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A NEW APPROACH IN SOFTWARE EDUCATION IN METROLOGY AND QUALITY ASSURANCE – AN EMPIRICAL STUDY

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Abstract: Future engineers working in the field of metrology and quality assurance will require more profound software knowledge than today. In addition to that it is often claimed that measurement science is not that close as it should be to daily practice [1]. The following article describes a new approach in education developed and applied at the Technische Universität Ilmenau. Based on a SQL database server and a Microsoft Office client students are enabled to develop customised software solutions to problems of practical relevance without having any specific knowledge in advance. Furthermore the paper details which difficulties occurred most often. It is also discussed to what extent the developed software solutions are likely to be deployed in industry as a cost efficient alternative.

Keywords: education in metrology, education in quality assurance, database and Microsoft Office

1. MOTIVATION

University education has it strength in teaching theory and methodical understanding. Nevertheless practical relevance is sometimes absent or acquired knowledge could not be adopted and therefore is forgotten promptly.

At the same time it could be ascertained that most students still have deficiency in software knowledge. That implies the capability to describe a problem in an abstract manner in order to be later implemented easier into software as well as to be well versed with a sort of software tools which are considered as elementary. The necessary knowledge of a certain programming language can thereby differ from case to case. Both Microsoft Office packages and SQL databases are considered as very useful tools by the authors of this article in the context of measurement and quality assurance.

Microsoft Office (MS Office) is maybe the most distributed commercial software package around the world as it could be widely used and customised by the user himself. Microsoft Office tools offer various possibilities, e.g. for statistical metrology [2] or quality assurance in industry [3]. By using quasi-standard software like MS Office possible weak points within the software [4] could be openly discussed and so corrected in the long run [5].

SQL databases are the most commonly used type of databases. A database is an important element of every bigger software information system as it provides a simultaneous access and the possibility of storing and retrieving huge quantities of data. For measurement purpose e.g. it might contain personnel and material master data, data of machinery and inspection devices as well as the measuring data.

The lack of software knowledge in industry today is shown in a variety of international surveys [6, 7, 8]. Accordingly, most software projects in enterprises are failing. Either they are cancelled or they are completed at the cost of budget or time overrun or with a reduced functional scope (fig.1).

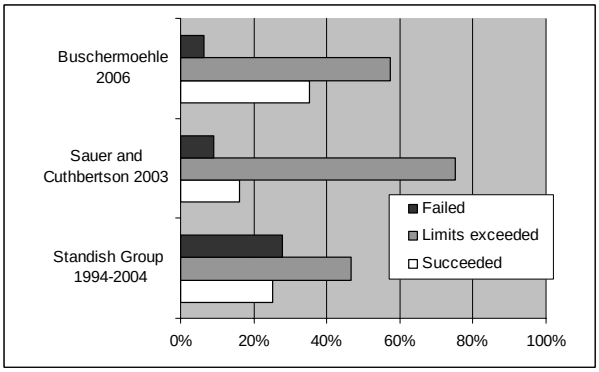

Fig. 1: Outcomes of surveys investigating software projects in enterprises [6, 7, 8]

Nowadays there are different alternatives to consider for software development: in-house development, outsourcing/ commercial off-the-shelf (COTS) procurement and more and more Free/ Open Source Software (F/OSS). Studies on the application of software for quality assurance in Germany show that only one third of all users purchase commercial off-the-shelf software for quality assurance [3, 9, 10]. Most companies either disclaim the application of any specialised software solution or develop it by their own respectively in-house development. The latter are often based on the Microsoft Office package [3]. But as long as software systems are not connected with each other by appropriate interfaces, the same data have to be entered into each system several times. Additionally the quality of data decreases due

to the lack of a common database. The efficiency of software depends very much on the data quality as every party is interested in clear and transparent information.

Therefore, the British Computer Society (BSC), referring to the mentioned deficits in industry, perceives correctly: "Improving (software) education will not make an immediate change to practice, but is a vital part of a long-term solution to the problem…" [11].

2. CHALLENGE AND PURPOSE

Based on the fact of a virtual enterprise, students had the task to develop small software modules to be applied in metrology and quality assurance by using MS Office clients connected to a SQL database server. MS Office and SQL databases are as described above widely-used standard software and be able to handle it could be very useful afterwards. Moreover, these components can be easily used to build up a distributed software system for multi-user purpose. The new approach in education shall pursue the following objectives:

- Enhance knowledge in metrology and quality assurance through typical use cases,
- Gaining understanding about the process of software-development and architecture of multi-layer software systems,
- Learning to work with important standard software like MS Office and SQL database for later job,
- Training of presentation and teamwork.

