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AsTRA – An Assessment Tool for Recognition and Adaptation of Prior Professional Experience and Vocational Training

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Abstract. Educational systems in most countries are differentiated by level and entail transitions between different school types. The different school types do not always support a transition without gaps or repetitions. For students, this can be very frustrating, demotivating and time-consuming. For example, many graduated IT specialists bring work experience, a number of relevant competencies and previous knowledge from their vocational education and training into a degree programme in computer science – yet they still have to take the associated courses and pass examinations. To improve this situation and value the competencies brought along, we implemented a project to develop a comprehensive system to honour the prior knowledge of these students in various ways. One of our goals is to promote permeability between vocational and higher education, not only in computer science. The core element of this System is AsTRA, a comprehensive assessment tool which we developed to evaluate the common learning content and its difficulty level. This system is designed to credit previous knowledge and to adapt the students' learning paths, based on reliable decisions. In this paper, we present our tool AsTRA that supports these decisions as well as a brief overview of our resulting recognition system.

Keywords: Higher education, vocational education, adaptation, permeability, assessment, assessment tool, educational systems, IT specialist, competence, recognition, recognition of prior learning, study programme, bachelor computer science

1 Introduction

All differentiated education systems have one challenge in common: Ensuring a smooth transition of students between the different parts of the system. In Germany, the education system is very diverse. Students can switch between different pathways in secondary education as well as in vocational and higher education. The latter two fields tend to compete rather than interact in many professional fields such as computer science. Therefore, students with general university entrance qualifications how have completed

dual vocational training¹, e.g., as IT specialists (generally recognised apprenticeship), can take up higher education studies, but the competencies they have acquired during their apprenticeship are only partly recognised by the universities. This means that students like these IT specialists bring work experience, personal and professional competencies, and previous knowledge from their vocational education and training into a degree programme, for example in computer science; yet they still have to take all the associated courses and pass examinations.

Apprenticeships in computer science, such as IT specialists, are widely considered to be of high professional quality, and many IT specialists work hand in hand with academically educated computer scientists [1]. Furthermore, in a study addressing multiple training in terms of vocational education and university studies, Jacob [2] concluded that for many high school graduates, vocational education before university studies is not considered a detour but has a value of its own. In the students' perceptions, university studies subjectively build upon vocational training in their specific field of study [2, p.156].

Nevertheless, the universities hardly recognise competencies acquired in vocational education or during a professional activity. Crediting more than a few modules fails due to knowledge about the extent of overlap between vocational and higher education [3]. Universities argue that vocational training is located at level four of the DQR (“Deutscher Qualifikationsrahmen für lebenslanges Lernen”)² [4] – the national implementation of the EQF (European Qualifications Framework)³ [5, pp. 82-83] – whereas bachelor modules (duration: 6 semesters) are classified at level six. This difference in levels, as well as the different focus (professional vs. academic education), makes the implementation of permeability concepts between vocational training and university studies challenging. On the other hand, increasing permeability between these vocational education and training and academic education has been on the agenda in education politics for some time now (cf. [6]).

For this reason, we started a project that introduces and systematises the *formal recognition of professionally gained competencies of IT specialists in computer science as a prototype* and thus, promotes comprehensive permeability between vocational and academic education as a first example for such a general recognition system. Our tool AsTRA is an essential part of this project. It is an important result as well as an important tool for further use.

¹ *completed dual vocational training*: students attend vocational school for their profession and are paid apprentices of their training companies for 3 years. The dual vocational training ends with a final examination approved by the state.

² https://www.dqr.de/content_en/home.php

³ <https://europa.eu/europass/en/european-qualifications-framework-eqf>

2 Foundations of the Project

2.1 Formal Recognition of Former Competencies in Higher Education

At later stages of their career, some of the professionally trained individuals go on to professional further training or study at university to gain additional competence and to achieve a degree. They do so for better progression and promotion in their professional development. Some of these students continue to work in their company and take up part-time studies, often at distance learning universities such as FernUniversität in Hagen.

