Experiences of Teaching Two Web-based Courses on Mathematical Modelling

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1. Introduction

In this paper, two web-based courses on principles of mathematical modelling are introduced and the experiences in teaching these courses as well as the student feedback gathered during and after the courses are discussed. A draft for an improved course is also presented. It is based on the student response, author’s own experiences of the courses and the comparison of the courses.

There exists a global interest in the utilisation of the information technologies in learning. Ideas about an emerging knowledge society are influencing the perception of education [15]. The learning based on computers is commonly referred to as e-learning. There is an ever growing interest towards experimentation with on-line courses and distance learning. Web-based teaching is an approach to distance learning in which computer-based training is transformed by the technologies and methodologies of the Internet and courses are offered to the students on-line. Web-based teaching presents up to date content that can be modified and retouched at anytime. A web-based or an on-line course is a course that offers the course material to the students using the Internet and uses e-mail in the communication between the teacher and the students. The web-based materials are available for students with an access to the Internet at all times and anywhere. This allows self-directed, self-paced instruction in any topic. In addition to this, there exists different computer software that can be used over the internet [14]. Universities all over the world are excited about this new way of teaching and are offering their courses on the Internet [1, 7, 9, 12].

An approach to the web-teaching is rationalizing the completion of mass courses that are very common in the beginning of all studies. Usually the mass courses place heavy demands for the lecture halls and the course organisation. These problems may relieved by having some parts or perhaps entire courses available on-line. The students taking the course on-line could take the final exams with the rest of the students, while studying the material independently from the Internet.

More specialized courses could also be offered through the Web in order to utilize the experts in the field. It is possible to feature guest lecturers from all over the world and producing learning material as well as improving existing teaching methods can be planned as collaboration of different universities. The co-operation of this kind could provide the students with the best lecturers and materials available.

The benefits of web-based courses are well documented [15]. Such courses have the ability to reach a geographically dispersed audience with consistent training content. If an Internet connection is available, the training materials can easily be accessed from anywhere, including from home. The information in the training program can effortlessly be updated and redefined. This enables the utilization of the material without concern for material’s accuracy and being up to date.

Mathematical modelling is an area of science where a connection is built between the real, observable world and mathematical equations [4]. This is achieved by creating a mathematical model of the phenomenon at hand. If the aim of a first course on
mathematical modelling is to introduce different kinds of models and basics of modelling, the course does not include complicated or advanced theory and does not perhaps warrant physical lectures. A modelling process can be introduced and visualised with the help of different computer software, such as Matlab, Simulink, Excel etc [3]. It is possible to distribute educational packages that use these programs over the internet. When these facts are taken into account, it becomes evident that an introductory course on mathematical modelling is an appealing ground for a web-based course. The material can include readymade programs and other pedagogic materials that allow the students to experiment and acquaint themselves with the theory and its applications.

The author has been involved in teaching of two web-based courses. The first course was a part of the Finnish National Virtual University Project [2]. It took place in the spring 2002 and eight Finnish universities participated on it. The course was based on video-taped lectures and the A&O learning environment [8]. The students watched lectures given by six different professors on their own computers or at school. After each lecture, they solved some problems presented by the lecturer. The assignments were returned to the learning environment in which the students’ reports could be discussed with other students. At the end of the course the students concentrated on a more extensive modelling problem and presented their results in a video-conference.

The second discussed course was organised by the System Analysis Laboratory of the Helsinki University of Technology in the summer 2002 for the third time [3]. The course resembled a traditional correspondence course, only it was based on the Internet and e-mail. The students retrieved the necessary materials from the course home page and returned their reports via e-mail to the teaching assistant. At the end of the course the students made a web-excursion and reported it in writing.

After the courses, the students were asked to fill a questionnaire and present their own ideas for improving the courses. The questionnaire consisted of nearly forty questions and a panel for freeform feedback and ideas. The sample gathered from the students was not vast enough to warrant a meticulous statistical comparison between the courses. Therefore the courses are compared mostly based on the freeform feedback and the grades given to the courses are mostly used to support the findings.

Both of these course formats have their positive sides and at the end of this paper these attributes are combined with other ideas to suggest an improved course. This draft of a developed course format also uses some alternative ways of producing web-based learning content [11, 14].
2. Web-Teaching in General and Examples of Virtual Universities

The idea of a virtual university is a continuation of university models, where there has been a need to spread the university's influence outside the university. In many countries, like USA, Canada, Australia and Great Britain, it has been possible to take courses far away from the university for a long time (see, e.g. [1,9,12]). First the courses were held as correspondence courses and later with the development of technology through the Internet. In countries like Canada and Australia the main motivation behind offering such virtual courses has always been the great distance between universities and people.

Around the world there are several formats for university collaboration in the area of web-teaching. The larger universities in the USA, Canada, Australia and Great Britain have perceived this emerging market and are in the process of producing their own alternatives for on-line learning. Financially strong consortia are formed between large universities and private companies that are interested in setting up global commercial internet-based universities.

