MULTIMEDIA-BASED EDUCATION IN CHIP DESIGN: CBT PRODUCTION AND EVALUATION

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ABSTRACT
LogiSyn is a computer based training program (CBT) on chip design and a representative of numerous recently created CBTs using our *reference model* for fast and economic CBT development with Authorware. In order to measure CBT efficiency in support to, or even as a substitution for traditional teaching methods, two extensive evaluations of students participating in lectures on chip- and system design are presented. Furthermore, the concept of a reference model for low-cost low-time production is sketched: CBT design should only take two to four times longer than traditional design of printed lecture material.

KEY WORDS
E-learning, Evaluation, Reference Model, Chip- and System Design (VLSI)

Introduction

Universities and companies all over the world are developing and researching on E-learning concepts. We live in the era of computers, internet, and information at our fingertips, in which teaching and learning methods are influenced by several technical innovations and digital connectivity. Books and blackboards as standard classroom tools are being replaced by computer displays and keyboards, while internet and multimedia techniques support virtual learning environments providing not only diversity of information and interaction, but also giving students the freedom to learn when and where they want to [1].

This recent evolution in the delivery of education has resulted in much debate on the efficiency of distance learning, raising important issues on the pro and cons [2,3]. Despite this discussion, we seem to be in the midst of an internet revolution in which yesterday's local bounded education has become a subject of e-commerce dealing knowledge and education as a commodity. Here, management consultants prognosticate one of the most lucrative business segments of the near future [4].

Much more than conventional lecturing, computer based training (CBT) can apply cognitive and constructive concepts of modern didactic learning methods. Using audio, video, and animation in combination with interactive and explorative design, a CBT can make learning become an experience. However, in reality this goal is very hard to reach because the design of good CBTs can be extremely time consuming and expensive. The established concept of students sitting in an auditorium with a lecturer may not be replaced by CBT too soon, but it will be enhanced by CBTs right now.

For this purpose, we developed a *reference model* (RM), making the production of high quality CBT much easier and faster. Based on the RM, numerous CBTs have been produced with the restriction that the production time must not exceed that of corresponding printed lecture material by a factor of two to four.

All of our recently produced CBTs offer interactivity to a high degree and typically include synchronized music, voice, video, and animation making them true multimedia applications. Every year, our students get a CD with about seven CBTs requiring 500 Megabytes of disk space (*LogiSyn* takes about 50 Megabytes), in conjunction with the other lecturing material. As an alternative, we are offering students to download the CBTs. The high demand on storage capacity disqualifies them for true online Web Based Training (WBT), because the required internet bandwidth is extremely high and not always available to the students at home. Another major aspect disqualifying true WBT deployment is the integration of special chip- and system design software like hardware simulators or circuit placement and routing tools in some CBTs that cannot be distributed online. Specific operating systems are needed (others than Windows), the software licence is too expensive, it comes in combination with special hardware or the package would simply be too big. But because WBT is only a subset of CBT, the presented findings should also apply to WBT and will point out some interesting perceptions.

LogiSyn covers logic circuit synthesis as an important part in high-level chip- and system design. Basically, it teaches how a register transfer model designed with the hardware description language VERILOG [5] is translated into a gate model using special hardware libraries. In order to measure the learning efficiency of *LogiSyn*, we performed two student evaluations in 2001/02 and recently in 2003/04.

A CBT reference model

A prerequisite for developing high quality CBTs is a powerful and comprehensive authoring tool supporting complex interactions and the use of synchronized multimedia content. Since six years now, we find Macromedia's Authorware to serve this purpose well, being one of today's leading products of this kind [6]. In addition to animation of visual contents, Authorware provides a powerful script language; the latest release (version 7.0) also understands JavaScript. This enables the CBT designer to control the program flow, interact with the user, and analyze his overall behavior in order to apply special calculations on the presented content or to execute external programs or functions. This is also of particular interest, when one wishes to save and evaluate user data like adaptation time and test results using a learning management system (LMS). Of course, Authorware supports SCORM [7] and AICC [8] standards.

We put high demands in functionality, quality, and didactical aspects on the RM like complex user navigation. Actually, the RM's primary purpose is to support the designer with an easy to use framework so he can concentrate mainly on implementing the contents as shown in figure 1.

