit emphasis on personal competences in the educational process is due to the fact that the BA and MA programs do not only act as an way to access the next degree level in higher education, but are also associated with the training of students for the labour market in terms of employability (ib. p. 11).

3 Identifying the Dimensions of a Competence-orientated GIS-Education

Based on the GQF, there is a structural frame made of general KSC descriptions which define relevant competence areas within the GIS&T-domain. In this chapter we will offer a summarizing analysis of curricular documents which are substantial for training and education within GIS in higher education. Then we will attempt to identify the dimensions of GIS competence that students must have in order to successfully master operations within GIS.

3.1 Analysis of current documents for GIS-Education in higher education

The main objective of our comparative analysis of various descriptions of GIS competences is to find out which structural and thematic similarities and differences exist in the documents delineating KSC within the GIS&T-domain. So far we have identified three main documents: First, there is the Geographic Information Science & Technology Body of Knowledge (GIS&T BoK) (DiBiase et al. 2006) and secondly, the Geospatial Technology Competency Model (GTCM) (Careeronestop 2010). Both documents are characterized by a long-term and expert-based work process and have a particular significance to the needs of the GIS&T-industry sector in the US-American labor market (Gaudet, Annulis & Carr 2003, DiBiase et al. 2006, U.S. DoL 2010). While the GIS&T BoK incorporated the GIS&T-domain in general, the GTCM lists all relevant knowledge areas, skills and competences that are crucial for the GIS&T-sector. The third document is the so-called Kerncurriculum Geoinformatik (GrGI 2009). This core curriculum represents the first attempt at defining essential KSC for the B.Sc. study programs of Geoinformatics in Germany.
Fig. 1: Analysis of relevant KSC to master GIS
Using an analysis matrix (Fig. 1), we can reflect the breadth, depth and function of each curriculum document, all of which serve different target groups with specific goals, requirements and competences within the GIS&T-domain. In addition, the analysis scheme includes the concept of competence defined by the GQF (ch. 2). Thus, we will establish a conclusive link that connects the wide range of KSC in the field of GIS&T to the theoretically discussed concept of competence within higher education in Germany.

Focusing on the identification of relevant GIS competences we obtain three major competence dimensions. First, all documents emphasize the capacity for spatial thinking and reasoning as a basic competence dealing with GIS. The GIS&T BoK explicitly states in its knowledge area ‘Conceptual Foundations’: “The GIScience perspective is grounded in spatial thinking. [...] this knowledge area forms a basis for the other knowledge areas” (DiBIASE et al 2006, p. 58). Another important competence dimension derives from the wide range of technical and methodological subject-specific knowledge and skills within the GIS&T-domain (professional competence). Within the area of personal competences, generic or transferable capabilities such as problem solving & decision making and critical & analytical thinking appear to play a particular role. With respect to their operationalization for modelling and measurement of competences (ch. 4) these generic and transferable personal competences (explicitly defined in the GTCM, cf. Fig.1) can be summarized as problem-solving competence (cf. SCHULZE, REUDENBACH & KANWISCHER 2011). The role of GIS for the positive development of problem-solving skills within the learning process has also been noted by AUDET & LUDWIG (2000), KERSKI (2000), BEDNARZ (2004) and FALK & SCHLEICHER (2005). Furthermore, there have already been a variety of problem-based learning environments for GIS developed (e.g. MELERO 2005, SINTON 2009, http://www.gitta.info, http://gisbsc.gis-ma.org/).

3.2 GIS-workflow and the required dimensions of GIS competences

Once we have determined the three dimensions of GIS competences in the context of the analysed curricular documents, we will go on to relate the relevance of these dimensions to the practical level of work processes involved in GIS in higher education (Fig. 2).

By definition, there is an inherent integration of GIS into a ‘real-world context’. Since geographical information systems are used as a methodological tool to solve spatial (geographic) issues and problems, their utilization within the problem-solving process itself can be considered as both a technical and cognitive solution process, which is used in order to change a specific situation (problem) into an unrealized solution (cf. FLEISCHER, WIRTH, RUMANN et al. 2010). Using an information system, this solution process generally occurs on the basis of the variable processing of data and algorithms.

Another key process involved in using GIS relates to the cognitive modelling of geographic information as a major precondition for the technical creation of spatial data, i.e. spatial and temporal definition of characteristics of geo-objects (features). This process includes three important steps: Mental abstraction, generalization and modelling. One of the results of this cognitive activity can be, for example, the selection of appropriate data models and -types or scales of spatial and temporal resolution. Thus the GIS-user already needs skills and competences in spatial thinking to create an appropriate data basis to solve a spatial problem. Finally, there are a number of technical and methodological KSC needed to successfully work with GIS, e.g. data modelling and manipulation, -analysis, etc.
This conceptual perspective indicates a fundamental role of problem-solving competences for the development of spatial thinking skills and technical KSC, because both areas contain a unique subject-specific and practical knowledge that is critical for problem-solving processes.