From the scientific point of view, the frequent problems during software development and the evaluation of quality of software solutions were of particular importance.

3. APPROACH

To build up a complex software system it is necessary to apply a systematic approach [12]. The software lifecycle could be divided into at least four main steps: requirements analysis, design, implementation and maintenance. Modelling plays also an important role during software development: models are used to facilitate communication between different stakeholders, in metrology e.g. physicists and software engineers on the other side [13]. Using an adequate modelling language, tools can help to verify the underlying model as well as to generate executable code.

In practice data models are of an outstanding importance at the development of complex software systems. Data are the core of every software information system. Data do even exist without a certain program and therefore have a higher stability then the program itself. Although the data model is just one part of system development, it has a strong impact on the later software, i.e. user requirements, application integration and costs [14]. A data model provides a method for describing the real-world information requirements in a manner understandable to all stakeholders. It also serves as a blueprint of the database system for the developers (fig. 2).

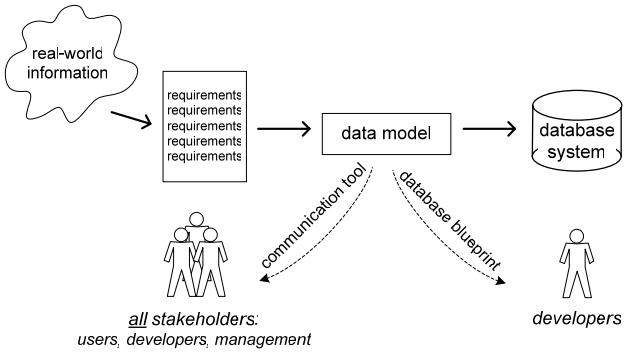

Fig. 2: Data model for communication and database blueprint [16]

The adopted approach to create an Office - database centred software system is shown in fig. 3. All main steps mentioned above are included. The selected technology – except MS Office – is popular Open Source software: a Eclipse plug-in [15] as database design tool and MySQL [16] as database system. Connection between the software components was made through SQL via JDBC and ODBC middleware.

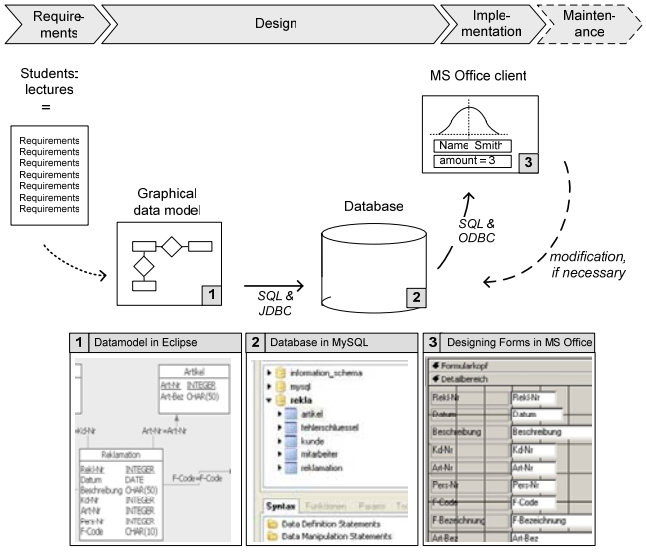

Fig. 3: Process and tools applied for students software prototypes

Every group was made up of two or three students and had to select a typical field of interest in metrology analysis or quality assurance to be later realized with software. At the beginning each student had to give a lecture which should include the theoretical basics as well as a plausible example to the other students. The lecture was also seen as the requirements document and the result of requirements analysis.

4. RESULTS

With one exception all groups had shown viable MS Office clients either using MS Excel or MS Access. Typical tools which had been realised are, among others:

- Machine and Process Capability Analysis,
- Measurement System Analysis,
- Statistical Process Control (Control Charts),
- …

Relevant data as master data and measuring data could be entered into the program by manual input, by data file like *.csv or even through connection to the database using SQL-commands. The measuring object itself was not part of the project so students were free to create their own sampling data for demonstration. To complete the measurement process a connection to the database had to be made to save the results back to the system, e.g. for further analysis (fig. 4).

