A Method for Learning Software Tools in Engineering Education

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Abstract - Software tools are an essential part of the teaching environment in engineering studies. Introducing new technologies into the curriculum means a considerable amount of work for the teacher, and many teachers do not feel comfortable unless they completely master a software application and all aspects of a technology. In an already pressured schedule, it may be difficult to find the time to do so. Consequently, students often use older software or the teacher’s preferred software, even though the applications may not be suited to the students’ tasks. This paper addresses the concept of forming training classes consisting of teachers and students, with the purpose of learning software tools and new technology in a quick and efficient way. The idea originates from the experience the authors had teaching a group of students the basics of the engineering calculation software Mathcad. The method is general and can be used for learning all kinds of software, and is not limited to software for engineering purposes.

Index Terms - Engineering software, pedagogy, software tools, student participation.

INTRODUCTION

Software tools are an essential part of the teaching environment in colleges and universities, and engineering students use several advanced tools in their studies. Students spend considerable time learning specific tools in order to do their project work. Sometimes they need a certain tool for a special project, and may have to learn the software in the course of a few weeks in order to perform their work. On the other hand, for teachers it can be a serious challenge to become familiar with new tools and technology.

Many teachers will not integrate new technology into the study program until they master the software application and all aspects of the technology. This may become a hindrance to giving instruction in the latest technology, and the teachers’ knowledge may easily become outdated. Although it can be argued that once the students are familiar with certain software they will easily learn other applications, this should not be used as an argument against teaching up-to-date technology and the use of modern tools suited to the students’ tasks. A project team at the faculty of Engineering, Oslo University College, explores the idea of a tool-learning workshop. It is our experience that talented students quickly learn new technology and software. When these students graduate, the knowledge disappears with them. We decided to benefit from the students’ knowledge by involving them in a process developing a method for learning new software. The work resulted in a program where teachers and students learn by teaching each other, and simultaneously create instruction material using Power Point presentations.

PROJECT BACKGROUND

The idea of developing a general concept for learning new software was explored by the authors of this paper at Oslo University College during the spring term of 2006. A project team consisting of two staff members and four students was formed, and in the course of 3 months, 14 students have participated on the project. Oslo University College collaborates with the Engineering College of Copenhagen, Denmark (IHK), where the engineering software application Mathcad is used excessively. One of the authors of this paper was in Copenhagen and received basic instruction in Mathcad in December 2005 in order to establish core skills. This knowledge was then passed on to another member in the team. A Power Point presentation tutorial covering the basic topics was created simultaneously. This presentation was used when instructing a group of four students who were going to use Mathcad in an engineering project for a consulting company.

The next step in the project is to instruct teachers and students in the building department, and in this way, the skills can be passed on to most of the students and teachers at the college in the course of a few months.

1. Motivation

Teachers are pressured for time, and exploring a variety of software tools in order to decide which is the most suitable is time-consuming work. Therefore, teachers often use their preferred software even though it may be less suitable than other tools, and do not always recognise the necessity of introducing new tools.

The project team set out to explore the suitability of the software Mathcad for engineering purposes. By incorporating the exploration of the software’s possibilities into the tool-learning project, the gain was many-fold: Learning to use the software, deciding on the suitability of the
tool, and incorporating the students into the teaching process, thereby gaining from their skills. Project participants were teachers and students from the departments of Computer Science, and Energy and Environment. The assumption was that when experts from various fields participate, the information obtained would be more varied and hence improves the project results.

The students very soon felt comfortable using Mathcad in their final year project, and launched on the complicated task of calculating the operative temperature at a specific point in a room under varying outdoor temperatures, in order to determine if the thermal conditions in-doors are appropriate on for instance, a very cold day. The details of this calculation method are presented below, and document the suitability of the software for solving complex engineering tasks.

2. Project Aims and Methods

The aim of the learning project is to create a team of teachers and students working together on the tuition of students and teachers, creating the instruction material, and exploring the benefits of this method of learning. The assumption is that there is a certain surplus value to be obtained from a collaboration effort of this kind. The students participate on the project on a voluntary basis, and are obliged to share their knowledge and experience with the rest of the team and their fellow students.

