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Game Play in Engineering Education—Concept and Experimental Results*

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Dynamic simulators combined with educational games may create a new and improved learning culture by taking advantage of the new knowledge and skills of today's students obtained from extensive use of interactive computer games. This paper presents a design basis and a set of online learning resources based on dynamic simulators that takes advantage of game-related features. The e-learning resources are used in basic engineering courses. Feedback from approximately 1200 engineering students is analysed, the main conclusion being that students clearly view game-related learning resources as having a positive learning effect.

Keywords: dynamic simulation; games; engineering education; e-learning; user feedback.

INTRODUCTION

ENGINEERING EDUCATION faces a number of challenges because of the recruitment situation in many countries. According to a recent survey [1] by The International Council of Academies of Engineering and Technological Sciences Inc., which has member academies in over 25 countries, attracting young students to careers as engineers, technologists, or technicians is a serious problem. Another citing describes the situation in the U.S.A. This country lost 25% of its undergraduate population in engineering between 1982 and 2000 [2]. The practical consequence of this decline is that on average the students are less gifted and less motivated, which may jeopardize current curricula in the sense that a significant number of students fail to achieve their final degree. Basic courses such as physics and mathematics are particularly vulnerable. An example of the latter is a failure-rate of between 29% and 37% in the basic undergraduate mathematics course at the Norwegian University of Science and Technology (NTNU) during the period 2001–2003, a rate unheard of some 10 years ago.

Today's student population is equipped with knowledge and skills from extensive use of computer games, or more generally interactive game software [3]. A computer game is a game composed of a computer-controlled virtual universe that players may interact with in order to achieve a goal. Characteristics of such games include a high degree of interactivity, advanced graphics, a highly dynamical virtual universe, and an incentive system to promote prolonged and more advanced use. Computer games are quite diverse and can be subdivided into genres such as action games, adventure games, arcade games, strategy games, puzzle games, racing games, role-playing games, classic games, and massive multiplayer online role-playing games (MMORPG). Typically young people have solid experience from several of these game categories. Reference [3] provides an in-depth discussion of the fact that the students have radically changed, in the sense that they think and process information differently from their predecessors. Reference [3] refers to today's students as digital natives since they can be viewed as 'native speakers' of the new technology. They have grown up with computers and computer games, in contrast to the 'digital immigrants', the previous generation, who only mastered computers in adulthood.

There is a huge amount of online learning resources available today as, for instance, summarized in the yearly-published repository by *The Internet and Higher Education* [4]. The use of online learning resources has spread across the engineering disciplines, and is used at virtually all higher-level teaching institutions. Some selected publications show this.

Reference [5] offers a thorough discussion on the replacement of traditional laboratories by remote and virtual laboratories available on the Internet for control education. Reference [6] presents a similar discussion focused on chemical engineering education. This study also includes validation by surveying student users.

Reference [7] presents an online computer-based training module for student education in software project management. The objective is to provide computer science and software engineering

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students not only with technology-related skills but, in addition, a basic understanding of typical phenomena occurring in industrial software projects. Reference [8] describes a management game in a different sector: construction or, more specifically, earthmoving. Student feedback emphasized how the game gave them insight into the reality of projects that theory by itself did not allow. Yet another example from management and planning is provided in [9] where the focus is on manufacturing planning and control within automotive component production. The game is used for training in both an academic environment as well as an industrial environment. Reference [10] reports on e-learning courseware for industrial engineering. An important feature is the capability to create computer-based material for case problems in a flexible and efficient manner.

Reference [11] provides information on the impact of Internet-based distribution on microwave and RF education. Further, specific challenges related to this engineering field are identified, and the importance of online learning resources as a contributor to resolve these challenges is emphasized.

Reference [12] focuses on power engineering where a case study shows how a design project can be used to provide intuitive insight when teaching power system design.

There is a growing understanding that educational games may create a new and improved learning culture [13]. New models that integrate learning theory and educational games are emerging [14, 15], and learning resources based on such models are also materializing [16].

It is quite clear from the cited literature that e-learning resources have enabled more interactive and advanced learning material. The scope of this paper is to test the hypothesis that e-learning resources supported by dynamic simulators, which include games, provide a useful concept for developing online learning resources within the engineering domain, especially for basic undergraduate courses.

This paper is structured as follows. First, a design basis that takes advantage of the new knowledge and skills of today's students is presented. Second, it is shown how the design basis is implemented into a coherent set of online learning resources. Thereafter, results from testing on a group of approximately 1200 users are reported. The users are engineering students at the Norwegian University of Science and Technology (NTNU), and the disciplines are mathematics, physics and control engineering. The paper ends with a discussion and some conclusions.