This professional development path is relatively common for IT specialists who bring several competencies as well as professional experience and previous knowledge into their studies. But their competencies are usually only credited and recognised with credit points (CP) selectively by the universities (cf. for example in the context of the NEXUS⁴ or the ANCOM project⁵ [7]). However, crediting previously acquired competencies, qualifications, and skills is a key element in the transition from a vocational training path to university studies. Hence, in 2002 the “standing conference of the ministers of education and cultural affairs” (KMK) put a resolution into effect to promote a smooth transition by *formal recognition of previous gained competencies* [8] [9]. The various projects (e.g., [10] or [11]) of this initiative have not yet achieved a broad impact. One factor is the academic self-image of the universities, which want to maintain the academic nature of the studies. Another reason for the missing impact could be that universities and other higher education institutions rely on the elaborate judgement of experts (such as professors) when it comes to questions of recognition (cf. [12]). These experts then decide according to their respective expertise. The sole assessment by one person can bias the recognition decision since it is influenced by the individual attitude towards recognition in general and other conscious or unconscious factors. That means that existing recognition systems lack a decision-making process based on transparent, reliable, and binding criteria [13, pp. 60-61] that can be understood by others (cf. [14]). This situation is unsatisfactory because transparency and reliability are quality criteria in the context of recognition [15, p. 238] and will therefore be addressed explicitly.

In our project, we base the recognition system on existing recommendations for higher education in computer science [16] as well as on facets of existing competence models for IT specialists [17] [18] and computer science education. For example, the MoKoM project group (e.g., [19] [20, pp. 77-96]) developed a comprehensive competence model for computer science. For this competence model, the researchers implemented competency level tests with several facets. They defined different knowledge dimensions, the level of connectedness, combinatorial complexity, and the level of the necessary understanding of systems of computer science [21, pp. 199-216]. Although this model was developed to measure individual competencies, some of the different parameters could be used to generally evaluate the levels of competencies gained in vocational education. Other competence models focus on general education -- such as

⁴ <https://www.hrk-nexus.de/projekt-nexus/information-in-english/>

⁵ <http://ankom.dzhw.eu/know-how/anrechnung>

the KUI model [22] – or address only certain aspects of computer science like OOP [23] or privacy [24] and are thus not suitable for direct use in our project.

Therefore, an important part of our project is to develop a reliable, transparent, and comprehensible tool to evaluate and assess prior skills and competencies – to become more or less independent from expert ratings.

2.2 Research Questions

Although the project aims to develop and evaluate an exemplary recognition system to promote permeability for IT specialists at FernUniversität in Hagen, the aim of the project part presented in this paper is to develop a tool for assessing the equivalence between the prior knowledge and the competencies to be acquired at higher education. The tool will initially be used for the transition from IT specialist to the bachelor programme in computer science. After successful evaluation, it will gradually be used for other professions and degree programmes.

Considering the current situation of formal recognition for vocational education, the following questions arise:

1. How can competence descriptions from vocational education and training be systematically and comprehensibly compared with those from higher education?
2. What would a system or a tool look like that would support this comparison?
3. How must an assessment tool be designed so that it can make statements about the equivalence of competencies without in-depth expert knowledge?

To answer the research questions, we implemented the interdisciplinary research project called “Permeability”⁶, which we describe in sec. 4. Within the framework of this research project, we developed the tool AsTRA as an answer to these questions.

2.3 General Approach

We use methods from design science (cf. i.e. [25]) and develop the planned recognition system by a cyclical approach. In this approach, we develop several process flows that will be used to implement and later to manage a comprehensive recognition system. These process flows will also be evaluated, further developed, and validated in several cycles while implementing them into a functioning system at FernUniversität in Hagen to support our students.

