From Digital Competence to Informatics Education. Structuring a Wide Field.

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Currently, in Austria there is a major reform of the final exam (Matura) on the way and will be implemented in 2015. All subjects, Informatics included, will be affected in different forms. The underlying philosophy of this reform is a strong competence orientation, thinking educational processes in terms of students' outcomes which are based on clear expectations and standardized objectives. There are central regulations in the main subject areas languages and mathematics, whereas in other disciplines, including Informatics, recommendations and guidelines have been developed, consisting of competence models, objectives in form of descriptors and prototypical tasks. Based on a preceding Austrian competence model for digital competence and basic Informatics education at lower secondary level, this paper discusses the current state of a similar coherent and comprehensive framework for Informatics education for upper secondary level. It will be shown that this framework provides a broad and consistent picture of school Informatics for general education, and specifically, supports teachers of Informatics with recommendations for competence-oriented tasks corresponding to the framework. Finally, one sample task will be presented in order to illustrate how abstract objectives can be associated to competencies.

1 Introduction

Since the late 1980s, Informatics, ICT and Digital Media education at the lower and upper secondary levels in Austrian schools for general education have shown a very inconsistent picture. Although there are many ambitious local and regional Austrian initiatives, ICT and Informatics are still not adequately represented in Austrian schools which provide general education.

This paper outlines the ongoing development of a comprehensive and coherent framework, including Informatics, ICT and digital literacy for all Austrian pupils and students at secondary level. Accordingly, Austria is in line with some other countries and organizations which endeavour to implement ICT and Informatics (computing) in schools according to the challenges of our digital society.

Besides some major initiatives, e.g. the UNESCO/IFIP curriculum (Unesco,2002), the ACM K-12 model curriculum (ACM, 2010) and the framework "Principles and Standards for Informatics", published by the German Society for Informatics GI (GI, 2010), there are many regional initiatives to legitimize and structure this major educational concern. For historical and political reasons, Switzerland's 26 cantons and Germany's 16 federal states put much energy in establishing ICT standards separately. The Austrian situation at the lower secondary level is currently even more fragmented. Due to the lack of a national ICT framework and curriculum, schools and teachers act independently, teaching, if at the lower secondary level at all, Informatics and ICT according to school specific curricula. As an undesired consequence, schools and pupils proceed and perform at extremely different paces. Whereas the framework for lower secondary level has been triggered by the Digital Agenda (DA, 2008), the competence model for upper general education is due to a major reform for the Austrian school leaving exam (Matura) which will presumably start in 2015.

2 A Viable Distinction: CS, IT, dl and TEL

In contrast to traditional subjects such as German, English, Mathematics and Natural Sciences with elaborated curricula for each age-group, computing at schools has still to fix the problem of an unclear terminology. Due to many international efforts of organizations and engaged people involved, it seems that this latent reason for uneasiness among educational researchers and reflective practitioners in the field is on a good way to be resolved.

It is important to look at computing at schools in a holistic way. Above all, digital competence is a field actively integrating into other disciplines and areas. Such a view suggests the definition of a framework as a means for promoting multi-disciplinary approaches while maintaining a clear identity of the field. Based on the European Reference Framework for Key Competences for Lifelong Learning (EU, 2007), digital competence ranks after the first and foreign language, Mathematics, and basic competence in science and technology in fourth place.

Beside this major program to promote digital literacy for all, Informatics is still in a process of defining itself. This phenomenon is not only restricted to some European and Asian countries where the term "Informatics" is widely used, but also to "computer science". There are severe public misperceptions about CS due to its confusion with programming, computer literacy and information technology. Frameworks and curricula cannot be developed on the fuzzy basis of a confusing terminology. Due to current worldwide efforts in this respect, a silver lining on the horizon gets visible. Prominent organizations of UK, including the Royal Society, agreed on four main fields describing computing at schools with a clear distinction and sound definitions (UK, 2012).

Herein "Computer Science (CS) is the study of the foundational principles and practices of computation and computational thinking, and their application in the design and development of computer systems", whereas "Information Technology (IT) deals with the creative and productive use and application of computer systems, including considerations of e-safety, privacy, ethics, and intellectual property."

Both, Computer Science and Information Technology are disciplines that can and should be encountered by pupils from early stages onwards. Both fields can be considered as proper, rigorous disciplines, not merely as low-level functional skills.

