INTERNET-BASED E-LEARNING PLATFORM FOR AN INDIVIDUALLY CONTROLLED PROGRAM WITH SEQUENTIAL STRUCTURE AND OBLIGATORY TESTS FOR PERFORMANCE EVALUATION

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Abstract: An Internet-based e-learning platform has been developed and evaluated. It allows individual remote teaching with password-controlled access. Different measures have been established against misuse. The main components of the platform are the body of learning content, the examination part, the glossary and the picture gallery. The learning content is sequentially structured in sections and subsections. Subsections consist of a learning module and an examination part and have comparable weight. Each learning module has to be completed successfully with a multiple-choice test before advancing to the next subsection is possible. This test together with other measures (e.g. recording of time parameters) allows the monitoring of progress and the evaluation of individual learning performance. Evaluation of both the platform and a learning subject has been performed by students in higher master courses. The learning subject has been the cardiac pacemaker with an introduction into cardiac functional anatomy and electrophysiology. The students have used their private computers. The evaluation has revealed some deficits, but also a high degree of acceptance by the students.

Key words: **Internet-based e-learning, sequential knowledge presentation, performance monitoring, integrated multiple-choice test, evaluation results**

Introduction

Modern life style requires new educational methods with the special consideration of lifelong learning. These new methods may either supplement or replace the traditional mode of face-to-face or classroom teaching. They should allow individually matched and self-controlled progress with access at every time and from every place. Especially in those engineering disciplines including interdisciplinary fields like Medical and Biological Engineering with an actual knowledge lifetime of only about 5 years, lifelong learning is essential for both the updating and the extension of the personal knowledge. Lifelong learning is therefore one of the most essential demands of the Bologna Declaration [1], especially with regard to the labor market qualification and its rapidly changing demands. Another request of the Bologna Declaration is the harmonization of higher education within the signature states not later than 2010. Remote teaching and tele-learning have a promising potential for providing independence from local restrictions and teaching deficits and hence may become an essential component of this harmonization process.

Presently available technologies offer different approaches for the realization of e-learning, e.g. based either on data carrier (e.g. CD-ROM, DVD) technology or on Internet technology. Both approaches have their specific advantages, shortcomings and constraints. The data medium based approach provides an offline procedure and may require special user equipment. It allows only restricted applications of interactive operation and no real evaluation of individual progress and performance. Knowledge updating or extension of the content requires the distribution of another data carrier with the revised version. There is no safety against the employment of outdated versions, comparable to the problem with textbook-based learning. The Internet-based approach allows online access and extended possibilities for interactive operation. Knowledge updating and extension of the content as well as performance evaluation are rather simple if an organizational structure with centralized database management is employed. Applications are possible on usual PCs and do not require special equipment. Both approaches are sensitive against different kinds of misuse, e.g. misuse by users in order to affect the results of their performance evaluation, or the manipulation of knowledge with hidden integration of commercial information and advertising. The Internet technology, however, renders possible, in contrast to data carrier based technologies, different and more effective measures against misuse by the users, due to the online connection to a server.

Taking into account all aspects and assessing the future potential of the different technologies, it was decided to use the Internet technology.

E-learning offers a challenging potential that cannot be utilized completely if it is understood simply as the “electronic presentation” of textbooks or manuscripts which are prepared for classroom teaching. It

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requests new methods of knowledge presentation. For the adequate organization and presentation, different strategies are available, e.g. the linear or sequential mode or the "conceptual network" mode [2]. Both strategies offer different advantages, shortcomings and constraints.

In case of the conceptual networks, the learning process is more or less an "intuitive exploration of the knowledge environment". The process accords with surfing through a hypertext. It is started at one point in the network, e.g. a keyword. This point is linked with several other points, each of which is again linked with many other points. At each point the user can determine which of the links he wants to follow to another point. By this way, the user himself controls both the extent and the depth of the acquired knowledge. This exploration strategy can stimulate the curiosity and play instinct of users, especially if they are trained from the web to apply such methods. This kind of learning process may even help to support the memorizing of the acquired knowledge. However, the learning process is neither systematically executed nor does it allow the continuous monitoring of the user's progress or performance. This strategy seems therefore to be more suitable for postgraduate courses, when users want to compensate individual deficits in their knowledge.

