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van den Bogaard, M.E.D.; Klaassen, Renate

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The effects of curriculum overhaul: investigating the students' experience.

M.E.D. van den Bogaard
Leiden University, Leiden, The Netherlands
m.e.d.van.den.bogaard@iclon.leidenuniv.nl

R.G. Klaassen
Delft University of Technology, Delft, The Netherlands
r.g.klaassen@tudelft.nl

Abstract: *In this study, the final part of an overarching project on curriculum design and implementation executed at Delft University of Technology is presented. The last step in this research is to establish how the students perceive their new curricula. To that end a survey was developed using standardized questions on self-determination, motivation, self-efficacy, engineering education attributes, doability and study load of the programme. In addition, measures of student progress were collected in a programme for Architecture and the Built Environment and electrical Engineering. Relationships between the variables were established, but the relationship with progress was not strong. There were significant differences between the programmes, some of which may have a relationship with the way the curriculum was designed.*

Introduction

The Dutch Ministry of Education, Culture and Science signalled in 2010 a low student success rate particularly at the technical Universities in the Netherlands. To improve this situation the Ministry and the Universities amongst which Delft University of Technology made performance agreements on a number of KPI's on study duration and student retention. Failure to achieve these KPI's had major implication for the universities funding.

A task force identified a number of essential changes, that had to be made in each curriculum (Werkgroep Didactiek, 2011). The bachelor programme boards of each faculty were responsible for any programme improvements alongside the proposed changes and the implementation of improvements and changes in the programme.

The 4TU (previously 3TU) Centre for Engineering Education (CEE) evaluated these processes using the taxonomy of Van den Akker (2003) focusing on the curricula as designed, as implemented and as experienced. In this model it is implied that the extent to which curriculum goals have been achieved, can be measured by looking at student experiences within the curriculum, after it has been implemented. Fullan (2007) points out sustainable curricular change can only be realised if, amongst others, the intrinsic motivation of students and teachers is stimulated by the proposed reforms. This means that the reform contributes to goals that are important to students and teachers.

In previous work, the intended programme changes of the three Universities were studied to identify their possible success and fail factors (Gommer, Klaassen, & Brans, 2015). In the implementation phase, two programmes were studied in the three universities of technology that form the 4TU Centre for Engineering Education: Architecture and the Built Environment and Electrical Engineering (Verkroost, Van den Bogaard, Oude Alink & Schellen, 2015). The two programmes pursued different goals and used very different approaches to the design and implementation of their curriculum. In this paper we briefly describe the main findings of the previous study and discuss the third part of the evaluation in which we try to find out (1) to what extend these efforts have led to the achievement of the goals the programmes had set for themselves. (2) We will explore how student perceptions of (a) motivating curriculum elements in Architecture and the Built Environment (ABE) and Electrical Engineering (EEng) correlate with (b)student motivation and (c) success. These outcomes will be related to the goals the programme boards had set for the curriculum overhaul. In this paper we present preliminary results of this study.

The curriculum overhaul (implementation) at Delft University of Technology

At EEng student enrolment had declined to about 50 students in 2005. The programme management decided to create a broad programme in which all the disciplines constituting EEng were clearly represented and to create projects aimed at integrating knowledge representing the various disciplines of EEng. In this process it was decided early on that the programme should continue to focus on the technical and analytical side of EEng. Regular courses already in place were left unchanged for two reasons: (1) the programme management wanted to continue to use the existing high-quality learning materials that were tried, tested and complete, and (2) it was of importance to maintain the visibility of the constituent elements which together cover the field of EEng. These courses offered knowledge that had to be be applied in the projects that would run in the second half of each semester. The committee had put a lot of effort into looking at the order in which topics needed to be offered and at the increasing levels of difficulty and complexity of courses and projects throughout the programme. The new curriculum was implemented in 2010/2011 and improved in 2012: it proved to be successful in attracting more students and retention rates went up with approximately 10 per cent.

