The INNOMET Taxonomy of Competences and Skills

Work Package 1

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Summary

This report provides a foundation for a discussion about and a specification of workplace skills, personal competence and educational objectives and their relations. The report may serve as a guideline for employers, teachers, human resource personnel, researchers, or anyone that is interested in advanced vocational education. However, the main purpose of this document is to provide the necessary input to the INNOMET II system – a tool for competence inventory and course development. The starting point of the work described in this report is the skills framework defined by the INNOMET I project (a predecessor to INNOMET II).

This work has expanded the definition of *skills*, defined by INNOMET I, by introducing and defining the terms *(foundational) knowledge*, *(applicable) skill*, and *(professional) competence*, based on definitions found in literature. In the previous framework these terms were all hidden in the definition of a *skill*, but it was almost impossible to tell the difference. All of these terms can be seen as elements of a taxonomy of competences and skills, where the terms can be related to the different levels in graded scales. These scales can serve as a common input and reference point for the above categories of personnel as they consider the following:

- Identifying the knowledge and skills required for a certain job
- Estimating the knowledge and skills of current or future workers
- Describing individual skills
- Identifying the educational objectives and assessment methods for developing and evaluating the proper knowledge and skills

The report includes a survey of a number of taxonomies used for defining educational objectives, from which a proper taxonomy for the INNOMET II project is suggested. Using such a taxonomy of competence to develop descriptions for different categories of educational objectives, work tasks and professions, an approach introduced in this part of INNOMET II is to find related groups of common elements in these descriptions, which can be used to form so-called *competence modules*.

A further idea in order to simplify this process is to have a computer-based so called *Competence Template*. That is a digital form in which the knowledge, skills and competence required for a certain type of job or profession, or achieved in a certain educational activity, can be entered, using the pre-defined terminology of the taxonomy. By using such a template, one can eliminate some of the problems of using different terminology for describing the same level of competence and one can also provide help by giving clear definitions of the meaning of different words in terms of the level of competence that they describe.

Contents

1 Introduction

The INNOMET I project was a success although it left a number of questions unanswered. One has to do with the definition of the core concepts *knowledge*, *skill* and *competence*. The INNOMET I system may be used to describe educational objectives of courses and for companies to specify their requirements on competence required for a certain profession or job, but it doesn't provide any explanation about the meaning of the content. Unless INNOMET defines these basic concepts there is an obvious risk that the information that goes into the system will not be uniform, and as a result, misinterpreted. Hence, it would not be possible to compare the curricula or learning outcomes of two courses, nor would it be possible to compare two professions.

Innomet I was concerned with a number of issues as illustrated by the following statements.

Within Innomet I and Innomet II a large number of knowledge/skills/competences are mentioned. Are all these really unique? Need for standardized skill definitions?

Course descriptions are not modularized.

It is difficult to compare educations, on a European as well as a local level. European initiatives such as ECTS (European Credit Transfer System) have increased the transparency but this is not enough. Schools around Europe follow the system when it is suited for them.

The questionnaires will not be uniform unless we define and structure the underlying concepts.

How to verify that the students and employees respectively have achieved the required competence and knowledge?

How to harmonize the curricula and professions of the different countries using the INNOMET II system?

2 INNOMET and the Ontology of Competences and Skills – Deliverable 1.1

The idea of developing some kind of language for the description of skills, competences, and knowledge has been present all since the beginning of INNOMET I. **The rationale is to support course development, and competence inventory and assessment by defining competence of an individual as a function of (foundational) knowledge and (applied) skills.** By defining such a language it would be possible to compare, evaluate, and develop (often certified) courses based on content making sure that educational portfolio really corresponds to the demands of the industry and certification authorities.

Feature/property	INNOMET I	INNOMET II
The definition of a *Skill.*	Skills graded from 0-5, the possibility to define a skill by a simple text string.	The starting Skills graded 0 – 5 with a clear definition of each level.
The definition of *competence* and *knowledge.*	INNOMET I does not differentiate between *skills*, *knowledge*, and *competence*.	INNOMET II extends the definition by stating that competence is the sum of knowledge and skills and by introducing the concept of competence modules. The definition of a competence module makes it possible to distinguish between *knowledge*, *skills*, and *competence.*
Potential benefits for companies.	Works as a tool for competence inventory, based on company/branch specific professions.	Works as a tool for competence inventory that does not require professions to be defined and maintained.
Potential benefits for education suppliers.	Promotion of courses that are based on an up-to-date view of the companies needs.	Promotion of courses that are based on an up-to-date view of the companies needs. Supports the definition of educational objectives and assessment methods.
Potential benefits for education coordinators.	Better market overview (customer demands). Support for course management.	Better market overview (customer demands). Support for modularised course management.

