THE INFLUENCE OF TEACHER CUES ON SELF-DIRECTED LEARNING IN MATH EDUCATION

Annoesjka Cabo, Renate Klaassen

Delft University of Technology, Faculty of Electrical Engineering, Mathematics and Computer Science (EEMCS), Delft Institute of Applied Mathematics (DIAM)
4TU.CEE, Centre for Engineering Education
The Netherlands

ABSTRACT

Increasing class sizes forces universities to change their education in ways that allow for independent learning for students. This study looks at a case where blended learning was introduced to alleviate some of the educationally negative consequences of large class sizes. Independent learning requires the students to become more self-regulated while at the same time they need efficient feedback from lecturers to enact these self-regulated learning activities. In this paper, we investigate whether at Delft University of Technology (TU Delft) student perceptions of lecturing behaviour is such as to stimulate student's independent learning and whether self-regulated learning behaviour results in more active engagement with the learning materials.

KEYWORDS

Curriculum Renewal, Mathematics, Blended Learning, Standards: 1, 2, 3, 4, 7, 8, 9, 10, 11, 12.

INTRODUCTION

In 2014 at TU Delft the "PRogramme Innovation Mathematics Education" (PRIME) was initiated in order to conceive a different approach to the math courses for engineering students. As a result of increasing student numbers group sizes in mathematics courses were growing. At the same time, this led to the desire to improve the quality of *active* learning. The premise was that large classes tend to reduce student engagement, to reduce student – teacher interaction, to reduce formative feedback, to diminish critical thinking and much more (Ramachandran et al., 2015). Blended learning was chosen as the solution to mitigate the negative effects of the large classes However, this requires more independent and self-regulated learning. Self-regulation is improved when reflection cues are added to the learning environment (van Laar, 2018). We have investigated the perception of the students on the role of the teacher in providing cues to students in monitoring and scaffolding, and hence in self-regulated behaviour.

PRIME

At TU Delft about 48 fte staff members are involved in over 150 courses in interfaculty education: teaching math to engineering students. At the moment the courses under review of PRIME are basic Calculus, Linear Algebra, Probability & Statistics for first and second year Bachelor students in Engineering programmes, like Civil Engineering, Mechanical Engineering, Aerospace Engineering and more. The goals of PRIME are to improve academic success, to improve the connection between mathematics and engineering and to increase student activity and participation in the math courses. The topic of this paper is mainly concerned with this last goal. We investigate whether active student participation in maths increases if the student perceives receiving stimulating cues to self-regulate their learning behaviour.

The organisation of PRIME

The initial project team consisted of a group of six dedicated lecturers from Delft Institute of Applied Mathematics (DIAM), an e-learning developer, an educational advisor and a project leader. The project was supported by the Executive Board of the university. After two years of running the project, the team has expanded into a team of a senior project leader, two coordinators, 16 instructors, an educational advisor and more than 10 student assistants.
The initial assignment was to develop a lesson plan with learning outcomes, which was then used to develop educational material: pre-lecture videos, lecture slides, online and book exercises, context examples (meaningful examples from the specific study programmes). Also, an overview graph of topics for each course and their interrelationship in terms of prior knowledge and connectivity was developed. The courses all have a blended design. The blended learning cycle as developed for PRIME distinguishes three phases in student activity: Prepare, Participate, Practice as illustrated in Figure 1.