The team decided to try out the learning method using the calculation software Mathcad. The software is an engineering tool, which makes it possible to perform, document, and share calculation and design work. According to the vendor, Mathcad is easy to learn and use, and no special programming skills are required. At the Faculty of Engineering, mathematics is taught in the traditional way using the blackboard, pencil and paper, or by the use of Mathematica, a powerful calculation application used by mathematicians and scientists. Mathematics is not incorporated into the engineering disciplines, but regarded as a separate discipline. This has been a point of discussion for some time, and the project team discussed the possibility of developing engineers providing the necessary mathematics tuition themselves. It seemed that Mathcad would be a suitable tool for this task.

The students were given a three-hour introductory course, and were soon able to use the software in their project, learning the more advanced features while working with it. An important issue here is that the Copenhagen College team acted as support team. The students could send questions by e-mail and receive help quickly. The Copenhagen experts also plan to visit the College and give an advanced course. After the first stage when the four students were taught the basics of the program, two students from the original group instructed a second group of 10 students. This was also a three-hour course. After the introductory course, the students were interviewed about their experiences.

Once the students have acquired basic skills, they start using the software on their own, exploring the more advanced features of the software. The students share their acquired knowledge with students and the teachers on the team, so that the information can be collected, and passed on to new groups of students, who are also obliged to be a part of the team. In this manner, a large group of students and teachers will master the software application in a short period.

MATHCAD USABILITY

The engineering software for our purpose must meet with the following requirements:

- Overall ease of use
- Ease of learning
- Ease of interpretation
- Good documentation possibilities
- Low cost

One of the reasons for choosing the software Mathcad is the low user entrance. This makes it possible for new users to start using the program after a short introductory course. Another important feature of the program is the possibility of five different roles, respectively as

- an engineer who can set up the engineering problem of interest
- a mathematician who can solve the problem of interest mathematically.
- a developer who can program the problem.
- a teachers or an engineer who can present the problem in a pedagogical way for the students or colleagues
- an author of the documentation of the task, which has been solved

Documentation is an important feature, which often does not get the proper attention. One of the reasons for this is that it is a time consuming task, which is often performed at the end of the project, when the money has run out or is limited. Another reason is that documentation is not integrated in the program / process. This means that it has to be done in another program, which again means that it is necessary to update the documentation either in a parallel process or after finishing the programming phase. In Mathcad, this can be done simultaneously in an integrated process. This means that the documentation process is a result of conscious reflection rather than a complicated time-consuming task after the project is finished.

Private engineering companies who have been using Microsoft Excel are switching to Mathcad for the documentation reason. In Microsoft Excel the feasibility for documentation is very limited since it is based on cells holding the formulas. This means that a user has to go into every cell to see its content, and then switch to another program to write the documentation. Getting an overview of a complicated problem is therefore a time-consuming process. Private engineering companies experience that when employees leave

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their job in the company and new employees take over, it is very difficult to understand the programs constructed in Microsoft Excel, because of the lack of documentation. This can in some cases be nearly an impossible job, and it would seem easier to construct a new program in Microsoft Excel. This is one of the reasons for the changing from Microsoft Excel to Mathcad. Another reason is of course the great number of engineering features inherent in Mathcad compared to Microsoft Excel.

THE USE OF POWER POINT PRESENTATIONS AS TUTORIAL FORMAT

Traditional tutorials and user manuals are large and often hard to understand for the novice, the same information is presented several times and in different ways, and there is little or no distinction between important and less important issues. The use of Power Point for creating the tutorials has certain advantages. There is limited space per slide, and the information presented is therefore very concentrated. Using a Power Point format ensures that the most important information is presented first, and details are postponed until a later stage. Practical examples and solutions to exercises are incorporated into the presentation.