The list could be made more extensive and a more thorough definition of the main concepts (in italics) is given in the next chapters. However, the table intends to clarify that the INNOMET II project proposes a new approach altogether.

3 Theoretical foundation for the definition of skill, knowledge and competence – Deliverable 1.2

First of all we need to define what we mean with the terms skill, knowledge and competence. A good starting point is to look at the definition of these terms in a dictionary. However, first of all let us look into the proposed title of this work package: *"The INNOMET ontology of competencies and skills"*. Is that a properly formulated title? The terms *taxonomy* and *competences* have also been frequently used above. Is there any difference in meaning?

3.1 Competencies/Competences or Competency/Competence

Competence means ***having legal or practical ability to perform.*** **Competency** means the same thing, but is less frequently used except in educational argot (jargon), where **Competencies** are ***the various skills students are to be taught and teachers are to be prepared to teach***. The plural form **Competences** occurs infrequently. In one article we found a distinction between ***technical competences*** (interpreted as for example the ability to apply certain methods to a work task) and ***behavioural competencies*** (interpreted as for example the ability to function well as a member of a team) [reference].

With this as background we suggest that we use **Competence(s)** as we focus on technical education and knowledge, albeit improved behavioural competencies might be another goal.

What is the difference between competence and skill?

Once again, according to a dictionary:

Competence: Possession of a satisfactory level of ***relevant knowledge and*** acquisition of a range of ***relevant skills*** that include interpersonal and technical components.

Knowledge: Familiarity, awareness, or ***understanding gained through experience or study***.

Skill: ***Ability***, proficiency, facility, or dexterity that is ***acquired or developed through training or experience***.

∴ Competence=Knowledge+Skills

What is the difference between taxonomies and ontologies?

The terms taxonomy and ontology are used with more or less care, and sometimes as synonyms, therefore we also need to clarify the difference between them:

Taxonomy is defined as (1) *Division into ordered groups or categories* and (2) *The classification, or categorization, of things*.

For example, *A Web taxonomy would* ***classify*** *all the sites on the Web into a* ***hierarchy*** *for searching purposes*

Ontology is defined as (1) *The structure of a system* and (2) *A systematic arrangement of all of the important categories of objects or concepts which exist in some field of discourse, showing the relations between them.*

For example, *An ontology is typically a* ***hierarchical structure*** *containing all the relevant* ***entities and their relationships*** *and rules within that domain*

In this project we will focus on taxonomies, as these are more basic and general. To be able to develop an ontology you first need a taxonomy.

3.2 An overview of taxonomies

In an effort to define the skill levels a number of taxonomies have been studied. These are the Bloom Taxonomy of Educational Objectives [ref], Anderson's Revised Taxonomy, the SOLO "Structure of Observed Learning Outcomes", and the Feisel-Schmitz Technical Taxonomy. Blooms taxonomy is a classification system used to describe the way student should "behave, think, and feel" after participating in a course. Anderson's Revised Taxonomy is a modernized version of Blooms taxonomy. Feisel-Schmitz Technical Taxonomy is as the name implies adapted to technical issues, whereas the SOLO taxonomy describes level of increasing complexity in a student's/participant's understanding of a subject. In all cases the assumption is that each level embraces previous levels and adds something more.

All taxonomies are developed to describe goals/objectives of courses/education programmes in terms of knowledge and skills acquired by any student/participant fulfilling the course/programme requirements, but from slightly different viewpoints.

3.2.1 The Bloom Taxonomy of Competencies and Skills

The Taxonomy of Educational Objectives was created by Benjamin Bloom in the 1950's [2]. This classification system was used to describe various kinds of thinking after participating in a course expressed in measurable observable formats (instructional objectives). Bloom's taxonomy of educational is divided into three overlapping domains: the cognitive, affective, and psychomotor domain of which the first one is the most commonly used. The taxonomy is one of the most commonly used methods for course planning and assessment.

In the process of developing curricula (e.g. objectives of a course) (cf. Table 1) it is possible to identify the patterns of Blooms verbs that accompany any technical topic. It provides a sequential model for dealing with topics in a curriculum and suggests a way of categorizing levels of learning. Thus, in the cognitive domain, training for a technician may include knowledge, comprehensions, and applications but not analysis and above, whereas full professional training may be expected to include analysis, synthesis, and evaluation as well.