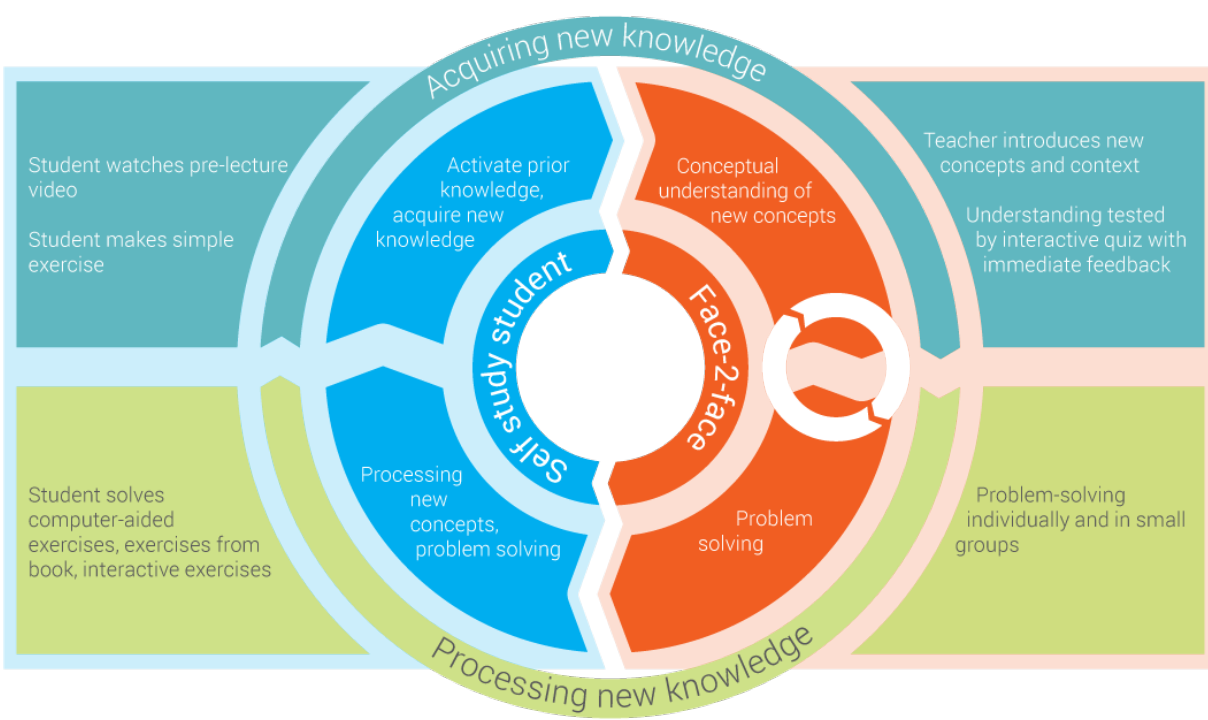


Figure 1. The blended learning cycle developed in PRIME

The student prepares before coming to class by watching a video, doing exercises from the book and/or doing exercises on an online exercise platform (with automated feedback). In the second part, during the face-to-face session (one session of 2 times 45 minutes), the student actively participates by answering interactive quiz questions about the pre-lecture activities. After this, the lecturer typically explains some new theory for say 20 minutes, there are a few other interactive quiz questions and time to work in class on exercises from the book. After the session, the student is supposed to practice. For this, an online exercise platform is made available in the collaborative learning environment (Brightspace at TU Delft). The platform provides exercises at different levels with feedback and dashboards for reference of level and understanding. Also, exercises from the book and old exam questions are on the to-do list for the student. This whole procedure requires an active and self-regulated attitude from the students in order to be successful.
It is important to know that the lectures are given by 8 to 13 teachers in parallel, to groups of 40 to 80 students, depending on the size of the Bachelor programme in question. The “teachers” involved are dedicated lectures, but also other academic staff (assistant, associate and full professors). The lecture slides developed in PRIME therefore also ensure uniformity of the content taught in the different groups.

THEORETICAL FRAMEWORK

Introducing blended learning makes the capacity for self-regulated learning more critical to student success as the students need to take more initiative, to plan, to seek help and to organise their study environment. Equally, the role of the teacher becomes more important in providing the relevant formative feedback, which helps the student to engage in a process called assessment for learning. Assessment for learning is focused on continuous formative feedback, where teachers actively observe and scaffold the next learning activity, building on students strengths and weaknesses. The teachers help students to find out what they already know such that more valid (tailored) learning can take place. When students in this context focus on the final programme outcomes, have time to internalise the materials offered, without necessarily being tested incrementally and take responsibility for their own learning process, more active involvement in the learning process may occur. The premise thus being that active involvement by staff and stimulation of students to be responsible and engaged may result in better learning results. This involves dialogue, trust and participatory relationships on top of feedback provided (Azevedo & Aleven, 2013). The argument is that modern higher(engineering) education, should move beyond the system of marking and grading to dialogic processes which assure standards of learning by sharing tacit and theoretical knowledge through active involvement in understanding the learning process and its outcome standards in the discipline or professional field.

