

## STATLAB: LEARNING DOE BY DOING !

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*Statlab is an interactive web-based tool for teaching Design of Experiments. It is freely available through [www.win.tue.nl/statlab](http://www.win.tue.nl/statlab) and can be used to introduce large groups of students to practical strategies for experimenting through virtual case studies. Starting point is an adaptive approach, in which the program flow is influenced by the student's decisions throughout the DOE-process. Furthermore, Statlab forces students to think pro-actively about practical details since it hides options that students do not ask for. Once a design is generated, realistic experimental data can be simulated for further model estimation, evaluation and eventually optimisation using response surface methods. Furthermore, Statlab provides direct feedback with training exercises and contains an automatic grading system regarding the student's actions and decisions. Students generally are enthusiastic about Statlab and consider it to be a stimulating teaching environment.*

### INTRODUCTION

Methods from the field of Engineering Statistics have proven to be quite helpful when designing new products, modeling manufacturing systems or controlling the quality of production processes. In planning adequate experiments a good working knowledge of DOE (Design of Experiments) is important for both industrial statisticians and engineers. It is therefore essential that statistics courses pay sufficient attention to this topic. However, as DOE requires a pro-active attitude, its teaching requires an approach that forces students to actively think about several aspects of setting up an experimental design, without steering the student too much. In this approach there should be room for the student to make mistakes and learn from them. At the Eindhoven University of Technology in the Netherlands we have developed a web-based, pro-active DOE-teaching environment, Statlab (see Figure 1). It supports Factorial Designs, Response Surface Methods and Taguchi Methods.

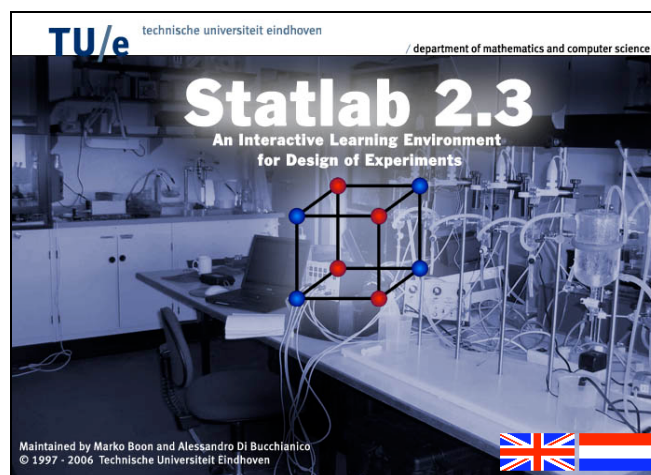


Figure 1. The opening screen of Statlab at: [www.win.tue.nl/statlab](http://www.win.tue.nl/statlab)

Statlab adapts itself to the student, who is being led through one of several possible case studies. It is used for several years now in statistics courses at various departments of the Eindhoven University of Technology and in continuing education. Statlab has been receiving positive reactions from our students, who generally consider Statlab a stimulating teaching environment.

In this paper we describe the underlying principles of DOE-teaching with Statlab. We report details of its technical implementation and describe our experiences, using Statlab for

several years now in engineering statistics courses for large groups of students. Finally, we present our future plans.

### DOE-TEACHING WITH STATLAB: UNDERLYING PRINCIPLES

In our teaching of DOE to engineering students, we find it crucial that they realize that DOE, unlike many other statistical techniques, is a pro-active activity in which collecting relevant information on the goals of the experiment and on the facilities available is crucial for the selection of an appropriate experimental design. They should get a feeling for the required choices and learn from the consequences of omissions. Standard statistical packages are not suitable for this, because they present many options to the student, who either accepts the default settings or simply chooses options that the software offers. Therefore, we have developed Statlab, a teaching environment that forces students to actively think about the construction of an experimental design, as well as analyzing data collected from such a design. In order to stay close to practice, we expect students to go through a number of phases (see, e.g., Robinson, et al., 2004; Anderson-Cook et al., 2000):

- Gather information about the goal of the experiments.
- Gather information about the experimental facilities.
- Construct an appropriate design.
- Analyze data collected from the chosen design.
- Formulate conclusions and recommendations.

Since statistical software often has an interface to a catalogue of experimental designs, we require that students are able to intelligently choose a design rather than have to construct designs themselves like fractions of factorial designs. We thus have the following requirements for our teaching environment:

- Ability to adapt to student behavior.
- Ability to answer questions about the experiment.
- Hide options unless asked for.
- Force students to make choices.
- Create designs.
- Ability to simulate data from chosen design (including steepest ascent optimization, see Figure 2).
- Ability to analyze simulated data (including determination of stationary points of response surfaces).