By 2005, the Bachelor programme in ABE came in last in terms of retention. The programme was fragmented: there were many courses with a small number of EC taught in parallel. As a result of the fragmentation, there were many exams and resits scheduled in the same timeframe. Students tended to procrastinate their studies, large numbers of students were failing their exams and students prioritized the design projects over their foundation courses. Senior management identified three focal points: professionalisation of the staff, assessment policy, and improving the doability of the Bachelor programme by removing barriers within the programme. Besides improving the programme’s doability the faculty had a number of content related goals: [1] to update the programme, such as addressing current and future design challenges in the area of redevelopment and transformation; [2] to increase the academic level of the programme; [3] to remove overlap between courses, such as the overlap between foundations of architecture, foundations of urban development and history of architecture. The rationale for the new programme were six content-based ‘learning lines’ that comprised related and integrated courses over the three years of the Bachelor programme. The core competency in this curriculum is 1) Design. A good design requires a strong background in 2) Building Technology, 3) Societal Issues and 4) Foundations of Architecture and the Built Environment. 5) Academic and Research Competence comprise skills required for designing, and a building engineer also needs to be able to 6) Communicate his or her designs to others. A number of starting points were defined: students need to work on integral assignments that combine knowledge from courses (from the old curriculum) that feed into the design project, there would be fewer partial grades awarded, and all relevant topics should be addressed during the terms in which a module is offered. Every semester contains a design project and the topic of the design project leads the choice of modules in that semester.

In this project three key attributes specific to engineering were identified: the inclusion of design activities; the use of authentic engineering problems, and cross-disciplinarity within and across courses. Although in both programmes a different approach to the curriculum design was chosen, both curricula clearly comply with these three attributes of engineering education (Godfrey & Parker, 2010; Van den Bogaard, 2015).

Theoretical framework of the study

Student success is among the most widely studied topics in higher education. In those studies, student success is often operationalized with units such as the number of credits students obtain, the average grade, or passing or failing some kind of progress requirement. Studies on student success would commonly include some student attributes, attributes of motivation, behaviour and perceptions of the learning environment. In Figure 1 we present a general model for student success, which is explained in detail below.

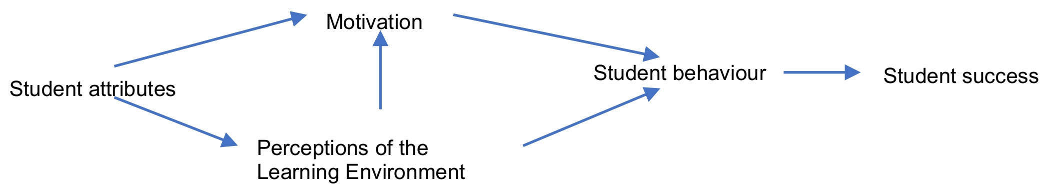

Figure 1: General model of student success (adapted from Jansen & Bruinsma, 2005; Van den Bogaard, 2015).

In this study we have used, in addition to the engineering attributes, this general model for student success that is grounded in research. The variables will be explained briefly below.

Student dispositions: motivation and self-efficacy

Ryan en Deci (2000) have established a well-known theory on motivation and postulate that there are three intrinsic needs that contribute to kindling and sustaining positive behaviour. These three needs are:

1. The need for competence (the extent to which student scan control the outcomes of their learning or experiencing success),
2. The need for autonomy
3. The need of relatedness (the need to interact with one's environment).

In an effective curriculum these needs are met. This theory is known as 'self-determination theory'. The amount of 'self-determination' student experience, can be supported by challenging students, by giving ample high quality feedback, by providing a supportive learning environment and to create opportunities for teachers and students to build effective relationships. As a result, students' interest and creativity can be increased and this would increase the students intrinsic motivation for a programme. (Ryan & Deci, 2000; "www.selfdeterminationtheory.org"). Students with little 'self-determination' tend to attribute their success or failure to external factor, which leads them to experience a lack of control over their situation.

Pintrich and De Groot (1990) found that intrinsic value and self-efficacy are related to student performance. Intrinsic value concerns students' reasons for doing a task: students who attach more value to a task will engage in more strategic study behaviours. According to Bandura (1997) the term 'self-efficacy' indicates the confidence people have in their capacity to achieve goals. Persons with a high level of self-efficacy often view difficult tasks as things that can be learnt, rather than seeing them as things that should be avoided.

Perceptions of the learning environment

A third element in the general model for student success pertains to students' perception of their learning environment. An environment can be supportive to students in objective terms, but if students' do not perceive it as such, the environment becomes a burden (Ginns, Prosser, & Barrie, 2007; Prosser & Trigwell, 1999). Student perceptions of the learning environment are therefore of importance when studying student success.

The term 'learning environment' is quite broad. Van den Bogaard (2015) established in a study at Delft University of Technology that the most important elements of the learning environment pertained to the quality of the teachers, the facilities including student support services, assessment and the educational organisation. The perceived quality of the teachers is important for the amount of relatedness (see self-determination theory), the quality of the educational organisation and assessment are important because organisation and the transparency of assessment procedures are an important element of the extent to which students perceive their curriculum as 'doable' (Werkgroep Didactiek, 2011).

