MATCHING, MONITORING AND ASSESSING LEARNING OUTCOMES OF STUDENTS IN PRACTICAL ASSIGNMENTS

***D. Greve*[1], *P. Schonk*[2], *P. van der Aa*[3]**

[1]Faculty of Nature and Science, Hogeschool Utrecht,
University of Applied Science, Utrecht, Netherlands, dan.greve@hu.nl
[2]Faculty of Communication and Journalism, Hogeschool Utrecht,
University of Applied Science Utrecht, Netherlands, pim.schonk@hu.nl
[3]Staf Education and Research, Hogeschool Utrecht
University of Applied Science, Utrecht, Netherlands, paul.vanderAa@hu.nl

Abstract
In engineering programs an important part of the learning process takes place in practical assignments like capstone projects, internships and co-op assignments in industry. The assignments are very divers. Students have different roles, work in different environments and the learning outcomes are not uniform.

So how can the individual learning outcomes or growth competencies of the assignments be determined?
To cope with this question the authors developed and implemented a method to monitor and assess the individual learning outcomes of the assignments. The method can be used to match a student to his next assignment in such a way that he can build his individual learning track. The method defines three aspects of an assignment: the role of the engineer (i.e. project leader, designer, researcher), the domain(s) of the assignment (i.e. user interface, software engineering) and a general results matrix that describes results and the level required to produce them.
To manage the process learning outcomes are defined as products so project management methods can be used to plan, monitor and assess learning outcomes.

Key aspects of the method are:
1. A general results matrix for engineering assignments
2. Learning outcomes that are defined as results in the matrix and these results can be assessed.
3. The results have levels so the learning outcomes can grow during the programme.
4. The method can be used to match, monitor and assess students on one assignment.
5. The method can be used to match, monitor and assess students for the entire programme.
6. The tools that are developed are based on an industry standard for project management.

Keywords: learning outcomes, competencies, assignments, project, knowledge worker

INTRODUCTION

Many engineering degree courses in the Netherlands have undergone far-reaching changes of recent years. In particular, the introduction of competency-oriented teaching methods means that student learning outcomes play a much more central role than they did in the past. However, the need for effective monitoring of competency development throughout a degree programme remains unchanged. This applies both to the overall competency development of all students within a given module and the demonstrable competency development of individual students in a given phase of their education. The way in which competencies are currently described often does not lend itself to effective monitoring and recording of competencies on the way to achievement of the final teaching goals.

A key problem in this connection is that of establishing the connection between the competencies that a student has demonstrably acquired through successful preparation of a number of professional products and the final learning outcomes defined for the degree course in question. This is particularly difficult if the student worked on these products in a group, outside the supervision of the relevant member of teaching staff.

Many university departments have been found to struggle with this problem. To create some synergy in the solution of questions of this kind, the management of the degree programmes in Digital Communication and Industrial Management at Hogeschool Utrecht (HU-University for professional education) have been working together since 2005 on the JOIN innovation project (JOIN is a mixed Dutch-English acronym, from 'Joint Onderwijs Innovatie' = joint educational innovation). The objective of this project is to improve the quality of project work and to develop methods for monitoring, assessing and matching the competencies acquired by the students working on these projects. This gradually led to the establishment of the JOIN model of competency development.

1. JOIN COMPETENCY DEVELOPMENT MODEL

A competency can be seen as the power to achieve a desired result, on the basis of a combination of knowledge, attitude, skills and other personal characteristics. Competency-based assessment of students following a degree programme or other professional training may thus be compared with a decathlon: the student will get his diploma if he has been able to show that he is able to achieve the desired results in the various professional assignments set.

The next question is which professional assignments should be set in a given degree programme, and what intellectual and practical height the student should be expected to clear in each exercise. The *JOIN competency model* has been developed in order to organize our thoughts on these issues. It is also necessary to know how the degree programme should be set up in order to teach the student the necessary competencies. We have formulated the *JOIN educational model* to provide support in this area. It goes without saying that the educational model and the competency model may be seen as two sides of the same coin.

1.1. JOIN educational model

Professional education is aimed at enabling students to solve relevant professional problems. One of the means to this end is to give the students a graded series of professional assignments. Initially, the tasks set will be well defined and placed in a simple context. As the course proceeds, students will be expected to show more independence and the complexity of the assignments will increase. At the start of the course, the teaching staff will determine whether the student has achieved the desired results, but by the end the student himself will be expected to demonstrate that his results meet the relevant criteria. (figure 1) The student will also have to take independent steps to acquire the knowledge, skills and attitudes needed to carry out the assignment. This work style is also characteristic of the professional practice of an engineer.