As previously described, one of our aims is to reduce the influence of expert assessments on the recognition decision by developing clear guidelines and decision-making aids. Our solution, a comprehensive system to assess and compare competencies from different education systems will be presented in the next section.

⁶ <https://e.feu.de/permeability> (in German)

3 *AsTRA* – Assessment Tool for Recognition and Adaptation

Our guiding questions are how to recognise the right competencies and how to support the students by enabling them to study more efficiently. To recognise the right things, we needed a tool to assess and compare competencies described in the official documents from vocational education with our bachelor programme. To master this challenge, we required a system to translate and compare the difficulty and complexity of both education systems within the DQR (IT specialist: DQR level 4, bachelor programmes in higher education: DQR level 6). Although the level description verbs of both DQR levels are based on the taxonomy of Anderson & Krathwohl (AKT) [26], it must be examined to what extent the actual DQR level descriptions correspond to each other.

Furthermore, the German vocational education system's regulatory documents are based on a work process and competence-oriented description (e.g., “Apprentices develop and extend software components”). Competence has been defined as “vocational action competence” which includes the facets of professional and personal competence [27]. In contrast, similar documents for higher education have a subject logical structure (e.g., “Introduction to theoretical computer science” or “advanced aspects of operating systems”). For this reason, we assume that “*competence in the field*” (work experience, ability to contextualise theoretical knowledge and skills) is a fundamental differentiation criterion between an IT specialist and a computer scientist from university. This means, that questions arise whether, e.g., “they *implement* programmes in a high-level programming language” (competence model for IT specialists [17]) has an equivalent meaning both in vocational and academic education. Or – more abstract – what conclusions can be drawn from a possible equivalence in the *learning contents* as well as in the *level of the educational programmes*.

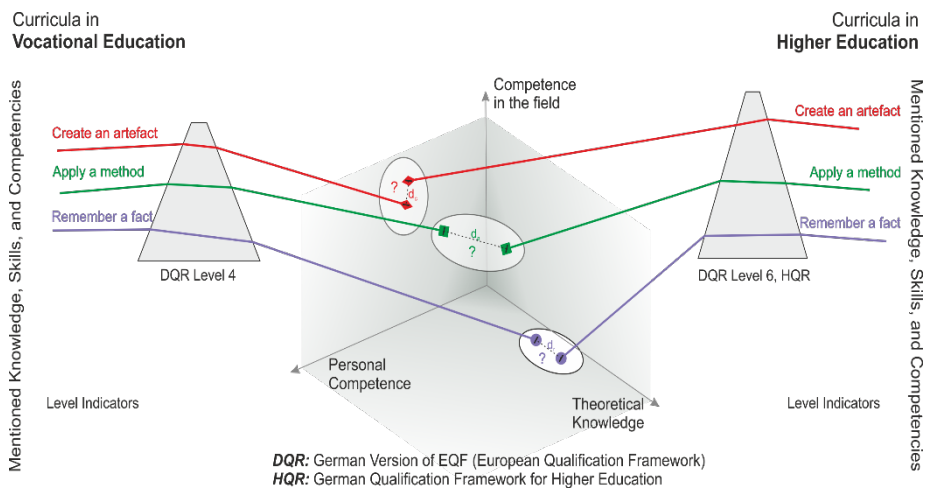


Fig. 1. AsTRA development approach: conceptual idea of matching knowledge, skills, and competencies from vocational to higher education in computer science.

3.1 Development of AsTRA

In the context of recognition "equivalence" does not mean "equal". However, a general definition of this equivalence does not exist. Therefore, we developed such a definition by including several aspects and dimensions:

The DQR proposes *professional knowledge and competency* as a key aspect. Another facet that should be included is *personal competence* (e.g. the competence to organise oneself, to work independently, to work and communicate in teams). As we see "*competence in the field*" as a differentiation criterion, this should be the third aspect. The latter is a combination of experience, professional knowledge, and personal competence. Hence, this aspect is orthogonal to the other two. This results in our 3-dimensional model to assess the inherent equivalence of both educational systems, which can be seen in Fig. 1.