In this study we consider a number of curriculum attributes that are related to the subject of the programme. E.g. at ABE one of the goals of the overhaul was to contribute to the training of better engineers through incorporating more challenging design assignments by combining authentic engineering cases of high societal relevance with topics from the theoretical foundation courses, that require students to collaborate (Goldberg & Sommerville, 2014; Sheppard, Macatangay, Colby, & Sullivan, 2009).

Student attributes

A number of relevant student attributes have been included in this study. Ability is the most consistent predictor of success in higher education and is usually operationalized as achievements in prior education (Pascarella & Terenzini, 2005). Gender is also a relevant variable, as women consistently report different experiences in the learning environment as do men (Seymour & Hewitt, 1997; Tonso, 2007). Besides these student attributes, a number of other attributes are included in the study presented in this paper: programme, student cohort, first year of enrolment in the programme, enrolment status and prior education.

Research questions and methodology

The goal of this study is to find out to what extent the goals of the curriculum overhaul have been achieved. The research questions that are leading in this study:

1. How do the students perceive the elements of engineering that have been embedded in the programme?
2. In what ways do the curricula at Architecture and the Built Environment and Electrical Engineering contribute to student motivation and student success?
3. What knowledge and skills do students think they are still missing in the new curriculum?

Methods

The researchers developed an online questionnaire fort his study. The questionnaire was based on standard scales that have been validated in similar contexts and complemented with questions on other relevant topics. The questionnaire was available in English and Dutch.

All bachelor students in these two programmes were sent a unique link to the questionnaire. Two reminders were sent out. The questionnaire was available for about 18 days.

At EEng there were 99 respondents and at ABE 37 students participated. These students came from the three years of the bachelor programme. The data was cleaned, cases with 50 percent or more data missing were removed. In the end 136 cases were included in the analysis: in ABE: 20 females and 15 males were included (2 respondents did not indicate their gender), at Electrical Engineering 5 females and 85 males were included (9 respondents did not indicate their gender). The response rate for EEng was 21 per cent, for ABE the response rate was 8 per cent. Data was explored visually and analysed using linear techniques.

Analysis

Research question 1 deals with the question to what extent the attributes of engineering education have been embedded in the programmes successfully. The questionnaire contained a scaled question on engineering education attributes, of which the items are included in the table below. Questions were answered on a 5-point Likert scale.

Table 1 Engineering Education (EE) scale items

	Engineering Education (EE) scale items	Alpha
EE1	There are plenty of proejcts, design and/or other project in the programme	.735
EE2	Project assignments are relevant for and related to the theoretical courses in this programme.	
EE3	The project assignments are appropriate for the level of this programme.	
EE4	Project are representative for issues from real life practical engineering problems.	
EE5	The project assignments are challenging and motivating.	

The alpha-score of this scale is higher than the lower cut off score of .7 that is commonly used (Field, 2013). The mean for the EEng students on this scale is 4.15 (SD: .46) and for the ABE students is 3.73 (SD: .55). The means for these groups are significantly different (F=21.202, p=.000). Architecture scores significantly lower on EE2 (F=17,569, p=.000), EE3 (F=11.640, p=.001), EE4 (F=10.410, p=.002) and EE5 (F=10.534, p=.001). There have not been any measurements prior to the overhaul, so it is not possible to compare these outcomes, but based on the means and the standard deviations it is clear that at Architecture there is room for improvement of the elements of EE in the programme. The response rate at ABE was very low and could explain the low scores on this scale.

Research question 2 deals with the issues of motivation and student success. To measure motivation we drew from various theories: Self-determination theory and theories on self-efficacy and intrinsic motivation. The items of the scales are presented below.

Table 2 Self Determination Theory scale items

	Self Determination Theory scale items	Alpha
Competence 1	I have difficulty making decisions during my learning process, in deisgn or project oriented courses.	.303
Competence 2	I have experienced a lot of pressure in my studies.	
Competence 3	I find it difficult to oversee all my options during the learning process in deisgn or project oriented courses.	
Competence 4	I realise in time when I am stuck in the learning process.	
Autonomy 1	The programme offers a number of predefined choice/electives that support my learning process, such as master track choices or minor programmes.	.586
Autonomy 2	Within courses I can make independent choices ith respect to my personal interests.	
Autonomy 3	I have the liberty to make my own decisions regarding the course and course assignments.	
Relatedness 1	In my courses I have plenty of opportunities to ask questions about the topic/assignment.	.787
Relatedness 2	I feel I am taken seriously as a student in this programme.	
Relatedness 3	My teachers are very approachable.	
Relatedness 4	The communication between the teachers and students is clear.	
Relatedness 5	Ther is enough support available in the programme.	