Digital literacy, abbreviated deliberately in small letters "dl", is defined as the "ability to use computer systems confidently and effectively, including basic keyboard skills and experienced mastering of standard software and navigating and harnessing the internet." Digital

Literacy is a cultural technique and a must for persons to function in a digital society. It is the foundation of Digital Competence.

Using digital technologies in education can and should improve learning in the particular subject. It is not a back-door way to teach IT or Computing. TEL (Technology Enhanced Learning) is not part of the curriculum in the way CS, IT, and dl are. “The technology serves learning; it is not the object of learning.”

Terms and definitions (can) change in the course of time, and no definitions serve everyone. But this sound distinction of the main building blocks CS (Informatics), IT, dl, TEL (E-Learning) of computing at schools can hold as a widely accepted and sustainable basis.

3 Competencies in Context

Educational systems in general always seem to be in a stadium of a major or minor reform. In some European countries one major reform is the irreversible development to a rigorous output orientation in form of clear expectations about results of learning in schools. In this context the buzzword “competence” has come into play, focusing more on students’ applicability of knowledge and skills than on curricula and teaching plans. The acquisition of competence and the degree of achievement is measured by completing tasks and solving problems. According to a prevalent definition (Weinert, 2001), competences include skills, knowledge and motivation to cope with new situations.

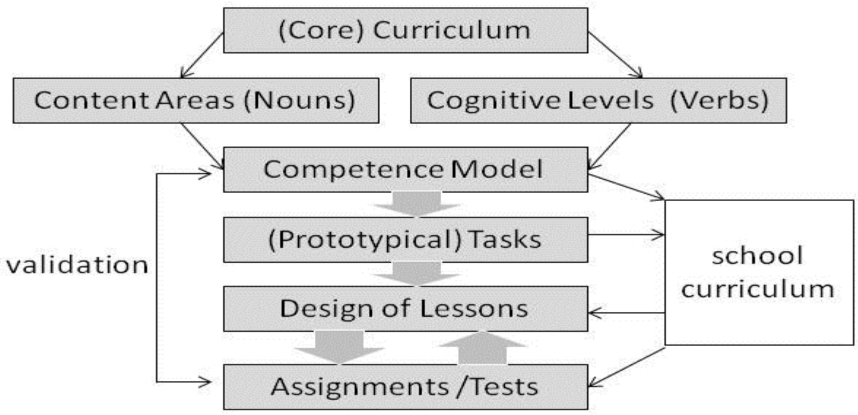

Figure 1: General Model for Educational Standards

Competence models play a well-defined and central role on the long way from abstract objectives to their implementation within an effective classroom management and, finally learning activities resulting in verifiable learning outcomes. Typically, they are deduced from a core curriculum and form the basis for so called educational standards. A competence oriented approach, aiming at concrete learning outcomes, has to be illustrated by appropriate and corresponding tasks and should be principally assessed by methods of testing. That is exactly what educational standards are about: Clear educational objectives based on competence models, illustrated by appropriate tasks and problems, accompanied and evaluated by assessments.

4 The Austrian Aproach

The Austrian school system encompasses elementary (grades 1 to 4), lower secondary (grades 5 to 8), and upper secondary level (grades 9 to 12/13). At the lower secondary levels the Austrian school system is divided into two types of obligatory schools, namely secondary general school (Hauptschule, HS) and the secondary academic school (Gymnasium, Allgemeinbildende Höhere Schule, AHS). Since two years, there is a large pilot project, called new middle school (Neue Mittelschule, NMS), exploring new pedagogical approaches. According to current political intentions, all HS will be converted into NMS and the traditional Gymnasium will remain as a school type in its own right also in the foreseeable future. Currently about two thirds of the pupils attend the HS (NMS) and about one third attend the lower level of the AHS for four years. The fist competence model presented in this paper refers to all pupils aged 14 years at the end of lower secondary level. After more than twenty years, the vision is to finally come to a national agreement on clear and binding objectives within a sound and acceptable framework of ICT/Informatics. The current Austrian situation is explained in the next chapters.

4.1 Preliminary Considerations

Lower secondary education – in Austria encompassing the age-groups 10 to 14 – must be regarded as a window of opportunity and important phase of formal Basic Informatics education. Standardized learning objectives with clear expectations for teachers and students, based on a consistent, coherent, and outcome-oriented reference framework, are overdue. Not least triggered by the Digital Agenda, a framework for "Digital Competence" has been developed by an Austrian task force, consisting of representatives of informatics didactics, school boards, and teachers as well.

