Academic Learning Outcomes:  
A Conceptual and Empirical Approach

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Abstract
Learning outcomes or end qualifications of students will be a key  
factor in future quality assurance in higher education in Europe. The  
three Dutch universities of technology have developed a  
system of learning outcomes for academic education, which is  
described in this paper. This system is believed to be much better  
from a conceptual as well as a practical point of view than the so-  
called system of Dublin Descriptors that is now being used in the  
European Community. The 3TU system has received considerable  
support from other European universities of technology. In the  
second part of the paper an empirical approach is described for  
the evaluation of academic study programs and of students in  
terms of the developed system of learning outcomes.

Introduction
The Bologna Declaration committed the member states of the  
European Community to more transparency in higher education. It  
aimed at the harmonization of the various cycles in education  
and at degrees that are more easily readable. The aim of this  
restructuring was, among other things, to increase mobility in  
higher education in Europe. Many countries have implemented a  
bachelor-master structure by now, or are in the process of  
implementing it in some form (the picture is complicated). From  
the beginning it was clear that a more harmonious structure of  
higher education by itself is not enough to make more mobility  
possible. In addition, explicit learning outcomes or end qualifi-  
cations of students at the end of the first (bachelor) and second  
(master) cycle are essential. These learning outcomes have  
become even more important, now that future quality assurance  
and accreditation systems will be based on them. There will be a  
transition from a process oriented to a product oriented approach  
in higher education.

Under the auspices of the European Community, a system of  
learning outcomes has been developed under the name of Dublin  
Descriptors. It consists for the bachelor program of the five  
following competences. Students should

- have demonstrated knowledge and understanding in a field  
of study that builds upon and supersedes their general  
secondary education, and is typically at a level that includes  
some aspects of the forefront of their field of study;
- be able apply their knowledge and understanding in a man-  
er that indicates a professional approach to their work or  
vocation;
- have the ability to gather and interpret relevant data to  
inform judgments that include reflection on relevant social,  
scientific or ethical issues;
- be able to communicate information, ideas, problems and  
solutions to both specialist and non-specialist audiences;
- have developed those learning skills that are necessary for  
them to continue to undertake further study with a high  
degree of autonomy [1].

This system of Dublin Descriptors has two main disadvantages  
for universities: (i) it does not include ‘design’ as an academic  
competence, which is very important for universities of tech- 
nology; (ii) it is phrased in very general terms and therefore hard  
to give it operational value. For example, on the basis of these  
learning outcomes it is almost impossible to discriminate between  
a program at a research university and a program at an institution  
of higher vocational training (or an applied science university). In  
the recent evaluation of university programs in the Netherlands  
not a single program was rejected because of not fulfilling the  
Dublin Descriptors. These disadvantages have been an important  
reason for many universities to look for an alternative system.

3TU system of learning outcomes
Any system of learning outcomes for university programs should  
fulfill the following design criteria:

- it should be generally applicable, i.e., it should not be disci- 
pline specific and should apply to all engineering programs;
- it should have discriminative power (distinguish between  
programs at research universities and programs at univer-
 sities of applied science);
- it should have practical or operational value;
- it should contain independent categories of competences,  
overlap should be avoided;
- it should be complete, covering the whole study program;
- as a whole it should capture our intuition of what we mean  
by ‘academic’;
- easy to memorize for staff; no system will work in practice if  
it is too complicated.

In addition to these general learning outcomes, each program will  
have discipline-specific end qualifications. These will be different  
for mechanical engineering and computer science, to mention two  
examples. This paper only addresses the general learning  
outcomes.
At Eindhoven University of Technology a system of learning outcomes has been developed over the last three years that aims to live up to these design criteria. Since the notion of ‘competence’ is used in so many interpretations, it is necessary to specify our notion in advance. By ‘competence’ we mean the integration of knowledge, skill and attitude. A student has a certain competence if (s)he has the relevant knowledge, if (s)he is able to apply this knowledge in appropriate contexts, and if (s)he has the attitude of using this knowledge in these contexts.

The developed system of learning outcomes distinguishes between student competences in the following three domains: the scientific discipline, the scientific method, and the context of science and technology. Within these domains a further distinction has been made between
- existing knowledge or the development of new knowledge;
- the understanding of phenomena or the making of new artefacts;
- between specific or generic methods of science, where the latter is subdivided into individual work and team work;

The resulting map of competence areas is the following:

![Diagram of Competence Areas](image)

**Figure 1: Areas of Competence**

For each of these competence areas five to eight key competences have been defined which are thought to belong to the core of the area. Examples of these competences are given in the table below, where a distinction has been made between bachelor and master versions of these competences. For a complete account see the Appendix to this paper [2].