Level	Illustrative Verbs for stating specific learning outcomes
6. Evaluation	Appraise, compare, conclude, contrast, criticize, describe, discriminate, explain, justify, interpret, relate, summarize, support.
5. Synthesis	Categorize, combine, compile, compose, create, devise, design, explain, generate, modifies, organize, plan, rearrange, reconstruct, relate, reorganize, revise, rewrite, summarize, tell, write
4. Analysis	Differentiate, distinguish, identify, illustrate, infer, outline, point out, relate, select, separate, breakdown, categorize, diagram, inventory, outline
3. Application	Change, compute, demonstrate, discover, operate, predict, prepare, produce, relate, show, solve, use
2. Comprehension	Convert, defend, distinguish, estimate, explain, extend, generalize, give examples, infer, summarize, predict
1. Knowledge	Label, name, describe, list, match, identify, outline, reproduce, select, state

Table 1 The levels of the cognitive domain with associated verbs

3.2.2 Anderson's Revised Taxonomy

During the 90's Lorin Anderson (a former student of Benjamin Bloom) worked on a revised version of the taxonomy that was more up-to-date.

It has some changes in emphasis. The revised taxonomy is a more applicable to for course planning (i.e. curriculum planning, education, and assessment) and competence planning (i.e. competence inventory).

Level	**Illustrative verbs (examples)**
6. Creating (*Evaluation*)	design, construct, plan, produce
5. Evaluating (*Synthesis*)	check, critique, judge, hypothesise
4. Analysing (*Analysis*)	compare, attribute, organise, deconstruct
3. Applying (*Application*)	implement, carry out, use
2. Understanding (*Comprehension*)	interpret, exemplify, summarise, infer, paraphrase
1. Remembering (*Knowledge*)	recognise, list, describe, identify, retrieve, name

Table 2 Anderson's version of the levels of the cognitive domain with associated verbs

In a attempt to exemplify the levels of understanding according to Anderson's revised taxonomy we have given some sample sentences and matching activities, containing one or more of the illustrative verbs.

Level	**Sample sentences to promote things specific to each level of the taxonomy**	**Potential activities and products**
6. Creating (Evaluation)	Will a design theory support the creation process?	PRODUCE production drawings for a specified product
5. Evaluating (Synthesis)	Is the drawing complete?	JUDGE/CHECK the details of the drawing
4. Analysing (Analysis)	What drawing views do I need to understand the product?	ORGANISE/COMPARE drawing views to ensure they are not redundant
3. Applying (Application)	Does the company have any drawing standards?	USE the company rules and standards
2. Understanding (Comprehension)	Why are the views in a drawing positioned as they are?	EXEMPLIFY the difference between ISO and ANSI standards
1. Remembering (Knowledge)	How to position the views in a drawing?	Make a LIST of the main building blocks of a 2D drawing,

Table 3 Samples

3.2.3 The SOLO taxonomy (Structure of Observed Learning Outcomes)

The SOLO taxonomy shows what the learning outcome should be on each level. In each step the level of understanding raises. All students/participants do not get through all the stages, neither does the teaching/training. In some cases "less training" gets them all the way.

Extended abstract level	• students make connections beyond the immediate subject area • students generalise and transfer the principles from the specific to the abstract
Relational level	• students demonstrate the relationship between connections • students demonstrate the relationship between connections and the whole
Multi-structural	• students make a number of connections • the significance of the relationship between connections is not demonstrated
Uni-structural	• students make simple and obvious connections • the significance of the connections is not demonstrated
Pre-structural	• students are acquiring pieces of unconnected information • no organisation • no overall sense

Table 4 The levels of learning outcome as described in the SOLO taxonomy

Since the SOLO taxonomy is using a different way of describing the learing come it may be hard to compare it with Bloom's and Anderson's taxonomies. The following figure has a number of verbs defined to each of the levels. Again, though, a single verb does not tell you what level you have reached.