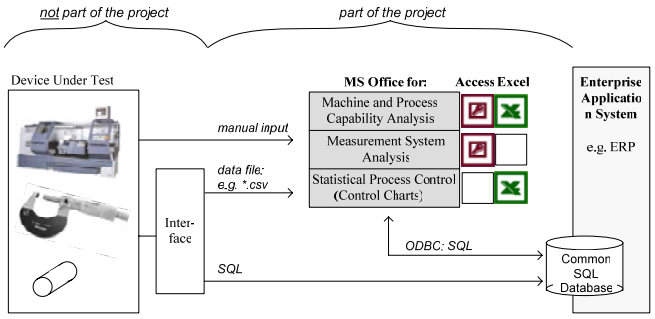

Fig. 4: Application scenario in Metrology with MS Office client and SQL database server

Although quality of software was quite different between different groups due to a necessary additional programming effort [12] some useful software solutions had been developed as the following examples should illustrate.

4.1. Machine and Process Capability Analysis

Purpose: Analyzing Machine and Process Capability of quantitative characteristics at standard distribution. For this purpose relevant master data and inspection data could be introduced by a MS Access client to be stored in the MySQL database. Alternatively data could be imported by a MS Excel client via *.csv-file. The calculation of capability indices was made with MS Excel. As both MS Access and MS Excel are based on the same programming language VBA (Visual Basic for Application) and both clients were connected to a common database the users were free to choose their preferred program, fig. 5.

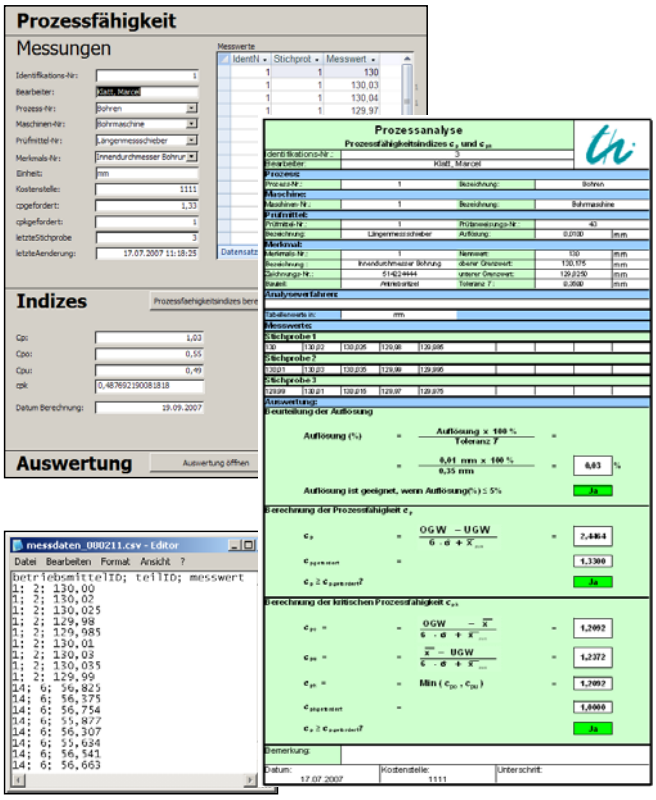

Fig. 5: Example (1): Machine and Process Capability Analysis

4.2. Measurement System Analysis (MSA)

Purpose: Measurement System Analysis using type-1 study (Cg/ Cgk) and type-2 study (Gage R&R). All data input has to be made through the MS Access client: master data like personnel data, material, inspection devices, company standards, etc. and the measuring data. To calculate users could choose between different methods and print results in a report, fig. 6.