The alpha scores for the Competence and Autonomy scales are too low to be considered any further, as dropping items from the scale do not contribute to a better alpha. The alpha for the relatedness scale meets the criteria. ABE again scores lower on this scale than EEng (F=10.623, p=.001). We cannot establish if students feel motivated by their programmes.

The second element of this research question pertains to student success. To measure student success, we included a scale on self efficacy and one on intrinsic motivation in the questionnaire. These scales were taken from the MSLQ. Again, questions were answered using a 5-point Likert scale.

Table 3 Intrinsic Motivation (IM) and Self Efficacy (SE) scale items

	Intrinsic Motivation (IM) and Self Efficacy (SE) scale items	Alpha
IM1	I like the content of the courses in my programme.	
IM2	I often choose topics of which I will learn something, even if they require more work.	
IM3	It is important to me to understand the quint-essence of the courses.	
IM4	I am very much engaged by the programme's topics.	.652
IM5	I prefer teaching materials that are truly challenging so I can learn new things.	
IM6	I think I will be able to apply what I learn in my courses in the rest of my study programme.	
IM7	Being able to understand and apply the subject matter in diverse settings is important to me.	
SE1	I am certain I will master the skills taught in class during my courses this year.	
SE2	I can master almost all the work in my courses if I do not give up.	
SE3	I am certain I will figure out how to do the most difficult course work.	.825
SE4	Even if the work is hard, I can learn it.	
SE5	I can complete even the hardest assignments in my courses if I try.	

The alpha for the intrinsic motivation scale does not meet the low cut off point. Removal from any items will lower the score further. The alpha for self-efficacy does meet the requirements for scales. For both these scales there are no significant differences for ABE (IM: mean= 3.97, SD=.38. SE mean= 3.94, SD= .58) and EEng (IM: mean=4.01, SD=.41. SE mean= 3.98, SD= .53). An important element of student success pertains to the extent that a programmes is deemed doable by students.

Table 4 Doability and Studyload (DS) scale items

	Doability and Studyload (DS) scale items	Alpha
DS1	The course load is well spread over the year.	
DS2	It is clear how different course elements in my programme are related. (e.g. design, knowledge oriented courses, research, projects etc).	
DS3	The exams and tests are well spread out over the year.	.727
DS4	Assessment procedures are transparent and clear.	
DS5	Teachers and supervisors engage me during lectures and other educational activities.	
DS6	The various courses in this programme are clearly related.	

The ABE mean on Doability and Study Load is 3.43 with a SD of .51. The EEng mean on this scale is 3.84 with a SD of .52. ABE scores significantly lower on all items but DS5: DS1 $F=19.107$, $p=.000$, DS2 $F=14.098$, p=.000m DS3 $F=5.015$, $p=.027$, DS4 $F=6.100$, $p=.015$, DS6 $F=8.733$, $p=.004$. In the ABE programme the board chose to integrate the curriculum fully, which may be a reason why the programme scores low in comparison to EEng where courses and disciplines are more clearly visible. Another explanation could be that overload has always been an issue at ABE. The fact that if the SD is subtracted from the mean the score is close to 3 indicates that the doability and study load of the programme can be improved, but that this is not an urgent issue.

In Table 5 below we present the Spearman correlations of the means of the scales discussed and student progress. Progress is taken here as self-reported number of credits obtained in the first semester of the academic year.

Table 5 Spearman correlations of the means of the scales and student progress in ECTS

	ECTS	EE mean	Rel mean	IM mean	SE mean	DS mean	FS mean
ECTS	1.0	.049	.136	.007	.181*	.189*	.101
EE mean		1.0	.453**	.398**	.298**	.545**	.212*
Rel mean			1.0	.349**	.377**	.659**	.146
IM mean				1.0	.508**	.342**	.314**
SE mean					1.0	.356**	.145
DS mean						1.0	.259**

Spearman correlations. *=p<.05, **p=<.001

What stands out in this table is that ECTS hardly correlates with any of the scales. There are two small correlations with self-efficacy and doability and study load. These relationships are expected, but they are very weak. 'Future skills' shows mediocre correlations with EE and DS. The first correlation makes sense: in project work students are likely to get more exposure to new technologies. The most interesting correlation are between DS and EE and DS and Relatedness. Students who report higher scores on their perceptions of elements of EE in their programme and on their experience with relatedness, also report higher scores on how doable to the programme is. The correlation between intrinsic motivation and self-efficacy is to be expected based on the literature. When we consider the question on how the curricula influence student motivation, we note that EE correlates with Relatedness, IM and SE.

Research question 3 concerns the question what knowledge and skills students feel is lacking in their new curriculum. We asked the students to indicate to what extent future skills have been incorporated in their programmes and to indicate what is still missing in an open question. The questions on future skills are based on work by Kamp (2016). They are presented below.