Pat-El (2013) argues that assessment for learning builds on the alignment of instruction in support of learning. Support of learning is divided into two parts (1) Scaffolding: Supporting students managing their own learning process and (2) Monitoring: Stimulation of self-regulation of student’s progress. Scaffolding by the teacher allows students to achieve a task beyond unassisted efforts and to progressively grow towards greater independence (van Laar, 2018). Scaffolding and monitoring require interaction between the teachers and the students. Bennet (2018), shows that students must evaluate their understanding of the learning task and the learning environment by picking up appropriate cues which help them to make judgements about their goals and plans of action to actively engage with the study material available. Equally important is the role the teacher has in stimulating students to engage (with the available cues), to seek help or to ask feedback. The teacher gives guidance and assists the students and points out the critical pitfalls (strengths and weaknesses) which help students to realise monitoring activities of their own learning process (Kzric et all, 2018). After the initial teacher supported scaffolding and monitoring, the support materials in the blended learning environment should provide further scaffolding and monitoring opportunities self-regulation of the learning process.

RESEARCH QUESTIONS

Firstly we investigate what the student's perception is of the teachers' cues on monitoring and scaffolding in the PRIME learning environment. Secondly, we look into its relationship with the level of engagement with the study materials available in the courses under investigation as described above. Lastly, the contribution of separate activities with the learning materials on the reported engagement with the course material is considered.

The hypothesis is that reported engagement with learning materials is significantly enhanced by perceived monitoring and scaffolding cues from the teacher. If this hypothesis turns out not to be supported by the data, can we construct a better model?

RESEARCH METHOD

The monitoring and scaffolding questionnaire is based on the assumption that there is often a mismatch in perception in what teachers think they convey and the cues students perceive in supporting students' (self) evaluation of their learning (Pat-El, 2013).
A validated questionnaire from Pat-El (2013) was used: this includes the monitoring and scaffolding constructs and a five point Likert scale measuring the extent to which the perceived behaviour was applicable either to the teacher stimulating the students or to the students themselves when the questions start with "I". Finally, seven questions were included in the survey about the active engagement of students with the learning materials in the blended learning environment. Discriminating background variables were gender, math and physics grades at the end of secondary school, level of highest obtained diploma and discipline.

The survey has been distributed among 800 1st year students from Civil Engineering and Mechanical Engineering doing their 1st year calculus course. The learning materials offered are equal in each group. The students were taught in 22 groups by 16 different teachers. The response rate was 39% (316) of which 14 were non signed and 14 signed but not filled out. The final number of forms that could be used was 300.
A reliability analysis showed that the reliability of the questionnaire across the 40 items had a Cronbach's alpha of .88. Cronbach's Alpha is used to establish the reliability of the construct monitoring and scaffolding. A score of between .70 and .90 on Cronbach's alpha is generally considered as a sufficiently reliable score of the consistency within the sub-scale (Field, 2013). The Cronbach's alpha for the Monitoring construct was 0.88 and for the Scaffolding construct 0.80. These indicate that the constructs are reliable enough to pursue further analysis.

The responses were further divided between 245 males and 55 females which is equal to 81 % and 18% respectively. The overall population has slightly more girls in their programme (30 %). The sample under study is reasonably representative of the total population.

The average age of the respondents is between 18 and 19 years old. Around 99% is in the 1st year of their bachelor studies. Of these respondents 98% has a VWO diploma, which is a diploma at the highest level of secondary education, preparing pupils for university level education in the Netherlands. 90% is of Dutch origin. Other countries represented in the sample are Belgium (3), the Dutch colonies (2), US/UK (2), the Arab world (2), Italy (1) and Kenia (1).

Math and Physics grades were on average 7.8 (SD= 1.06) and 7.5 (SD= .85) respectively on a scale from 1 lowest to 10 highest at the secondary education level. It is noteworthy that the girls score significantly better in math (8.3 on average), than the boys (7.7 on average). For physics, there are no differences in the population. As there is a significant difference in math grades we decided to also consider the gender differences as one of the parameters to be studied. Gender differences tend to be persistent throughout STEM education and the teacher behaviour may be perceived differently by female or male students (Hofer & Stern, 2016).

RESULTS

Monitoring

The construct "monitoring" is representative for how students perceive the stimulation of the teacher to engage in self-directed learning with the learning material. In Table 1 we find the averages (standard deviation) for each score.

When comparing mean scores between men and women on the perception of the stimulation of the teacher to perform certain activities that support the students assessment for learning we note the following: On average lecturers do not perform all the feedback activities in class in such a way that students feel stimulated to reflect on their learning or demonstrate self-regulated learning. The lecturer typically demonstrates a teacher focused activity such as discussing assignments in class and by giving guidance to help understand the subject master (questions 12, 13). The lecturer tends to be more task focused by stimulating students on how they can improve and gives freedom in how to achieve that goal (questions 8, 5). This is a great start, yet there seems to be room for improvement. However, questions 14 and 15 show that the girls perceive the lecturers discussing the learning progress with the boys and not with them to a significant extent. Equally the improvement tips seem to significantly be less useful for girls than for boys. Although not strongly significant, differences are equally found on questions 1, 4, 10 and 11 (with a range from 0.05 to 0.09) where the girls consistently score lower than the boys. Apparently, there is less of a match between the views of the lecturers and the participating girls.

