Approaching Inclusive Universal Access on the Computer Science Curriculum Level

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Abstract - In previous work, we extended the concept of Universal Access in the context of technology-enhanced learning in engineering education by including essential non-technological aspects resulting in a concept we call Inclusive Universal Access (IA). IA denotes a paradigm that is aimed at fully involving students in learning and assessment, at addressing them on all levels of learning including intellect, skills, and personality, and at employing universally accessible tools to support educational activities. In this paper, we present the “Active Curriculum for Computer Science” project to illustrate the systematic inclusion of multiple dimensions of IA on a curriculum level, in particular the consideration of all levels of learning, learner-centered learning goals, inclusion of stakeholders and students in curriculum development, assessment, e-learning and specifying various kinds of dependencies among courses and modules within the curriculum. Through this work we aim to make the curriculum more learner-centered, or in other words, one that dynamically meets current challenges of industry, science and society.

Index Terms – Inclusive Universal Access, Computer Science Curriculum

INTRODUCTION

Industry and academia agree that CS graduates need more than subject-matter knowledge to succeed at the workplace. They need to communicate and negotiate with clients and coworkers to collaboratively contribute to business solutions and projects. The awareness about the fact that subject-specific knowledge nowadays is not sufficient to succeed in the workplace is reflected by a shift from teacher-centered to learner-centered teaching methods and educational environments, particularly in higher education [1].

At last year’s FIE conference we proposed the concept of Inclusive Universal Access (IA) to provide a theoretical foundation for guiding that transformation by promoting IA in engineering related courses. IA is based on the philosophy that any product or service needs to be inclusive of all its potential users during planning, design, implementation, and provision/delivery as well as consider individuals at the levels of knowledge, skills and attitudes. We elaborated a number of dimensions that span the space of inclusive universal accessibility in technology-enhanced courses in engineering curricula. However, current change processes, particularly in Europe, not only affect course and module designers/instructors, but—at a super-ordinate level—also policy makers and curriculum designers. In particular, the so called “Bologna Process” [2] is prescribing the modular structure of curricula and also the skill sets to be acquired by students in terms of subject-specific competences as well as generic qualifications. We observe in our own context that the implementation of the Bologna Process is hard work, involving many stakeholders and decision makers. That kind of involvement and inclusion of various stakeholders is what makes IA a foundation to consider for implementation. In a nutshell, this paper aims to demonstrate that the IA dimensions are relevant and important aspects in guiding transformation and implementation processes at the curriculum level.

The paper is structured as follows. The next section presents the concept of Inclusive Universal Access and its main dimensions as relevant to the course and curriculum levels. The third section briefly presents current curriculum transformation processes in Europe and their implementation at the Faculty of Computer Science, University of Vienna. The fourth section presents a handful of strategies for implementing curricular change based on IA. The final section concludes the paper with a summary and an outlook.

INCLUSIVE UNIVERSAL ACCESS

Origin and Philosophy

Inclusive Universal Access (IA) is rooted in the older concept of Universal Access (UA). UA is both a design-time and a run-time philosophy for products and services; a service is considered as universally accessible when it addresses all potential users and is available to anyone, anywhere, at anytime, regardless of user characteristics, capabilities, disabilities, cultural background, etc. [3, 4] Even though the classic notion of UA is currently an important research topic particularly in information technology domains, it is not restricted to the use and provision of technology. This was demonstrated by the authors at last year’s FIE conference by including essential non-technological aspects in UA and thus extending the concept to Inclusive UA [5]. This extension stresses the fact that in modern and effective engineering education user (i.e., student) inclusion and involvement are essential components. In [5], we proposed four dimensions of IA and
demonstrated their relevance for effective design and delivery of learner-centered courses. In brief, these dimensions are stated as follows (note that the term “product” might refer to any entity that is designed and provided using the IA philosophy, e.g., a service, a course, a piece of software, etc.):

- **Inclusion** requires addressing all potential users of all levels of their personality;
- **Adaptability** addresses issues like customization and personalization of a product according to specific user needs;
- **Usability** requires the product to be designed so as to be simple and usable also by non-specialist target users;
- **User involvement** demands that users and stakeholders be involved in all stages of the product lifecycle.

**IA on the Curriculum Level**

In this paper, we demonstrate how IA and its four dimensions can be used to shape and maintain what we might call interdependence-oriented maximizes sharing between coordinated, self-organized and cooperative partners engineering curricula. To do so, we first need to identify the differences between the course level and the curriculum level, which is illustrated in Table I.