Another strategy is based on the linear or sequential mode of knowledge presentation in which depth and extent of knowledge are determined by the learning program that has to be gone through in the prescribed sequence. Obviously this strategy is not very different from the traditional style of classroom teaching where the student is rather a "passive consumer" than an "active searcher". The acquisition of knowledge can be systematically and hierarchically organized, and the presentation can be optimized with proper regard of didactic demands. However, the user has to follow strictly the sequential course independent of his actual level of knowledge in that field. Progress in learning can be easily monitored, and an evaluation of the performance can be achieved, even if the execution of the learning process occurs on an individual time base. Feedback can be provided to the user that informs him about his current state of assessment. This strategy seems to be more convenient for users who prefer or need a complete and systematic introduction to a special field, i.e. for students primarily in lower courses like bachelor and master courses. Evidently this strategy is much better suited for the harmonization of higher education than the "conceptual network" strategy.

Taking into account these aspects and with regard to the concerned students it has been decided to employ the sequential or linear mode.

Materials and Methods

This chapter provides a brief survey on the system configuration, the shell, the content and organization of the learning material, and finally the evaluation procedure.

The system configuration

The system configuration is realized by a three-tier-architecture (fig. 1):

- the database layer;
- the application and business logic layer;
- the presentation layer.

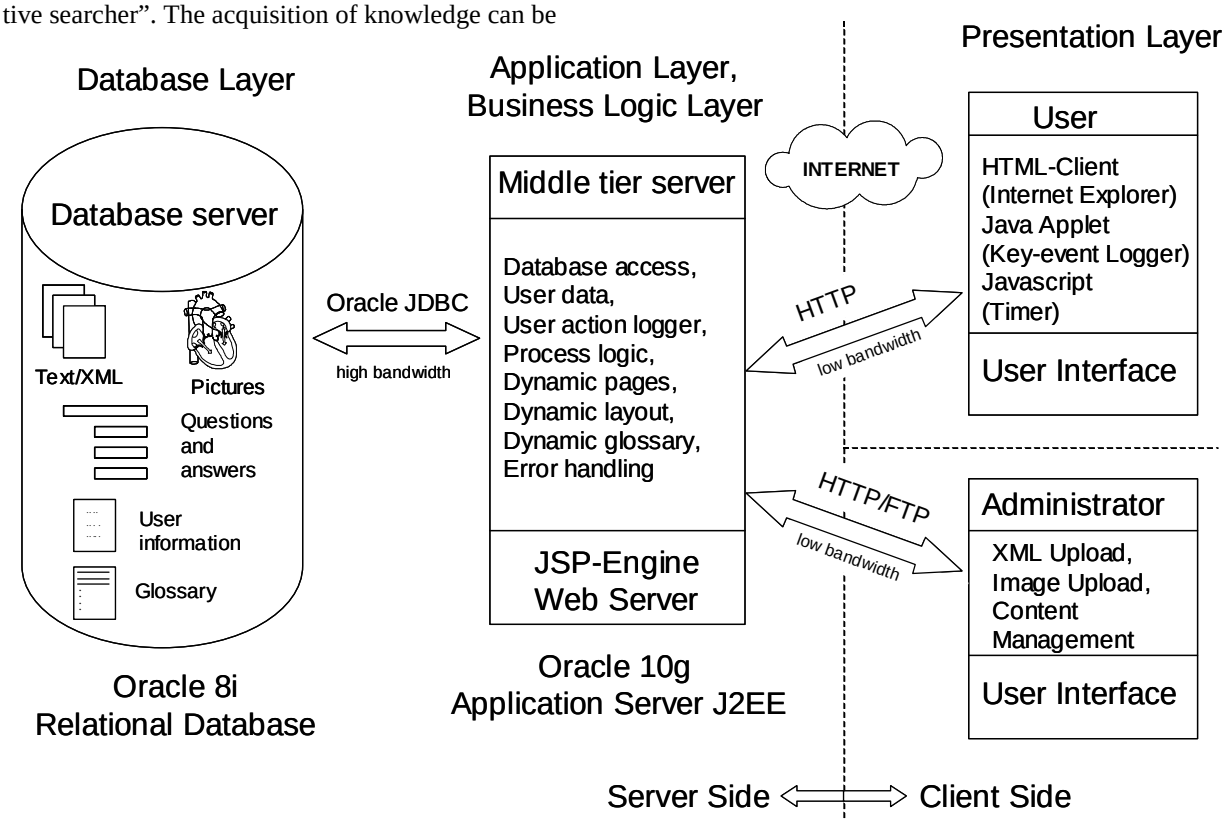

Figure 1: 3-tier system architecture of the developed e-learning platform