4 Approaches to the Operationalization of the Dimensions of GIS Competence

After analysing the curricular documents and reflecting on the GIS workflow, resulting in the identification of the three dimensions of GIS competence problem-solving, spatial thinking and technical abilities, we will introduce operationalizations indispensable for a further empirical study of our assumptions. The following theoretical concerns need to be taken into account. A suitable approach for modelling problem-solving competences can be found in the problem type ‘system analysis and design’, tested in PISA 2003. According to PISA, the goals of this problem type is identifying “[…] the relationships between parts of a system and/or designing a system to express the relationships between parts” (OECD 2004, p. 29). Within the tested problem-solving tasks students have to show their capacities in: understanding the problem, characterizing the problem, representing the problem, solving the problem, reflecting on the solution and communicating the problem solution.

For the development of an appropriate psychometric instrument other aspects must be paid attention to. First, there is the issue of classification of problem-solving skills in GIS either solely as personal competence (cf. BAUMERT et al. 1999) or as a crucial part of professional
competence (cf. LONGLEY et al. 2005). Secondly, it needs to be investigated how the problem-solving process is affected by the application of software, i.e. usage of tools, predefined order of work steps and processes, prerequisites for data processing and so on. Finally, there needs to be a profound discussion on whether problem-solving in GIS can be characterized as part of either an analytical or a dynamic problem-solving process (cf. FLEISCHER, WIRTH, RUMANN et al. 2010).

To structure the area of spatial thinking skills, we have to look to different international discussions of these skills. Helpful categories of spatial thinking in terms of geographic information and GIS are presented in the NRC (2006): ‘Concept of Space’, ‘Tools of Representation’ and ‘Process of Reasoning’. These three elements are useful for designing a meta-framework in conjunction with other theoretical concepts which also include relational concepts of space, see i.e. WERLEN (1993), GOLLEDGE (1995) GERSHMEHL & GERSHMEHL (2007), GOLLEDGE, MARSH & BATTERSBY (2007), JO & BEDNARZ (2009).

Subsequently, it has to be considered to what extent the GIS&T BoK can be used to describe dimensions of technical KSC within GIS&T. Since there is the large number of more than 1600 learning objectives contained in the GIS&T BoK, this model curriculum has to be downsized for simplicity. Therefore, the functional components of GIS, defined as Input, Management, Analysis and Presentation (cf. *EVAP-Model*, BILL 1999) can serve as a very productive framework.

5 Conclusion

The development of a GIS curriculum for higher education has progressed steadily over the last decades. For the German debate on competence in higher education, the *German Qualifications Framework for Lifelong Learning*, which uses the *European Qualifications Framework for Lifelong Learning* as its main reference, is the crucial document. The GQF stresses that the development of professional and personal competences must go hand in hand. Similarly, the analysis of international documents on GIS curricula indicates that both, professional and personal competences are important for the work with GIS. The three dimensions of GIS competences, extracted from the wide range of competences within the GIS&T-domain, are problem-solving, spatial thinking and technical KSC within the GIS&T. It turns out that problem-solving capabilities have a fundamental impact on the development of spatial thinking skills and technical KSC within the GIS&T-domain, as well as on the actual utilization of GI-Systems. The debate is now at a critically important stage. Following the HERODOT network Benchmark Statements for Bologna-based GIS Education (DONERT 2009, HERODOT NETWORK 2009) and as part of the structured discourse on curricular content the three dimensions must be operationalized in a next step in order to guarantee a valid empirical test of our model assumptions. In concrete terms, this includes the definition of respective competence elements as well as the modelling of their inner relationship in the form of competence clusters. To overcome this comprehensive challenge, experts from cognitive science, geoinformation science, geographical science and educational science related to GIS must work together, so that reciprocal content and psychometrical references can be taken into account from the very start.

In general, the question about the relation between subject-oriented and generic competences within GIS education is of particular interest because it is fundamentally linked to
the design of learning environments. Sui’s bipolar paradigm of teaching about GIS vs. teaching with GIS (SUI 1995, KERSKI 2008) leads to a separation of technical and education-oriented teaching contents. Within the current debate on outcome-oriented GIS curricula this separation seems too inflexible to promote GIS competences and GIS teaching as an integration of knowledge, skills and competences. Learning with and about GIS are two sides of the same coin, inseparably united in GIS teaching and learning (SCHULZE, KANWISCHER & REUDENBACH 2010).

References


BAUMERT, J. et al. (1999), Erfassung fächerübergreifender Problemlösekompetenzen in PISA. Berlin.


LONGLEY, P., GOODCHILD, M., MAGUIRE, D. J. et al. (2008), Geographical information systems and science. 3th Ed. Chichester: Wiley.


