AC 2011-1354: PERCEIVED LEARNING EFFECT AND GUIDANCE IN PROJECT BASED ENGINEERING EDUCATION

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Perceived learning effect and guidance in project based engineering education

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1. Introduction

This paper describes a study concerning the effect of the guidance of students' project work on their learning performed at the Engineering Faculty of the K.U.Leuven.

The K.U.Leuven is a Catholic University situated in the Dutch speaking part of Belgium. The university organizes approximately 60 Bachelor's programs and more than 125 Master's programs in three main fields: Humanities and Social Sciences; Science, Engineering and Technology and Biomedical Sciences. In 2010 approximately 37000 students were enrolled at K.U.Leuven. The Engineering Faculty is part of the Science, Engineering and Technology group. In the current academic year 4369 students are enrolled at the Faculty of Engineering. The engineering curriculum consists of a three year Bachelor's program that prepares the students for a subsequent Master's program of two years. The Faculty organizes Master's programs in several disciplines, like Architecture, Electrical Engineering, Mechanical Engineering, Chemical Engineering, Materials Engineering, Civil Engineering, Biomedical Technology, Computer Science, Energy Engineering, Nuclear Engineering, Industrial Management, Nano science and Nanotechnology, Mathematical Engineering, Bioinformatics, Statistics, …

The Engineering Bachelor's program is divided in two subsequent phases. The first phase of the Bachelor lasts three semesters and is common for all engineering disciplines with the exception of the study leading to the degree in architecture.
For the subsequent three semesters, this is the second phase of the Bachelor's program, the students choose a Major and Minor discipline, that prepare the students for the subsequent Master's program. That way the Faculty of Engineering combines teaching a broad base of scientific knowledge with educating very specialized technological knowledge and skills.

The performed study took place in the first phase of the Engineering Bachelor's program, which is common for all engineering students. The courses are subdivided into three groups: mathematics, energy and material science, information and communication science. Parallel to the regular coursework, all engineering students take the project based course '*Problem Solving and Engineering Design*' (acronym 'P&O' in Dutch) that introduces them from the first semester onwards into real engineering practice and teamwork. The concept of this course is to integrate basic principles of the regular scientific courses while working in small groups on design projects[1]. That way the students gradually acquire technical and social skills like information and simulation tools, experimental work, systematic approach to problem

solving and engineering design, teamwork and communication skills, critical attitude and creativity. Throughout the first three semesters of the bachelor, a gradual transition from solving closed engineering problems to working on open-end design projects is implemented[2]. The assignments of the first year relate to one technological area, from 2003 until 2006 this area was aerospace engineering, from 2006 until 2009 energy within the students' environment and currently the first year students are working on problems related to health science and sports.

A lot of attention goes to the guiding of the first year students. Each team of eight students is assisted by a *tutor*. He facilitates the teamwork and provides the students with individual feedback on the content of the project, the process of problem-solving and the team functioning. He does not provide ready-made answers, but emphasizes self-support. In addition to the tutors, *course specialists* are invited as experts to explain more in detail the use of the basic principles taught in the regular scientific courses. This supports the course integration, an important objective of 'Problem Solving and Engineering Design'. The course specialists act as experts and they do not know the details of the assignments themselves.

This paper describes a study that was performed during the academic years 2005-2006 and 2006-2007. By means of extensive questionnaires feedback was obtained from the students regarding the guidance of the teams and the students' perceived learning effect. That way the relationship between different guidance-tasks and the student learning can be investigated. This is important, because due to the limited resources (the teamwork is facilitated by three tutors per fifteen student teams) most effort should be put into the most effective coaching roles. In the remainder of the paper the hypotheses of the study will be described, together with the subjects and methods used. At the end the findings are discussed in detail and the conclusions contain recommendations for the guidance of future project work.

2. Hypotheses

Based on literature, five guidance-tasks were defined that have an effect on the student learning in a project based course:

1) guidance of the team cooperation[3-9];
2) guidance with respect to the content of the assignments[3;5;8;9];
3) clarifying objectives and evaluation of the course[3;7];
4) stimulation of self-activation[3-6;8;10-12];
5) providing individual and team feedback[3-5;7;13].

In this study it was hypothesized that all these five responsibilities for the guidance of teamwork contribute positively to the student learning.

In addition the tutors are involved in the evaluation process of the student teams and monitor individual contributions of team members. This last task is not incorporated within this study.

3. Subjects

During two subsequent academic years (2005-2006 and 2006-2007) several hundreds of students participated in this study. Exact numbers of students are listed in table 1.

Table 1. The number of students that participated in the study during two subsequent academic years (from 2005 until 2007).

Year	Moment 1 (= Semester 1)	Moment 2 (= Semester 2)
3 (= 2005-2006)	381	363
4 (= 2006-2007)	383	324

4. Material and methods

Guidance
At the end of each semester (moment), the students filled out a questionnaire consisting of 34 items measuring the perception of the students concerning the five responsibilities of the tutor and course specialists. Items were constructed based upon the following guidance-tasks:

1) guidance of the team cooperation (7 items);
2) guidance with respect to the content of the assignments (8 items);
3) clarifying objectives and evaluation of the course (8 items);
4) stimulation of self-activation (6 items);
5) providing individual and team feedback (5 items).

A few examples of questions are: 'The tutor explains which results are expected.', 'The tutor encourages us to learn with and from each other.', 'The tutor knows the content of the team assignments well.', 'The tutor motivates our team to look for solutions independently.', 'The tutor formulates individual feedback for individual team members'.