The tutorial is created ‘on the fly’, while using and learning the software. Both teachers and students contribute with their acquired experience. The instruction material created in this manner is highly flexible, can easily be changed, and updated, for instance, when there is a new version of the software. Should the software be replaced, the new software will most likely include many of the same aspects as the old, and parts of the instruction manual can still be used. The project involves using a standard Power Point template developed by the author Jørgen Erik Christensen in a pedagogical project [1]. In this way, we ensure that since many people are involved in the creation and updating of slides, the work is performed according to a standard, which is easy to maintain.

A PRACTICAL EXAMPLE OF THE USE OF MATHCAD

The following example shows how far students can reach after having received only three hours of instruction. Two of the students who participated in the Mathcad workshop were working on their final year project for their bachelor degree, and wished to use Mathcad in the project. The task is to design a new office building in Oslo.

The students wished to explore comfort conditions in rooms with big window areas. The outside air temperature is closely related to the temperatures on the surface of the walls and the windows. Since the isolation in walls in Scandinavia is 4 to 15 times better than the isolation through the glass, the inside surface temperature is much more affected on the inside glass than on the inside wall. Designing rooms with big glass areas therefore has a great effect of the thermal comfort in the rooms. When calculating the consequences for the indoor thermal climate, the surface temperature is an important factor. To find a simple measure for the heat loss from a person, the operative temperature can be used. The mean radiant temperature plays an important part in calculating the operative temperature:

\[ t_o = 0.5 \cdot t_r + 0.5 \cdot t_t \]  

(Formula 1.3 in [2])

where \( t_o \) is the operative temperature \( [\degree C] \)

\( t_r \) is the mean radiant temperature \( [\degree C] \)

\( t_t \) is the air temperature \( [\degree C] \)

The air temperature can easily be measured, or it is set to a fixed value, for example 21ºC. The difficult part is the calculation of the mean radiant temperature for a person:

\[ t_r = F_{p,i} \cdot t_i + F_{p,2} \cdot t_2 + \ldots + F_{p,n} \cdot t_n \]  

(Formula 1.1 in [2])

where \( t_r \) is the mean radiant temperature \( [\degree C] \)

\( t_i \) is the temperature of surface \( i \) \( [\degree C] \)

\( F_{p,i} \) is the angular factor of surface \( i \) [–]

The surface temperature can easily be measured or calculated. However, the angular factor between a seated person and a rectangle on the wall, floor or ceiling is far more complicated to calculate. In most cases the angular factor is read from a figure, for example figure 1, which shows the mean value of angular factor between a seated person and a vertical rectangle.

### FIGURE 1 – DETAIL OF DIAGRAM

**The angular factor between a person and a surface**

In order to calculate the mean radiant temperature and from this calculate the operative temperature, an equation system is used. When one wants to find the angular factor between two surfaces, one can find a specific equation for the
angular factor to be used in the calculations [2]. However, the real problem is calculating the mean value of angular factor between a seated person and a vertical rectangle. In reference [3] the students found a complicated explanation on how to calculate the angular factor, which is done from the following equation: (Formula (67) in [3] – note that there is a minor error in the formula)

\[
F_{\text{PA}} = \frac{1}{2\pi} \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \left[ 1 + \left( \frac{x}{y} \right)^2 + \left( \frac{z}{y} \right)^2 \right] \frac{f_p}{z} \frac{d(z)}{d(z)} \, dz
\]

Equation (67) turns out to be complicated to use because of the projected area factor – \(f_p\) is a function of the azimuth \(\alpha\) and the altitude \(\beta\), figure 2. P. O. Fanger has studied this in detail in [3] for persons and has combined all this data into one diagram for a seated person – figure 2.

**FIGURE 2**

Projected area factor for seated persons, nude and clothed to an infinitely small surface [3].