Stanford, Oxford, Princeton and Yale universities launched in the year 2000 a "distance learning" venture to provide on-line courses for their undergraduate students and alumni [12]. According to the four universities plans, in the future their offerings will be made available to a wider public. The alliance will provide on-line courses and interactive seminars and live as well as taped coverage of campus speakers. Topical Web sites that include links to research information will be assembled. Multi-media programs, exhibitions, other events and offerings are also planned. Through this alliance, the member universities will explore the possibilities that the Internet and other technologies offer for teaching and learning. Where appropriate, innovations developed by the alliance are incorporated in the schools' core campus programs. In October 2001, the universities kicked off the pilot phase of the project with 10 online courses.

Canadian Virtual University (CVU) is a partnership of 13 Canadian universities who have experience in distance education [1]. CVU offers learners over 200 university degree, certificate and diploma programs all available through distance learning or completely through the Internet. 120 of the courses are available completely online. Others use a variety of distance technologies, such as mail, television or radio, teleconferencing, computer communication, videos or audio tapes. Most courses offer telephone, fax and e-mail communication with the course professor or tutor. In the year 2001 CVU partner universities received over 150 000 registrations to distance education courses.

British Open University (OU) has for years had its aspirations in the use of the new technologies to improve the quality of education for students and to broaden their access to it [9]. E-learning has formed for several years a major part of the university's courses and student support services. Today the OU is regarded as the Britain's major e-learning institute. About 160 000 OU students and their tutors are online, using the university's e-mail conferencing system to contact each other and have online discussions via their PCs. One in ten of all OU assignments (80 000 assignments) are submitted electronically. 178
university's courses require the student to have an online access for delivery of course materials, study support etc. A further 97 courses allow the student to use online services if they wish.

Korean National Open University’s (KNOU) aim is to serve the world Korean educational market [7]. For example the UCLA has approx. 30% Korean students. KNOU was founded in 1972 as a cable TV station. Nowadays, it serves 350 000 students around the world digitizing 18 hours of video and audio programming each day.

Situation in Finland is somewhat different from the countries mentioned before. The university network in Finland is dense with 21 universities and 29 polytechnics spread throughout the country [6]. Finland leads all EU countries in highest percentage of an age group receiving higher education and the percentage is climbing steadily [5]. At the same time, Finland has a campus tradition as people go to study in university towns. In Finland the distance education has always been more of a way to enable students to take single stand-alone courses, instead of complete degrees.

The Virtual University of Finland is a development project that was initiated by the Finnish Ministry of Education during the year 2000 [13]. The aim is for a virtual university, which offers Web-based high standard courses also at the international level, to be set up by the year 2004. The 20 universities in Finland will form the foundation for the virtual university. Through co-operation involving these universities, colleges of higher education, research centres and private companies the quality and flexibility of training will be reinforced, and research networks will also be reinforced. In addition, the distance utilisation of the expertise of Finnish and foreign specialists is a subject of discussion.

Students who study on a full or part-time basis at the virtual university must be officially accepted at a physical university if they want to get a degree. University students do not have to pay for their studies in accordance with Finnish legislation. However, the universities can also sell courses and commissioned courses on the open market and thus provide courses with tuition fees for the international market, for example. Thus, Finnish universities could market abroad, e.g., their special expertise in areas of information technology and forestry through a virtual university.

2.1. Different Formats for Web-courses

2.3.1 Web-based Correspondence Course
The most traditional format of distance learning is a correspondence course. In the past, the correspondence courses were based on delivering the course material to the student via mail and later in the 20th century also via radio, television and fax. The material could consist of written documents, audio tapes or video taped lectures. Having studied the material the student returned his or hers assignments via mail or fax. Communication between the tutor and the student could be handled with mail, telephone or fax. Sometimes the courses included local study circles. Traditional correspondence courses could be rather time consuming and slow paced.
In transition to the virtual learning, the first natural step was converting the communication into an electronic form. If the course material is delivered to the student via e-mail or by offering it on the home page of the course, the delivery time is for all practical purposes non-existent. Such material can also be effortlessly updated and controlled, if any need for corrections should arise. The communication between the course personnel and the student is handled via e-mail or computer chat. A good example of a web-based correspondence course is given in the Sec. 3.2.

2.3.2. Lecture Based Web-course

A web-course can be formed to emulate a traditional lectured course. The main point in such a course is the availability of the lectures. Once they have been placed on a web server, they can be viewed at any time and at any place, if an Internet access is available. This arrangement brings the lectures to the students' home and solves almost all obstacles to following the lectures. It is also possible to review the most important parts of the lectures to help understanding.

Other material on a lecture based web-course can include slide shows, lecture notes, other video clips and animations. The Internet makes the delivery of the materials easy and the material update effortless. In addition, news groups and forums can be built for student interaction and discussion. The lecturers can be reached with e-mail or in chat sessions. A more extensive introduction to a lecture-based web-course is given in Sec. 3.1.