All items were scored on a six-point scale (1 = I strongly disagree; 6 = I strongly agree) and subjected to a principal component analysis with varimax (orthogonal) rotation [14]. Based on the 'Eigen value > 1' criterion five components were retrieved, explaining 59,75 % of the total variance. Five component-based 'guidance' scales were constructed by including all items loading high on the components (>|0.40|). Items loading on two components were excluded. The 'guidance' scales were calculated by summing the scores from included items and dividing this sum by the number of statements composing the scale. The constructed scales correspond generally well with the original guidance-tasks, on which the questionnaire was based. Because the newly constructed scales confirm the classification made on beforehand, the scales can be interpreted well. Theoretical minimum, midpoint and maximum scores on these scales are 1; 3.5 and 6 respectively.

1) The first scale, CB1, is constructed based on 8 items concerning the *'Tutor guidance of team learning and cooperation'*. The items loading highest on this component are: 'The tutor encourages us to listen to each other.' and 'The tutor encourages us to respect each other's opinion.' The scale's reliability coefficient is 0.90 (Cronbach's alpha[14]). A mean score of 4.20 (s.d. = 0.69) indicates that the students were merely positive about the guidance of the team learning and cooperation by their tutors.

2) The second scale, CB2, is based on 7 items concerning the *'Tutor content related guidance'*. The scale's reliability coefficient is 0.91 (Cronbach's alpha). The items contributing most to this scale are: 'The tutor knows the content of the team assignment well.' and 'The tutor is professional enough to provide guidance with respect to the contents.' A mean score of 4.45 (s.d. = 0.80) indicates that the students

were overall positive about the guidance with respect to the content of the assignments. During the project work in the design room most of the effort of the tutors goes to content related guidance. This is mainly due to the amount of content related questions the students tend to ask continuously.

3) The third scale, CB3, is based on 2 items concerning the *'Tutor feedback both to individual students and the group as a whole'*. The items loading on this component are: 'The tutor formulates individual feedback for individual team members.', 'The tutor indicates regularly the strengths and weaknesses of our team.' The scale's reliability coefficient is 0.62 (Cronbach's alpha). This relative low reliability coefficient and because the scale is constructed based on only two items, indicates that this scale is not that strong. A mean score of 3.41 (s.d. = 0.93) indicates that providing individual and group feedback can be improved.

4) The fourth scale, CB4, is constructed based on 3 items that concern the *'Tutor information about objectives, expectations and evaluation'*. The scale's reliability coefficient is 0.70 (Cronbach's alpha). The mean score is 4.01 (s.d. = 0.77). The items contributing most to this scale are: 'Enough information was supplied about the objectives and evaluation of the course.', 'Enough information is supplied about the assignments and the expected results.'

5) The fifth scale, CB5, is based on 2 items concerning the *'Input of the course specialists'*. The scale's reliability coefficient is 0.81 (Cronbach's alpha). The items contributing to this scale are: 'The contribution of the course specialists helps our teamwork progress.', 'The contribution of the course specialists with respect to the content of the assignments is relevant.' A mean score of 4.25 (s.d. = 0.96) indicates that the students appreciate the input of the course specialists as experts, while working in team. In the original classification of guidance-task, these items concerning the course specialists were incorporated in content-related guidance.

The items of the original task 'stimulation of self-activation' contribute to either scale CB1 'tutor guidance of team learning and cooperation', or scale CB2 'tutor content related guidance'.

Table 2 gives an overview the five 'guidance' scales. An overview of all items loading on the five components can be found in appendix (table 6).

Table 2. Descriptive statistics of the five 'guidance' scales that were constructed based upon a principal component analysis.

Scale		Number of items	Cronbach's Alpha	Mean score	Standard deviation
CB1	Tutor guidance of team learning and cooperation	8	0,90	4,20	0,69
CB2	Tutor content related guidance	7	0,91	4,45	0,80
CB3	Tutor feedback both individual and group	2	0,62	3,41	0,93
CB4	Tutor information about objectives, expectations, evaluation	3	0,70	4,01	0,77
CB5	Input of course specialists	2	0,81	4,25	0,96

Figure 1 shows the mean values of the five guidance scales per measurement. The graph confirms that most improvement can be done on scale CB3 about providing individual and team feedback. Figure 1 also shows the work that is done on content related guidance and the attention that went to the guidance of team learning and cooperation. All scales concerning the guidance of the tutor show a minimum in the first semester of the academic year 2006-2007 (Y4M1). This was the first implementation year of the new technological theme, so the tutors were less prepared. This stresses the importance of preparing new project assignments very carefully. Organizing a pilot project for a few students is thereby useful. Furthermore in the first semester of that year the guidance of the students was less optimal because of the absence of one of the experienced tutors, who was mostly involved in preparing the assignments. (This minimum is not present in the fifth scale CB5, concerning the input of the course specialists.)