DESIGN BASIS

To address the challenges described above, a design basis for an online learning system that targets engineering education will be described. Today's students usually have long-term experience from games, especially computer and video games. This experience may be defined by the term 'game play', although no universally accepted definition exists [15], and the aim will be to use these skills and knowledge actively to enhance the learning process. This target has at least two important implications. First, the e-learning resources will include functions such as a high degree of interactivity, attractive graphics, a highly dynamical virtual universe and an incentive system to promote prolonged and more advanced use. These functions are all familiar to young people, since they usually have experience from several game genres, and each genre applies its unique blend of functions. Second, the actual implementation of online resources will be performed by digital natives, i.e. the native speakers of the new technology, to take full advantage of these skills and make sure that game play experience permeates all parts of the educational resources.

Interactivity is critically important to obtain a fruitful dialogue between an e-learning resource and its user. The design philosophy tries to promote interactivity on different levels and time horizons and can be explained as follows.

- Fast feedback during game execution. An example of fast feedback is when the user performs real-time control of some system such as an inverted pendulum, a cart, a magnetic levitation train, or a heat pump. This activity provides the user with a learning experience through learning-by-doing, thus increasing motivation by mastering a given task.
- Feedback through small intermediate tests. The user should assess her/his own progress to uphold motivation. Quizzes are excellent ways of spurring enthusiasm. An example is a quiz to check the knowledge level of some part of an exercise. Provided the user has acquired the necessary knowledge level the user may be exposed to all the correct answers. If not, the user may be asked to redo the latter part of the exercise and retake the quiz. In any case the user obtains feedback on his or her progress.
- Feedback on a completed exercise. On submitting the assignment the user may obtain immediate feedback on, for instance, a pass/fail level. Moreover, the student may simultaneously receive the solution of an exercise. Again this feedback may enhance the learning process since the user should be motivated to take advantage of the moment and immediately compare her/his own test results with the correct answers.

The visual packaging of online resources is important and a parameter that influences the learning effect of an e-learning resource. To exemplify, the visual image of such a resource is shown in Fig. 1. The graffiti-inspired image may seem strange to a mature audience. The image has, however, been very well received by present undergraduate students as will be addressed later.

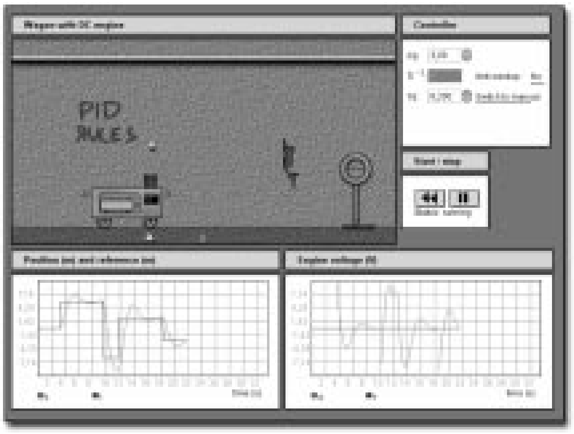

Fig. 1. An educational game—controlling a cart so as to catch falling balls—is presented through multiple views. The user can observe the simulation through animation as well as time-series plots.

A dynamic simulator constitutes a critical part of each learning resource. As mentioned earlier, a simulator reproduces, through the use of a mathematical model, the dynamic behaviour of a physical or abstract system such as the cart in Fig. 1. Such simulators provide two advantages. First, simulators support the concept of a dynamic universe and, second, simulators are excellent tools for conveying knowledge on physical phenomena relevant to the engineering domain.

Several factors should be considered when trying to turn a dynamic simulator into a game that is motivating, and at the same time maintains academic credibility and offers a realistic setting that supports the students' processes of reflection and knowledge development. Computer games are increasingly realistic, bordering on cinematic quality. Higher education institutions cannot compete with computer games with respect to playability, or sophistication in graphics and audio. Still, it is possible to make stimulating and interesting games simulations in 2D with simple audio effects. Children are, for instance, still delighted by the many simple Java and Flash games available for free on the Internet.

In our work important guidelines have been that the context chosen for the game should be easily recognizable, and the role of the system being simulated should be obvious in the game. The goal of the game should not be fully achievable through trial and error, and there should be several levels. The latter will in itself give the student valuable feedback on his or her progress and increase motivation. Further, using time or points as scores, gives a competitive edge that will increase the probability that users try several times. Finally, the use of humour is expected to increase motivation.

The outlined design basis may be disputed, in particular its belief in the use of a dynamic simulator, and knowledge and skills of the digital natives as a means to improve the learning process. This hypothesis will, however, be discussed later, after the presentation and evaluation of test results on a variety of student groups.

PROTOTYPE SYSTEM AND ONLINE RESOURCES

The prototype system used to develop and harbour the online learning resources will briefly be introduced in this section. Thereafter, selected e-learning resources that will be used in the subsequent user testing, are presented and commented upon.