<table>
<thead>
<tr>
<th>IA Criteria</th>
<th>Course Level</th>
<th>Curriculum Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inclusion</td>
<td>Inclusion of students at all levels of learning, phases, and activities.</td>
<td>Inclusion of stakeholders of the curriculum including students, academics (taught staff, graduates), employers; qualification profile, learning outcomes, competences; structure, methods, content, media, workplace awareness, aspects of “research–practice–teaching”</td>
</tr>
<tr>
<td>Adaptable</td>
<td>Course is customizable and adaptable to students’ interests, expectations and previous knowledge by offering space for course-relevant topics, tasks and activities proposed by students</td>
<td>Curriculum customizable and adaptable to needs of the society and personal interests and expectations of students by offering some flexibility in formulating learning goals</td>
</tr>
<tr>
<td>Usability</td>
<td>Course is usable when its activity structure, requirements, resources, and content are easily accessible and transparent, e.g., through using a web-based course platform</td>
<td>Curriculum is usable when its structure, goals and outcomes, content, and implementation are easily accessible and transparent, e.g., by using a web-based curriculum platform</td>
</tr>
<tr>
<td>User Involvement</td>
<td>Openness towards students’ requests in (all stages of) courses and involvement of students in evaluation of their learning</td>
<td>Involvement of stakeholders in the process of describing the qualification of graduates and involvement of students in the process of formulating learning outcomes</td>
</tr>
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</table>

**TABLE I**

**IA CRITERIA AT COURSE LEVEL AND CURRICULUM LEVEL**

**Session F2H**

Being aware of differences and commonalities on the course and curriculum layers, we identify the following components of a curriculum where IA could or should be considered during development and implementation.

- **Description of qualifications of graduates:** The description of the graduate’s qualifications in the curriculum is stated in the so called “qualification profile.” According to Bologna requirements, it needs to be formulated in terms of subject-specific and generic competences. As the description of the graduate’s qualifications should be in line with needs of the society, their elaboration would provide space for involving stakeholders like academics, scientists, teaching staff, potential employers, and student representatives.

- **Learning outcomes and competences:** Learning outcomes are formulations of what a learner is expected to know, understand and/or be able to demonstrate after completing a learning process [6]; they are often stated in terms of competences [7]. We suggest pre-specifying learning outcomes in a way to leave educators and students some free space for adaptation and focus during implementation of the curriculum. Thus, students and educators can consider education as their personal project with space for self-initiated activity and learning. Furthermore, the elicitation and specification of learning outcomes addresses the involvement of the learners by integration of three levels of learning: knowledge, skills and personality.

- **Structure of the curriculum:** Inclusion of (national and international) learners considered in the structure of the curriculum means to offer flexibility to choose individual learning paths. This flexibility is typically facilitated by some modular curriculum structure. A module is a group of courses assigned with an appropriate number of credit points. The modular structure and an agreed-upon, shared credit system facilitate transparency of the curriculum as well as mobility of students.

- **Teaching and learning methods:** Teaching and learning methods are related to learning outcomes and student workload of a course. We suggest teaching methods that provide space for IA at the course level. In our experience, a learner-centered mode of teaching and learning, which stands for shared responsibility where individuals (teacher and student) meet to inspire each other, proved powerful in several courses. However, we acknowledge that the choice needs to be made by responsible individuals based on the inclusion of their potentials.

**THE BOLOGNA PROCESS AND ITS IMPLEMENTATION IN THE COMPUTER SCIENCE CURRICULUM**

European curricula are currently facing change motivated by the Bologna Process, which aims to establish a European Higher Education Area (EHEA) by 2010. Some key issues of the Bologna Process are the adoption of a transparent and
comparable degree and qualification structure, the adoption of a system of transferable and comparable credits, the promotion of lifelong learning, and quality assurance and accreditation [8, p. 7]. According to these issues, current challenges of the European higher education sector are, for example [9, 10]:

- The adoption of the three-cycle qualification structure: bachelor, master, and doctorate;
- The use of learning outcomes in order to describe modules, study programmes and qualifications;
- The implementation of the European Credit Transfer and Accumulation System (ECTS) to promote student mobility;
- The assurance of sufficiently broad competences.

The three-cycle qualification structure of the European higher education sector is part of the European Qualification Framework (EQF), which illustrates a meta-framework for reference points of various national and sectoral education systems. It includes 8 levels of qualification, whereby levels 5 through 8 (bachelor, master, doctorate level) are of particular relevance to the EHEA.