Teaching staff guide the students' learning process by designing assignments with a level of difficulty and complexity appropriate for the current phase of the course. These assignments should preferably represent work for real customers from the world of professional practice. In the case of part-time students, this approach allows a link to be created between each student's work and his educational curriculum. Full-time students will often be given the task of finding a company where they can carry out an assignment relevant to the current phase of their course, with reference to clearly defined specifications.

Students will have to learn how to make certain professional products. To this end, the teaching staff will provide them with the necessary background information and theoretical instruction, will devise suitable exercises, support the students during the making of the exercises by providing feedback on the (interim) results and evaluate the final product. The extent to which students have absorbed the theoretical instruction given can also be tested by means of a written examination.

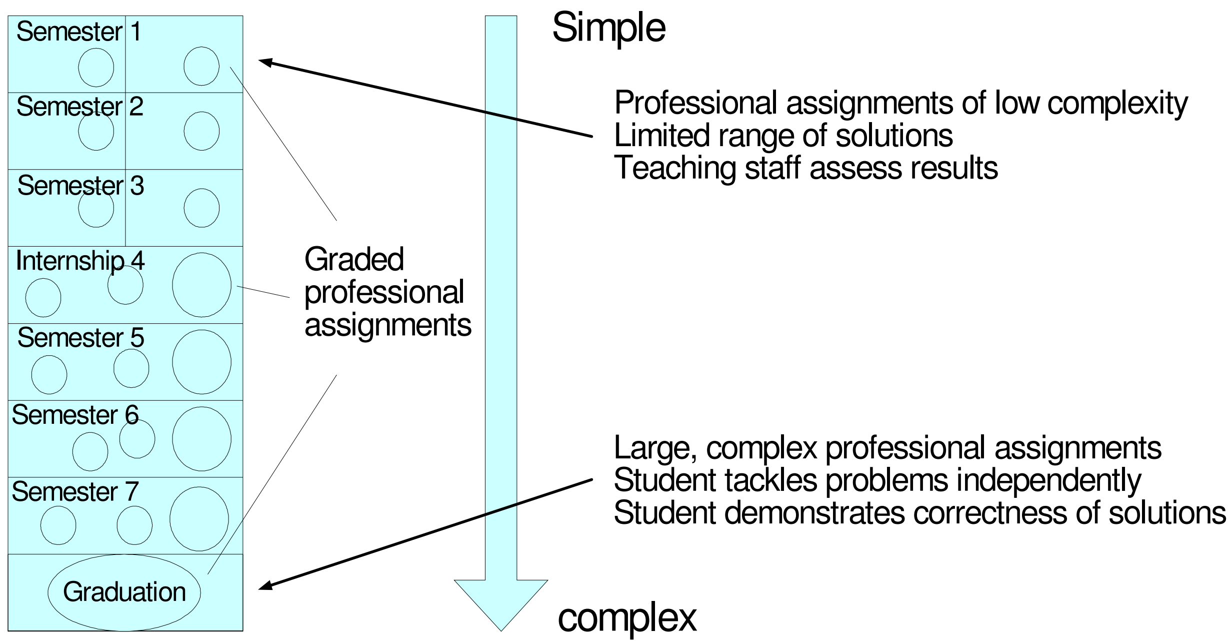

Figure 1 Curriculum

It thus follows that a great deal of the learning in the JOIN education model takes place during work on professional assignments, which may take the form of projects, internships or the graduation assignment. While theoretical instruction plays the main role in the degree programme, especially during the later phases of the course students will also have to learn a great deal from practical work. Learning to function properly as a knowledge worker can thus make a big contribution to the student's future professional prospects. But the required competencies do not grow on trees. The way they do develop is represented in the next step of our model, the JOIN competency development model.

1.2. JOIN competency model

Engineering competencies can be described with reference to the various professional tasks or assignments to be performed by an engineer, which in their turn can be described in terms of the *results* demanded, the *role* to be played by the engineer, the *domains* involved, and the level of the work.

Each assignment has to yield certain outcomes or *results*. We can gain greater insights into the nature of these results by placing them in the JOIN results matrix. (Figure 2) The columns of this matrix are formed by the different results to be delivered: the *product or service* in question, the *organizational process* required to arrive at that product or service, the *knowledge* needed to do the work and finally the *impact* the product or service is expected to have. The rows represent the different phases to be passed through on the way to the final result: *exploration, initiation, realization* and *reflection*. These various elements will now be discussed in turn.

