Curriculum Development in Engineering Education:
Evaluation and Results of the Twente Education Model (TOM)

J.I.A. Visscher-Voerman [1]
Head of Centre of Expertise in Learning and Teaching
University of Twente
Enschede, the Netherlands
E-mail: j.i.a.visscher-voerman@utwente.nl

A. Muller
Educational specialist, Centre of Expertise in Learning and Teaching
University of Twente
Enschede, the Netherlands
anne.muller@utwente.nl

ABSTRACT

The University of Twente has designed and implemented a major curriculum innovation in all its bachelor programmes since 2013, the Twente Education Model (TOM). TOM consists of a pre-defined curriculum structure of modules of 15 European Credits (ECTS) with a project, and specific didactic and educational starting points. After three years of implementation, evaluation data show that the structural change was successful. All modules have a project but not all modules are project-led yet. With respect to the didactic starting points, teachers use a larger variety in innovative learning and assessment methods. Data show that the number of students who get 60 ECTS in their first year has doubled. Current challenges for teachers are how to give students more control over their learning process, how to decrease the number of summative assessments and how to increase the number of formative feedback moments. The university has been developing the concept of Student-Driven Learning, as comprising many of the elements underlying TOM.

Conference Key Areas: Engineering Education Research, Curriculum Development, Attractiveness of Engineering Education

Keywords: Student-driven Learning (SDL), project-led education, TOM, modules

INTRODUCTION

The University of Twente (UT) is a research university in the Netherlands hosting 19 bachelor programmes, mostly engineering programmes. In the programmes,

[1] Corresponding Author

engineering and technology are combined with behavioural and social sciences. Back in 2009-2010, the vice-chancellor of the UT started a process of drastic curriculum development with a small group of deans and programme directors. Guiding questions were: how could we increase the attractiveness of engineering education? What could be the added value of a campus experience, when so many open and online learning resources in engineering education are available for potential learners? , which they can access at their own time, pace, and level, and oftentimes for free? This question was the starting-point for developing the Twente Education Model (in Dutch: TOM) that aims for sustainable engineering education. TOM is a rather revolutionary model for the bachelor programmes, combining both a clearly defined structure and specific didactic and educational starting points, needing a drastic (re)development of all curricula. After two years of piloting, all 19 bachelor programmes implemented TOM in their first year, in September 2013.

In this paper, the intended and implemented TOM curriculum are decribed and discussed. Curriculum development is a complex process, including many variables and actions. The authors intend to embrace the full complexity of this process rather than to focus on one single aspect in that process.

1 THE INTENDED TOM CURRICULUM

1.1 Drivers behind TOM

There are three different types of drivers for TOM. Firstly, back in 2010, the UT was working on the *renewal of her profile*. The UT has always strived for an interdisciplinary approach in its teaching and research, aimed at studying contemporary societal problems and developing sustainable solutions. This characteristic has been expressed in the university's phrase *High Tech Human Touch*. It connects to the realisation that, more than gaining knowledge, students need to learn to *develop and use* knowledge at a deep, abstract level, and have to develop a wide range of skills that enable them to transpose expert knowledge to different domains, and to communicate and interact with people from other disciplines, align with general academic, problem-solving, and co-creation skills. Another characteristic of the university has been the focus in the programmes on three different roles, e.g. researcher, designer and organisor. Also, the UT has a history in being entrepreneurial. The new education model should incorporate these elements.

Secondly, as reported by Vossensteyn et al, in the *Dutch education system* roughly 70% of first year students ever graduated, of which 50% within the discipline they started in [1]. For TOM, the ambitions were set that student dropout rates were to be below 30% and students should have at least 20 hours of guided activities (not *per se* classroom teaching) per week in the first year of the curriculum.

Thirdly, over the years, a lot of *educational research* has gone into the question "what makes learning effective?" Based on this research, the following didactical and organisational principles were formulated as guiding principles for TOM:

1. A steady workload is better than 'binge learning' for tests [2];
2. Frequent and adequate feedback helps students adjust learning [3];
3. A variety in teaching methods keep students engaged [4];
4. Community helps students help each other [5];
5. Ambitions must be clear and high, yet realistic [6]; and
6. Teachers work best in teams [7], with minimal regulation [8].