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The database layer is based on an Oracle 8i relational database. In the database layer the learning material is presented by XML-documents. Furthermore the database layer contains the picture gallery (figures, illustrations, tables etc.), the glossary, the questions and answers for the multiple-choice test, and also the user status information. The learning material, the picture gallery and the glossary can be opened by the user only in the learning mode, but not in the examination mode.

The application and business logic layer is realized by an Oracle 10g application server. It is connected with the database using a high bandwidth connection and Java Database Connectivity (JDBC) access. The main tasks of the application server are:

- control of the password restricted access to user status information and the learning content;
- provision of dynamically created web pages using JavaServer Pages (JSP), including the dynamic linking of images and key words [3];
- flow control in dependence on the user's individual progress in working through the learning material;
- error handling.

The Java 2 Platform Enterprise Edition (J2EE) has been employed for the development [4].

The user interface is based on a HTML compliant client (Microsoft Internet Explorer). JavaScript is employed for the realization of input control routines, and a Java applet as protection measure to prevent downloading of the learning material. In order to avoid conflicts with intermediate firewalls, only the Hypertext Transfer Protocol (HTTP) is used for the connection with the application server.

The administrative interface is also based on a web browser and primarily responsible for XML uploading (learning content), image uploading, and content management.

The shell

The structure of the shell is independent of the learning content. It determines how this material is presented. Furthermore, the shell reflects the learning strategy since it controls all procedural steps. Basically the shell consists of 5 main parts (fig. 2):

- A: general user instructions;
- B: learning material, organized in sequential mode;
- C: examination, i.e. multiple-choice tests with questions and answers which can be varied in their order for repetitions;
- D: glossary, i.e. key words with explanation;
- E: picture gallery, i.e. figures, illustrations, tables.