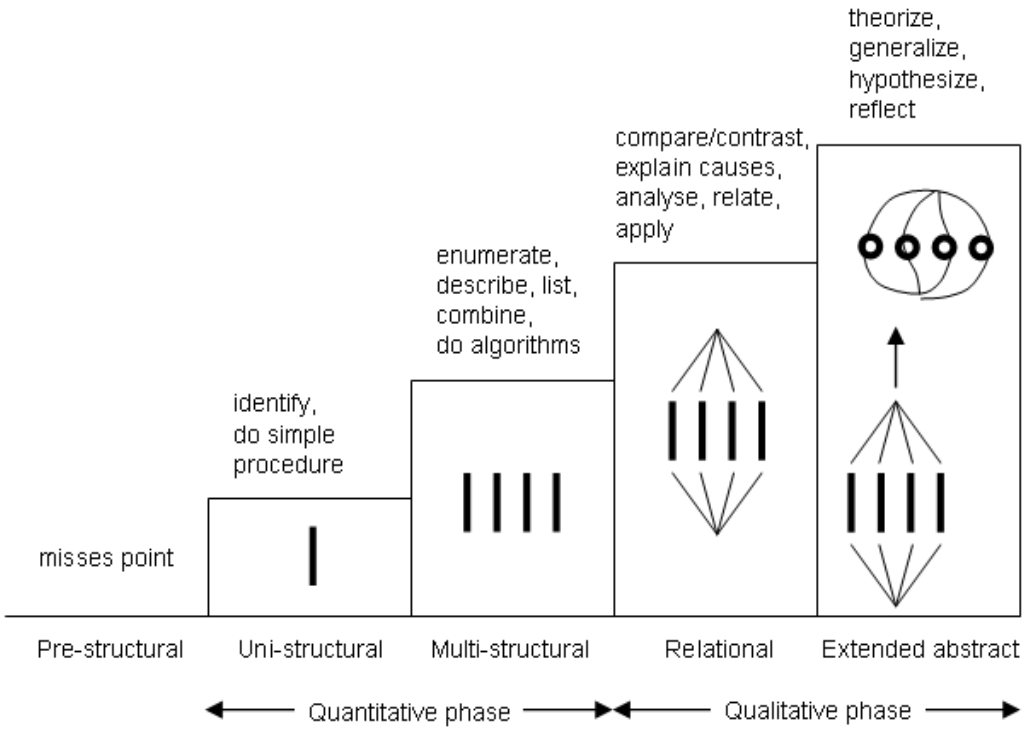


Figure 1 The learning outcome as described in the SOLO taxonomy with verbs

3.2.4 The Feisel-Schmitz Technical Taxonomy

The Feisel-Schmitz taxonomy is similar to the Bloom taxonomy, but it is adapted to technical applications. The Explain and Compute levels are contradictory to Blooms taxonomy. For some technical applications one does not need to fully understand a task in order to fulfill its requirements. Following a number of given rules and procedures can be good enough to get the desired result.

It is somewhat difficult to find references to this taxonomy. Therefore the description is short.

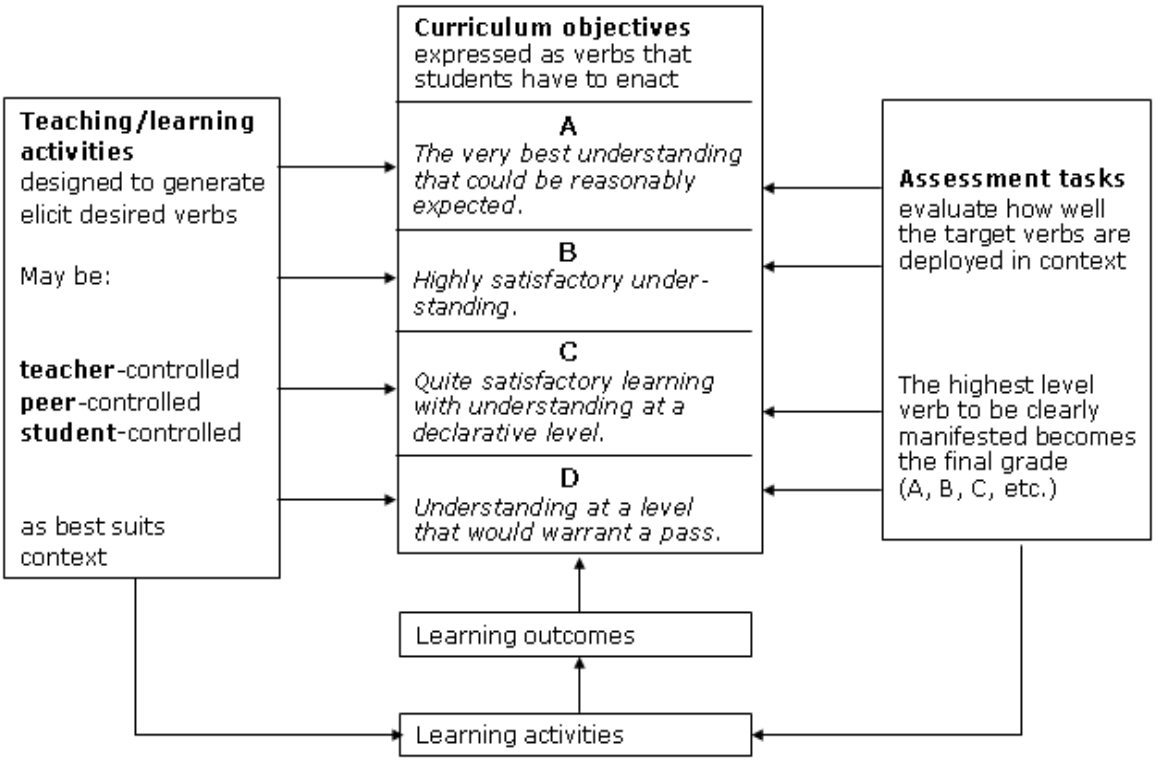
Judge	To be able go critically evaluate multiple solutions and select an optimum solution
Solve	Characterize, analyze, and synthesize to model a system (provide appropriate assumptions)
Explain	Be able to state the outcome/concept in their own words
Compute	Follow rules and procedures (substitute quantities correctly into equations and arrive at a correct result, Plug & Chug)
Define	State the definition of the concept or is able to describe in a qualitative or quantitative manner