The use of learning outcomes implies a fundamental paradigm shift in curriculum design for many European institutions offering higher education. The adoption of learning outcomes means a move of emphasis from content (what staff teaches) to outcome (what a learner is expected to know, understand and/or be able to do at the end of a learning process), or expressed in other words, a clear shift from a teacher-centered to a learner-centered perspective. These issues are closely related to teaching and learning methods as well as student workload. Definition of learning outcomes (instead of teaching inputs) promotes the idea of the teacher as being a facilitator of learning and recognizes that a great part of learning takes place outside the classroom. It promotes the idea of learners who are actively involved in planning and management of their own learning activities and who assume more responsibility for it [7].

ECTS points illustrate student workload in hours that an average learner at a particular level will need to spend in order to achieve specified learning outcomes. The implementation of ECTS is strongly related to a modular structure of curricula with comparable module “sizes”. Learning outcomes are commonly expressed in terms of competences [7, p. 6], which can be defined as “[...a dynamic combination of knowledge, understanding, skills and abilities]” [6, p. 9]. Competences are divided into generic (e.g. team competence, oral and written communication) and subject-specific ones. As competences can be demonstrated, they can be assessed, at least to some degree.

Local Implementation

At the Faculty of Computer Science, University of Vienna, a new bachelor curriculum of Computer Science [11] was created and implemented considering aspects defined in the Bologna Process. The curriculum is structured into modules with predefined ECTS points, whereby each module consists of a predefined set of courses (the typical module size is 6 ECTS, including 2 courses). There are three areas, where modules are allocated and taken as the granularity level for specifying subject-specific learning outcomes and content: the area of core computer science modules (e.g., Information Technology), an area including interdisciplinary computer sciences modules, and an area addressing particular applications (e.g., business informatics). Module and course goals are briefly outlined and described in the curriculum.

The formal curriculum released by the curriculum working group is the fundamental basis for the “active curriculum for computer science” (ActiveCC) project. The goal of ActiveCC is to support the implementation of the new curriculum by providing a web application, which serves as an interactive online environment that supports teaching staff at the faculty in cooperatively coordinating their course content, learning outcomes including subject-specific as well as generic competences, and in handling dependencies among courses and modules. An important success factor of ActiveCC is the participation of our teaching staff, who are actively involved and included in the process of organizational change through personal exchange (interviews, dialogs, workshops) in order to assess the current situation and expectations of our teachers.

In the following, the transition process and its guidance by IA criteria will be demonstrated by five generic strategic scenarios.

IA STRATEGIES AT THE CURRICULUM LEVEL

Strategy 1: Formulating Learner-Centered Learning Outcomes

Learning outcomes are allocated at different levels: in the description of graduates’ qualifications, in module descriptions, and in course goals. Learning outcomes of the various levels relate to each other; thus, they should be aligned with learning outcomes of the module descriptions, which should be in line with learning outcomes of the qualification description of the graduates.

To support the envisaged shift from teacher-centeredness to learner-centeredness, we argue that students should be involved in the process of formulating learning outcomes. Essentially, some free space for flexibility in order to include expectations concerning generic and subject-specific competences of the students should be considered. Furthermore, learning outcomes should be formulated in a way that includes the learner as a “whole person” and thus to address the learner on multiple levels of learning: intellectual knowledge, skills and attitudes/personality.

Learning outcomes in the qualification profile should be in line with needs of society. We see employers and the scientific community as users or consumers of the curriculum “product”, i.e., our graduates. Thus, the academic society and employers should be involved, together with student representatives and graduates, in the
formulation of learning outcomes at curriculum level. Examples for instruments that facilitate the inclusion of the stakeholders of the curriculum are at curriculum level: questionnaires for generic and/or subject-specific competences for academics, employers and graduates (see also [6, p. 9]), content analysis of vacancies, and/or the participation in the formal curriculum working group. As learning outcomes of the different levels relate to each other, requirements of the society are communicated in terms of learning outcomes through the whole curriculum.

At course level, students should be involved in tuning or tailoring course goals (including overall as well as individual goals expressed for example in personal expectations of a course or module) and in decision making regarding processes, structure and focus topics. Learning goals at module and course levels have implications on teaching and learning methods. In any case, learning goals as well as the choice of particular teaching and learning methods should not exclude the facilitator’s personality, his/her qualifications and skills. Note that, following this line of reasoning, the term “learner-centered” might not be the most inclusive one.

Table II gives an overview of the various levels of specifying learning outcomes considering stakeholders and possible instruments of inclusion of these parties.