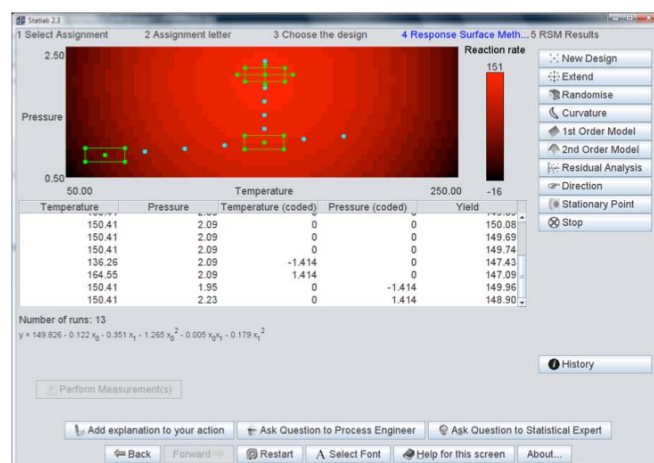


Figure 2. A screenshot of a response optimization assignment

As a preliminary for Statlab use we assume that students have already been introduced to the basics of DOE by lectures or self-study. At that point they should be helped to transfer their

theoretical knowledge to practical situations and develop a feeling for practical issues. With a virtual experimentation facility practical situations can be simulated even for large groups of students (100 and more), as is also known from other studies (see, e.g., Bulmer, 2004; Darius, et al., 2007; Schwarz, 2007).

Statlab currently contains 15 case studies with an indication of its difficulty. The difficulty of a case study depends on a number of issues listed below (between parentheses we list the corresponding statistical notions):

- Restrictions on number of runs (fractions, replications).
- Restrictions on number of experiments under similar circumstances (blocks).
- Restrictions on experimental region (factor level settings, step size).
- Irregularities in the collected data (outliers).
- Knowledge of interactions.
- Curvature of response surface (centre points, lack-of-fit tests).
- Stationary points of the response surface that are not optima (saddle-point).

Of course, there are also issues like randomization that are always part of the case study. Each case study begins with an assignment letter that describes the problem in general engineering terms. We took this idea from the DOE case study in the German on-line statistics tool EMIL@A-stat ([www.emilea.de](http://www.emilea.de)). Students have to determine what kind of design is appropriate for this assignment. We currently offer the choice between screening designs, response surface designs and robust (Taguchi) designs. Questions about the assignment may be asked to the process engineer through key words (see Figure 3). The tool has a long list of synonyms. The process engineers knows how many experiments may be executed, sometimes has knowledge about interactions, knows whether experiments may be carried out under similar circumstances etc. She has no background in statistics, so she cannot (and is also not willing to) answer questions about randomization or centre points. A statistical expert is available if students wish to get a brief explanation about statistical concepts (again through key words entered by students).

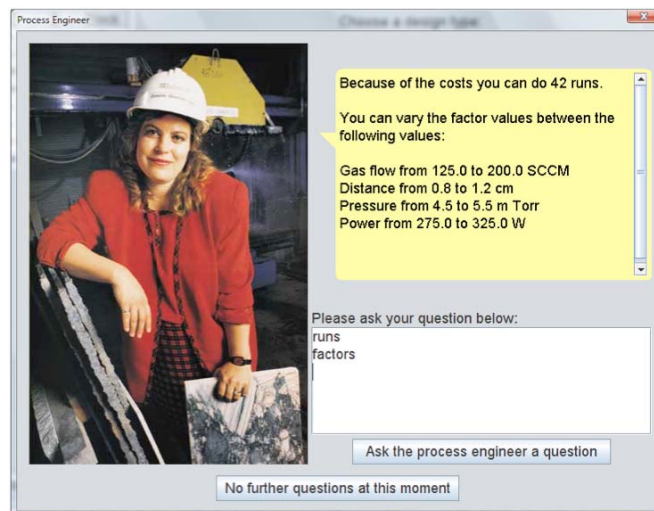


Figure 3. The student can ask questions about the assignment to the process engineer

In order to teach students that time is limited in industry, the process engineer display increasing levels of irritation when the student keep asking questions. The default list of possible designs presented does not contain blocked designs or fractional designs, unless students explicitly ask for it by entering appropriate key words in the *Design options*-field.

