# DEVELOPMENT OF AN ONLINE COACHING TOOL FOR MECHANICS OF MATERIALS ANALYSIS IN DESIGN PROJECTS

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**ABSTRACT**

This paper discusses the development of an online coaching tool that focuses on quantitative modelling of mechanics of materials aspects in product design. The main goal of this tool is to support both teachers and students in the new Bachelor engineering courses, as well as in design projects. The basis of the tool is a structured modelling approach. A question-and-answer structure with context-sensitive help guides students through the modelling steps and motivates and supports them in making engineering calculations. The structured report that is generated by the tool should provide the teacher with easy-access on the student's progress. A pilot version of this tool has been tested in a trial version of the mandatory engineering course 'Technical Product Optimisation'. Although the findings from this pilot were encouraging, several important improvements should be considered.

*Keywords: coaching tool, modelling, engineering design, mechanics of materials*

## 1 INTRODUCTION

This paper follows our previous work on the development of an educational software tool for our new Bachelor curriculum, which has been presented at the E&PDE conference 2007 [1]. Here, we have discussed the flaws of traditional engineering education, such as a focus on mathematical derivations and solving abstract textbook problems rather than using design contexts [2, 3] and a lack of explicit training in scientific problem solving [4-6]. As a result, students encounter many difficulties in applying the theory to solve real-world problems. Instead of fully grasping physical phenomena and laws, using a systematic and logical solution path to solve problems and exploring multiple design alternatives, students very often tend to get stuck in 'formula picking strategies' and carrying out routine calculations without relating their findings to the real world.

We have also briefly described the new competency-based Bachelor curriculum at our faculty of Industrial Design Engineering, which has started from September 2007 [7, 8]. The traditional engineering courses, such as mathematics, mechanics, materials engineering and electronics, have been integrated in design-oriented courses, which have a focus on quantitative modelling of product functions. The main goal is to improve the quality, efficiency and efficacy of engineering education by making it more appealing and relevant to students. However, a foreseen problem in this design and modelling oriented education is an increased amount of tutoring time (both in coaching and assessing). Individual design projects are most time consuming as each design proposal differs from the next and the modelling process should be reviewed more than once to provide useful feedback. Previous attempts in this area have often failed because of this reason.

Within this context, a 1.5 year project has been started in January 2007 to develop an educational software tool that supports both students and teachers in these new engineering courses an also in design projects throughout the curriculum. The aim of this tool is to a) partly replace the tutor by providing a structured modelling approach and context specific information, b) offer a user-friendly interface that activates and supports students in applying the engineering theory and motivates them to investigate the specific topic(s) more thoroughly, c) encourage students to use parameterizations and quantifications as a design tool and d) provide the teacher with easy-access on the student's modelling process in order to assess and give feedback

## 2 THE ONLINE COACHING TOOL

A structured modelling cycle forms the basis of the online coaching tool, as we find this aspect significant in a student's development of engineering skills. Being able to construct and use scientific models is an essential problem solving skill in the field of physics and engineering [5]. In the context of this project, a model is seen as a simplified representation of a real-world phenomenon, which can be used as a way of describing, explaining and making predictions. Based on the work of Hestenes [4], Halloun [5], Mauer [6], Etkina et al [9] and Pol et al. [10] and expert interviews with engineering teachers at our own faculty, the modelling approach from figure 1 is proposed.

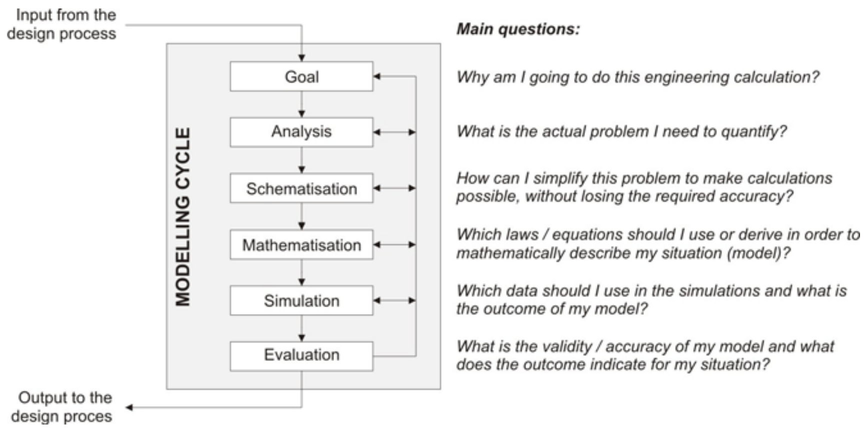


*Figure 1 Proposed modelling cycle and main question for each modelling step*

It can be seen from figure 1 that the modelling cycle is imbedded in the design process. A design proposal or design problem delivers the input for the modelling cycle and the output of the modelling cycle can be used to make design decisions. Figure 1 also shows that modelling is an iterative process, in which the insights gained in one step can influence all previous (and following) steps.