1.2 Pre-defined structure and specific didactic and educational starting points

TOM consists of an identical *predefined curriculum structure* for each bachelor programme, consisting of modules. A module is a full-time educational unit with a duration of 10 weeks, in which all learning goals and content are integrated. Students receive one grade and 15 European credit (ECTS) upon successful completion of each module. So, there are 4 modules per year, 12 in total (see *Fig. 1*).

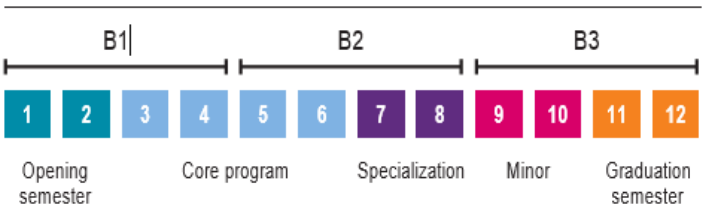


Fig. 1: Structure of each bachelor programme

In each module, students work in teams, addressing real-world problems, that are connected to an overarching module teme. *Project-led education* as described by Powell and Weenk [9] was chosen as overarching *didactic approach*, as a way to include the insights from educational research (see paragraph 1.1): project work adds a new learning mode to the already existing teaching methods; the project team serves as a community in which students help each other; projects usually keep students engaged, especially when working for external clients; it improves their motivation and helps set a steady workload; Connecting to the university's vision, projects are also a vehicle to help students develop an entrepreneurial attitude and explore each of the three roles. During the project, students are being supervised by tutors, who can give them frequent feedback or invite student peers to do so. All teachers also have to work in a team, to create a coherent module and project.

Whereas the curriculum structure with modules and projects was proposed as a top-down and strict design guideline, programme directors and teachers were given lots of freedom to design their own modules and projects, considering the educational research outcome that 'teachers work best in teams with minimal regulation'.

2 RESEARCH APPROACH

The implementation of TOM has been investigated through four methods. These have been summarized in *Table 1*. Note that, whereas the research questions have been the same for the implemented curriculum over years, the method or the respondent group has changed. This was a result of finding an optimal fit between the goal of the evaluation and the time investment it needed from the respondents.

3 THE IMPLEMENTED TOM CURRICULUM

3.1 Implementation of the organisational structure

Overall, the evaluation data show that the organisational change of TOM was very successful. Here, the implemented curriculum meets the intended curriculum. All programmes have a fixed curriculum structure, consisting of twelve modules of 15 ECTS (see https://www.utwente.nl/en/tom/modulemap/). This is in the opinion of the authors due to the fact that the University Board proposed this as a top-down and strict design guideline, and has managed to get every programme director on board.

3.2 Implementation of Project-led Education

Results of the interviews and questionnaires with teachers show that all modules have been designed around a theme, ánd do have a project, but that not all of them are project-led yet (See *Fig. 2*). Only when the module has been developed with the

Table 1. Research Methods used to evaluate TOM

What	Method
Teacher perspectives on the realisation of TOM in the module designs	Semi-structured interviews (2013) and questionnaires (from 2014) using a Maturity Model, which forecasts the transformational change of the bachelor programmes in 5 aspects from the TOM vision and its operation on a module level: character; educational culture; organisation; project and integration; and assessment [10]. Each aspects is described in five subsequent 'maturation' or 'growth' stages.
Teacher experiences with design and implementation	Formal and informal meetings with module teams (2013-2014) and with programme coordinators and educational advisors working in the departments (2014-2016), on *success stories of TOM* and on *issues/challenges*.
Student experiences	Digital Student Experience Questionnaire (SEQ), on organisation; perceived learning effect; integration; assessment; time investment; overall appreciation.
Numbers of enrollment, dropp-outs, pass/fail	University systems registrate student grades on tests. They also register the amount of students enrolling and dropping out during the modules. Over the years, these numbers add up to a good overview of the output rates of the individual programmes.

project as the core, full integration between module parts can be accomplished. Some coordinators perceive their whole module as one project, while others regard the project as just one of the module parts, amongst others. In some modules, students apply their knowledge in the project, but in other modules they gain new knowledge and skills as was intended.