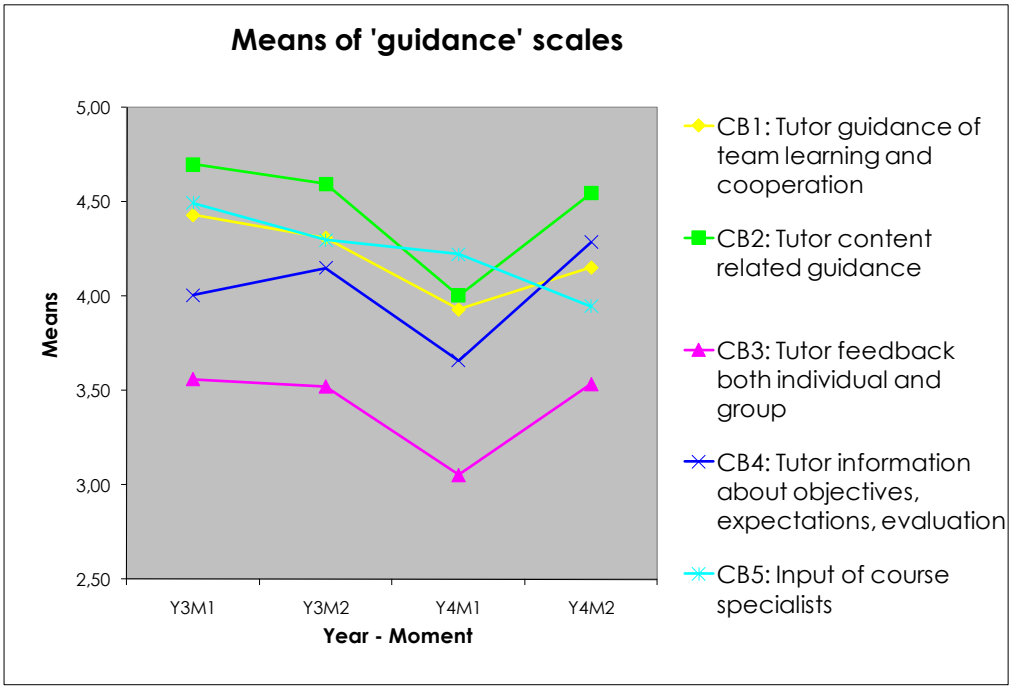

Figure 1. Means of the five constructed 'guidance' scales per measurement (Y3 = academic year 2005-2006; Y4 = academic year 2006-2007; M1 = semester 1; M2 = semester 2).

Student learning

Together with the 'guidance' questionnaire, students were presented statements about the concept of the course and the perception of their learning. Feedback was thus obtained from the students about the relevance of the course, the clearness of the assignments, the course integration objective and the gradual building up of technical competencies (systematic problem solving, modeling and experimenting, information skills), attitudes, communication and teamworking skills. All statements were scored on a six-point scale (1 = I strongly disagree; 6 = I strongly agree).

Because these questions were added each semester 'ad hoc' to evaluate and optimize the implementation of the course, the amount and wording of the statements differed slightly each semester. Therefore these data could only be analyzed per questionnaire. Per semester a principal component analysis with varimax (orthogonal) rotation was performed, and

corresponding component-based scales were constructed based on the 'Eigen value > 1' criterion[14]. In total, for the four semesters, seven scales were constructed by including all items loading high on the components (>|0.40|). Items loading on two components were excluded. The constructed scales are meaningful, can be interpreted in several semesters and confirm the classification of the statements made on beforehand. Because of the different questionnaires each semester not all scales are present in every semester and one and the same scale is sometimes constructed based on slightly different statements according to the semester. Meaningful items however load consequently on the same components.

Table 3 shows the percentage of variance explained by each principal component analysis and gives an overview of the constructed scales. An overview of the items loading on the components in each semester can be found in appendix (table 7). Because the newly constructed scales confirm the classification made on beforehand, the scales can be interpreted well. Theoretical minimum, midpoint and maximum scores on these scales are 1; 3.5 and 6 respectively.

1) The first scale *'Clear assignment'* only exists in the academic year 2006-2007 and is mainly based on the items: 'The assignments are formulated clearly.' and 'My team could sufficiently rely on tutors and course specialists to complete the team project with a good result.' The reliability coefficients are rather low in both semesters. In the first semester of 2006-2007 the low mean score of 3.68 (s.d. = 0.87) confirms the difficulties that occurred by introducing the new technological theme 'energy' with a new set of assignments and one of the regular tutors absent.

2) The second scale *'Integrative concept and relevance of P&O'* was constructed in each semester. Main items contributing are: 'I integrated basic principles of different regular courses to complete the team assignment.', 'Through the teamwork I understand better the basic principles taught in the regular scientific courses.' and 'I clearly see the relevance of the course for my engineering study.' The reliability of the scales and the mean scores are satisfactory in all semesters. The students confirm the added value of P&O for their engineering course.

3) The *'Teamworking skills'* scale only exists for P&O1, in the first semester of every academic year. This scale is constructed based on the statements: 'Through the group project, I learned how to divide a team efficiently into subteams.' and 'Through the group project, I learned about the roles of project manager and secretary of a team.' The reliability of the scales are satisfactory and the mean scores indicate that students believe to have mastered teamworking skills while working on their project.

4) The scale *'Contribution to independent learning'* is constructed in the two semesters of the academic year 2006-2007, based on the items 'Through the teamwork I learned to work more independently.' and 'Through the teamwork I learned how to master new information independently.' The reliability coefficients indicate a good scale and the mean scores reflect that the students feel they are able to learn more independently through the P&O courses.

5) The next scale *'Transfer of competencies beyond introductory seminar'* is based on the statements: 'What I learned during the introductory lecture about the design process, helped to complete the team project with a good result.' and 'What I learned during the introductory lecture about project planning, helped to complete the team

project with a good result.' Because these introductory lectures are scheduled in the second semester of each academic year, the scale only exists in two measurement moments. The scale's reliability factors are relatively high, but the mean scores are rather low. This confirms the feeling of the didactic team that the lectures about the design process and project planning are a bit theoretical for the students. They do not see how this lecture can be useful to their project. After introducing small examples in the lectures, in the academic year 2008-2009 a young engineer was invited to clarify the connection between the theory and his every day practice. Students reacted more interested and looked at the engineer like he was 'one of them'.