2.3.3. Learning Material on the Web

When creating a web-course, it might be a functional idea to discard old formats, that are based on the lecturer and the chalk board, completely and utilize the possibilities of the Internet to their fullest extent by designing the material purposely for the Internet. The material could be diverse and include, e.g., text documents, slide shows, videos, animations, speech and commentary. The ways of combining the ingredients are only limited by the imagination of the developer of the course.

A part of the OR-World project is introduced as an example of teaching material tailor-made for the Internet [11]. The OR-World is a joint venture of three universities and three enterprises from Germany, Finland and the Netherlands. It produces virtual study programs for Operations Research and Management Science using the Web technologies.

A good example of the project material available at the moment is the learning package that presents the theory of decision-making (see Fig. 1). The aim the package is to teach to the students the basics of value-tree analysis and its applications, in which the Web-Hipre can be utilized. The Web-Hipre is a software for supporting decision making developed in the System Analysis Laboratory of the HUT [14].
The material consists of four main parts: theory, cases, assignments, and evaluation. The theory part presents the theoretical foundations, methods, and phases of value tree analysis, which are then applied in practice in the case part. The cases consist of consecutive steps that correspond to a certain section in the theory part. In the case steps the most essential theory of the section is briefly summarized and then applied to the case context. The cases are introduced using text, video clips, animations, and synchronized commentary. The case steps do not cover the theory exhaustively, however. To get a broader view the student may have to refer to the corresponding theory documents. The different parts are closely linked, enabling the user to deepen the theoretical knowledge when studying the corresponding case part and vice versa. Still the parts are independent entities so that the students can only read the theory part or familiarize themselves just with the corresponding case example.

Having acquainted themselves with the cases and theory, the students can test their knowledge on value tree analysis in the assignments part. As in the case part, the questions are grouped in a way that they correspond to a certain section in the theory part. Also, assignments that cover the whole decision analysis process are available.

The evaluation part is not an educational element, but acts as a feedback channel. It can be used to get comments and feedback from the students, or to make surveys concerning the material, methods, learning environment or the learning itself.
The value-tree analysis learning package is a module that should take approx. 2-3 hours to study. Modules of this type could be combined to create an entire web-based course on decision-making. The learning package could also be used as part of a traditional course. The module could replace one lecture or take the part of an exercise session.
3. The Courses on Mathematical Modelling

3.1. The Web-course on Mathematical Modelling (National Virtual University Project).

The first discussed course on mathematical modelling is funded by the National Virtual University Project and is coordinated by Tampere University of Technology (TUT). It was organised for the first time in the spring 2002 [2]. In the following the course will be referred to as the NVUP course. Eight Finnish universities participate in the project. The course material is produced by the universities of technology in Tampere and Lappeenranta (LUT); universities of Tampere (UT), Oulu (UO) and Jyväskylä (UJy) and CSC, the Finnish IT centre for Science. In addition to the aforementioned universities, Helsinki University of Technology (HUT) and universities of Kuopio (UK) and Joensuu (UJo) used the course material by offering the course to their students. The course features several lecturers from many different universities. Every locale, in which the course was held, have their own teaching assistant to advice the students and to organize the practice sessions. Fifty students from the participating universities enrolled on the course.

The course is directed towards advanced students, who have studied for at least three years. The course prerequisites include basic courses on mathematics. The aim of the course is to introduce students with the concepts of mathematical modelling and models of different kinds. The use of the mathematical models in the different fields of science is used to present the modelling process and the utilisation of the resulting model. Some mathematical computer software is also presented to aid the modelling. The book “A First Course on Mathematical Modeling” by Giordano, Weir and Fox [4] is used as the course textbook.

The course itself is based on a few principal ideas. The videotaped lectures are available for the students on the course home page. The aim is to enable the students to watch the lectures whenever and wherever they have the access to the Internet. The second essential idea behind the course is the A&O-learning environment (see Fig. 2), to which the students return their reports and where they hold discussions about the course and each others’ answers. An illustration of the course format is given in Fig. 4. In the beginning and at the end of the course a videoconference is arranged between the participants.

The A&O-learning environment is a product of the TUT Hypermedia Laboratory [8]. The A&O is Java-based learning environment designed to support different learning and teaching strategies. It offers several tools (a message board, a group workspace, a discussion forum, e-mail etc.) for offering and taking a course. A&O is used with a browser through the WWW. A screenshot of the learning environment is displayed in Fig. 3.
The framework of the course consists of nine videotaped lectures. The lectures are given by six professors from faculties of five different universities. The topics of the lectures were given to the lecturers so that their lectures would form a comprehensive course on mathematical modelling. Each lecture lasts approximately two hours and is stored on web
server at TUT. The lectures are based on the "talking head"-format in which a slide show synchronized with the video portraying the lecturer. The lecture format is displayed in Fig. 3. The slides can also be studied separately. At all the universities a classroom was booked for watching the lectures every week. The lectures were to be published weekly according to original timetable. The final schedule of the course is shown in Table 1.