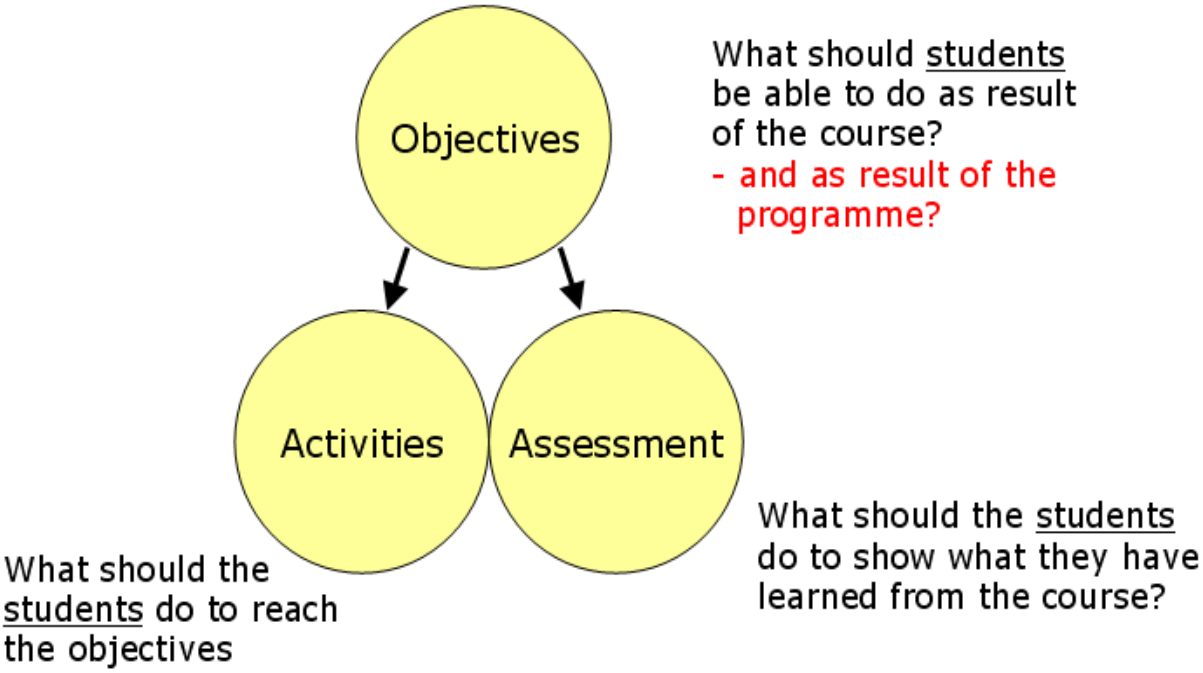
Table 5 The levels of the Feisel-Schmitz technical taxonomy

3.3 Constructive Alignment (Biggs)

It is not enough to specify proper curriculum objectives for a course to get a good learning outcome from completing the course. It is also necessary to define proper teaching/learning activities and proper assessment tasks. When these three factors support each other, we have achieved what Biggs call *Constructive Alignment*, which, according to Biggs, leads to a quality learning result. The figure on the following page tries to visualize the principle of constructive alignment by describing how educational objectives, teaching/learning activities and assessment methods are related.

However, we believe that not only courses could be described in terms of constructively aligned objectives, activities and assessment methods. The same should apply to the description of the ability to successfully take on a working task, or the description of how to specify and evaluate the competence required in a certain profession. Therefore, according to our belief, the principle of constructive alignment should be considered in specifying the competence modules, as they are described later in this report.





3.4 How to use taxonomies?

Taxonomies are used to formalise the terminology used for specifying levels of competence and skill and stating goals of courses and education programmes.

Is there any significant difference between specifying levels of competence and skill, and formulating goals of courses?