Let us assume by way of example that the assignment is given by a well-known engineering consultancy. The design may be regarded in this case as the *product or service* desired by the client. The quality of the product is determined by the way it is produced but the customer of the consultancy is not interested in how it is produced, as long as it 'works'.

Nevertheless, proper *organization* of the whole production process is also an important deliverable in a given assignment. It guarantees the quality of the final product, and ensures that the client can rely on the outcome right from the start. That is why the engineering consultancy lays down rules concerning the approach to be taken by staff in dealing with a given problem, in order to safeguard the good name of the company.

►Aspects► ▼Phases▼	**Production**	**Organization**	**Knowledge Mobilization**	**Interaction**
Exploration	Gaining insights	Acquiring assignment	Posing questions	Actors in picture
Initiation	Design	Project plan	Finding information	Interaction strategy
Realization	Implemen-tation	Quality control	Application	Working together
Reflection	Product evaluation	Process evaluation	Knowledge evaluation	Feedback on interaction
	↓ **Product Service**	↓ **Process**	↓ **Knowledge**	↓ **Impact**

Figure 2 JOIN results matrix

In addition, the client naturally wants the design (or advisory report) prepared for him to be well based. He may not be competent to judge this himself (that is why he engaged the services of the engineering consultancy in the first place). But the management of the engineering consultancy will feel the need to demonstrate the quality of the product or service delivered – preferably by using proven models and methods in its production. It is therefore important to base the assignment on *state-of-the-art knowledge* of the discipline in question, and to demonstrate that this knowledge is applied correctly. In some cases, however, it may be necessary to make use of new, as yet relatively unproved methods. It is then important to make the results obtained with the aid of these methods available to other members of the organization.

All the above-mentioned excellent features will however be of no use whatsoever if the product has no impact. It depends on the *interaction* with all persons concerned whether the right problem is solved, whether the people concerned grow with the solution and whether the design presented is actually implemented (or the advice given is followed).

The various aspects shown along the top of the results matrix (production, organization, knowledge and interaction) are always implemented in a number of distinct phases, viz. exploration, initiation, realization and reflection. Omission of any one of these phases will lead to poorer results in its own characteristic way:

- without exploration, you may well solve the wrong problem;
- without a coherent project initiation, your solution will be of poor quality;
- defective implementation means that the solution offered will not work properly; and
- without reflection, you don't know whether you really delivered what was requested, and you can't learn from your experience.

It may be necessary to go through these phases more than once, leading to a cyclical (learning) process known as Deming's [4] PDCA (Plan, Do, Check, Act) cycle that has become the industry standard for quality control.

Dimensions of an assignment
Now the results are described in general terms we can use the results matrix as a view of the world to describe the dimensions role, domain, and level of the assignment. (figure 3)

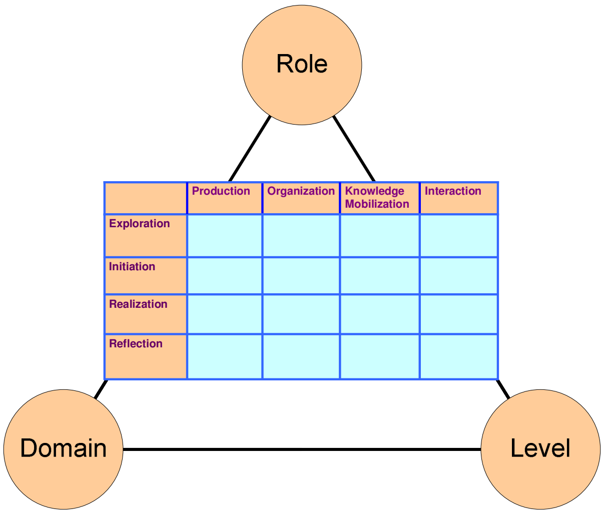

Figure 3 Dimensions of an assignment

Role
A student will assume an appropriate *professional role* during each assignment he undertakes. The role stands for the responsibility the engineer has towards the results of the assignment e.g. project leader, designer, consultant or entrepreneur. Typically an engineer has to learn to play 2-4 professional roles.

Domain or field
The professional task to be performed may lie in one or more *domains or fields*. A domain stands for a group of products. (e.g. user interface design, software engineering) In this sense engineering is a domain within knowledge work in general. Within engineering we can find the domain of for example industrial management. And if you zoom into industrial management you can again cluster the professional assignments in domains. (e.g. operational excellence, customer intimacy, product innovation) In general you can define an engineering course with 3-6 domains of problems. During the course a student has to master al domains and prove this by solving problems in the domain. A student has a certain degree of freedom in the sequence in which he performs the required activities in the different domains.