Table 1: The schedule of the NVUP course.

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction to Mathematical Modelling</td>
</tr>
<tr>
<td>2</td>
<td>Different Model Types</td>
</tr>
<tr>
<td>3</td>
<td>Fundamentals of Modelling</td>
</tr>
<tr>
<td>4</td>
<td>Differential Equations and System Theory</td>
</tr>
<tr>
<td>5</td>
<td>Discrete Models</td>
</tr>
<tr>
<td>6</td>
<td>Lecture was cancelled due to timetable difficulties</td>
</tr>
<tr>
<td>7</td>
<td>Stability and Equilibrium</td>
</tr>
<tr>
<td>8</td>
<td>Approximations and Scales</td>
</tr>
<tr>
<td>9</td>
<td>Computer Tools in Modelling</td>
</tr>
</tbody>
</table>

Each lecture is accompanied by a set of problems designed by the lecturer. The students solved the problems in groups of two or three. Every week the local teaching assistants held a voluntary two-hour exercise session. The students were not required to attend the exercise sessions. They could work on the problems on their own and ask the teaching assistant for advice via e-mail. The finished reports were transmitted by the teaching assistant into the A&O-learning environment at the end of each week. 60 percents of the course grade was based on these reports. In some universities, the course was graded on scale: approved/failed. In this case, the grade was not divided into quantitative parts.

The student groups' reports were placed on display in the learning environment and the students were required to comment each others' solutions in the discussion forums. The lecturers followed the discussion as it was weighed in the final evaluation as 20 percents of the course. No right answers were released, but if necessary the professors joined the discussion and gave their insight into the issues at hand. The picture of the course format including the returning of the reports, the student-lecturer interaction and the student-student interaction is shown in Fig. 4.
At the end of the course the student groups concentrated on a more extensive modelling problem. The subjects of these problems were suggested by the lecturers and students during the course. In the final evaluation of the course, this last report was weighed as 20 percents of the grade. The assignment reports were displayed in A&O and all the groups gave an oral representation about their work in the closing videoconference. The lecturers evaluated the final reports, and the students received extensive feedback on their work in the A&O-environment.

### 3.2. The Web-course on Mathematical Modelling (Helsinki University of Technology)

The web-course on mathematical modelling was first held by the System Analysis Laboratory of the Helsinki University of Technology in the fall of 1999 [3]. Since then, it has been held twice more: in the fall of 2000 and in the summer of 2002. In this paper, the course will be referred as the HUT course. The course resembles a classical correspondence course, only difference being the fact that all the material is distributed via Internet. All necessary material for taking the course (excluding the course textbook) is available on the course home page. The course prerequisites are the first-year mathematics, the basic course of probability and statistics. The book “A First Course on Mathematical Modeling” by Giordano, Weir and Fox [4] is used as the course textbook and the course loosely follows the book. The aim of the course is to familiarise the students with the process of mathematical modelling and present them mathematical models of different types from several fields of science.
The course format is quite straightforward. The course consists of ten sets of exercises to be solved independently. The theory necessary in solving the problems is found in the course book. The only personnel on the course is the teaching assistant, who is responsible for checking the students' reports and giving them advice in solving the problems. The communication between the assistant and students is handled mostly via e-mail, although the assistant is available for the students daily at his office during the course. The course structure is shown in the Fig. 5. 42 students enrolled on the course in the summer 2002.

![Figure 5: The format of the HUT course.](image)

The course material contains lecture notes, ready-made parts of programs and exercises. Some slides from an earlier course on mathematical modelling have been transformed into an electronic form and were used as lecture notes for the course. The students are expected to use mathematical software in solving some of the problems. In order to help the students without earlier experience of the software, they are offered simple Matlab-codes for use and modification on the course home page. Some of the exercise sets include pedagogic Excel-sheets that enabled the students acquaint themselves with the problem at hand by experimentation. An example of a pedagogic Excel-sheet over a portfolio optimisation problem is given in Fig. 6.
According to the course plan, the solution of each exercise set is meant to take about eight hours. The original schedule used in the earlier courses required the students to return one set each week, so that the course would last ten weeks. In the summer 2002, the course was given at more intense rate with the students returning two sets of exercises a week. The topics of the exercises are chosen to give a general understanding of mathematical modelling and some of the more applied exercises are basic problems from other courses offered by the System Analysis Laboratory of HUT. The course schedule is presented in the Table 2. In the tenth exercise was a “web-excursion”. In the web-excursion, the students are allowed to choose a topic of their choice in the field of mathematical modelling and search the web for information for writing a report in html-code. The references to the source sites are incorporated into the text as hypertext links. All the assignments were sent to the teaching assistant as e-mail attachments in the PDF- or PS-format.
Table 2: The schedule of the HUT course.