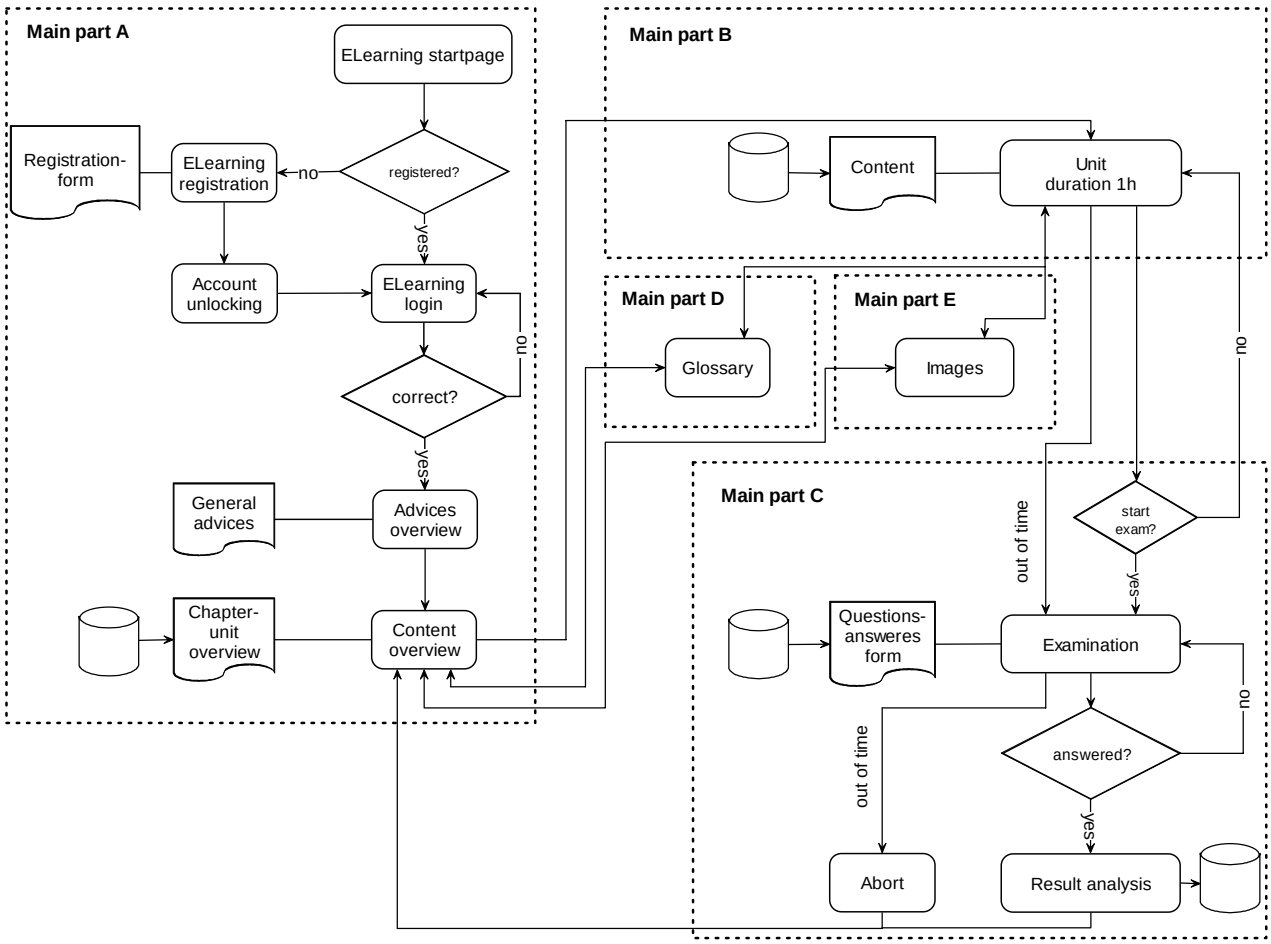

Figure 2: Elements of the e-learning shell

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When a user is logging in, the system checks his authorization before access is permitted to part A. Downloading of the learning material and the multiple-choice test are prohibited in order to exclude misuse. If the user nevertheless attempts downloading, he loses the password-based authorization. From part A the user can continue to the learning material in part B. He can start either with a survey on the whole learning material or directly with working in the learning material. He begins with his work in the learning material either in the first subsection, or – if he has already successfully completed some subsections - with the next non-completed subsection.

The user can decide whether he will quit without examination or when he wants to continue to part C, i.e. the examination part of this subsection. Both the time for working through the learning module and for the examination can be limited. This is another measure against misuse by the users. If the preset time for the learning module is over, the user can either start with the examination part of this subsection or quit without examination. If the preset time for the examination part is over, the user will be set back to the learning module of this subsection.

The user himself can quit at any time whether he is actually in the learning module or in the examination part. In all cases when the user has quitted a subsection without successful examination, the program controls that he starts at his next access again with the learning module of that subsection.

When the user is working in the learning mode, he has free access to all pictures in the gallery and to all key words in the glossary. Pictures and key words with special relevance to the learning material in the actually opened subsection are indicated in the text with the pictures in thumbnail size. If the user clicks on a keyword, the whole explanation is shown, and if he clicks on a thumbnail picture, that picture is presented in real size. Leaving the picture gallery or the glossary will bring the user back to that place in the subsection from where he had started to the picture gallery or the glossary.

All answers must be correct in order to pass successfully through the examination part. If the user fails, it depends on the "weight of failure", i.e. the number of false answers, whether repetition is required only of the respective subsection or the whole section. In case of repetition, the sequence of the questions and the answers to each question is varied. For evaluation of the individual performance different data are recorded by the application server and stored in the database. Such data may be the total login time, the time required for the learning module and the examination part of each subsection, the surpassing of the preset time and the "false" answers, both given for regular runs and for repetition runs.

The learning material

Sequentially structured learning material requires the presetting and limitation of its extent. The body of knowledge may range from fundamentals up to advanced levels. The borders of the respective field against other fields should clearly be considered.