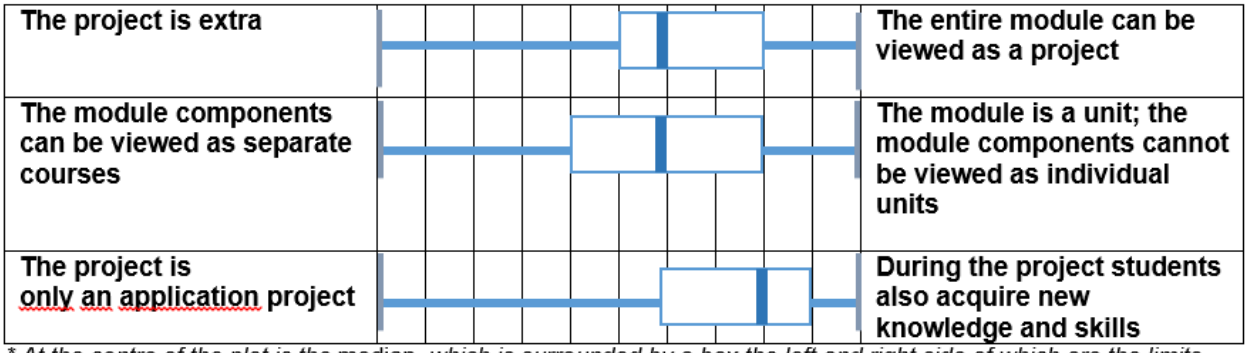
The freedom given to programme directors and teachers to make their own designs has consequently resulted in a variety of types of modules (see Fig. *3*). The left type of module mostly reflects a traditional programme, where the module units reflect separate courses, which are all being tested separately. The picture in the middle reflects a module with several subjects that are more evidently connected to and intertwined with each other. In the latter picture, the project is put central, and the module units are clustered around the project. Some of the module units are tested separately, others have no test; the learning is tested through the project deliverables. Although there is no formal data available yet, a rough estimate by students is that about 50% of the modules are of type 2 or 3.

3.3 Implementation of the three roles

With respect to the content of the projects, it can be concluded that all three roles (designer, researcher and organisor) are present in all programmes, but evidently not in an equal way, depending on the nature of the programmes. For example, the engineering programmes have a larger focus on the role of design, supported by research and organisation, whereas the science programmes have a larger focus on research.

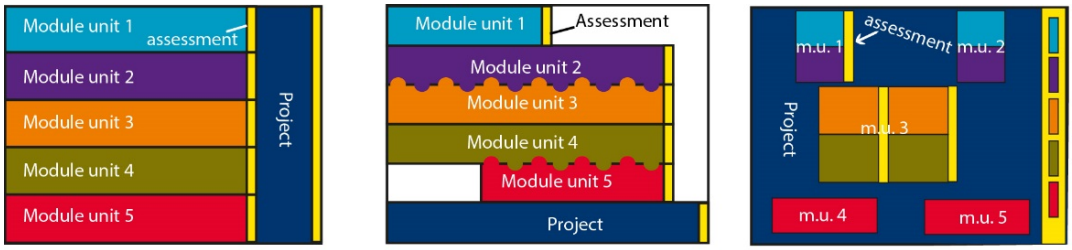
3.4 Implementation of the didactic and educational starting-points

Compared to the results of pre-TOM Student Evaluation Questionnaires (SEQs), TOM has made students work much harder than pre-TOM students. Whereas a considerable part of the pre-TOM students could report a *study load* of only 10-20 hours per week, TOM students report a study load of over 30 hours per week, adding up to over 50 (2013: 30-40 hrs: 27%; 40-50 hrs: 38%; >50 hrs: 17%; 2014: 30-40 hrs: 41%; 40-50: 25%; >50 hrs: 6%). Also, the workload has been spread more steadily over the modules.