The diagram in figure 2 for the projected area factor shows the factor as function of the azimuth \(\alpha\) and the altitude \(\beta\) to an infinitely small surface. In reality, the situation is like in figure 1, where a person is sitting in a specific position in relation to a surface. Figure 2 cannot be used directly to solve equation (67), for the case illustrated in figure 1. In order to solve this problem, the students needed to go through a complicated iteration process to find the projected area factor – \(f_p\). Since the students could not find the solution directly for the value \(f_p\), they reversed the process, and used figure 1 to find the solution for the angular factor \(F_{\text{PA}}\) from the diagram for a specific case, depending on the position of the seated person, the size of the window, and the distance form the window.

They entered this result into formula (67), and used iterations to find a solution for the projected area factor \(f_p\). This value of \(f_p\) could only be used for this one special case. For other values, the error becomes increasingly larger. In order to solve this problem, they created a 20 by 26 matrix for the specific case in figure 1, and iterated solutions for all the projected area factors \(f_p\). In this way, the error was reduced to less than one per cent.

Equation systems can then be created for the operate temperature for a general case. Real data for the specific case can be entered to calculate the thermal indoor climate, without having to spend time reading tables and making calculations. If the results show that the operative temperature under special winter conditions will be too low, the user can quickly make alternative calculations with other assumptions. For example, the glass in the window can be changed to a better quality with less loss of heat.

The solution to this problem turned out to be more complicated than the students expected. On the other hand, Mathcad has the advantage that the documentation can be written directly in the file – as opposed to Microsoft Excel, and when the solution first is found, this can be used by other students in other projects. In this way, students can build up complex models with good user interfaces.

**RESULTS**

The project had three main goals:

1. To create a method and environment for learning new software quickly and efficiently
2. To include the students in the teaching process
3. To use this method for evaluating different tools in order to decide their suitability for specific tasks.

In the course of three months, the project team has succeeded in teaching a number of students in the departments of Energy and Environment and Computer science to use Mathcad for engineering tasks.

The four students who originally learnt the program have now completed their final year project, and have successfully used Mathcad to solve complicated engineering problems. After three hours of instruction, these students were immediately ready to use the tool in their project. In the course of a few weeks, they mastered the software to such an extent that they were able to teach their fellow students the basic features of the tool, and also to demonstrate the advanced practical example described above. This proves the assumption that there is a surplus value to be obtained from this kind of collaboration effort. The students have acquired skills in both engineering, mathematics as well as in the use of the software, and they have imparted this knowledge to the rest of the project team, including several teachers.

Interviews with the students show that they appreciate being taught by their peers. They quickly understood the basic features, and were inspired to start using Mathcad in their work. They also gladly agreed to participate on the project, teaching more of their fellow students the basic features of the program. All the students said that they enjoyed...
using the software, which they characterize as flexible, easy to learn and recognizable, meaning that the look and feel of the program was familiar. Menus were easy to find, and the results were clearly interpreted. Several of the students have had previous experience with the tool Mathematica, and maintain that they would never have been able to do these complex calculations using that software. This does not mean that it would not be possible, but that Mathematica is not suited to solve engineering tasks in the same manner as Mathcad. The students stated that they had spent weeks learning the basic features of Mathematica, simple things they could have done using their calculators.

The project has demonstrated that the method can be used to evaluate software. The software is put to the test when used by advanced students to perform complex tasks. In our example, Mathcad met with the requirements. The conclusion is therefore that Mathcad is clearly an engineering tool, suited to solve engineering tasks. The college has now purchased a set of student licences for Mathcad, and an increasing number of students and teachers are using the tool.

**FURTHER WORK**

Now that the method has successfully been tried out and documented for the application Mathcad, it can be transferred to the instruction of other software applications for use in engineering education.

Industrious students can work on several projects, and receive payment for their work. This will also ease the teachers’ workload. Software tools that are suitable for this learning method are for instance CadVent, a software application for duct design, product selection, drafting and estimating processes for HVAC designers, and AutoCad, a design program for building engineers. In the computer science department there is the explicit demand for a course in the Microsoft .NET platform, and the programming language C#. Several students have acquired knowledge of this technology, and are using it in their projects. These students could be engaged to pass on their skills to teachers and fellow students.

**REFERENCES**

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