Those requirements are well met by the knowledge about cardiac pacemakers. The understanding of cardiac pacemakers requires broad basic knowledge in the medical-clinical as well as in the engineering area. The special knowledge in this field can be well separated from other fields in biomedical instrumentation. The high-level knowledge is related with rapidly advancing technology and growing fields of medical application.

For the learning material that has been used for the evaluation of the developed system, the content has been matched with the available knowledge of students in the 4th year of a 5-years program for Diplom-Ingenieur (equivalent with a master's degree), i.e. with good knowledge in engineering courses (e.g. applied physics, electronics, circuitry, signal processing), but only basic knowledge in biomedical engineering as well as in medicine. The body of the learning material has been subdivided into 5 sections:

A. Anatomy of the heart and cardiac mechanics;
B. Electrophysiology of the heart including the generation and spreading of excitations;
C. General functions, technology, pacemaker coding, classification and design of cardiac pacemakers;
D. Special functions and advanced technological features of cardiac pacemakers;
E. Problems, failures, complications.

Each section is again subdivided into 5 subsections of comparable length. The weight of each subsection with the learning module and the examination part was estimated to be approximately equivalent with 90 minutes or 2 academic hours in traditional classroom teaching. It was assumed that it should be possible for the user to complete a subsection with full concentration and without getting seriously tired.

It is recommended that 1 ECTS (unit of the European Credit Transfer System) shall be equivalent to 15 academic hours of regular lectures. For regular lectures, however, the student needs additional time for the preparation of examinations. On contrary, in the presented e-learning program the examination is an integrated component and does not require extra time. Therefore the total time requirement for all 25 subsections was considered to be equivalent to 2 ECTS.

The evaluation procedure

10 engineering students have evaluated on voluntary basis the total system with special regard to usability and educational relevance. The students were in the 3rd or 4th year of the 5-years electrical engineering program. Most of them had good knowledge in anatomy, physiology and biomedical engineering. Only some of them had already basic knowledge about cardiac pacemakers. Nearly all of them had "average" expertise about using the Internet for information searching. Some students had excellent experience with the development of software for different applications, whereas others had no real experience in that field. The students used their own PCs. The employment of dif-

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ferent types of PCs should help to identify technical constraints and problems. Minimum requirements for the PCs have been an Intel PII-350 MHz (or equivalent) processor, 64 Mbyte main memory capacity and the Microsoft Internet Explorer 6.0. The bandwidth of the Internet connection should be at least 56 kbit/s.

For the students this participation was recognized as working on a project. The students had been provided in advance with all background information including the purpose of the evaluation. They could obtain a mark comparable to that of a regular examination for a 3-hrs lecture. The mark was depending exclusively on 2 demands: (1) that marks were given as answers to certain questions concerning the system evaluation and (2) for free remarks, e.g. critics, suggestions for improvement, comments on detected problems and description of failures. Of course the students had to complete successfully the whole learning program, although the usual parameters for performance evaluation have not been considered for their mark. None of the students had solid experience in the answering to multiple-choice questions. In case of operational or other problems, the students could contact the system administrator directly by phone or email.

Results

In this section the results of the evaluation will be presented.

All 10 students have successfully completed the evaluation. They have given scaling marks to certain questions. Additionally most of them have supplied more or less extensive comments in free style. These comments have been both critical remarks, e.g. concerning software problems, and suggestions for improvement, e.g. concerning the operability.

10 features concerning the body of content and its presentation as well as the usability of the platform have been asked. Evaluation should be executed in a scaling mode using school marks, i.e. 1 = excellent, 2 = very good, 3 = good, 4 = poor, 5 = insufficient. The results are shown in tab. 1. The shown scaling mark is the calculated average for all 10 students.

The poorest scaling mark with 4.2 is given to the question No. 4 “Support provided by the figures in the picture gallery”. The explanation is that most of the students could not open the thumbnail sized figures to full-size figures on their PCs. Some students submitted proposals how this problem can be overcome by appropriate software features (what in the meantime has been accomplished). There were more technical problems than expected due to the use of different types of private computers (and possibly non standardized software) by the students. One of these problems was that return to the original position from where visits in the picture gallery or glossary were started was not directly possible. This explains the rather poor scaling mark of question No. 10 “Operability on the private computer”, but also of No. 6 “User friendliness of the operation of the e-learning program”. These problems together with the submitted free remarks underline the necessity to test such e-learning programs on a multitude of different PCs as long as no technical standards for PCs and software are defined.