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction to Mathematical Modelling</td>
</tr>
<tr>
<td>2</td>
<td>Modelling with Difference Equations</td>
</tr>
<tr>
<td>3</td>
<td>Model Fitting</td>
</tr>
<tr>
<td>4</td>
<td>Experimental Modelling</td>
</tr>
<tr>
<td>5</td>
<td>Simulation and Stochastic Modelling</td>
</tr>
<tr>
<td>6</td>
<td>Optimisation Models</td>
</tr>
<tr>
<td>7</td>
<td>Modelling with Differential Equations</td>
</tr>
<tr>
<td>8</td>
<td>Modelling with Systems of Differential Equations</td>
</tr>
<tr>
<td>9</td>
<td>Dimension Analysis</td>
</tr>
<tr>
<td>10</td>
<td>Web-excursion</td>
</tr>
</tbody>
</table>

The teaching assistant reviewed the reports and returned the incorrect or incomplete answers to students for further improvement. The correct answers were mostly left without feedback, because commenting all weekly reports would have increased the assistant's workload unreasonably. In problem situations, the students could ask the assistant for advice via e-mail or they could visit him during daily reception hours. The intention was to reply to the students’ e-mails on next weekday at the latest. This goal was achieved very commendably with little additional effort.
4. The Student Response and Observations on the Courses

4.1. The Questionnaire

After the courses, the students were asked to fill a questionnaire and present their own ideas for improving web-teaching. The questionnaire was carried out using Opinions-Online [10], which is a web-based software created in the System Analysis Laboratory of HUT. Opinions-Online has been designed for generating a site for interactive, web-based group decision-making, voting and surveys. Thus, it is a practical tool in collecting the student response from all around Finland.

The questionnaires consisted of nearly forty questions and a panel, where the students could give their freeform feedback and ideas. The questions were designed primarily to investigate students reactions to the course format and the technological tools used on the courses. Secondary aim of the questions was to reflect the students' opinions on how successful the course was and their opinions on web-based learning.

It should be noted that on the NVUP course on mathematical modelling the students filled two questionnaires, one at the midway point of the course and one having finished the course. On the HUT course the questionnaire was filled after the completion of the course and thus the results do not represent the students who dropped out.

4.2. The Web-course on Mathematical Modelling (National Virtual University Project)

The course was held for the first time in the spring of 2002 and the production of the material was finished only weeks before the end of the course. Thus, it suffered from “teething problems” and timetable breakdowns throughout the semester. The continuing uncertainty about availability of the material and constant fluctuations of the deadlines resulted in additional work for the students. The majority of the work accumulated to the last part of the semester and even interfered with students' other courses. The course was considered laborious. This was emphasized by few rather difficult lectures, compared to the general level of difficulty and the course's prerequisites. According to the students freeform feedback, they felt that overall amount of work exceeded the two credits awarded for the course. In spite of all this, all the groups completed the course.
Students from eight different universities participated in the course (see Fig. 7). The participants major in mathematics, physics, computer science, system and operation research, and economics. Thus, the students had very diverse basic knowledge of the mathematics. The students were excited by the crossing of university borders and felt that it was interesting to see how things are taught in other universities. The consensus was that acquainting oneself with reports written by students from different backgrounds was useful. The course participants felt that it was especially educative to comment on other students' work (see Fig. 8). But the fact that in some exercises the students could choose between various exercises was a cause some moderate problems. Because of this sometimes the students were forced to comment on unfamiliar subjects and exercises they had not worked on themselves.

Figure 7: The distribution of students among the universities.

Figure 8: Grades for the usefulness of the commenting other students’ work, (1 = “Not useful at all”, … , 5 = “Very useful”).
The recipients of the comments didn't feel that they benefited from the commentary (see Fig. 9). The students would have hoped for more authoritative feedback; preferably from the person who had given the assignments. In the original plan for the course, the lecturers had hoped for intensive discussion between the participants in the A&O news groups. The student commentary turned out to be almost indifferent and the desired conversation never materialized. In the end the participants felt somewhat uncertain about the correct solutions and wished for some kind of official right answers.

![Figure 9: Grades for the usefulness of the received commentary, (1 = "Not useful at all", ... , 5 = "Very useful").](image)

The idea of video taped lectures received praise from the students. They liked the fact that the lectures could be watched whenever and wherever. According to the freeform feedback, the students also utilized these possibilities. 40% of the students followed the lectures at home on their own computers and 22% at school when it was most convenient for them (see Fig. 10). However, the "talking head" -format of the lectures raised some
questions, because 48% of the students watched 0- 40% of the lectures offered (see Fig. 11). This low "attendance" would not be too worrisome on a regular course, but in this case almost all obstacles to following the lectures had been removed. It would appear that the students simply were not interested in watching a talking head for two hours at a time.