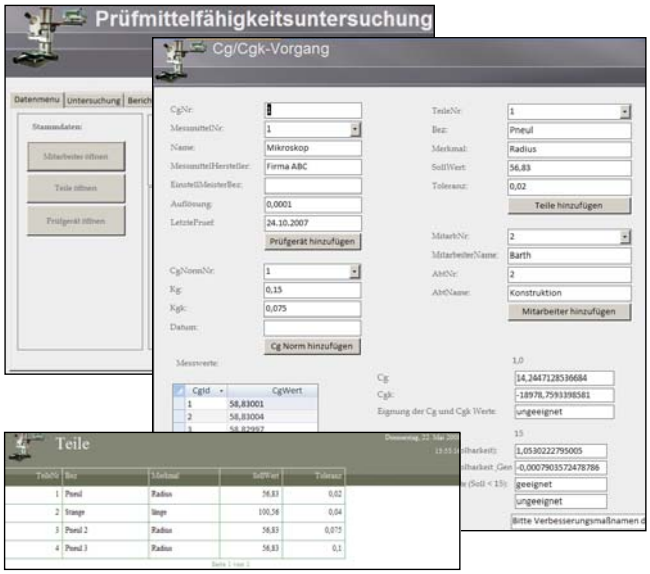

Fig. 6: Example (2): Measurement System Analysis

4.3. Statistical Process Control

Purpose: Monitoring a process routinely through the use of attribute control charts to measure failure per sample (binomial distribution) and failure per probe unit (Poisson's distribution). Software was solely realised with MS Excel connected to the MySQL database server containing the data of characteristics and the measuring data. At the beginning user has to choose the type of control chart to use and the characteristic to be measured. Afterwards program retrieves all measuring data from database and calculates corresponding upper/ lower control and action limit and finally plots the chart. Additionally user can add more data and save them in database or switch display between "order by time" or "order by number", fig. 7.

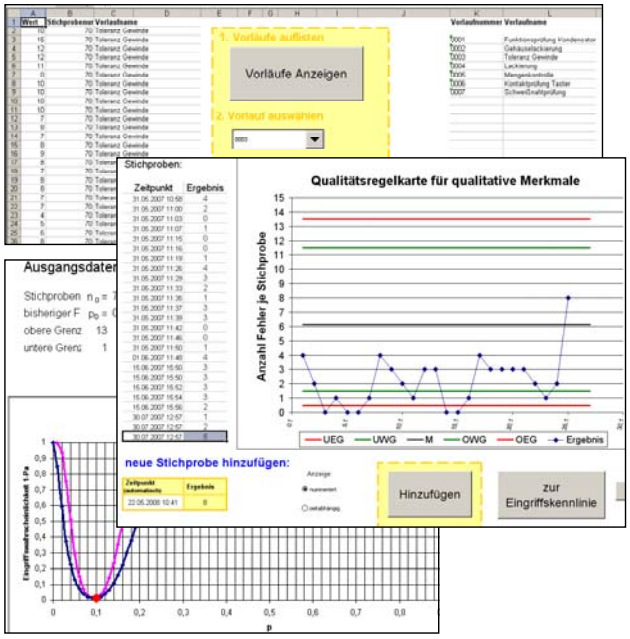

Fig. 7: Example (4): Statistical Process Control

5. DISCUSSION

Of the 68 students who attended the courses during that two semesters from the beginning only 47 passed it successfully. Those who changed (all within the first three weeks) reclaimed the additional effort regarding to a "normal" course. At the beginning and at the end of each semester a standardised questionnaire was handed out to each student. One intention was to evaluate student's knowledge concerning MS Office and databases both through self assessment and control questions. Fig. 8 shows a good correlation and an overall remarkable increase in knowledge.

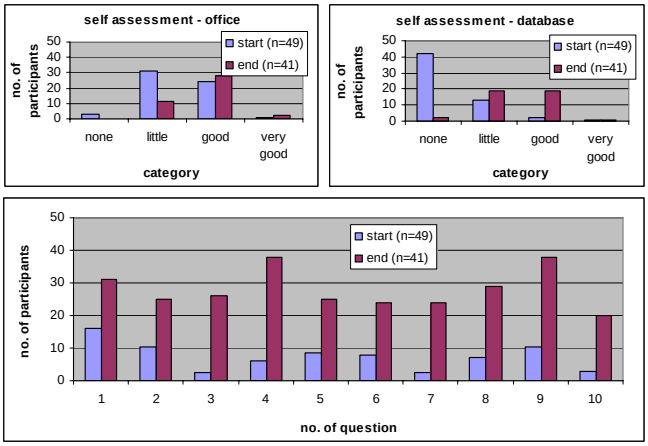

Fig. 8: Increased knowledge, above self assessment – below control questions (n=41, note: six forms were not applicable)

Another matter of interest was to find out what caused the most problems: developing the database or programming the MS Office client. For that purpose ten points had to be allocated. The number 10 stands for "most difficult". Fig. 9 illustrates the results as Box-Whisker Plot. According to this students had more problems with MS Office than with the database.