6) The following scale *'Gradual building up of competencies'* is based on statements that were also only part of the questionnaires at the end of the second semester of each academic year. Items loading high on this component are: 'Through working on the second project, in comparison with the first project, I now understand more about dividing a team efficiently into subteams.' and 'Through working on the second project, in comparison with the first project, I now understand more about a systematic approach to solve problems.' The scales' reliability coefficients are satisfactory and the mean scores indicate that students confirm the learning improvement from the first to the second P&O project.

7) The last scale constructed concerns the students' perception of *'Peer assessment'*. This scale is based on the items: 'Peer assessment is a valuable tool to evaluate the individual contribution of team members in group projects.', 'The formative peer assessment and feedback are useful.' and 'Completing the peer assessment form contributed to the development of my teamworking skills.' The reliability of the scales is satisfactory. The mean scores are rather low, mainly due to the fact that not all students believe to learn more about team functioning through completing the peer assessment form

Table 3. Overview of the 'student learning' scales constructed per semester (horizontal lines). The table contains the percentage of variance explained by each principal component analysis, the original numbers of the items loading high on the constructed scales, the reliability coefficient (Cronbach's alpha) and the mean score of every constructed scale.

			SCALES						
	Variance explained		Clear assign-ment	Integrative concept and relevance of P&O	Teamwor-king skills	Contribu-tion to indepen-dent learning	Transfer of competen-cies beyond introduc-tory seminar	Gradual building up of com-petencies	Peer assess-ment
Y3M1	56,90%	Scale number		C2Y3M1	C1Y3M1				C3Y3M1
		Number of items		2	4				3
		Cronbach's Alpha		0,63	0,72				0,72
		Mean score		4.74 (s.d.=.79)	4.31 (s.d.=0.68)				4.09 (s.d.=0.90)
Y3M2	61,21%	Scale number		C4Y3M2			C2Y3M2	C1Y3M2	C3Y3M2
		Number of items		2			2	7	3
		Cronbach's Alpha		0,72			0,87	0,85	0,74
		Mean score		4.35 (s.d.=0.90)			3.50 (s.d.=1.12)	4.33 (s.d.=0.71)	3.93 (s.d.=1.01)
Y4M1	55,14%	Scale number	C5Y4M1	C1Y4M1	C4Y4M1	C2Y4M1			C3Y4M1
		Number of items	3	9	3	5			3
		Cronbach's Alpha	0,56	0,84	0,68	0,80			0,75
		Mean score	3.68 (s.d.=0.87)	4.53 (s.d.=0.62)	4.34 (s.d.=0.75)	4.11 (s.d.=0.70)			3.77 (s.d.=1.03)
Y4M2	57,32%	Scale number	C6Y4M2	C1Y4M2		C3Y4M2	C4Y4M2	C2Y4M2	C5Y4M2
		Number of items	2	6		4	2	4	4
		Cronbach's Alpha	0,52	0,80		0,74	0,83	0,79	0,65
		Mean score	4.20 (s.d.=0.79)	4.45 (s.d.=0.66)		4.05 (s.d.=0.73)	3.25 (s.d.=1.20)	4.27 (s.d.=0.78)	4.00 (s.d.=0.84)

Scales 2 to 6 refer directly to student learning objectives. Scale 1 concerns the clearness of the assignment and scale 7 is about the evaluation process. Because these two do not measure the student learning directly, scales 1 and 7 will be excluded from the remainder of this study. To evaluate the results of this perceived student learning measurement, a correlation was made of the remaining five student learning scales with the scores the students obtained for the P&O course. Table 4 shows the results for each semester. Besides the Pearson correlation coefficients between the scale and the score on the course per semester, also the partial correlations were calculated[14]. For this partial correlation correction was made for the academic achievement of the student by taking into account the corrected total end score of the student, this is the end percentage of the student, corrected for the score on the particular P&O-course. The correlations between all courses of the first year of the bachelor are all significant and quite high (between 0,4 and 0,8).

The results show a positive correlation between the score on the course and the students' perspective on the integrative concept and the relevance of P&O (scale 2). Main items in this scale are: 'I integrated basic principles of different regular courses to complete the team assignment.', 'Through the teamwork I understand better the basic principles taught in the regular scientific courses.' and 'I clearly see the relevance of the course for my engineering study.' Students that agree upon these statements, tend to have better results on the course.

Table 4. Correlations between the student learning scales and the scores the students obtained for the course. Numbers in the table indicate significant correlations (p < 0,05).