Level
It will be clear that a junior engineer will not be appointed to a company's Board of Management, and that doctor who has just received his basic qualifications will not be allowed to carry out open heart surgery. In other words, big differences can exist between the levels of different assignments and hence between the results expected of different players. If we restrict ourselves to students in this connection, the main characteristics that need to be taken into consideration are the level of A:<u>independence</u> manifested by the student in completing the assignment and the B:<u>complexity</u> of the context.

A. Degree of independence in execution

- **0.** Reproductive: The problem, the approach to be taken and the solution are all defined.
- **1.** Task-oriented: The problem is defined, but the approach may be chosen within certain limits. The solution must be justified.
- **2.** Problem-oriented: The problem has to be delimited and the method chosen. The correctness of the solution must be demonstrated
- **3.** Situation-oriented: The student proposes, delimits and solves the problem himself.

B. Complexity of the context

Factor	Score 0	Score 1
Stakeholders	Few	Many
Project team	Small	Large
Support	Much	Little
Knowledge	Existing	New
Knowledge	Basic	Expert
Quantitative	Hardly	Very
Technology	Existing	New
International aspects	No	Yes
Market	Existing	New

Determine the complexity for the various factors involved and add up the separate scores.
The level goes up by 1 point for each 3-point rise in complexity.

The overall level of a result is determined by adding the scores for independence in execution and the complexity of the context.

In figure 4 below you can find an example of a semester 3 project assignment in our Business Engineering course. This project is based on a school based case so the exploration phase is graded as task oriented (1). The initiation phase is graded as problem oriented (2). The realization and reflection phase are graded as problem oriented (2) although interaction is graded as situation oriented (3). The complexity of the case scores only for the factor quantitative so no points are added for complexity. For every aspect we can now determine the average level.
The domain of the project is a combination of the Operational Excellence domain and the Customer intimacy domain. The roles are project leader and consultant. In this case there is no level difference between the roles.

After successfully closing the project the student gets his EC's and scores for role, domain(s) and levels are added to the competence chart of the student (see description below)

►Aspects► ▼Phases▼	Production	Level	Organisation	Level	Knowledge mobilization	Level	Interaction	Level
Exploration	Gaining Insights	1	Acquiring assignment	1	Posing questions	1	Actors in picture	1
Initiation	Design	2	Project plan	2	Finding information	2	Interaction strategy	2
Realization	Implemen-tation	2	Quality control	2	Aplication	2	Working together	3
Reflection	Product evaluation	2	Proces evaluation	2	Knowledge evaluation	2	Interaction feedback	2
		↓ 2		↓ 2		↓ 2		↓ 2

Figure 4. Example of the rating of the levels of a third semester Business Engineering assignment

1.3. Join Competency development

In order to monitor student progress, we note his scores for the various assignments in the JOIN Competency Chart. (figure 5) Roughly speaking, the assignments during the first two years of the degree programme are at level 2, while in year 3 and 4 they are at level 3 or 4. The student will pass if he gets up to level 3 on average in all domains. It is also possible for a student to build his own study profile by electing to do assignments at level 4 in some domains and at level 2 in others.

The student selects his study profile in consultation with his tutor, and discusses with him which roles he should play in the various projects and which internships (including the important internship for the graduation project) he should choose in order to fit in with the selected study profile. He determines, in consultation with his team or internship host, which competencies he needs to work on in each module, and records these in his Personal Development Plan. At the end of each module, the student shows his tutor what results he has achieved, and the latter notes these in the student's competency chart. When the degree programme is completed, this chart provides the vital evidence that the student has satisfied all the requirements for awarding of his Bachelor of Engineering diploma.

Competency Chart	Production	Organisation	Knowledge Mobilisation	Interaction		Mean (rounded off)
Roles						
Role1	4	3	4	4		4
Role2	3	3	3	3		3
Domains						
Domain 1	3	3	2	4		3
Domain 2	2	2	2	3		2
Domain 3	3	3	3	3		3
Domain 4	4	3	4	4		4
Domain 5	4	3	3	3		3
Highest value from all domains	4	3	4	4		

Figure 5 JOIN competency Chart

2. JOIN IN PRACTICE

The JOIN models are currently used in the complete Business Engineering (Technische Bedrijfskunde) bachelor degree course at the Hogeschool Utrecht. Although not scientifically tested, students and teachers find the models useful and think the quality of monitoring and assessment of the assignments has gone up considerable. As a result the quality of results has improved. The use of the competency chart for individual students is still in pilot face. The JOIN models were at the base of the reports that were used in 2008 for the accreditation of the Business Engineering course for the NVAO (= Dutch Flemish Accreditation Organisation). All relevant facets received a GOOD verdict. Furthermore the JOIN models are used in parts of the Digital Communication and the Communication and Media Design course and at this moment several engineering courses at the Hogeschool Utrecht have decided to start working with the models.