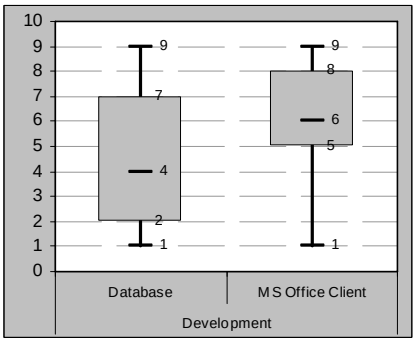

Fig. 9: Problems at the development: 10 – difficult, 0 – easy (n=41)

Although most students had indicated fewer problems with database it was evident that in most cases data models could only be applied to that special use case for which it was planed. By using the relational data model and suitable database design tools, building a database is not that difficult in fact. The problem lies more in the modelling effort or rather the development of models of higher quality [17] (fig. 10).

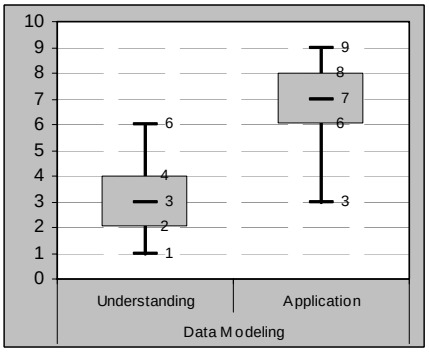

Fig. 10: Problems at the data modelling: 10 – difficult, 0 – easy (n=41)

In principle there is always more than one solution to a certain (modelling) problem. The quality of a data model refers to understanding and evaluating the data model regarding customer's expectations [18]. In literature a lot criteria frameworks have been proposed which can be used to understand and evaluate quality of data models [18, 19, 20, 21]. Those quality criteria which are frequently mentioned and most important are:

- Correctness: A model should conform to the syntax rules of the particular notation.
- Completeness: Does a model include all needed information? What can be expressed?
- Flexibility: Changing requirements should not cause changes to the data model or at least no drastic changes.
- Understandability: It can be achieved through simplicity and naturalness.

Some empirical studies on data modelling [18, 20, 22, 23, 24] have shown that:

- Data modelling novices don't have problems using simple semantic constructs. Difficulties had increased by dealing with complex constructs and on a larger domain of interest.
- High quality data models can be achieved by a systematic approach. Experts are able to create better models due to there ability of abstraction, they use patterns of former projects and spend more time to review their models than novices do.

Regarding fig. 9 only few students weighted "database development" higher respectively more difficult. It may be assumed that those students put more effort to adjust their data model and so created better models, see fig. 11.

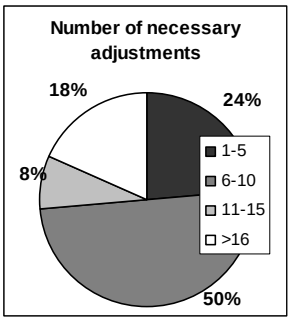

Fig. 11: Number of adjustments to data model (n=41)

6. CONCLUSION

As it has been outlined, students were able:

- To create small individualized applications for measurement and quality assurance using MS Office clients and a SQL database system,
- Without any previous software knowledge (fig. 8),
- And to develop and customise it by their own in a relatively short time – a necessary attribute for effective working with software.

During development every group became well aware of all those problems and necessary steps which have to be overcome and are so typical in every major software project.

This training approach had been enabled only through broad application of Open Source software tools, rapid testing and customizing as well as through good software documentation on the Internet and program assistance within the tools.

Most developed software solutions were limited to the initially proposed course examples instead of covering a more general application range. This was mainly due to limitations of the underlying data model. Developing high quality data models needs both comprehensive expertise and data modelling understanding. Nevertheless the majority of all participants were very enthusiastic regarding the new approach in education compared to standard courses (fig. 12). Interestingly nearly one half of the students were quite sceptical at the beginning of the course.

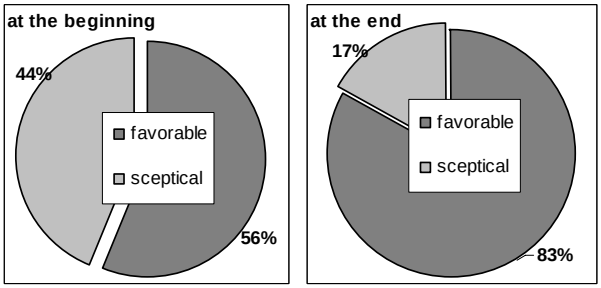

Fig. 12: Attitude to course at the beginning and at the end (n=41)

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