Table 6 Future Skills scale items

	Future Skills scale items	Alpha
FS1	New innovative technologies are integrated in the lectures and project assignments.	.785
FS2	The newest insights from science and technology are discussed in class during a course.	
FS3	I have plenty of opportunities to experiment with new technologies in my programme.	

The alpha meets the criteria and no differences were found between the two programmes, however, the means for this scale are relatively low: Future Skills ABE mean= 3.21, SD= .85 and EEng mean=3.03, SD= .73. This means that the students feel they are not adequately prepared for the future. This also shows in the answers students gave on the open questions on what knowledge and skills were lacking. Students could give multiple answers. All the remarks were categorized and counted. At ABE a total of 47 remarks were made, at EEng 21 remarks were made.

In terms of skills that are lacking in the curriculum at ABE, students mention design software skills, such as working with Indesign, Revit and Autocad most often (10 times). Nine students mention technical knowledge and skills, such as material sciences, construction, etc. Reflection and critical thinking are mentioned 7 times, presentation skills are mentioned 8 times. This ranges from skills to present in 2D and 3D, but also to give presentations. Four students mention that skills and knowledge regarding design are lacking: they feel there is not enough focus on social implications of design and the design itself, rather than the presentation of design. Three students state they miss practical and entrepreneurial skills. The EEng students mention topics relating to circuit design 6 times. Five students mention presentation and writing skills. Two students mention the soft skills and the link to professional practice is also mentioned twice. A topic that is mentioned only a few times by both groups of students is collaboration. In ABE it is clear that students feel they are not able to experiment with new technologies, specifically in software. The fact that relatively many students state that there is not enough focus on building technology would also explain why the programme scores low on the Future Skills questions. The low score on the questionnaire questions at EEng is harder to explain based on the open question.

Conclusions, limitations and discussion

We set out to finish the overarching research project into the curriculum overhauls. We have no data to compare with the situation prior to the curriculum overhaul. Overall the scores on relevant scales are all 3 and higher on a 5-point scale. The students report that there are plenty of EE activities in their curricula, although ABE scores significantly lower than EEng.

We established some relations between curriculum attributes, motivation, self-efficacy and student success. The correlations between student progress and the other variables however were weak and only significant on a 95 per cent probability level: correlations were only found for SE and DS. The relations between the other variables were mediocre to strong. A few relationships stand out: there is a correlation of .659 between Relatedness and Doability and Studyload. Students who report that they feel supported by their learning environment also report that the programme is doable for them. DS is also strongly related to EE: students who report that the projects are meeting standards that are expected from this level of education also report higher scores on DS. A continuous effort to maintain and, where possible, improve the doability of the programmes should translate in higher scores on relevant variables and progress. Additionally, it will be worth wile to try to understand how the scores on DS emerge from student attributes and students' experiences in the educational environment.

In terms of future skills and knowledge and skills that are lacking, the students report that they feel they are not well prepared for their future. Students in ABE report they want to have more exposure to the use of software, they would like ot have more grounding in technology and construction and they feel that they are not trained well enough to deal with societal issues. Students from EEng report they would like more circuit design. Students from both programmes report they would like to learn more about presentation skills: oral, written, 2D and 3D, with a focus on critical thinking and reflection. Again, it is not possible to say whether or not the current curricula are an improvement compared to the previous curricula. Students do not report values under 3 out of 5 on the scale means and students do not consistently report clear omissions in their programmes. As overload is a serious concern in EE is might prove difficult to add more to the programme. The challenge for the programme boards will be to see where improvements can be made

A limitation of this study is that not all scales that had been selected as part of this research could be verified in this study: two out of three scales representing self-determination theory could not be validated. For future studies it is important to revise the scale items and test them. A more fundamental limitation of this study is the question to what extent student experiences and perceptions of different versions of a curriculum can be compared: student have nothing to compare the curriculum they are enrolled in with. This issue should be further explored to see if it is possible to create benchmarks that would allow such comparisons. When we compare the two programmes, we see that EEng seems to do better in certain aspects than ABE. The question here is if the differences can be attributed to the to the curriculum design or that they are due to other factors.

To further this study we intend to collect more data at the ABE programme and run some more analyses. Additionally, we intend to do a number of focus groups at both programmes to find out how the students look at the data collected in this study and to find out if they come up with more specific issues that need to be addressed. We would like to improve the questionnaire and include more programmes in this study to find out if we can establish benchmarks that will help us understand the curriculum as perceived by the students better. That way we can close the circle and provide better input for future endeavours of curriculum design and implementation.

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