The current version of Statlab has the following additional features:

- Adds a trend if the student forgets to randomize.
- Adds outliers to simulated data.
- Has a Design Wizard that creates and visualizes blocked fractional factorial designs (including the alias structure).
- Gives students feedback on their work by mentioning possible mistakes.
- Allows students to add explanation to their choices when needed.
- Implements an automatic grading system of student work that provides relevant feedback to the student.

Outliers should be noted by students and reported to the process engineer, who will ask the lab to investigate the suspicious observations. Currently the students get the answer that the observation was indeed wrong and obtain a corrected measurement. The feedback to students only gives possible mistakes, in order to avoid students to push some extra buttons without understanding their omissions. The Design Wizard is also separately available through [www.win.tue.nl/statlab/designApplet.html](http://www.win.tue.nl/statlab/designApplet.html) and may support lectures on construction of fractional factorial designs.

#### TECHNICAL IMPLEMENTATION

Statlab is a Java program that is freely accessible through [www.win.tue.nl/statlab](http://www.win.tue.nl/statlab). However, it can also be run as a stand-alone application using Java Webstart. The minimum required Java version is 1.4. In order to use Statlab during official examinations, the Java security settings must allow Statlab to save the results to the user's hard disk, and send an email to the teacher. When Statlab is started for the first time, the user is prompted to grant these permissions. But even when the Java security settings are correct, firewalls or virus scanners might prohibit Statlab to send email messages. This is why the opening page of Statlab contains a "Detect Java Security" button that checks whether the right Java version is installed and whether Statlab is allowed to save results to disk and send an email. Students should always run this security check on the system that they will use during the exams. By using Java Webstart, the tool can also be used off-line. When the tool is used on-line, automatic updates of the software will be installed without bothering the user. In this way we circumvented managing updates with users of our tool. Currently, our tool supports two languages (Dutch and English), but the software architecture has been set up in such a way that we can support more languages. The tool automatically detects browser and language settings of the user.

#### EXPERIENCES

For several years we have been using Statlab as a tool both in regular statistics courses and during examinations for Bachelor and Master's students of the Mathematics, Chemical Engineering, Industrial Engineering and Mechanical Engineering Departments at the Eindhoven University of Technology. Furthermore, Statlab is also used in our DOE courses for members from industry, which we organize within the C-triple-E initiative (Continuing Engineering Education Eindhoven, [www.win.tue.nl/ceee](http://www.win.tue.nl/ceee)). Using Statlab during lectures usually gave rise to lively discussions about experimental design. Initially, students find it difficult to ask simple questions about designs. It is often an eye-opener that in practice the number of experiments that can be executed is restricted. A class demonstration together with the on-line student manual has proved to be sufficient for students to get acquainted with Statlab. Part of the case studies can be accessed freely so that students can practice. Case studies that we use for official examinations are password protected.

We specifically ask questions about student experiences with Statlab in the standard course evaluation forms. Most students indicate that they feel that Statlab made statistics more attractive to them because it made them experience the practical sides of statistics. Furthermore, they indicated that using Statlab enhanced their understanding of applying DOE in practice. A minority adapts a minimalist approach by trying to work through the case studies using pre-defined lists of design options and questions to the process engineer. Since at our university all students possess a

personal notebook, it is the responsibility of the students to ensure that Statlab runs well on their notebooks. Over the years we had several hundreds of students using Statlab during official exams, but we only had very few cases where Statlab did not work during an official examination. For such emergency cases, we always have one or two spare notebooks available. Furthermore, special measures are taken during exams to prevent any communication between notebooks until the assignment has been submitted officially through the internet. Grading of examinations is easy since Statlab generates an easy-to-use, extensive grading report for each student where errors and omissions are marked in red. Instructors have the ability to overrule the grading results of Statlab.

#### FUTURE PLANS

Statlab is in continuous development. Although the number of case studies is large compared to other tools that we are aware of, we would like to have more case studies so that users with different backgrounds can choose case studies with context that appeal to them. We welcome feedback and ideas for new case studies from other instructors. There is a teacher manual that will be sent on request to persons that identify themselves as being involved in teaching. We plan to add more complexity in the initial and reporting phases of the assignment, to add functionality in communication with the virtual process engineer in order to imitate real-life situations more closely. Finally, we would like to add other types of designs like mixture designs and optimal designs.

#### ACKNOWLEDGEMENTS

The authors would like to thank the Dutch Ministry of Education for a grant to start the development of Statlab. We would also like to acknowledge the significant contributions to the initial development of Statlab by Leendert van Gastel and our former colleagues Mark van de Wiel and Michel Vollebregt.

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