We believe there is not – provided that the goals of courses are expressed as the knowledge and abilities a student/course participant should have after completing the course requirements

3.5 Conclusions

All taxonomies are similar. In all cases the assumption is that each level embraces previous levels and adds something to the next level.

The typical verbs used in the taxonomies can not be unambiguously assigned to a specific level of competence. A single verb can appear on several levels. It is the combination of verbs that shows what level one has reached.

Lower levels in taxonomies typically deal with knowledge – higher levels describe skills

There is no need to make a distinction between general and professional skills and competences. These are handled by the levels.

4 The INNOMET Taxonomy of Competences and Skills – Deliverable 1.3

With the terms competence, knowledge and skill defined, our belief is that we are talking about competence, even though we are using all three terms. To support course development and competence inventory we need the terms knowledge and skill and therefore we cannot leave them out.

In early stages of WP1 we talked about professional competence as a function of foundational knowledge and applied skills. When talking about professional competence we often get back to how many hours/days/weeks an individual have worked with a certain task. Also we believe that professional competence deals with the ability to apply old skills on new tasks. Putting this into consideration professional competence is a higher level of competence, where lower level competence is competence one can earn from courses with theoretical and practical learning methods.

The competence template has during the project been revised to include only one "set" of levels. This takes care of the whole range of competence we need. The answers from the survey that was made do not interfere with this new competence template, which is shown in Appendix 1. Appendix 2 and 3 shows an example on how the competence template can be mapped to a course description.

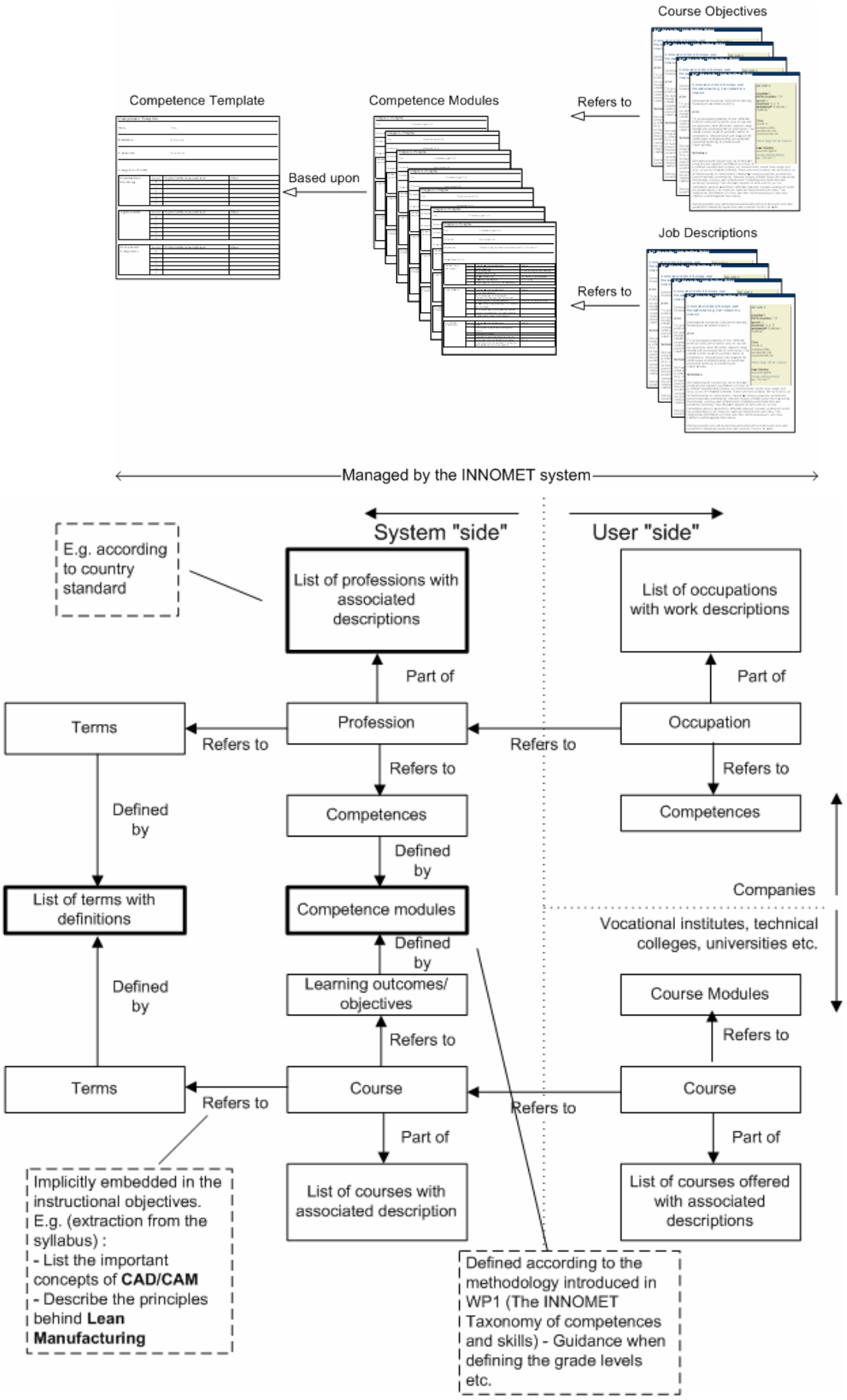
We believe that competence demands can be transferred into course modules by using the competence templates. Considering the principles of constructive alignment the course modules should contain not only objectives but also activities and proper assessment tasks to properly get the desired quality of the course outcome.