4.2 Basic structure and terminology of the Competence Model

4.2.1 Remarks on Nouns (Content Strands)

The content of the reference model respectively competence model has been divided into two levels: lower secondary (11-14 years) and upper secondary level (15-18 years). At each level there are four distinct sections. Each strand includes several topics, called strand units that form the basic sections of the content to be covered (Tables 1, 3 and 4).

Lower Secondary Level	Upper Secondary Level
Information Technology, Human and Society	
Informatics Systems	
Software Applications	Applied Informatics
Informatics Concepts	Practical Informatics

Table 1: Main Content Strands

4.2.2 Remarks on Verbs (Activity Strand, Cognitive Levels)

One dimension in the competence matrix resembles Bloom's Taxonomy (Bloom, 1956) to a certain extent and distinguishes clearly between lower and upper cognitive levels. Verbs keep stable in the course of time whereas nouns and denotations for specific contents can change in the field of ICT. This applies especially for (software) tools. Due to its self-conception, a competence model must be (software)tool-invariant.

Lower Cognitive Skills	**Knowing** (Remembering Information): *Define, identify, list, match,…*	**Applying** (Using tool knowledge in concrete situations): *Modify, chart, use, calculate, …*	**Reflecting** (Thinking of activities): *Analyse, plan, organize,...*
Higher Cognitive Skills	**Understanding** (Comprehension: explaining the meaning): *Explain, describe, stmate,…*	**Designing** (Producing and Creating digital products): *Create, design, sketch,…*	**Evaluating** (Making judgements about concepts and tools): *Critique, judge, select,…*

Table 2: Cognitive Levels and Associated Verbs

Actually, it can be observed that in the field of computer science (Informatics), not in the domains of IT, dl and TEL, the rate of change slowed down in the last years which does not mean that there is no progress any more. Innovations do not affect the foundations and concepts whereas tools come and go. Both competence models have an abstraction level which guarantees a high degree of sustainability and longevity.

4.3 A Framework for Digital Competence at Lower Secondary Level

After two years of occasional meetings and reviewing regional, national and international curricula and frameworks, an Austrian task force decided to develop a new balanced competence model and framework as a sound compromise of informatics and media education. It can be considered to be equivalent with the Austrian concept of educational standards for traditional subjects at the lower secondary level.

Finally, it can serve as a solid fundament and preliminary stage for further Informatics and ICT teaching at the upper secondary level. After many years during which an overall concept has been lacking at the lower secondary level, it makes sense to build the house systematically from the first floor.

	Content	**Levels of Competences**		
		Knowing Understanding	**Applying Designing**	**Reflecting Evaluating**
Media Reflexion Related Topics	**Information Technology, Human and Society**			
	Impact of IT in Society			
	Responsibility in Using IT			
	Privacy and Data Security			
	Developments and Vocational Perspectives			
Digital Media Knowledge	**Informatics Systems**			
	Technical Components and their Use			
	Design and Use of Personal Information Systems			
	Data Exchange in Networks			
	Human-Machine Interface			
Use and Production of Digital Media	**Software Applications**			
	Documentation, Publication und Presentation			
	Calculation and Visualization			
	Search, Selection and Organisation of Information			
	Communication and Cooperation			
Principles and Computational Thinking	**Informatics Concepts**			
	Representation of Information			
	Structuring of Data			
	Automatization of Instructions			
	Coordination and Controlling of Processes			

Table 3: Model for Digital Competence (and Basic Informatics Education) in Austria's Lower Secondary Level

The competence model "Digital Competence" for lower secondary level (Table 1.) incorporates many aspects. It is integrative and consistent as well as interdisciplinary and multidisciplinary in its orientation.

A detailed description, explanation and discussion of the structure and exemplary descriptors can be found in (Micheuz, 2011, 2012). In general, curricula can be regarded as results of cultural traditions and findings from science and empirical research, and not least from framework conditions given by educational policy. The competence framework for lower secondary education has been developed without referring to a valid national (core) curriculum because currently there is none. As a consequence and for the time being, it has to be considered still informal with no obligations for schools, teachers and pupils. However, the first feedbacks from teachers about this model are promising.