3. BACKGROUND OF THE JOIN RESULTS MATRIX

Many factors contributed to the design of the JOIN results matrix and the competency development model. The germ of the idea underlying these models is the consideration that students must be prepared to engage in a lifelong learning process to make a professional contribution to society as knowledge workers in a constantly changing world. This is often expressed by means of the circular equation Learning = Work = Learning of the Knowledge worker. (van Weert ea 2005) [15]

Aspects (columns)
The columns *production, knowledge mobilization* and *interaction* are derived from the 3-I learning model of a knowledge worker from Tissen, Andriessen, & Lekanne Deprez (1998)[13] , who described the learning process as based on the three elements: information (corresponding to our knowledge mobilization column), interaction and intellect (= production) . These authors identified three enabling competencies for each of the three I's. The *organization* column was added by van Weert (2005)[15] to create the O3I model for knowledge work.

Phases (rows)
Professional work should always be based on a systematic approach to the problem under consideration. Such systematic approaches, involving from 3 to 10 different phases, have already been developed for many professional products. In almost all cases, the phases distinguished in these methodologies can be matched to the four phases of the JOIN results matrix.
For example, the national guidance document for Bachelor of Engineering degree programmes in the Netherlands, by HBO-raad (2006)[7] stipulates that all student project work should involve the separate steps 'gaining insight', 'design', 'planning' and 'execution'.
Similarly, project management methodologies such as the de facto industry standard Prince2 [10] are generally also based on a phased project implementation structure. Four phases are distinguished in the basic form of Prince2.

The importance of reflection, the fourth phase of the JOIN results matrix, was already stressed by Argyris and Schön (1974) [2,3,11] in their Reflective Professional concept and Double-loop learning model.

As mentioned above, repetition of these phases can lead to a cyclical (learning) process known as Deming's PDCA (Plan, Do, Check, Act) cycle that has become the industry standard for quality control. (Shewart 1939, Deming 1986)[4]

Levels
The degree of independence levels: task-oriented, problem-oriented, situation-oriented are based on Van Weert (2001, 2005) [14,15] who in turn emphasises the similarity's with Ellström(1999) [6] . These levels coincide with the levels novice, advanced beginner and competent from Dreyfus and Dreyfus (1986) [5] This model has been extremely influential, particularly in the field of nursing. (The levels proficient and expert in this model are only reached after several year of working experience.)

At level 3 of the JOIN results matrix the student has to achieve the results independently. This means that the students general competencies cover the Dublin descriptor for the bachelor level. The matrix ensures therefore that at each task the final attainment levels are on the screen.

Other considerations

The Institute for Business Engineering course at Hogeschool Utrecht uses the internationally recognized 4C/ID (four-component instructional design) model (van Meriënboer 1999, 2007)[8,9] as a basis for curriculum development. In this model, the hierarchy of skills plays an important role in the analysis of competencies.
The 4C/ID model uses complexity levels in the planning of the sequence of assignments. These levels are reflected in the levels associated with the JOIN results matrix.

4. REVIEW AND CONCLUSIONS

In the autumn of 2008 the JOIN team organised an external review with four educational researchers from different Dutch universities.[16] At the start of the review process the design team compared the results of the development process with the criteria that were set at the start of the project. The results and the dilemma's were presented to the external experts who could indicate if they recognised them and could give directions for possible solutions. From this the JOIN design team draw conclusions as basis for further development. The main conclusions are:

- The JOIN results matrix is solid and works in practice for teachers and students when matching, monitoring and assessing practical assignments
- The way the level of an assignment is rated is insufficiently reproducible. The dimensions *independence* manifested by the student in completing the assignment and the *complexity* of the context are valid but further development is necessary.
- The wish to create scientific evidence for the JOIN method and models is still out of reach.
  Instead of directly striving for scientific evidence the reviewers recommend to choose to be a learning organisation. If that happens in a good manner, with clear criteria and a transparent process, this will give a good basis for scientific justification on the long run. Therefore: this is a good start, work along this path, work transparent with clear quality standards, let reviewers look at your work, improve the JOIN models and their implementation on this bases.

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