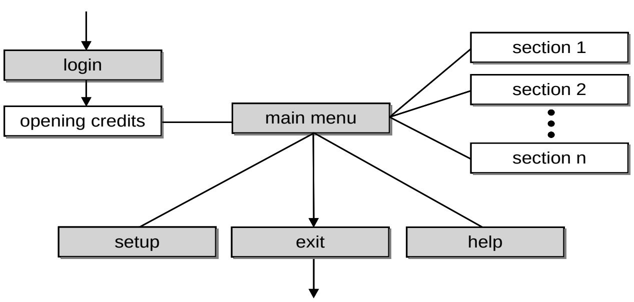

Figure 1: RM-automated parts (dark) and contents to be implemented by the CBT author (white)

The second purpose of the RM is to provide an intuitive user interface to the learner as shown in figure 2, including controls for pages, page groups, chapters, an automatically generated table of contents, a pause function, a learning history, and bookmarks.

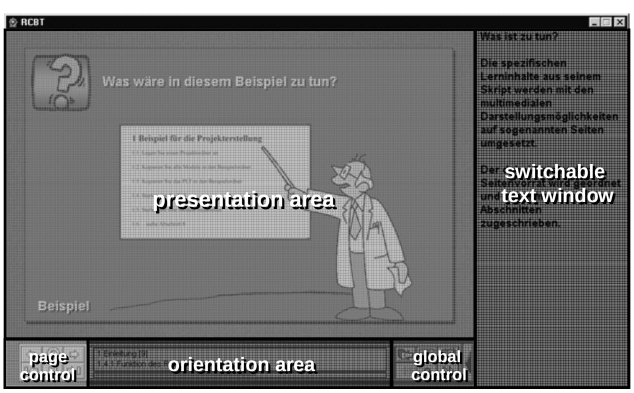

Figure 2: CBT layout with the RM

The RM package also includes three CBTs as a systematic introduction on how to use the RM most effectively and what else should be taken into consideration when designing a CBT. Finally, the package includes the *project linking tool* (PLT) enabling the CBT designer to create learning systems by combining various CBT modules, shown in figure 3.

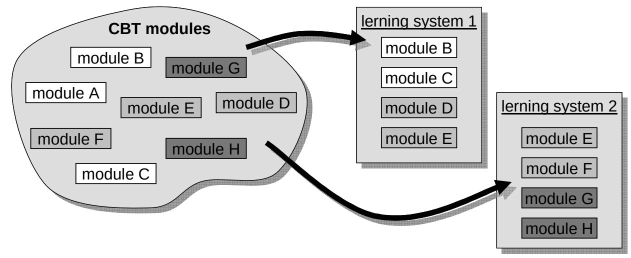

Figure 3: Combining CBT modules to learning systems with the PLT

Striking a balance

We started to design our own CBTs in 1997, since existing commercial CBTs of that time did not satisfy particular claims for blended learning. For example, the learner could not actually practice complex chip design CAD-tools. For the purpose of reusability and interoperability, the concept of our universal reference model was developed, to create interactive multimedia CBTs with speech support. Today, we have produced 41 CBTs on chip and system design and gathered a great deal of experience doing low-cost low-time CBT production.

Since 2000, we are participating in the *e-learning Academic Network of Lower Saxony* (ELAN Niedersachsen) project [9], with the purpose to support universities on integrating new e-learning concepts and multimedia into their teaching. Since then, we have improved and enhanced the RM. In January 2004, it was included as a "best practise" example of ELAN and made available to the ELAN participants.

Low-cost low-time CBT production

For the last six years, we are offering a multimedia lab to our students in which they can develop a CBT on a given topic in chip- and system design in teams of three to four students over a period of only 12 weeks. As a preparation for this lab, students have to participate in a lecture on chip- and system design and take an introduction on the authoring tool Authorware. The multimedia lab is coached by a graduated student and supervised by an assistant.

Figure 4 shows the four phases of the multimedia lab. It starts with the **conception phase**, where students develop a rough idea of the learning targets and how this goal might be achieved. This includes the definition of prerequisite knowledge, specification of the CBT structure and collecting ideas for appropriate tests. The conception phase takes one week.

During the following **scripting phase,** teams will develop a detailed structure of chapters, sections, and pages. CBT key frames are sketched, and spoken text explanations are drafted, but we do not demand students to put down strict screen layouts; they may still use good ideas during implementation. They also need to set up a time schedule for the oncoming implementation phase. The scripting phase takes two weeks.