One function of this model is to provide schools with guidance for implementing educational objectives. These can serve as a road map for policy makers, teachers, pupils, and parents as well. A second is to form a basis for assessing the educational outcomes in terms of these widely, but still informally, accepted objectives. The competence matrix can also provide an orientation for individual diagnosis and supplementary support measures.

This framework and classification scheme (Table 3) with four main categories and four content areas each, together with about 70 "I can …" descriptors, is currently disseminated among Austrian teachers. Prototypical tasks have been developed to illustrate and concretize the expected objectives and competencies. Some prototypical tasks have been tested with a good feedback from teachers and pupils.

Provided that there will be a broad agreement on the reference model and its standardized learning objectives, the autonomous schools then will be faced with the challenge of effectively and efficiently meeting them. Integrating ICT in existing subjects and/or implementing a new (interdisciplinary) subject will be a key question. Another task will be the supply with enough competent teachers and the development of competence-oriented curricula, and teaching material for the grades 5 to 8.

Currently, it does not seem to be realistic to implement compulsory Informatics lessons at lower secondary level in a short time. But there are indications and signals that, within a major curricular reform in a window of polical opportunity, a new integrative and innovative discipline covering the broad subject area of Digital Education could be established. By now, in schools which offer no or little formal IT/Informatics lessons it is up to the creativity of the administration to provide pupils with an opportunity to acquire a reasonable set of digital competencies within other subjects.

4.4 A Similar Competence Matrix for Informatics at Upper Secondary Level

General education does not stop at the age of 14. Besides vocational schools, secondary academic schools (AHS, Gymnasium) impart a broad general education at pre-university level. In these schools the subject Informatics is obligatory in grade 9 and elective in the grades 10-12. Due to a major reform on the school leaving certification process (Matura) in 2015, there is a need for an educational guide providing recommendations for the structure and implementation of competence oriented final exams for Informatics.

	Content	Levels of Competences: Knowing Understanding	Applying Designing	Reflecting Evaluating
Media Reflexion Related Topics	**Information Technology, Human and Society**			
	Impact of IT in Society			
	Responsibility in Using IT Privacy and Data Security			
	History of Computing			
	Vocational Perspectives			
Digital Media Knowledge	**Informatics Systems**			
	Technical Basics and Functionalities			
	Operating Systems and Software			
	Networks			
	Human Computer Interaction			
Use and Creation of Digital Products	**Applied Informatics**			
	Production of Digital Artefacts			
	Calculation Models and Visualization			
	Search, Selection and Organisation of Information			
	Communication and Cooperation			
Principles and Software Developement	**Practical Informatics**			
	Concepts of Information Processing			
	Algorithms, Data Structures and Programming			
	Data Models and Databases			
	Intelligent Systems			

I can reflect my responsibility when using IT systems in terms of quality and quantity.
I can evaluate and recommend various measures to protect data and IT systems.

I can design calculation models for solving problems.
I can analyse data with specific software.
I can visualize data appropriatly.

I can explain important technical terms and concepts in the context of tables.
I can describe, explain and sketch database models and relations between tables.

Table 4: Competence Model for Informatics Education in Austria's Upper Secondary Level

For the first time within more than 25 years, this gives the opportunity to reflect on the subject Informatics at upper secondary level and to provide teachers and students with a comprehensive competence model. This should give all persons involved a clear picture of the subject and field. A ministerial working group has been implemented in 2011 and worked out a competence model including recommendations with prototypical tasks (BMUKK, 2013).

The similarities with the competence model for lower secondary level are obvious and highly intended. Obviously, there are only a few changes in denotations which indicate the shift from digital competence (literacy) and ICT at lower secondary level to Informatics at secondary level. This model consists of four main categories, each further divided into four widely independent areas. Currently 80 (rather abstract) descriptors in form of “I can …” describe the competencies. The requirements are laid down in descriptors, which provide a more detailed information on the objectives and the topics indicated. The competence model, descriptors and the prototypical examples are tools used to generate a clear picture of the educational standards.

The combination of both models is complete in the sense that it covers all aspects in the context of Informatics, IT and digital literacy at each level of secondary education.

5 Sample Blueprint of a Competence Oriented Task

The screenshot of a so-called "URL Shortener" of a well-known search engine provider serves as possible starting point for competency-based questions and tasks wherein all cognitive dimensions of the competence model are covered.