Based on this first model concept, we discussed the possible implementation. We assume that a typical task on a certain level has typical characteristics in both vocational and higher education contexts. These characteristics can be seen each as a triple of values which defines a point in the 3-dimensional model. The open question at this stage is, what is the decision criterion? Is it enough to evaluate the distance d between the points, or does the mutual position of the points in relation to each other also have to be evaluated? This question is a fundamental part of the development of our tool named AsTRA.

As depicted in Fig. 1, we decided to develop a system that translates the AKT level indicators between the two education systems. It became apparent soon that in the first step, we should develop this transfer system based on a specific module. As the module "*Introduction into Imperative Programming*" is a promising module for recognition, we decided to use it as the prototype. Thus, we analysed several documents and sources of information:

The formal documents from vocational education such as *curricula* and *formal training regulations* have a low granularity. Therefore, we used an existing competence model for the profession of IT specialist [17] which we improve by analysing further information gained of previous final examinations. Furthermore, we took a close look at the *module descriptions* and *exercises*. Especially the module descriptions are not always detailed and precise. For this reason, we also analysed the course texts and the several exercises and quizzes which have to be mastered by the students.

As a result, we obtained a comprehensive and structured list of learning outcomes – represented by a level description verb and a learning content noun – with different granularity from both education systems. These statements allow the mapping to the AKT levels and therefore a more precise comparison of competencies. The list contains statements such as "IT specialists *extend* existing software with customer-specific functions or interfaces" or "IT specialists *implement* source code for small problems" from vocational education as well as "students *master* small programming tasks" or "students *complete* a given programme according to specification" from university level. The challenge here is that the content areas are similar, but sometimes very different level indicators are used. For example, in vocational training, the statement "IT specialists *develop* algorithms and functions for processing given lists" can be found, while in the

bachelor programme the competence “they *use* simple dynamic data structures such as linear lists” has been described. Although these two competencies are different in terms of level, they refer to the same area (data structures/lists). The question of equivalence can therefore not be decided by looking at individual characteristics and statements alone, but the entirety of the contents of the training and the modules under assessment, and their level must be considered.

Therefore, we postulate that equivalence can only be achieved if there is first equivalence in terms of content (necessary but not sufficient criterion). Only then can equivalence be assessed by evaluating the level in the second step. Hence, we developed AsTRA in a way that each assessment consists of two stages:

First Stage: Content Analysis. To assess whether the content and level of vocational education and training as IT specialist is equivalent to the module “Introduction into imperative programming”, we first used AsTRA for a content analysis. We grouped the statements of both education systems by content areas such as “testing”, “modelling”, or “implementing and programming” (see Table 1). We found that all content areas from university studies are also part of the apprenticeship as an IT specialist. Moreover, the content priorities are similar in both programmes. Areas such as software ergonomics, documentation, data security and data protection are not addressed in the module but are part of the training. Only one single aspect from the module is not part of the vocational training, namely recursion, which is not a core aspect of the module. Therefore, we assume equivalence in terms of content.

Table 1. Content analysis: Content areas in the module “Introduction into Imperative Programming”. The numbers show the ratio of statements in each area. Total: 40 statements for IT specialists, 45 statements for the university module.