Year - Moment		SCALE: Integrative concept and relevance of P&O	Teamworking skills	Contribution to independent learning	Transfer of competencies beyond introductory seminar	Gradual building up of competencies
Y3M1	Scale number	C2Y3M1	C1Y3M1			
	Pearson Correlation with score on P&O	0,176	-			
	Partial Correlation with score on P&O by corrected total score	0,142	+			
Y3M2	Scale number	C4Y3M2			C2Y3M2	C1Y3M2
	Pearson Correlation with score on P&O	0,180			+	0,186
	Partial Correlation with score on P&O by corrected total score	0,168			0,127	0,222
Y4M1	Scale number	C1Y4M1	C4Y4M1	C2Y4M1		
	Pearson Correlation with score on P&O	0,148	-	-		
	Partial Correlation with score on P&O by corrected total score	0,137	-	+		
Y4M2	Scale number	C1Y4M2		C3Y4M2	C4Y4M2	C2Y4M2
	Pearson Correlation with score on P&O	+		+	-	+
	Partial Correlation with score on P&O by corrected total score	0,131		+	+	+

Legend

- scale does not exists in this semester (grey)
- signifant positve correlation (coefficient > 0,200) (dark green)
- signifant positve correlation (coefficient < 0,200) (bright green)
- no signifant correlation, correlation coefficient > 0 (light green)
- no signifant correlation, correlation coefficient < 0 (light yellow)
- signifant negative correlation (red)

5. Findings

To test the hypothesis that the five defined guidance-tasks have an effect on the student learning, regression analyses were performed[14;15]. Because the 'student learning' scales are constructed per semester, different regression analyses are performed per semester with the 'student learning' scale as dependent variable and the 'guidance' scales as independent variables.

Table 5 shows the partial correlation coefficients for each regression analysis. The numbers show significant correlations ($p < 0.05$). The explained variance of each regression analysis is reported in appendix (table 8). The results confirm the importance for the student learning to provide clear information about the course objectives, the expected results and the evaluation procedure. Scale CB4 'Tutor information about objectives, expectations and evaluation' contributes positively to most of the 'student learning' scales. Furthermore the results also confirm the significance of coaching the cooperation and team learning. Scale CB1 'Tutor guidance of team learning and cooperation' also correlates positively to all 'student learning' scales.

An interesting observation is the lack of correlation between the 'student learning' scales and CB2 'Tutor content related guidance'. There even seems to be a bit of a negative trend. Mainly when transfer between introductory seminars and subsequent P&O sessions is objected, a negative correlation is revealed. While most of the effort and time of the tutors goes to this task of answering content related questions of the students. The input of the course specialists however correlates positively with most of the 'student learning' scales. These course specialists provide also guidance related to the content of the assignments, but in theory they do not know the assignments in detail and act as experts. This makes their contribution more relevant with respect to the student learning objectives incorporated in this study.

The latter scale 'Tutor feedback both individual and group' does not reveal any significant correlations. This scale is not very strong.

Table 5. Partial regression coefficients for regression analyses performed per ‘student learning’ scale per semester (‘student learning’ scale = dependent variable, ‘guidance’ scales = independent variables). The numbers in the table are significant partial regression coefficients ($p < 0,05$).

		SCALE				
		Integrative Concept & Relevance of P&O	Teamworking skills	Contribution to independent learning	Transfer of competen-cies beyond introductory seminar	Transfer of competen-cies beyond p&o sessions
Y3M1	2005-2006 Semester 1	C2Y3M1	C1Y3M1			
Y3M2	2005-2006 Semester 2	C4Y3M2			C2Y3M2	C1Y3M2
Y4M1	2006-2007 Semester 1	C1Y4M1	C4Y4M1	C2Y4M1		
Y4M2	2006-2007 Semester 2	C1Y4M2		C3Y4M2	C4Y4M2	C2Y4M2
INDEPENDENT VARIABLES	CB4	+	0,116			
	Tutor information about	0,267			+	0,282
	objectives, expectations,	0,208	0,118	0,162		
	(Cronbach alpha= 0.70)	0,339		0,208	0,127	0,141
	CB5	0,109	0,163			
	Input of course specialists	0,184			0,125	+
		0,197	0,229	0,188		
	(Cronbach alpha= 0.81)	+	+	-	+	+
	CB2	+	+			
	Tutor content related guidance	-			-	-
		-	-	-		
	(Cronbach alpha= 0.91)	-		-0,143	-0,111	-
	CB1	0,262	0,202			
	Tutor guidance of team learning	0,166			0,145	0,293
	and cooperation	0,103	0,115	+		
	(Cronbach alpha= 0.90)	0,111		0,215	0,186	0,269
	CB3	-	+			
	Tutor feedback both individual	-			+	-
	and group	-	-	+		
	(Cronbach alpha= 0.62)	-		+	+	-

Legend

scale does not exists in this semester	no signifant correlation, correlation coefficient > 0
signifant positve correlation (coefficient > 0,200)	no signifant correlation, correlation coefficient < 0
signifant positve correlation (coefficient < 0,200)	signifant negative correlation

6. Conclusion

All first year engineering students at the K.U.Leuven take the project based course 'Problem Solving and Engineering Design'. The concept of this course is to integrate basic principles of regular scientific courses while working in team on design projects. The teamwork is facilitated by three tutors per fifteen teams of eight students. The didactic team as well as the students feel this is the absolute minimum for a proper group functioning. The tutors have several responsibilities: answering content-related questions, guiding the problem solving process, providing information about the objectives and deliverables, giving feedback and assessing the students. Because the limiting resources most effort should be put into the most effective coaching roles.

The results of this study confirm the importance for the student learning to provide clear information about the course objectives, the expected results and the evaluation procedure. Furthermore the results also confirm the significance of coaching the cooperation and team learning.

Interesting is the lack of correlation between the students perceived learning and content related guidance by the tutor. The input of the course specialists however correlates positively with most of the 'student learning' scales. These course specialists provide also guidance related to the content of the assignments, but in theory they do not know the assignments in detail and act as experts. This makes their contribution more relevant with respect to the student learning objectives incorporated in this study.