![Figure 11: Distribution of the students by the percentage of the lectures watched.](image)

The students were seemingly familiar with the necessary technology to complete the course. The watching of the lectures required installing the RealPlayer application, but all the students either had the software or could download it without trouble. The returning of the assignments was also almost 100% trouble-free, although in some cases the students were forced to return their reports to the teaching assistant as e-mail attachments for some tinkering and uploading to the A&O-system. The use of the learning environment on the other hand was not as straightforward. The user interface was found to be rigid and illogical. The system was criticized for being too slow and cumbersome. The grades for the level of functioning of A&O are given in Fig. 12. The necessity and usefulness of a "learning environment" were questioned. The grades for the usefulness of A&O are given in Fig. 13. Some students felt that a regular newsgroup and a suitable web page could fill the course’s needs perfectly.
Figure 12: Grades for the level of functioning of A&O, (1 = ”Does not work at all”, … , 5 = “Works very well”).

Figure 13: Grades for the Usefulness of A&O, (1 = ”Not useful at all”, … , 5 = “Very useful”).

A&O also had a number of features (notepad, calendar, bulletin board…) that were left completely unused during the course. In the questionnaire, the students were asked assess, how often they used different features of A&O, by grading the available tools on the scale “1 = Did Not Use At All” through “5 = Used All the Time”. The grade averages for all the tools are displayed in the Fig. 14.
Despite the timetable fluctuations and the clumsiness of A&O, the main problem on the course was the lack of coordination between the lecturers. The lectures did not form an integrated whole and some students felt that the general view given on mathematical modelling was left obscure. In addition to this, the difficulty of the lectures and accompanying exercises varied greatly. Some exercises could be easily solved without even watching the lecture and some exercises proved out to be almost impossible even with the lectures. The students also hoped for more references to the literature. The course textbook did not cover all the topics that the lecturers chose to present. The course participants hoped for an integrated handout that would cover the entire course. This handout could be delivered to the students alongside the other material.

In retrospect, the course was a moderate success at best. The students were asked to grade the complete course on a scale from 1 to 5. The grade average was 2.67. The distribution

Figure 14: Averages for frequency of the use of the A&O features, 
(1 = “Did not use at all”, … , 5 = “Used all the time”).

Figure 15: Grades for complete NVUP course.
In retrospect, the course was a moderate success at best. The students were asked to grade the complete course on a scale from 1 to 5. The grade average was 2.67. The distribution
of the grades is shown in Fig. 15. This grade was quite good considering course’s first-time nature and all the teething problems; one can only try to imagine the response a traditional course with same kind of problems would have received. The format of the course with video taped lectures and freedom in viewing the lectures were the major pros for web-learning. The students were interested in web-learning in general (see Fig. 16) and most importantly, 69% of them would recommend the course to their fellow students. They believed that with some more fine-tuning the course could become a respectable alternative for traditional teaching.

![Figure 16: Students’ interest in the web-teaching, (1 = “Not at All Interested”, ..., 5 = “Very Interested”).](image_url)

4.3. The Web-course on Mathematical Modelling (Helsinki University of Technology)

The questionnaire was filled by fifteen students. The respondents were from several departments of HUT as follows: 10 studied Engineering Physics and Mathematics, 3 studied Electrical and Communications Engineering, and 2 studied Industrial Engineering and Management. Out of these students, two studied full time, seven worked in the field of technology and six were otherwise employed during the summer the course was held. The course was aimed for students in their second and third year of studies and they formed the majority of the participants (see Fig. 17).
The HUT course received very positive feedback from the students. The course format was functional. The respondents felt that the course worked well as a summer course and did not interfere too heavily with other summer activities. This claim is of course biased, because the questionnaire was presented to the students who completed the course. Some of the students, who started the course, dropped out after their first or second report were returned as inadequate. It would seem that an effortlessly taken course is also easy to drop out. It is also possible, that the students who did not complete the course had simply overestimated their available time during the summer. The course was found to be especially suitable for graduate students and students working during the course. The absence of obligatory meetings was a positive.

The material was suitable for self-study (see Fig. 18), but somewhat meagre. The course followed loosely the course textbook that contains most of the theoretical background needed for the completion of the course. Some of the exercises were based on the basic course of probability or concerned some basic economics problems. In these cases, the lecture notes had room for improvement and the students would have hoped for more references to the literature. The students would also have hoped for more supplementary material on the course home page. In the students’ opinion, the exercises were educative and interesting overall (see Fig. 19 and Fig. 20). The material had enough instructions and advice to assist independent pondering and in problematic situations students received the necessary guidance via e-mail from the teaching assistant.
Figure 18: Grades for the lecture notes,  
(1 = “Not good at all”, … , 5 = “Very good”).

Figure 19: Grades for the level of interest of the exercises,  
(1 = “Not interesting at all”, … , 5 = “Very interesting”).

Figure 20: Grades for the usefulness of the exercises,  
(1 = “Not useful at all”, … , 5 = “Very useful”).
The course format was functional (see Fig. 21). Returning the reports via e-mail was easy and effortless. The e-mail tutoring worked well and the one-day delay in the response was not bothersome (see Fig. 22). The few things, the students would have hoped for, were exemplary answers and more feedback on their approved reports.