After a demand evaluation, students start with the **implementation phase**. During only seven weeks, the CBTs are implemented by "filling out" a copy of the reference model, including the creation of visual animations and recording of all audio material.

In the final **evaluation phase**, finished CBTs will be exchanged among the teams for review. This gives each team a chance to compare and to receive feedback. We found that students engage quite seriously in evaluation and make constructive suggestions.

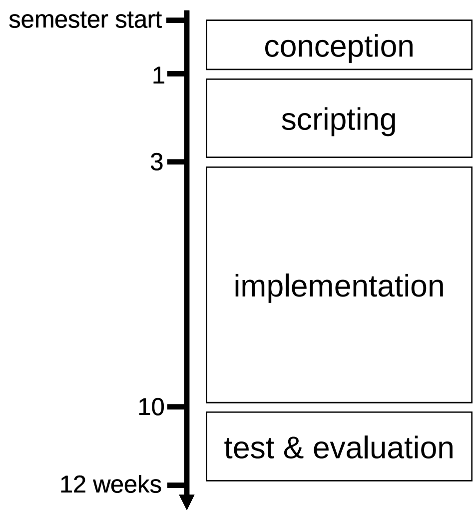

Figure 4: CBT design phases during the multimedia lab

CBT motivating students

As a result, we are now able to cover a relevant part of content from the conventional lecture by CBTs, which makes it possible to empirically study the efficiency of our CBTs in direct comparison with conventional lecturing.

How effective are CBTs when used in conjunction with traditional lecturing or even as a substitute? How will students assess CBTs, when using them to prepare for a test? To find the answers, we performed an extensive evaluation among students of chip- and system design, based on a selected chapter on logic synthesis [10] that takes about two weeks in the conventional lecture. The CBT LogiSyn covers the relevant learning content comparably.

We asked our students to volunteer in an anonymous test. Since we were especially interested in the amount of time they would spend on learning, we asked them to keep a record of their learning behavior while preparing for the test. As shown in figure 5, we divided them into three groups: **Group A** was asked to use all the material and resources offered, including lecture participation, lecture textbook, and the CBT *LogiSyn*. **Group B** was allowed only to visit the lecture and to use the textbook, while **group C** was only allowed to use the CBT without lecture participation. This partitioning should demonstrate CBT efficiency on both, as a lecture addition or as a substitution.

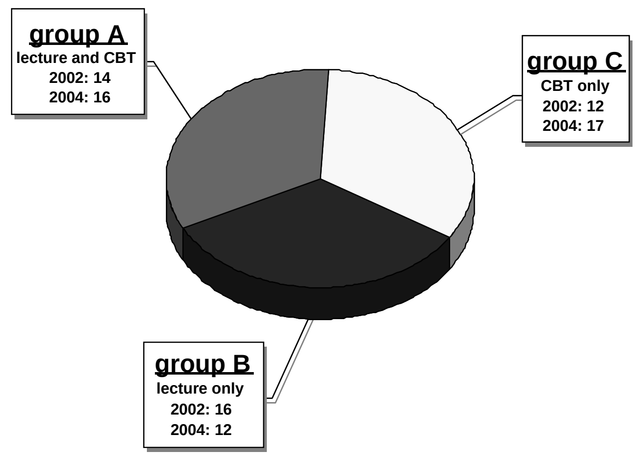

Figure 5: Student distribution during evaluations

We were convinced of our CBT and assumed group C to achieve a result comparable to group B, because both groups would miss one resource of information, while group A should achieve the best test result having both resources available. Furthermore, we predicated:

- If A and B do better than C, this would indicate a lack of CBT quality.
- If A and C do better than B, this would indicate a positive CBT effect.
- If B does better than A and C, we should doubt the usefulness of our CBT.

Evaluation 2002

The first evaluation took place during the winter term 2001/02. 57 students participated, 50 of them attended the test, and 49 returned a time record and a questionnaire. Eight Students stated that they had no time to prepare for the final test, so we excluded their results.

Figure 6 shows the average test results of all groups that only slightly vary by less than 5%. As we predicted, this proved our CBT to be qualified for transferring knowledge to the students. In addition, since group A could not profit on having both resources available, we may suppose that there has been no disadvantage for a specific learning method, neither for E-learning nor for the conventional learning. For example, such a disadvantage would be an exercise that can only be answered correctly using the CBT.