The competence template includes 6 levels of competence, where the lower ones are typically knowledge and the higher ones are combined knowledge and skill.

Each level has a number of illustrative verbs which in the right context answers to a typical expression that describes the levels objectives.

4.1 Using the competence modules

- Course selection to achieve certain competence (student, public)
- Course development (Teachers)
- Competence evaluation (HR personnel, managers, certification authorities, teachers)
    - Competence for employment
    - Competence for certification
    - Competence needs
    - Competence inventory


Course Objectives
Competence Template
Competence Modules
Refers to
Based upon
Job Descriptions
Refers to
Managed by the INNOMET system
System "side"
User "side"
E.g. according to country standard
List of professions with associated descriptions
List of occupations with work descriptions
Part of
Part of
Terms
Refers to
Profession
Refers to
Occupation
Refers to
Refers to
Competences
Competences
Defined by
Defined by
Companies
Vocational institutes, technical colleges, universities etc.
List of terms with definitions
Competence modules
Defined by
Defined by
Learning outcomes/ objectives
Course Modules
Refers to
Refers to
Terms
Refers to
Course
Refers to
Course
Part of
Part of
Implicitly embedded in the instructional objectives. E.g. (extraction from the syllabus) : - List the important concepts of CAD/CAM - Describe the principles behind Lean Manufacturing
List of courses with associated description
List of courses offered with associated descriptions
Defined according to the methodology introduced in WP1 (The INNOMET Taxonomy of competences and skills) - Guidance when defining the grade levels etc.

5 Conclusions

All taxonomies are similar. They use typical verbs to describe the different levels of knowledge and skills. These typical verbs can not be unambiguously assigned to a specific level of competence.

Lower levels in the taxonomies typically deal with knowledge – higher levels describe skills. There is no need to make a distinction between general and professional skills and competences. This is handled by the different levels.

Our recommendation to the INNOMET II project is to the ideas and structure of Anderson's revised taxonomy as base for describing competence templates and modules in the INNOMET system.

Constructive alignment should be considered in specifying the competence modules.

6 References

[1] How to write and use instructional objectives, Gronlund, Norman E., 2000

[2] Taxonomy of Educational Objectives: Taxonomy of educational objectives: the classification of educational goals., Bloom, B. S., 1956

[3] Innomet I Report,

[4] Biggs, John B, Evaluating the quality of learning: the SOLO taxonomy (Structure of the observed learning outcome), New York, Academic Press, 1982, ISBN 0-12-097552-1

[5] Lorin W. Anderson, David Krathwohl, A taxonomy for learning, teaching, and assessing: a revision of Bloom's taxonomy of educational objectives, New York:/ Longman, 2001, ISBN 0-8013-1903-X

[6] CDIO

[7] ATHERTON J S (2005) Learning and Teaching: SOLO taxonomy [On-line] UK: Available: http://www.learningandteaching.info/learning/solo.htm Accessed: 19 January 2006

Appendix 1: Competence template

Competence Template

Title *Title*

Definition *Definition*

Comments *Comments*

Competence Profile

Type of competence	Level	Typical competence demonstrated	Illustrative verbs
Knowledge and skill	5		design, construct, plan, produce
	4		check, critique, judge, hypothesise
	3		compare, attribute, organise, deconstruct
Knowledge/Skill	2		implement, carry out, use
Knowledge	1		interpret, exemplify, summarise, infer, paraphrase
	0		recognise, list, describe, identify, retrieve, name

Appendix 2: Competence module matching the course module Basic MCAD

Competence Module

Title	*Basic MCAD*
Definition	*Mechanical CAD*
Comments	*General Competence Module based on a KTH CAD course*