<table>
<thead>
<tr>
<th>Level</th>
<th>Learning outcomes defined in…</th>
<th>Inclusion &amp; involvement of stakeholders</th>
<th>Inclusion instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curriculum</td>
<td>Qualification profile and module description</td>
<td>Academic community; Employers; Governmental representatives; Student representatives</td>
<td>Questionnaires for generic and/or subject-specific competences for academics, employers and graduates; Content analysis of vacancies; Workshops and interviews; Participation in the formal curriculum working group</td>
</tr>
<tr>
<td>Course</td>
<td>Course goals</td>
<td>Students; teaching staff</td>
<td>Students’ expectations qualification of the teaching staff</td>
</tr>
</tbody>
</table>

Thus, IA criteria in learning outcomes at the curriculum level can be considered in terms of:

- The openness of the formal curriculum working group leads to the curriculum’s adaptability to needs of particular stakeholder or generally to the needs of the society;
- Delivering module descriptions that leave some free space for students’ interests;
- Modular structure with paths offering choice of paths, modules, and free space in at least some courses.

**Strategy 2: Implementing a Web Application as Virtual Space for Cooperation**

To further transparency, communication and interactivity among teaching staff, teachers are provided with a web application as virtual information and meeting space. For instance, the web application can be used for communication and collaborative sharing of course descriptions (e.g., course goals, course content, teaching methods, learning methods, student workload, assessment), module description (e.g., learning outcomes, student workload, pre-conditions, module coordinator), and the specification and visualization of dependencies among modules and courses. Virtual communication facilities such as online discussion boards and wikis are included to enhance communication among teaching staff.

The ActiveCC Web presents the curriculum’s structure and content transparently within the CEWebS environment [12]. CEWebS offers Wiki support and was extended in functionality to meet ActiveCC requirements such as the implementation of graph visualization functionality into the Wiki in order to collaboratively edit graphs illustrating the structure, dependencies, and components of the curriculum. The ActiveCC Web is organized into three layers: the curriculum layer that contains general information (including the qualification profile of graduates) and a linkable graph of the whole curriculum which illustrates all modules of the curriculum as well as dependencies among modules (dependencies stated in the formal curriculum document plus additional dependencies related to course contents). The module layer provides Wiki pages for each module using a predefined template for module description. The module descriptions include, for example, the module title, identifier, coordinator, a linkable graph of the module and its relationships to other modules, units of content, learning outcomes, and links to the predefined set of courses of the module. At the course layer each course is described using a uniform description template. The structured description of the course includes, for example, the name and type of the course, credits, methods, and mode of assessment.

IA criteria addressed by this strategy are transparency (to increase usability), inclusion of media, provision of access to all information among all involved staff, and adaptability by offering a collaborative wiki space.

**Strategy 3: Specifying Content Dependencies**

The illustration of dependencies of the curriculum’s content divided into modules aims to facilitate transparency in order
to giving insights into what particular topics the other teachers cover in their courses. A so-called “e-content base”, a common repository of the curriculum’s content, supports access to core material and lecture notes, slides, and other learning and teaching materials. This kind of transparency facilitates a minimum of redundancies in course contents and can help to discover points of thematic reference among modules, which can be included in the course.

In the ActiveCC project we organized access to the content of our teaching staff using the ActiveCC Web. Links to core material and lecture notes are offered. In cooperation with the University project “Phaidra” [13], a project to develop and implement a digital asset management system at the University of Vienna, a concept of saving “teaching of the 21st century” was elaborated. The vision includes that not only teaching materials shall be saved on a central place with various access rights (e.g., access for teaching staff of the faculty or the university, for students of the faculty, for the whole world), but also a backup copy of e-learning environments of particular courses can be captured for long-term preservation.

Addressed IA criteria are inclusion of media and the provision of access to teaching and learning materials among teaching staff, transparency of content and dependencies within content to increase usability of teaching and learning materials.

**Strategy 4: Identifying Generic Competences and Dependencies**

The adoption of generic competences in European curricula (in terms of learning outcomes, and teaching/learning methods) is becoming more and more important for preparing students for their future role in society. The identification or elaboration of a set of certain generic competences should include stakeholders of the curriculum (academics, employers, graduates, students) in order to meet the needs of the society. Furthermore, we argue that generic competences (as well as subject-specific competences) should be facilitated by including students at all levels of learning (knowledge, skills, attitudes) in order to facilitate whole-person and thus significant learning. To strengthen generic competences throughout the curriculum, these need to be focused in at least some modules of different context and level within a curriculum [14]. Transparency of the systematic implementation of generic competences is given, when dependencies among modules aimed at facilitating particular generic competences are illustrated and communicated (e.g., in the module and course descriptions).