![Figure 21: Grades for the format of the HUT course.](image)

The web-excursion received the poorest feedback. According to the students, it was too easy and unnecessary. The biggest trouble in writing the excursion report was filtering the relevant web pages out the thousands completely useless pages. According to the students, the web-excursion's learning value was minimal. But some of them found it a refreshing manner for studying new subjects. Perhaps the students should have been encouraged more to revise each other's web-excursion reports, because in the author’s opinion they were very interesting.

![Figure 22: How well did the e-mail based tutoring work?](image)
Overall, the course was a success. As one can see in the Fig. 23, the students gave the course very good grades. The average of the grades is 3.65. The student feedback could be considered to be better than on an average course offered by System Analysis Laboratory of HUT. The majority of the respondents (10 out of 17) preferred the course to a traditional course and 88% of them would recommend the course to their fellow students.

4.4. Observations on the Courses

The students were extremely passive on physical events. On the HUT course, only two students utilized the possibility to visit the teaching assistant during the reception hours and on the NVUP course, there usually was no one in attendance at exercise sessions. Although the students listed the lack of obligatory meetings as a positive, it would be wise to try to maintain physical contact of some kind with the students.

It is also important to bring the students in contact with each other in discussion forums and news groups. This would to diminish the students' feel of isolation, which might help in reducing the dropout percentage. As witnessed on the NVUP course, none of the students taking the course in groups dropped out. Being part of a group also raises the threshold of dropping out.

Because there was no final exam on the courses, there remains some uncertainty over the measure of students' learning outcome. In the beginning of the course, it should be made clear to the students, what they should know after the course. This would help the students in their independent work. The students should be presented with exemplary answers after each exercise set or at the end of the course. Their work also should be commented as much as possible. It might be a good idea to have a final exam of some kind or an extensive report after the course to evaluate the students' true learning outcome.

To the author’s understanding, the HUT course material was reasonably effortless to create. The creation of the web-based exercises required only a little additional work in
comparison to traditional exercises. The organisation of the course and revising the reports engaged the teaching assistant full time during the course. This assessment includes the fact that the course was held in half the time compared to the original course plan. The NVUP course was much more laborious to arrange. In addition to producing the lectured material, the filming of the lectures took about three hours per lecture. Afterwards the lecture recordings had to be synchronized with the slides and converted into a format suitable for distribution through the internet. This post-production required about 12 hours of work per lecture session. Under the duration of the course the course employed teaching assistants at every locale and the lecturers were available for tutoring via e-mail. It should be noted that the involvement of the personnel was only part time.
5. Draft for an Improved Course

Next we describe a draft for an improved web-course. It is based on the student feedback collected with the questionnaire and the author’s experiences from participation. The best alternative from the three types of courses introduced in Sec. 2.3 probably would be a combination of them all; the course could incorporate the working elements from all the courses. The proposed course is basically the HUT course presented in Sec. 3.2, but the material is designed in the same way as the self-study learning material in Sec. 2.3.3. The course necessitates a teaching assistant to tutor and guide the students, but no traditional lecturer or teacher.

The improved course will follow the HUT course in terms of purpose and contents, because the student response has proved the HUT course to function well. The aim of the course is to provide the students with basic theory of mathematical modelling and introduce them to models of different types. The prerequisites are basics on mathematics and probability. The course is directed to students in their second year or further in their studies. According to the student response, the book “A First Course on Mathematical Modeling” by Giordano, Weir and Fox [4] is a suitable text book.

In the beginning of the course and perhaps even in the beginning of each exercise set, it is important to clarify to the students what they should know after the course or after the exercise set. Since there are no lectures and the participants do not necessarily meet the teacher, the most important parts of the course have to be emphasized in order to be able to reduce the students' uncertainty over the matter. At the end of the course, the participants are given the official right answers to the problems handled.

The best time for the course is during the summer. If it is organised during the semester, the idea of distance learning may seem ridiculous to the students as they go to school anyway. The great availability of the material can in extreme cases even cause additional stress as the course work shifts to the students' homes.

The course begins with the students forming groups of two or three, in order to minimize the dropout percentage. The members of the group do not have to come from the same location. If the students form an inter-city group, they get a real feel of distance education, but this may cause slight complications in solving the problems. This obstacle should not be insuperable, as the members of the group can communicate with each other via e-mail or by telephone. The students are encouraged interact and discuss the exercises and their solutions in a news group or discussion forum. If the course is taken alone and without contact to the other course participants, the students may feel isolated and are more likely to dropout.

The group acquaints oneself to the materials provided on the course home page and receives problems to be solved and reported. The reports are delivered to the tutor as e-mail assignments or uploaded to the course home page (see Fig. 24). The tutor can be contacted via e-mail or visited at reception hours for advice. Contacting the tutor with telephone during the reception hours could also work. If the group faces more extensive problems, a physical visit to the tutor's office and face-to-face guidance should be
recommended. If the course is organized during the semester, an obligatory weekly meeting could also come into consideration. This meeting could be used for tracking the students' progress and receiving student feedback on the course. Making this meeting obligatory would be imperative to overcome the students' passivity towards physical meetings, as was observed on the two courses presented in this paper.