<table>
<thead>
<tr>
<th>Competence Area</th>
<th>Competence Example Bachelor Level</th>
<th>Competence Example Master Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Competent in one or more scientific disciplines</td>
<td>Understands the knowledge base of the discipline (theories, methods, techniques).</td>
<td>Has a thorough mastery of parts of the discipline extending to the forefront of knowledge</td>
</tr>
<tr>
<td>Competent in doing research</td>
<td>Is able to assess research within the discipline on its usefulness.</td>
<td>Is able to assess research within the discipline on its scientific value.</td>
</tr>
<tr>
<td>Competent in designing</td>
<td>Is able to work at different levels of abstraction, including the system level.</td>
<td>Given the process stage of the design problem, chooses the appropriate level of abstraction.</td>
</tr>
<tr>
<td>A scientific approach</td>
<td>Has insight in scientific practices (research, publication system, etc.).</td>
<td>Has knowledge of current debates about the scientific practice.</td>
</tr>
<tr>
<td>Basic intellectual skills</td>
<td>Is able to reason logically within the field and beyond;</td>
<td>Is able to recognize fallacies.</td>
</tr>
<tr>
<td>Competent in co-operating and communicating</td>
<td>Is able to communicate the results of learning, thinking and decision making with colleagues and non-colleagues in a second language.</td>
<td>Is able to communicate about research and solutions to problems with colleagues and non-colleagues in a second language.</td>
</tr>
<tr>
<td>Takes account of the temporal and social context</td>
<td>Is able to analyze the ethical consequences of scientific thinking and acting</td>
<td>Integrates these consequences in scientific work.</td>
</tr>
</tbody>
</table>

**Table 1: Examples of Competences**

The resulting set of academic competences has gained a lot of support. In the Netherlands it has been adopted by the three Universities of Technology (Delft, Eindhoven and Twente), hence its name 3TU system, as well as by the University of Nijmegen [3]. In Europe, German research universities intend to integrate the set of competences in their future system of quality assurance, while Swedish and Italian universities of technology are seriously looking into this possibility. CESERA, the society of universities of technology in Europe, has expressed explicit support for the approach taken by the Dutch universities.

**Levels of competences**

Any system of competences has to define levels on which these competences are mastered. Just mentioning a competence is clearly not enough. For example, the competence ‘understands the knowledge base of the discipline’ can be mastered on an entry level but also on an expert level. The real challenge, then, is to define these levels. This is the hard problem to be solved. One way to this is to use Bloom’s well-known scale. He made a distinction between: the ability to reproduce information (theories, ideas, facts), to understand information, to use information for the solution of problems, to see patterns in information (perception, analysis), to generate new ideas from information (synthesis), and to evaluate information, ideas, theories, methods. Several of our competence definitions echo elements of Bloom’s scale, to distinguish between bachelor and master levels. Other approaches used to define competence levels are in terms of the problems being solved (with a range from simple problems to
complex problems), or in terms of the supervision that is needed when doing scientific work (with a range from fully supervised to completely independent). In this section we will describe a different approach.

When developing the 3TU system of academic competences, four types of activity were thought to be especially characteristic of an academic way of thinking and acting. These are analyzing, synthesizing, abstracting and concretizing. An academic engineer needs to master them at an adequate level. In order to define that level, the following operational definitions have been developed for these activities, which are meant to be generic for all scientific disciplines:

- Analyzing is the unraveling of phenomena, systems or problems into sub-phenomena, sub-systems or sub-problems with a certain intention. The greater the number of elements involved, or the less clear it is what the elements of the resulting analysis are, the more complex the analysis.
- Synthesizing is the combining of elements into a coherent structure which serves a certain purpose. The result can be an artefact, but also a theory, interpretation or model. The greater the number of elements involved, or the more closely knit the resulting structure, the more complex the synthesis.
- Abstracting is the bringing to a higher aggregation level of a viewpoint (statement, model, theory) through which it can be made applicable to more cases. The higher the aggregation level, the more abstract the viewpoint.
- Concretizing is the application of a general viewpoint to a case or situation at hand. The more aspects of a situation are involved, the more concrete the viewpoint.

These activities and the corresponding competence to perform them, have a special status in that they are not just further items on the list, but are orthogonal to the earlier defined competence areas. Being able to analyze, synthesize, abstract or concretize is an essential part of many of the key competences of the seven competence areas. That can be used to identify the level on which competences are mastered.