<i>Content Area</i>	<i>IT Specialist</i>	<i>University Module</i>
Modelling Concept Development	10.0 % knowl., 20.0 % skills	4.4 % knowl., 0.0 % skills
Software Ergonomics	2.5 % knowl., 2.5 % skills	-
Implementing & Programming	0.0 % knowl., 45.0 % skills	4.4 % knowl., 73.3 % skills
Testing	2.5 % knowl., 5.0 % skills	2.2 % knowl., 15.6 % skills
Documentation	2.5 % knowl., 5.0 % skills	-
Data Security & Privacy	2.5 % knowl., 2.5 % skills	-

Second Stage: Level Analysis. The DQR classifies a finished bachelor programme at level 6. Students reach this level step by step. For this reason, we first introduced a *level translation* for modules. We assume that students start their studies at level 4 on average, because the vocational baccalaureate diploma as university entrance is also located on this level. By acquiring credit points and gaining competencies, they reach level 6 at the end of their bachelor studies. Our exemplary module is located in the study entry phase, and we assume that students reach a maximum of DQR level 4.5 in the first year of study. We further assume that after second year of study, students reach level 5, and

after the third year, they finally reach level 6. We define this value as *relative module complexity* (cf. Fig. 2).

Vocational Training								Bachelor Programme																
Complexity Adjustment Factor				Absolute Complexity				Overall Indicator (2:1:2)	Absolute Complexity				Complexity Adjustment Factor											
Theoretical Expertise	Personal Competence	Competence in the Field	Theoretical Expertise	Personal Competence	Competence in the Field	Theoretical Expertise	Personal Competence		Competence in the Field	Theoretical Expertise	Personal Competence	Competence in the Field	Theoretical Expertise	Personal Competence	Competence in the Field									
DQR 4									Relative Module Complexity: 4,5								DQR 6							
Creating	0	0	1	4	4	5	6,00	5,33	4,5	3,5	3,5	0	-1	-1	Creating									
Evaluating	1	1	1	5	5	5	6,71	5,33	4,5	3,5	3,5	0	-1	-1	Evaluating									
Analyzing	1	0	1	5	4	5	6,57	5,33	4,5	3,5	3,5	0	-1	-1	Analyzing									
Applying	0	0	1	4	4	5	6,00	5,33	4,5	3,5	3,5	0	-1	-1	Applying									
Understanding	0	-1	-2	4	3	2	4,22	4,86	4,5	3,5	2,5	0	-1	-2	Understanding									
Remembering	-1	-2	-2	3	2	2	3,35	4,01	3,5	2,5	2,5	-1	-2	-2	Remembering									
Weighted vector length for each level								5,475	Unweighted mean of level vector lengths								5,03							

Fig. 2. AsTRA -- Level translation of the module "Introduction into Imperative Programming".

The overall indicators for each AKT level on both sides are weighted to give more weight to professional than to personal competencies. The overall mean was calculated unweighted over all AKT levels.

The next step was to estimate a *complexity adjustment factor* to consider both the individual difficulty and requirements of the module and the working field in apprenticeship. This is the only step that only depends on the inherent knowledge and experience of the assessing person. In our example, to master the basic programming module, students need only little personal competence or competence in the field -- so the adjustment factors lower the absolute complexities of each AKT level for these factors. The resulting triples of absolute complexities describe 3-dimensional position vectors in the coordinate system of Fig. 1. Calculating the (weighted) lengths of the vectors provides an *overall indicator* for each AKT level (see Fig. 2). Comparing only the length seems sufficient in the first development cycle, as the position vectors are very close to each other and therefore the absolute length is sufficient as a criterion. A refinement including the position is planned for the next development steps.

The learning content from vocational education is rated as more complex and on a higher DQR-related level in this case. To improve this first result, we evaluated the statements of the content analysis again. We subsequently calculated the (relative) complexity of each AKT level (see Fig. 3), which also takes the relative frequency of the different level statements into account. As a result, we obtained a complexity level, based on the weighted number of statements from the content analysis and the overall indicator of the module respectively the professional working field. In our first application, we defined equivalence if the deviation between the scores is not more than 20%, referred to the complexity of the university module.