Table 1. Mean scores for monitoring for men and women

	Monitoring	Mean (SD) men	Mean (SD) women
1	The lecturer encourages me to reflect on how I can improve on my assignments	3.01 (.99)	2.7 (.95)
2	After examining the test results, the lecturer discusses the answers given to the test in class	2.86 (1.32)	2.7 (1.32)
3	Whilst working on my assignments, the lecturer asks how I think I am doing	3.20 (1.19)	2.94 (1.38)

4	The lecturer stimulate us to think about what we want to learn in university	2.94 (1.13)	2.65 (1.09)
5	The lecturer gives the opportunity to decide on my own learning strategies	3.90 (.819)	3.78 (1.07)
6	The lecturer inquires about what went well and what went badly in my work	2.90 (1.23)	2.75 (1.32)
7	The lecturer encourages me to reflect on my learning process	2.96 (.99)	2.73 (1.06)
8	The lecturer stimulates me to think about how to improve next time	3.22 (.97)	2.98 (1.15)
9	The lecturer shows how to find my strengths concerning my study skills	2.52 (.96)	2.29 (.97)
10	The lecturer shows how to identify my weaknesses concerning my study skills	2.48 (.99)	2.20 (.97)
11	I am encouraged by the lecturer to improve my learning process	3.34 (1.06)	3.05 (1.08)
12	The lecturer gives me guidance to assist my learning	3.47 (1.15)	3.35 (1.28)
13	The lecturer discusses assignments to help us understand the subject matter better	4.38 (.76)	4.24 (,90)
14	The lecturer discusses with me the progress I make	2.13 (.98)	1.7 (.97)
15	After each assessment the lecturer informs us on how to improve the next time	3.04 (1.09)	2.44 (.98)
16	The lecturer discusses how to exploit my study skills to improve my assignment	2.4 (.95)	2.33 (1.04)
	Monitoring Construct Cronbach's Alpha = .88		

Scaffolding

Scaffolding activities refer to the learner's autonomy and initiatives to realise growth and develop strategies in overcoming obstacles. The initiative is not so much triggered by the teacher but rather by the perception of their own activities in response to teachers' suggestions. In table 2 we find the averages (standard deviation) for each score.

We found that question 21 shows a significant (.005) reinforcement of the monitoring questions 14 and 15, where the girls do not feel invited to share or show what they have learned. Almost significant are questions 24 (0.04) and 27 (.05), where the girls' report on their contribution and opportunities to ask questions turns out to be lower than that of the boys. Overall, however, question 24, 27 are scored rather high. It is unclear whether this is due to the fear of the girls or whether they feel less invited by the teachers' behaviour or whether they perceive fewer cues than the teacher would like to. The somewhat lower scores on question 18 and 26 might suggest students feel they get fewer pointers or pointers that do not help them to improve their work.

Table 2. Mean scores for scaffolding for men and women

	Scaffolding	Mean (SD) men	Mean (SD) women
17	I am aware of my weak point in the application of study skills	3.95 (.81)	3.90 (.67)
21	During class I have an opportunity to show or share what I have learned	3.41 (1.18)	2.91 (1.23)
28	I am aware of the criteria by which my assignment will be evaluated	3.98 (.93)	3.78 (.99)
29	When I receive an assignment it is clear to me what I can learn from it	3.86 (.90)	3.64 (1.04)
30	The assignments allow me to show what I am capable of	3.89 (.94)	3.89 (.93)
18	The lecturer offers strategies to improve my study skills	2.95 (1.09)	2.84 (1.03)
19	When I do not understand a topic, the lecturer tries to explain it in a different way	4.11 (.92)	4.01 (.99)
20	The lecturer provides me with hints to help understand the subject matter	4.02 (.86)	3.88 (1.04)
22	The lecturer asks questions in a way I understand	4.22 (.66)	4.22 (.71)
23	The lecturers asks questions that help me gain understanding of the subject matter	4.15 (.78)	4.12 (.84)
24	The lecturer allows for my contribution during the lesson	3.77 (1.06)	3.44 (1.19)
25	I have the opportunity to ask my classmates questions during class	4.33 (.77)	4.22 (1.05)
26	The lecturer makes me aware of the areas I need to work on to improve my results	2.78 (1.08)	2.51 (1.09)
27	There is an opportunity to ask questions during class	4.70 (.55)	4.53 (.74)
	Scaffolding construct Cronbach's Alpha = .80		

Engagement with learning materials in the course

Exploring the activities taken up by the students we found that different groups of students use different strategies to be actively engaged. In Table 3 the mean scores for the seven questions related to this topic are displayed.