For each of these four types of activity a scale has been constructed. This scale is discipline specific, since it ranges from the lowest level of these activities to the highest level in a particular discipline. The scales are constructed on the basis of examples in the discipline. These examples are not arbitrarily chosen, but are developed on the basis of a construction principle. The scale is constructed with recurrent steps, where the result of a previous step becomes the object of the activity in the subsequent step. For the activity of abstracting the scale looks as follows, where A is the example on the basis of which the scale is constructed, and B, C and D are reformulations of the example on a higher level of abstraction:

![Figure 2: Construction of the Scale of Abstraction](image)

Table 2: Scale for Analysis in Mathematics

<table>
<thead>
<tr>
<th>Level</th>
<th>Type of Analysis in Mathematics</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Qualitative specification of relevant trends in a set of times series measurement data.</td>
</tr>
<tr>
<td>2</td>
<td>Quantitative specification of trends from 1 to new data-sets (e.g. in terms of period or phase shift).</td>
</tr>
<tr>
<td>3</td>
<td>Structure description of quantitative trends of 2 (e.g. decrement of phase shift with increment of period).</td>
</tr>
</tbody>
</table>

Table 3: Scale for Concretizing Computer Science

<table>
<thead>
<tr>
<th>Level</th>
<th>Type of Concretizing in Computer Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Given an optical effect (“depth of field”) for a computer game, description of this effect in terms of image processing (“blurring”).</td>
</tr>
<tr>
<td>2</td>
<td>Given an image processing effect, description of this effect in terms of mathematical operations on image elements.</td>
</tr>
<tr>
<td>3</td>
<td>Given a series of mathematical operations on image elements, construction of an algorithm to perform these operations efficiently (separable convolution).</td>
</tr>
<tr>
<td>4</td>
<td>Given the algorithm of 3, elaboration of the algorithm into a graphical pipeline-model including scheduling aspects (memory access bandwidth).</td>
</tr>
<tr>
<td>5</td>
<td>Given the graphical pipeline-model for the algorithm above, coding the pipeline algorithm for a specific pixel shader.</td>
</tr>
</tbody>
</table>

The Conceptual Framework Applied

Quality assurance at universities and the accreditation of study programs require an answer to questions of the following type: What do lecturers aim for in their individual courses and how does this contribute to the development of the students' end qualifications? How well do students perform at the end of the bachelor / master program? Does the study program have the right profile, i.e. does it put the emphasis on what is considered to be
most important in terms of learning outcomes? These questions can be made more precise on the basis of the described system of learning outcomes, together with the methodology for defining levels of competences.

When evaluating a study program it is important to realize that there are at least three study programs: (i) the program as intended by the lecturers, (ii) the program as realized in the learning situation, and (iii) the program as realized in the students. In the empirical part of our research we have focused on the description and evaluation of (i) and (ii). It is only possible to describe and evaluate (ii) on the basis of observations in classroom situations.

**The Intended Study Program**

Giving an answer to the question whether a curriculum has the right profile, or how a study program (as intended by the lecturers) contributes to the development of the students’ competences, is not a trivial matter. It requires empirical research into the aims and ambitions of lecturers teaching courses in the curriculum, and a method of combining the results into an overall picture of the program. One of the problems here is to develop a measure for the importance of aims and ambitions that is intersubjective.

In the research project, data about the lecturers’ intentions were collected with interviews. The relative importance of aims and ambitions was ‘measured’ in terms of the time spent in a course on such aims and ambitions. This had the additional advantage of making it possible to construct a profile of a study program on the basis of information about individual courses. Special attention was given in the interviews to the standardization of language, for example with respect to terms as analyzing, abstracting, synthesizing and concretizing. Not only was this a methodological requirement, it also had the advantage of developing a common language and frame of reference among the members of the scientific staff with respect to the study program. The interviews also gave staff members a different perspective on their individual courses, since they had to think about the contribution of these courses to the development of key competences of students.

All mandatory courses in the bachelor program (three years) and the master program (two years) were included in the research project (together about 70 courses). After a pilot project with two study programs (Industrial Engineering & Management Science, and Innovation Sciences), three programs were evaluated (Applied Mathematics, Computer Science and Electrical Engineering), while two more programs in Industrial Design and Architecture, Building & Planning are in the process of being evaluated.

In the interview, lecturers were asked to indicate how much time they intended to spend during their course on each of the seven competence areas, and whether these competence areas are part of the examination. For the key competences in these areas a yes/no indication needed to be given. The same questions were asked about the time they intended to spend on each of the levels of the four scales earlier discussed, by comparing their courses with examples on these scales. The interview took about an hour and a half.