These are

- Knowing and Understanding (reproduction, knowledge)
- Applying and Designing (transfer, action)
- Reflecting and Evaluating (reflection, metacognition)

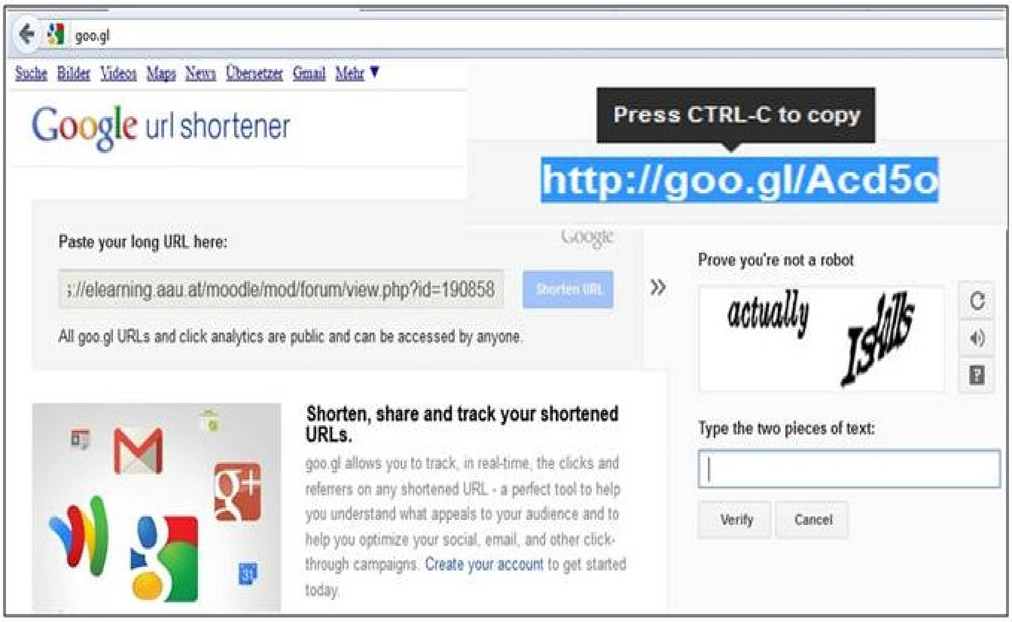

Figure 2: Shortening URLs: Screenshot of a Web-Based Human-Machine Interface

Here is a feasible set of questions and tasks, representing concrete and verifiable objectives, containing the verbs in Table 3 and associated with identifiable content areas of Table 4.

- Explain the acronym and concept of URLs.
- Describe which country represents the top level domain "gl".
- Explain the administration of the internet and to whom it belongs.
- Give reasons why the link "goo.gl" works without the prefix "http://".
- Analyze the website in Fig. 1 and describe the language behind it.
- List some elements of this language and demonstrate its effects.
- Explain the acronym HTML and argue why it is not a programming language.
- Explain why after entering the long URL to be shortened a so-called “Captcha” has to be solved.
- Explain the acronym “Captcha” and why it has to do much with the well known theoretical computer scientist Alan Turing.
- Implement a slimmed website which, after entering a long URL, yields a random string.

This sample of a complex task covers already a wide range of competencies in form of knowledge and skills. Each question respectively task represents an operational objective with an underlying competence, varying in difficulty, complexity and intellectual demand. Assigning each question and task to the competence matrix yields roughly a comprehensive competence pattern of this comprehensive task.

The next steps are sketched out. They can be easily identified by the development of prototypical tasks and a proof of concept. Moreover, an attempt will be made to merge both similar matrices to one reference model spanning the whole range of secondary IT/Informatics education. Conclusively, it can be expected that the dissemination of these Austrian initiative yields positive effects on Informatics teaching and learning.

6 Conclusion

In theory, this Austrian approach implies a smooth and balanced way from digital literacy and basic Informatics education to a comprehensive competence model for Informatics education at secondary level. These competence models for general education were overdue. Providing a coherent and complete picture of a wide field, they should lay the theoretical foundation for a stable and improved computing education in classroom practice. Currently, the preliminary concept of a common Austrian framework of reference for IT/Informatics in general education has to be seen as a starting point for a nationwide restart of a discussion among all stakeholders. Finally and in a foreseeable future, this holistic framework for lower and upper secondary education should lead to concrete decisions for autonomous school curricula and to a consolidated education within the wide field of computing in Austrian general schools.

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