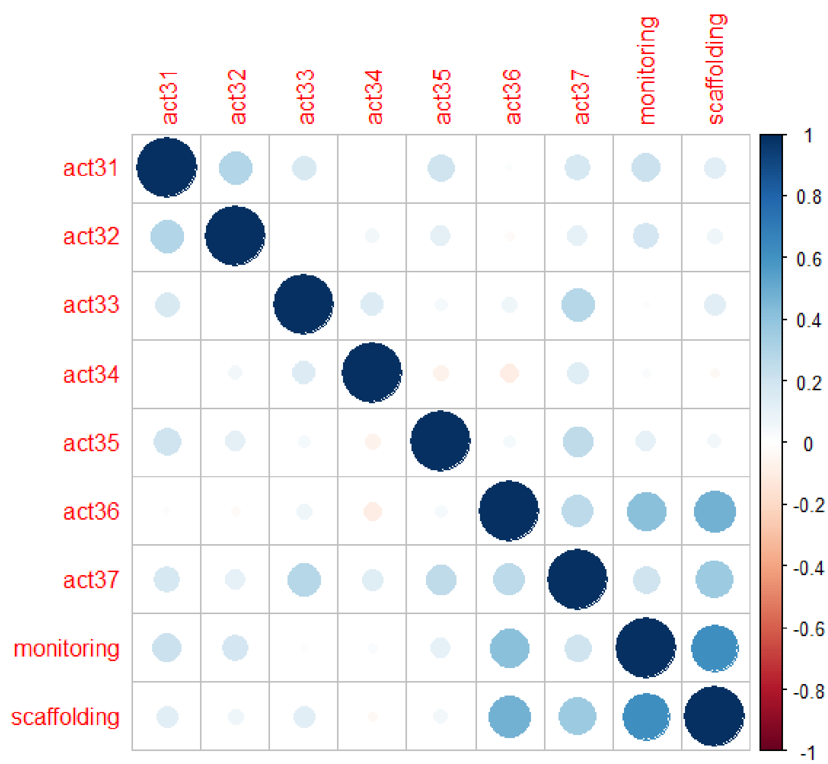
Table 3. Mean scores for Active Engagement: total and per gender

	Active engagement	Mean (SD)	Mean (SD) men	Mean (SD) women
act3.1	I have watched the video before each lesson	2.55 (1.42)	2.60 (1.45)	2.41(1.33)
act3.2	I have watched the video after each lesson	1.79 (1.09)	1.81 (1.08)	1.75 (1.14)
act3.3	I have attended every class	4.61 (0.79)	4.61 (0.72)	4.56 (0.71)
act3.4	I have practiced with the online assignments	3.57 (1.30)	3.36 (1.42)	3.58 (1.45)
act3.5	I have studied the study material from the book	3.57 (1.30)	3.50 (1.30)	3.98(1.18)

act3.6	I receive ample attention from the teacher to support my learning process	3.78 (0.98)	3.81 (0.95)	3.62 (1.05)
act3.7	I am actively engaged with the study materials available in this course	4.08 (0.88)	4.09 (0.87)	4.05 (0.87)

Computing correlations for these questions (see Figure 2), controlled for gender, level of education, maths and physics grade, shows that watching the video before class, attending class, practicing the online assignment positively correlate with active engagement (corr. .175, .293, .176 and sig. .004, .000, .004). The video after class was particularly watched when class was not attended. Also, high correlations are found on watching the video before class, studying the material from the book and active engagement (corr. .175, .253, sign, 004, .000). This seems to imply that students choose for the online materials or for the book.