On the basis of these data, profiles of study programs can be constructed. For example, a profile of the first year of the program, of a particular track of the program, or of the program as a whole. With the developed software a program director can make any profile he is interested in. A typical result for a bachelor program at Eindhoven is given in the following figure:

**Figure 3: Bachelor Profile in Terms of Ects per Competence Area**

These profiles can give information about missing competence areas in the program or missing key competences. It can also give information about the relative weight of the seven competence areas. On the basis of this a meaningful discussion can take place about the desired profile of a program and a standard can be set. Such a standard can then be used in future evaluation cycles.

Along the same lines histograms can be constructed for the levels of analysis, synthesis, abstraction and concreteness in the study program. Such a histogram shows the intended time spent on each level of the scale. The histogram can be constructed again for part of the program, for a particular track of the program, or for the program as a whole. An example for the activity of concretizing is given below.

**Figure 4: Relative Time Spent on the Levels of Concretizing**

The histogram gives information about the completeness of the study program with respect to the discipline (the scale shows the scope of that discipline). It also gives information about the relative weight of the levels in the program. This information is again useful for a discussion about desired levels and standards, and for future evaluations.
Competences of Students

The second part of our empirical research concerned the competences of students. The main question here was: How well do students perform in terms of the defined learning outcomes or end qualifications? In order to find out, a blueprint was developed that contains questions, assignments, and tasks corresponding to each of the key competences within a certain competence area. This blueprint is still generic. Many of the assignments, especially the ones in the competence areas 1-4, need to be "localized" for a particular discipline in order to be useful. This work was done by lecturers in the field.

A pilot project was carried out with master students of three study programs (computer science and electrical engineering), two at Eindhoven and one at Nijmegen. The assessment took two full days. Its main purpose was to develop a tool for the overall assessment of students’ competences. The design was such that it would generate information about the performance of students at the level of the population of students, not on the individual level. The latter requires much stronger requirements in terms of the reliability of the test.

On the basis of such an assessment profiles of student populations can be constructed, similar to the profiles discussed before. These can then be used to discuss desired profiles and to set standards which can be used in future evaluations.

The pilot proved the principle that it is indeed possible to develop an assessment for the evaluation of students in terms of the described system of learning outcomes. It also showed that additional development work is needed, especially with respect to the levels of complexity of questions and assignments. The initial aim of comparing the competences of students of the programs involved, made the development of the assessment very labor intensive [4].

Conclusion

Quality assurance at universities usually concerns individual course evaluations, efficiency evaluations of the study program as a whole (average study time, student drop out, etc.), and (sometimes) staff competences. At the curriculum level there is no tool to evaluate the content of the program or the end qualifications of students in terms of a systematic set of desired learning outcomes. The standard problems of quality assurance are well-known: there is a lack of clear evaluation criteria, there is no proper evaluation method, the results of the evaluation are not fed back into the system, and the responsibilities of the various actors are not clearly assigned.

The set of learning outcomes and the methodology for levels described in this paper can remedy two of these shortcomings. Firstly, they can be used as a common frame of reference and as a tool to set standards, both for the content of a curriculum and for the learning outcomes of students. Secondly, they can be used to evaluate study programs in these terms. Promising as they are, their full implementation in quality assurance systems at universities still requires a lot of additional research.

References


Perrenet, J.C., L. Wolters & D. de Gruijter, “Sure, they are educated; but are they academics? Exploring the measurement of the academic profile of university students”, submitted paper.

Notes

* This paper reports the results of the collaborative work of a project group at Eindhoven University of Technology, consisting of Tijn Borghuis, Anthonie Meijers, Loes Mutsaers, Kees van Overveld and Jacob Perrenet.

[1] See www.jointquality.org

[2] See also Meijers, Overveld and Perrenet, Criteria for Academic Bachelor and Master Curricula.

[3] The set of competences has also applications outside the engineering domain. The set is meant to be generic for academic programs. Study programs, then, have a profile in terms of this set, where some competences are considered to be more important than others.


Biography

Anthonie W.M. Meijers has a background in mechanical engineering and philosophy. Since 2000 he is professor in the philosophy and ethics of technology at Eindhoven University of Technology and head of the department of philosophy. At Eindhoven he is also the project leader of a group on quality assurance and academic education. He is editor in chief of the forthcoming handbook Philosophy of Technological Sciences (Elsevier 2007), and editor of the journal Philosophical Explorations.