** At the centre of the plot is the* median*, which is surrounded by a box the left and right side of which are the limits within which the middle 50% of observations fall. Sticking out of the box are two whiskers which extend to the most and least extreme scores respectively.*

Fig. 2: Box plots of scores on the Maturity Model for projects, for all modules



Module in which seperate theoretical module units are applied in the project and tested separately

Module in which seperate module units are applied in the project and tested separately. One or more units are connected with each other

Module in which the module is one large course in project setting and a variety of educational activities are offered. They are tested integrally

Fig. 3: Module variations

According to the module teams in 2013-2014, assessment was the biggest educational challenge in TOM. It seems that one of the drivers behind the TOM-model "*frequent and adequate feedback* helps students adjust their learning" had stimulated teachers to implement summative tests on a very regular basis, instead of diagnostic assessments or teacher or peer feedback moments that are not graded. To verify this finding, in 2014-2015 the number of assessments were counted in modules from quartiles 3 and 4. Indeed, the implementation of TOM resulted in many tests: Only 5 modules had 5 tests or less; 16 modules had between 10-15 tests, and 2 modules had more than 20 tests.

Teaching staff has increasingly realised that, although the implementation of a regular number of tests helps realise a steady study pace (see 3.4), it also likely leads to surface learning. This insight is gradually beginning to pay off: based on analyses of module guides and informal meeting results, the evaluators see a decrease in summative tests, and an increased focus on other methods to provide feedback, such as formative teacher feedback, peer feedback, or use of quizzes.

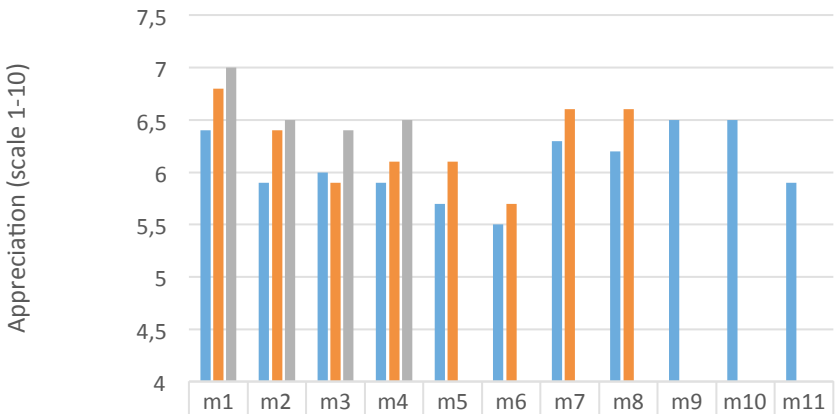
Accordingly, the evaluation data also show a *variety in innovative learning and teaching methods*. Teachers are, for instance, experimenting with voting tools, flipping the classroom or peer feedback; they also experiment with the amount to which they can have students influence their own learning process. With respect to *community*, students indicate in the SEQ to value learning and working with peers. More than 75% of the students stated to have developed specific skills through

working together in projects. Several programme directors and tutors are pleasantly surprised and have indicated that first year TOM students are already better in collaboration and working in projects than students from the traditional curriculum in later years. Thus, the increase in (innovative) teacher activities, the increased amount of feedback, as well as the increased work load for students seem to be paying off.

3.5 Teacher teams

Teachers report that it is rather difficult yet very worthwhile to work in teams. They have different interpretations of educational concepts and different visions on learning, which they need to align in order to build a coherent module. High workload has been reported consistently over years, due to communication and time for alignment.

3.6 Overall student appreciation



	m1	m2	m3	m4	m5	m6	m7	m8	m9	m10	m11
cohort2013	6,4	5,9	6	5,9	5,7	5,5	6,3	6,2	6,5	6,5	5,9
cohort2014	6,8	6,4	5,9	6,1	6,1	5,7	6,6	6,6			
cohort2015	7	6,5	6,4	6,5							

Fig. 4: Student appreciation per module

Figure 4 shows a rise in the overall student appreciation for the modules over years, usually with .3 of .4 points. The overall mean score for modules offered for the first time is around 6. Later, these scores raise up to around 6.4 to 7. Mainly because teacher teams continuously improve their modules. The variance among students is high (sd between 1.30 and 2.00).

Further analysis of the data of module 1 in 2013-2014 shows that the items that correlate strongly (r>0.5) with student appreciation are mostly on organisational aspects:

- During the module I continuously knew what was expected of me (r=0,77)
- The module was well organized (r=0,57)
- In general, the amount of study time I had to put in was doable (r=0,67)
- The module was put together logically (r=0,62)

3.7 Study success

From 2013 onwards, the proportion of students that obtain 60 ECTS in the first year has doubled compared to 2010 (53% in 2015 versus 26% in 2010; see Figure 5). The bachelor success rate from cohort 2008 onwards shows an upward trend (see fig 6). 50% of the re-enrolled students of the first TOM cohort 2013 completed their programme within the nominal study period (in 2008: 17%).