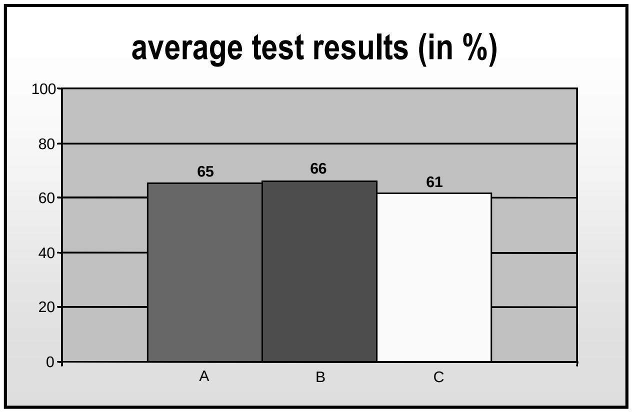

Figure 6: Average test results of groups A, B, and C during evaluation 2002

But how efficient was *LogiSyn* compared to the conventional lecturing? The analysis of the learning records and the questionnaire revealed success as shown in figure 7. Students of group C using only the CBT, had spent an average time of only 2:46 hours preparing for the test, while groups A and B both spent about 5:50 hours. Keeping in mind that the results of all groups did not significantly differ, this gap exposes that *LogiSyn* was almost twice as efficient as conventional learning. We conclude that using the CBT does not yield better test results, but it considerably reduces the time to reach a certain level of knowledge.

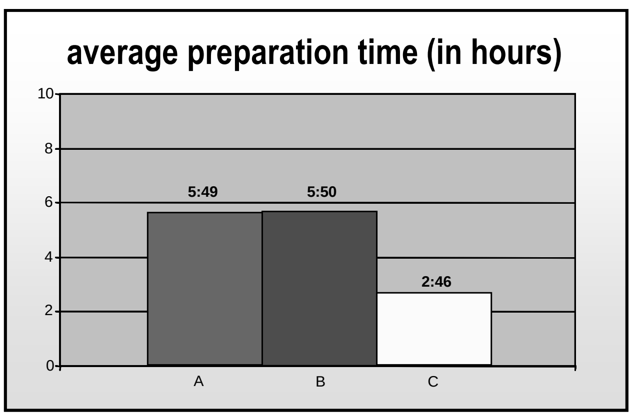

Figure 7: Average preparation time of student groups A, B, and C during evaluation 2002

Evaluation 2004

To fortify our positive findings of the evaluation in 2002, we scheduled a second evaluation during the winter term 2003/04 with a similar test configuration. This time 103 students participated, 60 of them attended the test, 45 returned a time record and the questionnaire.

Of course, we suspected equivalent results in this test, but as shown in figure 8, this time there was a significant difference between group B with an average test result of 51% and group C with an average of 69%. Since group A also did a considerable better job than group B, we saw our second predication fulfilled: The use of the CBT had a significant positive effect.

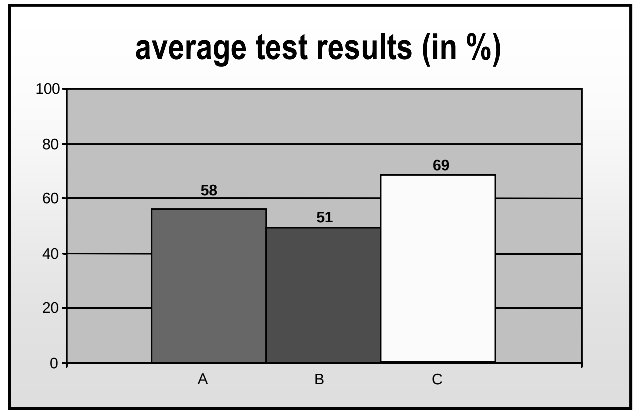

Figure 8: Average test results of student groups A, B and C during evaluation 2004

However, how could we explain that group C even did a significantly better job than group A who also had the advantage of the CBT? Should not group A be the winner, since they had all resources available? From the time logs, we found that group A had spent 76% of learning time in class and with the textbook, but only 24% on the CBT – obviously, this was not enough. As shown in figure 9, group C had spent only an average of 3:45 hours E-learning for the test. This is still a lot more than group A spending only about 1:30 hour E-learning and another 4:43 hours of learning using the textbook and conventional readings.