![Diagram of Course Format](image)

**Figure 8: The Format of the Suggested Course.**

The course material should be as ample as possible, but multi-media should not be forced in just for multi-media's sake. The significance of all the features in the material should be carefully considered. Comprehensibility should always come first and foremost. If the information is best presented as plain text, it should not be obscured with excessive animated graphics. On the other hand e.g., differential equations could easily be illustrated using animations. A pedagogic Excel-sheet could also be used to visualise model fitting and the effect of the variation of the model parameters. The correct use of various forms of material can be refreshing and raises students' interest level. For example, staring at a talking head for two hours may not appeal to the students, but shorter lecture clips might work as part of wider entity.

The course material should be divided into two parts: the essential and the supplementary. The essential material is the part of material that is absolutely necessary for the completion of the course. This material could be organized into a linear form where the theory and examples would alternate. In this presentation, video clips, demonstrations, commentary, animations and other possible forms could be used in addition to the plain text. Throughout the essential material, there would be links to the
supplementary material and appropriate Internet sites for the students to examine and visit, if they are interested. There should also be plenty of references to the literature.

If there is more than one person creating the material and the problems separately, the coordination of the materials and problems can not be overlooked. It is very important that the different creators of the material familiarize themselves with each others' parts of the material before the course. The material can not contain any discontinuations or severe fluctuations of difficulty.

In the end of the course, the groups' reports are compiled into portfolios. These portfolios replace the final exam and determine the students' grades. On a web-course, where the contact between the teacher and the students is limited, it is particularly important to have some kind of measure for students' learning outcome. The portfolio, representing the students' competence and investment on the course, might serve even better than a final exam. The final portfolios could be placed on the course home page.

Creating a course discussed here is not effortless. The value-tree learning module (see Sec. 2.3.3.) has taken at least 0.5 man-year to develop. The module corresponds to one lecture and the respective exercise set on the web-based course. Thus, the effort necessary in developing the entire course on mathematical modelling would be roughly 5 man-years. Creating the course from scratch is not reasonable. A more feasible approach is converting existing course material into electronic form and enhancing it further to utilise the possibilities of the web-learning. The HUT course (see Sec. 3.2.) could be improved by converting the exercise sets into learning modules resembling the value-tree package one by one. The final product would be a respectable alternative for a traditional course on mathematical modelling.
6. Summary

Around the world there exists an interest in web-teaching and its applications. As one can see in the student response discussed in this paper, the interest in the web-based learning is not only from the side of teachers and universities, but also from the side of the students. It is indisputable that web-based learning has some definite pros in comparison with the traditional teaching. Most importantly on courses offered via Internet, the students possess the freedom to study anywhere and at anytime provided that they have an access to Internet.

Although Internet offers a versatile platform for educational solutions, some caution must be maintained. Offering on-line courses for the sake of new technology and “being on-line” is not in the best interest of the students. The assets of web-based courses must be utilised to such extent that it is advantageous to study on-line. There are aspects that should not be neglected, such as efficient communication between teaching staff and students and minimising the students' feel of isolation. Most notably a live teacher or tutor is still necessary even on web-based courses.

The courses on mathematical modelling discussed in this paper were both successes in their own way. This proves that the mathematical modelling is a suitable subject for a web-based course. The basic theory behind the mathematical modelling is not overly demanding and different types of models can effectively presented using animations as well as illustrated with suitable software.

The HUT course is in its' current form a working educational package. There exists some areas of improvement of the course, but keeping in mind the retouching possibilities of Internet based material, this is a minor flaw. The HUT course would be a perfect platform for an improved course to be developed upon in the spirit of the OR-World Project.

The NVUP course was more ambitious from the beginning, trying to recreate a lecture hall in the Internet. Thus, the course's errors and failings became more evident. The course organisers seem to be committed to the "talking-head" format of the two hour lectures as well as to the A&O learning environment. In the author's opinion and according to the student response overviewed in this paper, the use of these approaches should perhaps be reconsidered. The “talking head” format was not well received by the students and the necessity of a learning environment was strongly challenged.

The improved course format introduced in Sec. 5 is a draft with many unanswered questions. However, it is an attempt to combine the best parts of the two courses and the web-based learning material presented in this paper. The author believes that such a course, if put to practise properly, could offer a respectable alternative for traditional teaching. Developing a coherent combination of learning modules, that forms a comprehensive course on mathematical modelling, will be effort consuming and takes time. But in the end, the resulting course that utilises the possibilities of on-line learning to their fullest extent could prove to be even superior in comparison with a respective traditional course. Thus, further investigations of the on-line learning and its possibilities must be strongly recommended.
References