The content of the tool consists of a question-and-answer structure that guides students through the modelling cycle. Although the general modelling steps could be applied in various scientific and engineering disciplines, these questions should be specific to a certain topic. We have chosen to focus on 'mechanics of materials' first, as our faculty traditionally pays much attention to this topic. As an example, a specific question from each of the modelling steps in the tool is stated below.

- Goal (context); “Which situations in the lifecycle of your design could be normative for its required strength and stiffness?”
- Analysis (material); “What can you say about the ductility of the material you have selected for the part?” (multiple choice: tough / medium / brittle)
- Schematisation (connections); “Which assumptions can be made on the connections between the part and its surroundings (boundary conditions)?”
- Mathematisation (stress); “From the internal loads and properties of the cross-section, the stresses in the critical points can now be determined [$\sigma = M.y/I$].”
- Simulation (data); “Give an overview of the data that is necessary to perform your simulation; unknowns, givens and variables.”
- Evaluation (conclusions); “Which consequences does the output of the model have for your design proposal (in the chosen situation)?”

Learning takes place as the students become aware of the questions that they should ask and answer themselves, in order to come to a useful model, output and corresponding conclusions. Because each student can use his or her own project as a starting point, the tool can never really know what problem an individual student has. Still, the various answers to multiple choice questions do create some form of ‘understanding’, which can be used to provide increasingly specific and detailed questions.

Besides the list of context-sensitive questions, four types of coaching are offered to support and motivate students in their modelling (and learning) process:

- Info-icons give a short elucidation or pop-up hint on the corresponding question; what type of answer is needed, what do I have to keep in mind? Sometimes additional questions are asked to invoke a train of thought.
- Help-links give an elaborate explanation on specific terms in the questions; what does this term mean, why is it important in the modelling cycle and where can I find more information? Real-world examples (visual) are added as often as possible to illustrate its context.
- Feedback, which is provided on the basis of one or several answers to multiple choice questions, gives the consequences of those answers for the design proposal or modelling process.
- In the mathematisation phase, the tool provides the laws, equations or models that correspond to the student’s situation (based on previous answers) and also offers methods and examples to work out the mathematical model.

Figure 2 gives a screenshot of the current layout of the tool (translated from Dutch). The modelling steps are shown on the left side of the screen, as well as an overview of the main questions within the ‘active’ step. Students can immediately fill out all the questions in the online tool (both multiple choice and open), as well as upload figures.

The tool can also generate a structured and coherent report that gives an overview of the student’s answers (HTML file). Of course, students are still able to adjust this report to their own liking, for example in Microsoft Word. We hope that this functionality will appeal to the students and will also make it easier for teachers to assess these engineering calculations.