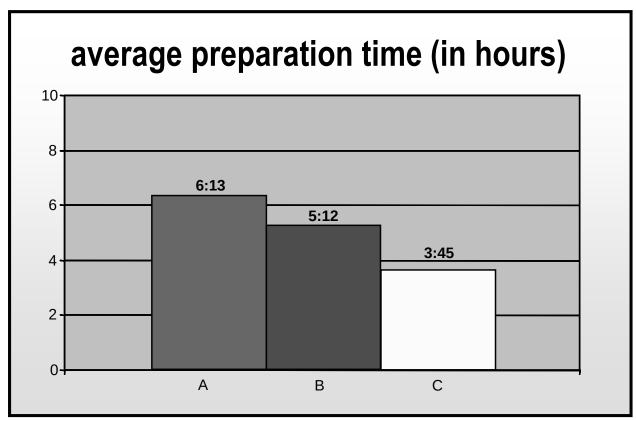

Figure 9: Average preparation time of student groups A, B, and C during evaluation 2004

We were delighted by these results because they had proven the efficiency of our CBT. This will be a motivation for us to promote the production of CBTs and to use them in lectures.

Questionnaire results

Besides the time log and the test results, also the questionnaire revealed some interesting facts. As we calculated the average points on every exercise for each group, the strengths and weaknesses of *LogiSyn* compared to the lecture became clear and encouraged us to particularly enhance some chapters. Figure 10 shows the detailed test results of the evaluation 2004. This was affirmed by the student answers on the question, whether they found the CBT precise enough (groups A and C only): 88% were satisfied in 2002 but 100% in 2004.

Even though *LogiSyn* received much approval, in 2002 about 95% of group A students would recommend to use the CBT in addition to the readings and almost 100% in 2004. An unambiguous vote for the concept of blended learning.

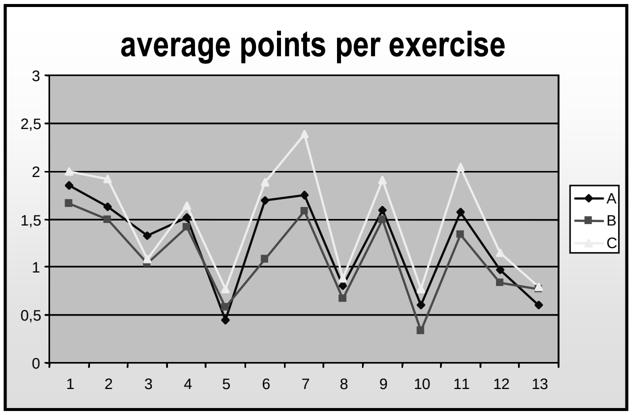

Figure 10: average points on every exercise for each group during evaluation 2004

But there are also some results that we cannot clearly explain. In 2002, students of group C criticized that they were missing the social component of the lecture. Since they did not meet each other, they did not discuss what they had learned, leaving some questions unanswered. We adjusted this disservice for evaluation 2004 by offering an online forum on our website. Expecting this to meet student's demands for communication and collaboration, we were surprised that it was not used at all. Perhaps the period of only two weeks was too short to establish online activities or students prefer to communicate face-to-face anyhow.

Conclusions

The reference model is a great help for designers to produce high quality CBTs in a short time exceeding classical textbook production by just a time factor of two to four. The partnership of trained students designing CBTs for prospective students is by no means a one-way exploitation of low-cost student power. Rather, in designing CBTs students become teachers thus expanding their own knowledge. We discovered that designing CBTs motivates students to thoroughly research the subject, developing ideas to communicate the content within the CBT. In addition, our two evaluations have proven that CBTs are serving well in terms of blended learning. They might even have the potential to replace the lectures but our questionnaires revealed that students do not whish a replacement, whether it is efficient or not.

Of course, these two evaluations might not give a complete point of view whether CBTs should be used in addition to or even as a substitute for conventional teaching methods. The selected chapter of logic synthesis is very suitable to be transcribed in a training program and enhanced by interactivity and multimedia, which might not always be the case with other contents. Nevertheless, this study has shown that it is a good idea to integrate e-learning methods, because learning using multimedia, and giving students the opportunity to interact and explore learning matters, is exceeding efficiency of conventional lecturing by far. We found that E-learning does the job quite well, but good grades should not be the only thing taken into account when we discuss the effects of E-learning.

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