Based on the results of this study, recommendations could be made regarding the guidance of student teams working on engineering projects. When the objectives include the mastering of technical, social and metacognitive competencies, it is beneficial for the student learning to make a clear distinction between the guidance of the problem solving process and the team cooperation on the one hand and input with respect to the content of the project (expert knowledge) on the other hand. For the P&O-course this means that the tutor explains the objectives of the course, the deadlines and deliverables; he or she coaches the team with respect of the problem solving process and the teamwork and gives feedback. The instructions, the P&O manual, the electronic learning environment and a (mini) library contain information about the problem solving process and the contents of the assignments to help the students solve the problems. The course specialists are experts and the students can ask them concrete questions about the content of the assignments, related to the application of the basic principles taught in the regular courses. It is thereby important that the educational staff do not provide readymade answers, but instead coaches the problem solving process and helps the students to look for the information they need.

More research is needed for defining the most efficient time use of tutors and the effect on the learning experience and learning efficiency of the students. Probably this depends also, at least partially, on the nature of the tutor and his or hers guiding style (more or less directive for example). Therefore it could be beneficial to train the tutors specifically for the different guidance-tasks. Such a training will have a positive effect on the student learning and should be included within the doctoral training program.

Because the amount of tutors is limited, the learning outcome could be improved by involving the students into the guidance process. By implementing Peer Assisted Learning, students can contribute to guidance tasks CB1 (Tutor guidance of team learning and

cooperation) and CB3 (Tutor feedback both to individual students and the group as a whole). These tasks are probably even easier to fulfill by team members than by the tutors, because the tutors do not take part in the teamwork. However a specific training will also be necessary for the students. Further research is needed regarding the involvement of the team members in these guidance-tasks. As a result the rather low score on CB3 (Tutor feedback both to individual students and the group as a whole) could be augmented and the team cooperation could be improved.

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Appendix

Table 6. Overview of the guidance items, corresponding mean scores (minimum 1, maximum 6), standard deviations and component loadings.

SCALE				ITEM			
		Number of items	Cronbach's Alpha		Mean sore	Standard deviation	Factor loading
CB1	Tutor guidance of team learning and cooperation	8	0,90	The tutor encourages us to listen to each other,	4,21	0,92	0,77
				The tutor encourages us to respect each others opinion.	4,38	0,91	0,71
				The tuter encourages us to explain difficult subjects to our team members.	4,01	0,97	0,69
				The tutor encourages us to discuss ideas within the team.	4,13	0,91	0,68
				The tutor motivates our team to look for sollutions independently.	4,54	0,81	0,67
				The tutor encourages us to learn with and from each other.	4,18	0,93	0,66
				The tutor thinks the team functioning is important.	4,32	0,87	0,65
				The tutor makes sure that our team works methodically.	3,87	0,91	0,47
CB2	Tutor content related guidance	7	0,91	The tutor knows the content of the team assignments well.	3,87	0,91	0,81
				The tutor is professional enough to provide guidance with respect to the contents.	4,5	1,02	0,81
				The tutor is well prepared for the team sessions.	4,53	0,97	0,78
				The tutor knows the objectives of the course well.	4,71	0,88	0,73
				The feedback from our tutor is useful and constructive.	4,32	0,98	0,64
				The tutors provides ways for us to find answers on our own questions.	4,28	1,01	0,57
				The tutor encourages us to complete the assignments with a good result.	4,23	1,05	0,51
CB3	Tutor feedback both individual and group	2	0,62	The tutor formulates individual feedback for individual team members.	3,3	1,09	0,61
				The tutor indicates regularly the strenghts and weaknesses of our team.	3,53	1,09	0,58
CB4	Tutor information about objectives, expectations, evaluation	3	0,70	Enough information was supplied about the objectives and evaluation of the course.	4,13	0,93	0,75
				Enough information is supplied about the assignments and the expected results.	3,77	1,08	0,7
				The tutor explains which results are expected.	4,14	0,91	0,53
CB5	Input of course specialists	2	0,81	The contribution of the course specialists helps our teamwork progres.	4,23	1,04	0,89
				The contribution of the course specialists with respect to the content of the assignments is relevant.	4,27	1,05	0,88

Table 7. Overview of the items that contribute to the ‘student learning’ scales. These scales are constructed per semester: (a) academic year 2005-2006, semester 1 (Y3M1), (b) academic year 2005-2006, semester 2 (Y3M2), (c) academic year 2006-2007, semester 1 (Y4M1) and (d) academic year 2006-2007, semester 2 (Y4M2).

(a) Academic year 2005-2006, semester 1 (Y3M1)

SCALE Y3M1				ITEM				
Y3M1	**Scale**	**Number of items**	**Cronbach's Alpha**	**Or. item nr.**		**Mean sore**	**Standard deviation**	**Factor loading**
C1Y3M1	Teamworking skills	4	0,72	X08	Through the group project, I learned how and when to organise efficient team meetings.	4,00	0,97	0,748
				X06	Through the group project, I learned about the roles of project manager and secretary of a team.	4,32	1,01	0,683
				X04	Through the group project, I learned how to divide a team efficiently into subteams.	4,36	0,92	0,650
				X01	Through the group project, I learned how to work efficiently within a team.	4,27	0,92	0,503
C2Y3M1	Integrative concept and relevance of P&O	2	0,63	X29	Through the teamwork I understand better the basic principles taught in the regular scientific courses.	4,01	1,09	0,809
				X28	I integrated basic principles of different regular courses to complete the team assignment.	4,80	0,89	0,790
C3Y3M1	Peer assessment	3	0,72	Y16	Peer assessment is a valuable tool to evaluate the individual contribution of team members in group projects.	4,29	1,15	0,825
				Y17	The formative peer assessment and feedback are useful.	4,22	1,31	0,770
				X30	Completing the peer assessment form contributed to the development of my team working skills.	3,40	1,26	0,736