4 DISCUSSION

On an overall level, the UT is well underway to reach the TOM vision, The intended steady study loads for students have gone up, compared to the much lower reported study loads by pre-TOM students. At the same time, students judge their study time

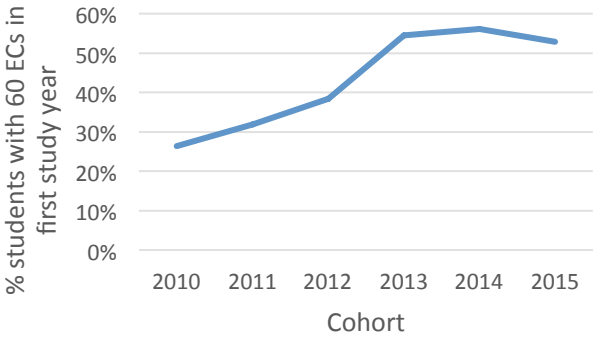


Fig. 5: Study success rate in first study year

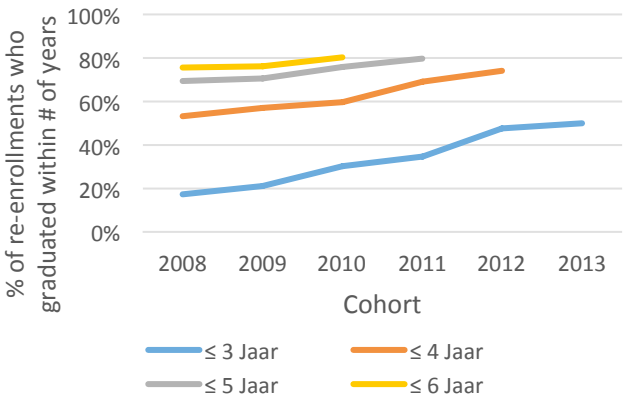


Fig. 6: Bachelor succes rate per cohort (re-enrollments)

as 'doable'. Accordingy, study success rates have gone up, which is a likely result of teachers paying more or better attention to students, and students working harder than in pre-TOM curricula.

But there are also differences between the intended and implemented curriculum. With many people involved in this complex innovation, there are multiple interpretations of educational concepts. Moreover, there is a continuous maturing of the intentions, based on the experiences with the implementation. It has become clear that the deliberate absence of regulation with respect to educational guidelines has been a struggle for many teachers. Teachers tend to develop a teaching style that closely mirrors the way they were taught themselves (Biggs in Gossman [11]. Since the TOM concept reflects more innovative teaching styles, teachers need more training and support than given thus far.

Some module teams struggle with intrinsically motivating their students and with offering formative instead of summative assessments, leading to students focusing on the short term assessments with possibly surface learning as a result. This corresponds to Biggs' findings that teachers who see teaching as knowledge transmission create classrooms where students score very low on the deep approach, while teachers who see teaching as facilitating student learning create classrooms where students score very low on a surface approach [12].

The UT wants to help students become professionals who are capable of steering their own career development, by giving them greater control over their own learning process. This notion is embodied in the concept of '*Student-Driven Learning' (SDL)*. Although this concept has been based on proven theories, including self-determined learning, SDL is a relatively new term, one which the UT is eager to further adopt and implement, since it comprises many of the elements that were underlying TOM. It can be described as the curricular foundation which supports and encourages students to develop self-determination and the "willpower" to steer their own academic progress. It allows students to regulate their learning, and to adapt their behaviour to correspond with their chosen goals and values [13]. Throughout the academic programme, students will learn how to be accountable for their studies with proper guidance. This aims to activate the intrinsic motivation of the students. An SDL curriculum thus requires students to undergo a mindshift from being a "following" or teacher-centred learner, to becoming a self-determined learner as befits the concept of lifelong learning [14]. We are fully committed to help teachers implement this concept in their curricula, through training, advices, good examples, and practices.

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