At the Faculty of Computer Science, we elaborated a set of generic competences (as illustrated in Figure 1) structured in competences at the personal level (communication competence and learning to learn competence), and competences placed on the system level (team competence). Critical-, analytical-, and system-thinking apply to both, the personal as well as the system level. These competences are derived from a complex procedure, taking into account the five disciplines of a learning organization [15], the Tuning project [6], material supplied by the teaching and learning center of the University of Vienna, as well as the Person-Centered Approach [16] [17], and are consistent with needs of our society:

- Team work is a common working method (not only in industry, but also in scientific communities);
- Communication competence is a key competence of our being which includes talking, presenting, listening, writing, reading with or without the involvement of new media;
- Learning to learn is a competence essential for an individual’s personal growth and thus it gives a basis for lifelong learning;
- Critical-, analytical-, and systems thinking is a necessary competence to recognize complexity, problems, structures, and to reflect these structures in a critical way. There are reference points to subject-specific competences of other disciplines, but it is also related to entrepreneurship and research competences.

**FIGURE 1**

**GENERIC COMPETENCES CONCEPT PROPOSED FOR COMPUTER SCIENCE EDUCATION**

The formal curriculum working group elaborated a statement in the preamble of our curriculum that focuses on the facilitation of generic competences, in particular learning to learn (in terms of self-directed learning, self-organized learning), communication and team competence. As one finding of personal interviews and exchanges with teaching staff, we identified critical-, analytical-, and system-thinking as a further generic competence that is implicitly facilitated in some modules of our curriculum. We organized a workshop concerning the formulation of learning outcomes and discussed as teaching community, if and in which modules we want to explicitly facilitate the proposed set of generic competences.

Considered IA criteria are the involvement of all students and employability aspects, transparency through dependencies, and inclusion of all levels of learning.

**Strategy 5: Adapting the U-process as Meta-process**

Considering IA on the curriculum level relates to several organizational changes, requiring activities to be embedded in an appropriate process.

ActiveCC activities are embedded in the “U-process” model [18] which is structured in three main phases: sensing, presencing and prototyping. The sensing and presencing phases are continually repeated in order to involve inevitable changes (e.g., new people, new developments, and new facts) during prototyping. The
sensing phase aims to gather an overall picture of the current situation as it is perceived by the people involved. Within this phase we sense the current situation of our curriculum in terms of observation of developments in the Bologna Process, at our university and faculty, as well as in terms of personal exchange (interviews, dialogs) with our teaching staff. Gathered information is published in a structured form on the ActiveCC Web. In the presencing phase, which aims to become aware of personal and shared purpose and visions, workshops (addressing topics like dependencies of content among modules, generic competences, learning outcomes or e-portfolio) were organized for our teaching staff. The prototyping phase aims to translate visions into concrete working models. In our case, the concrete working models are the courses, where teaching staff can realize the shared vision of our curriculum. Accompanying action-research activities help to navigate through the complex space and offer input for the next sensing phase that requires the process.

Addressed IA criteria are the inclusion of developments of the European education sector, at University and the faculty and involvement of the teaching staff and media.

CONCLUSIONS

In this paper, we demonstrated the relevance and applicability of the concept of Inclusive Universal Access (IA) to transformation and implementation processes of engineering curricula. The IA dimensions of inclusion, adaptability, usability, and user involvement were adapted from previous work focusing on engineering courses to be applied at curriculum level. This kind of research-based change facilitation was co-motivated by current challenges imposed on European higher education institutions by the Bologna Process. As a concrete application context of employing IA to facilitate the roll-out of a new curriculum, we presented the “Active Curriculum for Computer Science” project that is currently in progress at the Faculty of Computer Science, University of Vienna.

From our experience gained and research conducted during the first phases of the project, we distilled and described five generic strategies that demonstrate how IA can be considered during the implementation of a new curriculum. These strategies include the focus on learner-centered learning outcomes, the provision of a collaborative web space for teaching staff and module coordinators, the specification of dependencies among modules and content, the identification of generic competences (in addition to the “classic” subject-specific competences) involving stakeholders and students, as well as the consideration of an appropriate change-facilitation process.

Thereby, we particularly stressed the importance of the IA dimensions of inclusion and involvement of all involved parties (including students) in specifying curricular structures, learning outcomes, and teaching methods that are capable of creating and maintaining an educational environment for students and staff that closely matches future needs of industry and society.

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