(b) Academic year 2005-2006, semester 2 (Y3M2)

SCALE Y3M2				ITEM				
Y3M2	Scale	Number of items	Cronbach's Alpha	Or. item nr.		Mean sore	Standard deviation	Factor loading
C1Y3M2	Gradual building up of competences	7	0,85	X05	Through working on the second project, in comparison with the first project, I now understand more about dividing a team efficiently into subteams.	4,38	0,94	0,826
				X09	Through working on the second project, in comparison with the first project, I now understand more about organising efficient team meetings.	4,19	0,98	0,798
				X11	Through working on the second project, in comparison with the first project, I now understand more about a systematic approach to solve problems.	4,44	0,94	0,753
				X07	Through working on the second project, in comparison with the first project, I now understand more about the roles of project manager and secretary of a team.	4,07	1,03	0,685
				X02	What I learned in the first group project about efficient group functioning, helped to get a good result in the second project.	4,32	0,97	0,567
				X17	The experiment we performed while working in team was a good introduction into scientific experiments.	4,59	0,96	0,557
				X22	Through the teamwork I learned how to master new information independantly.	4,16	0,88	0,455
C2Y3M2	Tranfer of competences beyond introductory seminar	2	0,87	Y07	What I learned during the introduction lecture about the design process, helped to complete the team project with a good result.	3,42	1,19	0,851
				X13	What I learned during the introduction lecture about project planning, helped to complete the team project with a good result.	3,50	1,18	0,803
C3Y3M2	Peer assessment	3	0,74	X30	Completing the peer assessment form contributed to the development of my team working skills.	3,40	1,26	0,806
				Y17	The formative peer assessment and feedback are useful.	4,22	1,31	0,777
				Y16	Peer assessment is a valuable tool to evaluate the individual contribution of team members in group projects.	4,29	1,15	0,764
C4Y3M2	Integrative concept and relevance of P&O	2	0,72	X28	I integrated basic principles of different regular courses to complete the team assignment.	4,80	0,89	0,806
				X29	Through the teamwork I understand better the basic principles taught in the regular scientific courses.	4,01	1,09	0,729

(c) Academic year 2006-2007, semester 1 (Y4M1)

SCALE Y4M1				ITEM				
Y4M1	Scale	Number of items	Cronbach's Alpha	Or. item nr.		Mean sore	Standard deviation	Factor loading
C1Y4M1	Integrative concept and relevance of P&O	9	0,84	X24	I clearly see the relevance of the course for my engineering study.	4,78	0,94	0,742
				Y02	I am interested in the connection of theory and practice.	4,77	0,88	0,689
				Y01	Its relevance for my future profession makes this course fascinating.	4,38	1,04	0,660
				X26	The way the teamwork is organised, helps me to understand the connection between theory and practice.	4,43	0,90	0,625
				X25	The way the teamwork is organised, motivates me to participate actively.	4,38	0,91	0,624
				Y03	The course objectives are realistic at this point in my study.	4,59	0,86	0,611
				X29	Through the teamwork I understand better the basic principles taught in the regular scientific courses.	4,01	1,09	0,592
				X28	I integrated basic principles of different regular courses to complete the team assignment.	4,80	0,89	0,535
				Y05	What I learned during the instruction lecture and exercises, helped to complete the team project with a good result.	4,26	1,13	0,432
C2Y4M1	Contribution to independent learning	5	0,80	X19	Through the teamwork I learned to work more independently.	4,05	1,04	0,743
				X22	Through the teamwork I learned how to master new information independently.	4,16	0,88	0,714
				X20	Through this course I learned how to refer to relevant sources.	3,97	0,97	0,657
				X01	Through the group project, I learned how to work efficiently within a team.	4,27	0,92	0,597
				X23	During the team project, I reflected upon my activities to check whether I could improve on something.	4,21	0,90	0,494
C3Y4M1	Peer assessment	3	0,75	Y16	Peer assessment is a valuable tool to evaluate the individual contribution of team members in group projects.	4,29	1,15	0,826
				Y17	The formative peer assessment and feedback are useful.	4,22	1,31	0,752
				X30	Completing the peer assessment form contributed to the development of my team working skills.	3,40	1,26	0,706

Continuation (c)

SCALE Y4M1				ITEM				
Y4M1	Scale	Number of items	Cronbach's Alpha	Or. item nr.		Mean sore	Standard deviation	Factor loading
C4Y4M1	Teamworking skills	3	0,68	X04	Through the group project, I learned how to divide a team efficiently into subteams.	4,36	0,92	0,788
				X06	Through the group project, I learned about the roles of project manager and secretary of a team.	4,32	1,01	0,628
				X10	Through the group project, I learned to use a systematic approach to solve problems.	4,33	0,82	0,494
C5Y4M1	Clear assignment	3	0,56	Y13	The assignments are formulated clearly.	3,87	1,12	0,778
				X15	The tutors explain the criteria for a good scientific report.	4,11	1,11	0,693
				X31	My team could sufficiently rely on tutors and course specialists to complete the team project with a good result.	3,90	1,15	0,529