Figure 2. Correlation matrix for the active engagement questions



Negative or very small and insignificant correlations emerge for using online materials and studying the book. Students tend to do either one or the other. In the group who is more focused on studying the book, we found fewer correlations with attending class and teacher attention for the group. The highest correlational loading, however, is found on receiving ample attention of the teacher to support the learning process and monitoring (corr. .41 sign. .000). And on receiving ample attention of the teacher to support my learning process and scaffolding (.48 and sign. .000). Another high correlation is seen between monitoring and scaffolding (corr. .62 . sign. .000). Meaning the teacher may be the most important factor in stimulating students to monitor (or self-direct their learning), with the high correlation between monitoring and scaffolding showing the importance of the teacher to have students do the right things.
To test the hypothesis of the positive impact of monitoring and scaffolding on the reported engagement with educational course materials, we performed a multi-variate linear regression

taking act3.7 (“ I am actively engaged with the study material available in this course”) as the response variable and the construct monitoring and scaffolding as explanatory variables. The first analysis showed that perceived scaffolding cues are of significant influence on the engagement, but the perceived monitoring cues are not. The coefficient for the scaffolding construct in this model is 0.69, meaning that any unit increase in perceived scaffolding construct results in a 0.69 increase in the student’s self-reported engagement with the material. However, the explained variance for this model is only 13%.

The following model turned out to be a better one: taking act3.7 as the response variable, and adding watching the video before the lesson, attendance in class, studying the book, getting ample attention from the teacher as explanatory (dummy) variables increased R-squared to 23%, with the largest significant contribution to the outcome from the attendance: the higher the score on attending every class, the higher the students reported engagement with the material. Second highest influence comes from studying the book, attention from the teacher only contributes significantly for students appreciating this attention with the highest score.

Finally, the best model we were able to fit turns out to be the one constructed from the above model by adding scaffolding cues: in this case, R-squared increased to 29%, with attendance and scaffolding cues having the highest impact on self-reported engagement with the materials.

CONCLUSIONS

In this paper, we have examined whether monitoring and scaffolding activities have a positive impact on the level of self-reported engagement with study materials in the PRIME set up. Furthermore, we have looked at differences in the perception of girls and boys with respect to monitoring and scaffolding cues.
Self-reported engagement with study materials available in the course is significantly explained by watching the video before the lesson, attendance in class, studying the book, getting ample attention from the teacher and scaffolding cues. Monitoring cues were not found to give a significant contribution.

Perceived monitoring of students is influenced by the attention of the teacher and watching the video before class. Perceived scaffolding is related to teacher attention, class attendance, active engagement with the materials and monitoring capacities. The teacher seems to play a crucial role in helping students acquire appropriate self-regulated learning activities.

We have found that girls perceive the lecturing behaviour stimulating capacity or confidence building as significantly less supportive. Indeed other studies have pointed out that teachers evaluate the performance and capabilities of girls in physics education lower than of boys. It turns out that in general they give boys more attention, provide them with more challenging questions, and call more often on boys and addressing them more often in general (Hofer & Stern, 2016). This may mean girls need to be addressed in a different way to experience the same level of support or that teachers may need to acquire a different attitude, or insight in what cues are relevant to create learning success.

This study gives an impression of possible relations between the teachers’ behaviour and perceived cues by students and their active engagement. The teacher does make a difference in stimulating self-regulation and how independent and actively engaged students are. Yet many questions remain and need a follow up. These concern among others why apparently there is little engagement with the online materials, why do girls and boys perceive the cues of the teacher differently and which of the scaffolding/monitoring activities are the most salient. Furthermore, the next steps will consist of interviewing the teachers that were involved in the teaching of the course under consideration about their monitoring and scaffolding activities.

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BIOGRAPHICAL INFORMATION

Annoesjka Cabo is an associate professor in statistics and a lecturer of mathematics at TU Delft. Since August 2016 she is the director of studies of interfaculty education at the faculty of EEMCS. She is the leader of PRIME: Programme Innovation Mathematics Education, a university wide initiative to innovate mathematics education for engineering students. As such she is involved in developing learning material, researching data from the project and coordinating a growing group of staff involved.

Renate Klaassen is a programme coordinator and researcher, working at the 4 TU Centre for Engineering Education at TU Delft. She has been heavily involved in educational advising on the innovation of the BSc in Aerospace Engineering, and various other curriculum reforms at TU Delft. Consultancy activities include assessment (policy, quality and professionalization), internationalisation of university education and design education. Areas of research interest pertain to content, language integrated learning in higher education, conceptual understanding in engineering education and interdisciplinary learning.

Corresponding author

Dr. Annoesjka J. Cabo
Delft University of Technology
Van Mourik Broekmanweg 6
2628 XE Delft
+31-6404 301 36
a.j.cabo@tudelft.nl