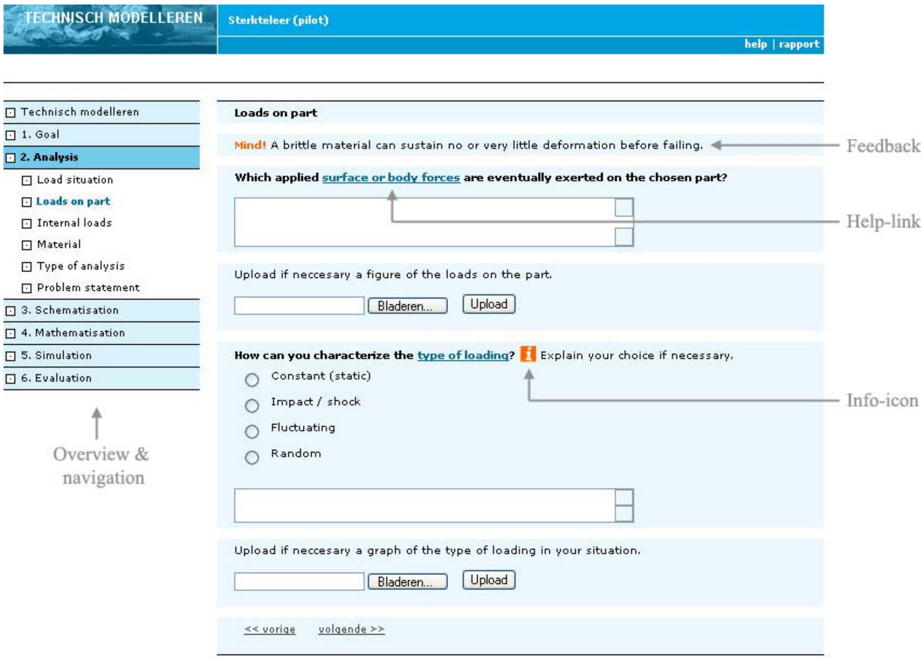


*Figure 2 Online coaching tool (screenshot)*

## 3 PILOT

In the 2nd quarter of this school year (November 2007 – January 2008), we have tested a pilot version of the online coaching tool in a trial version of the 2nd year course 'Technical Product Optimization' (TPO). Due to the switch between the old and new Bachelor curriculum, a group of 24 students was automatically enrolled in this mandatory course. These students were mostly 3rd year students or older that had already passed previous mechanics courses in the old curriculum. Although these students are therefore not entirely representative for the new TPO students, their level of prior knowledge proved to be considerably lower than expected.

TPO integrates mechanics of materials theory with construction, production and materials engineering. As a part of this course, groups of two students have to work on short engineering projects that involve specific mechanics of materials themes (bending, stress concentrations, fatigue). During these projects, students are obliged to use the online tool for making and presenting their engineering calculations. The entire group typically worked in one classroom with computer facilities and two coaches that observed and helped the students with the problems they encountered. The presentations were oral and students received immediate feedback from the coaches. At the end of the course, we conducted a survey to gain insight in the perceived usefulness and functionality of the tool. 17 students responded to this survey.

It should be noted that the results from this pilot (observations and survey) only hold for the general set-up of the tool (modelling cycle and question structure), as the pilot version of the tool still lacked the info-icons, help-links and most of the feedback described in the previous section. Still, some interesting results are discussed below.

- In the first weeks of the course, some important technical flaws were encountered, such as uploaded figures that did not display in the final report, browsers that crashed for no apparent reason and filled out question structures that were automatically saved, but could not be found again. Although it rightly frustrated the students involved, we as developers are pleased to have discovered most of these flaws with a relatively small group.

- In the end, the (educational) purpose of the tool was clear to all students. The structured modelling approach was recognized and appreciated and the tool stimulated and supported the students in considering the important mechanics of materials aspects in their designs. This also showed in their presentations.
- The main modelling steps were clear to all students and provided a logical structure. Although the questions within these steps were also logical to the students, they didn't find all questions to be clearly formulated or even relevant. It was too often unclear what type of input was expected from them.
- The students judged negatively on the amount of help that the tool has actually offered them, which has undoubtedly been caused by the lack of concrete help. This aspect also became clear during the projects, as students had many (similar) questions on specific terms, and were also very uncertain in making simplifications and working out mechanics principles and models. Still, 11 of 17 students found the tool useful in performing a mechanics of materials analysis.
- Although students were able to navigate freely through the modelling cycle, most of them found the tool too laborious and time-consuming, even after it was made clear that the tool could be used in a more flexible way, by filling out only the relevant questions. On the other hand, going through the entire modelling cycle is an essential part of the learning process and should not be discarded too easily.
- After the second and third project, many students started to use Word or PowerPoint directly. More than half of the students indicate that they would not use this tool again in future projects, indicating that the tool makes itself obsolete (which might be a good thing).
- Students found the structure and overview in the tool its main quality. Some examples of additional functionality that would be appreciated are sketching possibilities (for making simple drawings), a Maple plug-in for entering formulas, an export function to PowerPoint, possibility to upload other types of files (Excel) and being able to make several (types of) calculations simultaneously. The main complaint of the students was the large amount of (redundant) questions.

From this pilot we have concluded that the general set-up of the tool has succeeded. Students appreciate the modelling approach and the question structure helps them in considering and discussing the important mechanics of materials aspects. Also, the oral presentations demonstrated that students deliver interesting, structured and more useful output in their projects. Still, the pilot also showed several points of interest for the development of the tool:

- Improving the formulation of the questions and clarification of their meaning and relevance
- Improving the overview of / insight in the question structure and adding more flexibility in navigating through it
- Improving coaching and specific help for understanding and answering the questions and performing the actual calculations

Finally, we have seen that the tool should be an integral part of the course set-up and assignments and should also receive an elaborate introduction. Otherwise students will be very confused on the tool's functioning, output and learning goal.

## 4 FURTHER DEVELOPMENT

Currently, the tool is being revised and expanded with the knowledge gained from the first pilot. At the same time a second pilot is being performed within the actual TPO course with approximately 350 students (3rd quarter). Due to an elaborate introduction of the tool and the addition of info-icons, we already see a great improvement in the functioning of the tool. In the 4th quarter, many of these students will follow the mandatory 'Design Project 4' that focuses on embodiment design. Here, students will be obliged to make engineering calculations, which gives us the opportunity to see whether these students have incorporated the modelling approach. We hope to present the results at the E&PDE conference 2008.

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