Level Analysis		Bachelor of Science in Computer Science		Level Correction Factor		
Module:		Introduction to Imperative Programming		Study Entry Phase	-1,50	
Role in Study Programme:		Study Entry Phase		2nd Year	-1,00	
Complexity of Module:		4,50		Final Phase	0,00	
Proportion of level operators in the overall result:						
Level	Number of Statements		Ratio		Complexity	
	Vocational Education	Module	Vocational Education	Module	Vocational Education	Module
6	5	0	13%	0%	0,75	0,00
5	2	5	5%	11%	0,34	0,59
4	11	8	28%	18%	1,81	0,95
3	11	26	28%	58%	1,65	3,08
2	4	1	10%	2%	0,42	0,11
1	7	5	18%	11%	0,59	0,45
Complexity Level based on the weighted number of statements in table "content analysis":					5,55	5,17
Calculated deviation					7,30%	

Fig. 3. AsTRA – Level analysis of the module “Introduction into Imperative Programming”. The complexity of the contents from vocational education in this field is higher than of the resp. module. The calculated deviation has been based on the (relative) complexity of the module.

3.2 How can AsTRA Support Recognition?

We used AsTRA in this version for all modules that have been promising due to expert judgement to analyse for our project. We compared the results with several expert ratings and found only little need for change in our model at this stage. This tool allows us to evaluate whether or not a module could be credited by recognition. It also helps to support the development of adapted teaching material and to identify gaps in competencies reported by our students for individual recognition. Currently, we use AsTRA to evaluate courses and modules, and as a further step we plan to apply it also for the analysis of study programmes. Furthermore, AsTRA helps us to ask the relevant questions, such as ‘is it appropriate to adapt this teaching material for all students of a cohort (like IT specialists), because we can assume that most students already have certain competence?’, ‘does it make more sense to adapt the courses for the individuals?’ or ‘are there key aspects for individual recognition of a module we should take care of?’. In the next section we show how the implementation of the tool moves the project forward by using and evaluating it.

4 Structure of the “Permeability Project”

In our project, we defined *three pillars of recognition* to promote reaching our goal to create a comprehensive recognition system.

First Pillar – Blanket Recognition: For this recognition, students have only to submit their training certificate from their completed vocational training as IT specialist to the examination office. Assessing our course modules with AsTRA, we identified “*Introduction into Imperative Programming*” (5 CP) to be recognised on-demand for all these

students, and “*Basic Training in Programming*” (10 CP) from the second study year for IT specialists in application development.

Second Pillar – Individual Recognition: This can be applied to all modules whose learning content is not or only partially part of the vocational training. The procedure of individual recognition is an assessment of individual cases to acknowledge and recognise non-formally and informally acquired competencies with up to 20 CP by assessing a portfolio written by the students.

Third Pillar -- Adaptation of Learning Pathways: Using AsTRA, we found several modules (e.g., “*Databases*”, “*Operating Systems & Computer Networks*” or “*OOP*”) which have an overlap in learning content and level with vocational education. This overlap is not enough to recognise the whole course. Therefore, we offer the opportunity to use adapted (digital) course material that allows the students to design their learning pathways by getting recommendations for their next steps based on their prior knowledge. In this way, students can thus study more effectively by only working on the content that is new to them.

5 Conclusion

The tool named AsTRA that we presented in this paper is an essential part of the “Permeability Project” which scrutinises the permeability between vocational and academic education systems. We found that competence descriptions from vocational education and training, and those from higher education, can be systematically and comprehensibly compared by mapping them to a metric space and then calculating the distance. This has been implemented into our tool AsTRA that allows us to assess the previous competencies of students based on transparent, reliable, and binding criteria and formulae. It therefore provides the possibility to create a transparent, reliable, and comprehensive recognition system that has been practically implemented in Winter 20/21. Further work will show how we can deal with students who bring lots of competencies into their studies – but competencies that do not match our modules, for example because the students are physicists, or engineers, or something completely different.

So how can we value and recognise these competencies? To do that we need an approach that goes beyond our three-pillar model and AsTRA. Our intention is to formally value further competencies. For this reason, our future question is, what constitutes a degree programme and what role do individual modules play in the various degree programmes?

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