Competence Profile

Type of competence	Level	Typical competence demonstrated	Illustrative verbs
Skills	5	Suggest a method of producing a solid model of type of part not encountered before, based on the experience of creating a number of other solid models?	design, construct, plan, produce
	4	Is there a way of utilizing the solid model created of a given part for creating a new 3D CAD model of another part?	check, critique, judge, hypothesise
	3	Is the solid model of the given part modelled using the appropriate 3D modelling commands?	compare, attribute, organise, deconstruct
Knowledge/Skills	2	What 3D modelling commands can be used to create a solid model of this given part?	implement, carry out, use
Knowledge	1	How are the most common modelling commands in a solid modelling CAD system used, i.e. what are the required inputs and what is the result ?	interpret, exemplify, summarise, infer, paraphrase
	0	What are the most common 3D modelling commands in a solid modelling CAD system?	LIST/NAME appropriate commands

Appendix 3: Description of course module Basic MCAD

Objectives

After fulfilling the course requirements, the student will be able to perform the following types of activities using Solid Edge or a similar MCAD system:

- create parameterised part models
- create assemblies of part models
- create mechanism models and animate their motion
- create part drawings
- create assembly drawings with exploded views

Activities

- Two 2h lectures to introduce the proper terminology and give an introduction to the system and its user interface and functions
- Four prepared 2h CAD exercises covering the full range of activities described in the objectives, with expert assistants available
- One individual homework assignment including the same activities as in the CAD exercises, but for another product with similar complexity, of the student's own choice

Assessments

- Interactive demonstration of the results of each CAD exercise, with expert assistant
- Interactive individual demonstration of the results of the homework assignment, with teacher
- Delivery of required documentation of the homework assignment
- Different requirements on the homework assignment results and documentation for each grade

Requirements for grades

Grade 3:

- You create part models of all components in the product
- You create an assembly model where the components are correctly placed and oriented relative to each other
- You fully constrain at least one of the part models and make sure it is parameterised so that all essential dimensions in the model can be changed
- Document this part model in a drawing where all essential dimensions are shown.

Show the CAD models and the part drawing to the teacher and hand in two printouts, one that shows a clear view of the full assembly model and one of the part model that clearly shows the dimensions

Grade 4:

In addition to the requirements for grade 3, you have to:

- apply material properties (type and density) to all part models, calculate and document mass and centre of gravity for each part model and the top level assembly model.
- colour the components in the assembly model (and if you like, add other realistic graphical properties that applies to the material properties).
- document your product in an assembly drawing that shows a clear view of the product and also contains a parts list and an exploded view of the product. The parts list should contain relevant columns (at least *Item number*, *Title*, *Material* and *Quantity*) and be place correctly, i.e. without any overlap to the drawing views
- produce a complete product structure of all components in your product and document it in a proper way

Show the CAD file with the assembly drawing to the teacher and hand in a printout of it with clearly readable text on it. Also hand in a printout of the complete product structure and another one, a table, that shows material and mass properties of all part models and mass properties of the whole product

Grade 5:

In addition to the requirements for grade 3, you have to:

- create a mechanism model of your product, create the needed joints and motions and make an animation that shows the products parts moving in a realistic way.

Show the CAD file(s) including the assembly and mechanism models and a saved avi movie of the animation to the teacher. Hand in a printout that shows the mechanism model in at least 3 different positions during the animation, and a printout of a complete table of the joints and motions you have defined for your mechanism model. For each joint it should be clear which components in the assembly it relates to.

Examination: Individual demonstration, in front of a computer, to the teacher before Friday October 10th, 17:00. After that date and time you cannot get a higher grade than 4. If you demonstrate your work after the spring semester has started, you cannot get more than grade 3.

To the demonstration you have to prepare all the CAD files and printouts that applies to the grade you are aiming at.

Koppla till kompetens profilen i appendix 2	

Appendix 4: Competence template (the old one)

Competence Template

Title *Title*

Definition *Definition*

Comments *Comments*

Competence Profile

Foundational knowledge	**Level**	**Typical foundational knowledge demonstrated**	**Clues**
	0		*Know nothing*
	1		*Describe*
	2		*Explain*
	3		*Analyze*
	4		*Synthesize*
	5		*Evaluate, motivate*

Applied skills	**Level**	**Typical applied skill demonstrated**	**Clues**
	0		*Can do nothing*
	1		*Use*
	2		*Apply*
	3		*Operate*
	4		*Solve*
	5		*Create, Produce*

Professional Competence	**Level**	**Typical professional competence demonstrated**	**Clues**
	0		*None*
	1		*Apply to acceptable level*
	2		*Create to good level*
	3		*Support, Teach, Motivate*
	4		*Apply to a high level*
	5		