(d) Academic year 2006-2007, semester 2 (Y4M2)

SCALE Y4M2				ITEM				
Y4M2	**Scale**	**Number of items**	**Cronbach's Alpha**	**Or. item nr.**		**Mean sore**	**Standard deviation**	**Factor loading**
C1Y4M2	Integrative concept and relevance of P&O	6	0,80	X26	The way the teamwork is organised, helps me to understand the connection between theory and practice.	4.43	0.90	0,720
				X25	The way the teamwork is organised, motivates me to participate actively.	4,38	0,91	0,642
				X24	I clearly see the relevance of the course for my engineering study.	4,78	0,94	0,608
				X28	I integrated basic principles of different regular courses to complete the team assignment.	4,80	0,89	0,596
				X29	Through the teamwork I understand better the basic principles taught in the regular scientific courses.	4,01	1,09	0,576
				X17	The experiment we performed while working in team was a good introduction into scientific experiments.	4,59	0,96	0,484
C2Y4M2	Gradual building up of competences	4	0,79	X05	Through working on the second project, in comparison with the first project, I now understand more about dividing a team efficiently into subteams.	4,38	0,94	0,793
				X07	Through working on the second project, in comparison with the first project, I now understand more about the roles of project manager and secretary of a team.	4,08	1,03	0,731
				X09	Through working on the second project, in comparison with the first project, I now understand more about organising efficient team meetings.	4,19	0,98	0,692
				X11	Through working on the second project, in comparison with the first project, I now understand more about a sstematic approach to solve problems.	4,44	0,94	0,684
C3Y4M2	Contribution to independent learning	4	0,74	X19	Through the teamwork I learned to work more independently.	4,05	1,04	0,683
				X20	Through this course I learned how to refer to relevant sources.	3,97	0,97	0,683
				X22	Through the teamwork I learned how to master new information independently.	4,16	0,88	0,669
				X23	During the team project, I reflected upon my activities to check whether I could improve on something.	4,21	0,90	0,624

Continuation (d)

SCALE Y4M2				ITEM				
Y4M2	**Scale**	**Number of items**	**Cronbach's Alpha**	**Or. item nr.**		**Mean sore**	**Standard deviation**	**Factor loading**
C4Y4M2	Tranfer of competences beyond introductory seminar	2	0,83	Y07	What I learned during the introduction lecture about the design process, helped to complete the team project with a good result.	3,42	1,19	0,841
				X13	What I learned during the introduction lecture about project planning, helped to complete the team project with a good result.	3,50	1,18	0,781
C5Y4M2	Peer assessment	4	0,65	Y16	Peer assessment is a valuable tool to evaluate the individual contribution of team members in group projects.	4,29	1,15	0,810
				X30	Completing the peer assessment form contributed to the development of my team working skills.	3,40	1,26	0,591
				Y17	The formative peer assessment and feedback are useful.	4,22	1,31	0,591
				Y18	I think that the way the marking is done among group members, is fair.	4,46	0,87	0,587
C6Y4M2	Clear assignment	2	0,52	Y13	The assignments are formulated clearly.	3,87	1,12	0,674
				X31	My team could sufficiently rely on tutors and course specialists to complete the team project with a good result.	3,90	1,15	0,626

Table 8. Partial regression coefficients and explained variance (R Square) for regression analyses performed per ‘student learning’ scale per semester (‘student learning’ scale = dependent variable, ‘guidance’ scales = independent variables).

		SCALE				
		Integrative Concept & Relevance of P&O	Teamworking skills	Contribution to independent learning	Transfer of competencies beyond introductory seminar	Transfer of competencies beyond p&o sessions
Y3M1	2005-2006 Semester 1	C2Y3M1	C1Y3M1			
Y3M2	2005-2006 Semester 2	C4Y3M2			C2Y3M2	C1Y3M2
Y4M1	2006-2007 Semester 1	C1Y4M1	C4Y4M1	C2Y4M1		
Y4M2	2006-2007 Semester 2	C1Y4M2		C3Y4M2	C4Y4M2	C2Y4M2
Y3M1	R Square	0,238	0,219			
Y3M2	R Square	0,246			0,106	0,328
Y4M1	R Square	0,168	0,149	0,149		
Y4M2	R Square	0,261		0,167	0,140	0,207
INDEPENDENT VARIABLES	CB4	+	0,116			
	Tutor information about	0,267			+	0,282
	objectives, expectations,	0,208	0,118	0,162		
	(Cronbach alpha= 0.70)	0,339		0,208	0,127	0,141
	CB5	0,109	0,163			
	Input of course specialists	0,184			0,125	+
		0,197	0,229	0,188		
	(Cronbach alpha= 0.81)	+	+	-	+	+
	CB2	+	+			
	Tutor content related guidance	-			-	-
		-	-	-		
	(Cronbach alpha= 0.91)	-		-0,143	-0,111	-
	CB1	0,262	0,202			
	Tutor guidance of team learning	0,166			0,145	0,293
	and cooperation	0,103	0,115	+		
	(Cronbach alpha= 0.90)	0,111		0,215	0,186	0,269
	CB3	-	+			
	Tutor feedback both individual	-			+	-
	and group	-	-	+		
	(Cronbach alpha= 0.62)	-		+	+	-

Legend

scale does not exists in this semester	no signifant correlation, correlation coefficient > 0
signifant positve correlation (coefficient > 0,200)	no signifant correlation, correlation coefficient < 0
signifant positve correlation (coefficient < 0,200)	signifant negative correlation