A frequent suggestion by the students has been the request to permit again success to subsections which had already been completed successfully without having to pass once more through the respective examination part (and the following already completed subsections) in order to return to the actual subsection. This request is comparable with the possibility to go back to a preceding chapter in books. Another suggestion has been to show the running time for the learning module and the examination, respectively. Both requests and more features concerning user friendliness have been installed in the meantime, too. Some few suggestions which would have limited the controlling capability, the recording of individual performance parameters, and the exclusion of misuse were not considered, e.g. to show the correct answer instead of requesting the repetition of the whole subsection or, in severe cases, the whole section, if a false answer had been chosen.

There was another interesting finding: Those students who have submitted extensive free comments, both critical remarks and suggestions for improvement, have given better scaling marks than students who have not supplied any free comments.

Table 1: Evaluation results (average scaling by 10 students)

1.	Comprehensibility of the introductory and operating instructions	1.8
2.	Didactic organization and presentation of the learning material	2.3
3.	Relevance and completeness of the learning material	1.7
4.	Support provided by the figures in the picture gallery	4.2
5.	Support provided by the key words and their explanation in the glossary	2.6
6.	User friendliness of the operation of the e-learning program	2.5
7.	Comprehensibility and fairness of the multiple-choice questions	3.0
8.	Time budget availability for the learning part	2.0
9.	Time budget availability for the examination part	2.0
10.	Operability on the private computer	3.1

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Some students developed special and different strategies: In the one case they wrote a list of key words and statements from the learning module before they quitted without entering the examination part. Obviously they used this list together with textbooks to prepare for the examination. At the next access they started in the learning module of the non-completed subsection, where they stayed only for a short time before they entered the examination part. Remarkably these students did not at all or not frequently visit the glossary (this observation together with a poor scaling of No. 5 "Support provided by the key words" was the reason for interviewing them). Another strategy has been: After entering the examination part, the students read (and possibly copied) the questions with the multiple-choice answers. They used this material to identify the correct answers, possibly using books or with the assistance of fellow students. This became evident because those students quitted the examination part after some time without attempting to answer the questions. At the next access these students, too, started again in the non-completed learning module, but stayed there only for a few seconds and then entered the examination part, but now it was the second visit. These different strategies demonstrate the tactical and creative imaginativeness of the students. Possibly they were uncertain how their efforts will be recognized. Based on this uncertainty, they have employed their special strategy to combine three aspects "safety", "recognition" and "amount of additional work", e.g. to accept a high risk combined with high recognition by starting the examination directly after the learning module, a medium risk combined with medium recognition by quitting the learning module before entering the examination part, but with additional preparation using the own key word list, or a low risk combined with low recognition by quitting the examination part before attempting to answer, but after having copied the questions and answers for thorough preparation.

Discussion

There is no doubt that harmonization of higher education and lifelong learning with the aim to acquire a first or to continue the existing qualification for the labor market is a great challenge and requires new teaching and learning methods. One of the solutions might be e-learning, especially Internet-based remote teaching with special regard of self-control and individual timing. In the connection with the described evaluation it was found that most work by the students (although they were regular university students without the necessity of regular daily work for their living expenses) was accomplished late in the evening, during the weekends and especially during the holidays at the university. But until now only poor experience is available concerning the competitiveness of e-learning against traditional classroom teaching.

The described e-learning platform contains a shell that allows sequential structuring of the learning material, integration of examinations (e.g. multiple-choice tests), continuous progress monitoring, password-controlled access, and centralized database management. The shell can be filled with different learning contents which have to meet only few requirements. It must be taken into account, however, that the time which is necessary to prepare such learning material together with the questions and answers for the examination, the glossary and the picture gallery, can be about three to four times the time that is necessary to prepare the same material for a traditional classroom lecture.

The resonance by the students who have participated in the evaluation was very positive. There was a frequent request to make this e-learning program about cardiac pacemakers available as regular educational course.

Although different and complex safety measures have been considered in order to exclude misuse by the users, the students with creative imaginativeness have found tactical and surprising sideways which demonstrate the misuse potential of such programs.

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