PIDstop

The name of the prototype system is PIDstop. The name arises as an amalgamation of the terms 'pitstop' and 'PID-control'. Pitstop is a place to refuel or more generally perform maintenance on a racing car, the analogy in our context is 'tanking up knowledge'. PID-control is an important term within the control engineering domain, the starting point of PIDstop in 2002. Learning resources from PIDstop can be integrated into any modern Learning Management System. The system is implemented using HTML/CSS, powered by a PHP server for dynamic content and MySQL database for storing user data. The dynamic simulations and games are implemented using Java Applets meaning that PIDstop learning resources are available to anyone with a Java-enabled browser.

Online learning resources

Over the last couple of years a number of online learning resources have been developed within the PIDstop system. Three selected resources, focusing on harmonic oscillations, magnetic levitation, and hydrodynamic forces, will be presented in the sequel. Complementary information on PIDstop resources and also on the use in other areas such as recruitment to engineering education is available in [17].

Harmonic oscillators

This e-learning resource is based on a dynamic simulator of a pendulum and the educational goal is to convey knowledge on harmonic oscillations as well as the properties of an unstable system as encountered in an inverted pendulum.

The pendulum is depicted in two different wrappings in Fig. 2. The role of the simulator as a means of conveying knowledge on harmonic oscillations should be easily recognizable. Interactivity is crucial, the student may, for instance, vary the weight of the ball at the end of the pendulum, the length of the pendulum, and the initial conditions. Results may be viewed in different ways: through the animation of the pendulum itself, or through time-series plots. Further, the learning resource includes quizzes both for self-testing, and final and immediate approval of the assignment. If the student fails the final test, it must be retaken until passed. The learning resource includes standard

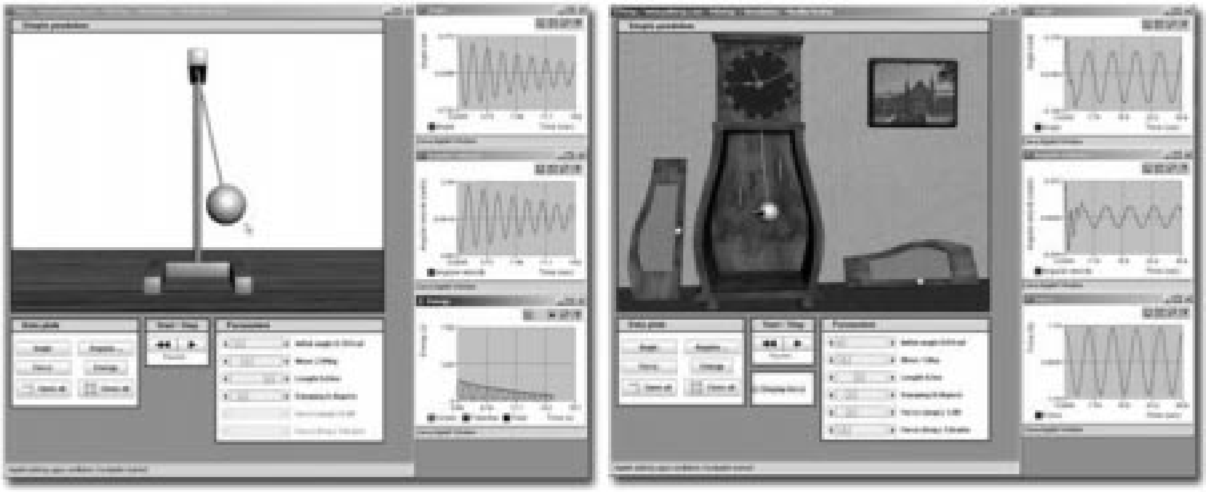

Fig. 2. A dynamic simulator of the same pendulum system used in two different learning resources: a stylistic pendulum and a grandfather clock.

background material on the physical system, such as a verbal description as well as a mathematical model. In Fig. 3 new elements are introduced. Emphasis is on an inverted pendulum and the simulator is wrapped into a game where the user needs to balance the fuel hose in an upright position and position the cart below the helicopter so as to refuel it. This is a fairly simple game that includes well-known game features: The user has a number of lives available: there is a highscore list, a high degree of interactivity, and multiple views. The score depends on the knowledge level of the user. In the latter case this means the user's ability to design a controller to stabilize the fuel hose efficiently so as to refuel the helicopter quickly. The students use the online resource in different modes, in a simulator mode and in a game mode, and users typically alternate between these modes.

Magnetic levitation

Magnetic levitation is an important physical phenomenon that is applicable in many situations. Two different e-learning resources, based on the same dynamic simulator, are shown in Fig. 4: a ball balancing in a magnetic field and a magnetic levitation train. The ball balancing in a magnetic field is designed as an interactive simulator to provide the students with a feel for magnetic forces, in particular how a varying current changes the magnetic forces and the severe nonlinearities, which characterises these systems. The magnetic levitation train is designed as a game where the user needs to steer the train in such a way that the passengers experience a rapid and smooth journey between two Norwegian cities. Again, the game itself is quite simple. When it is used together with an interactive simulator such as the ball balancing

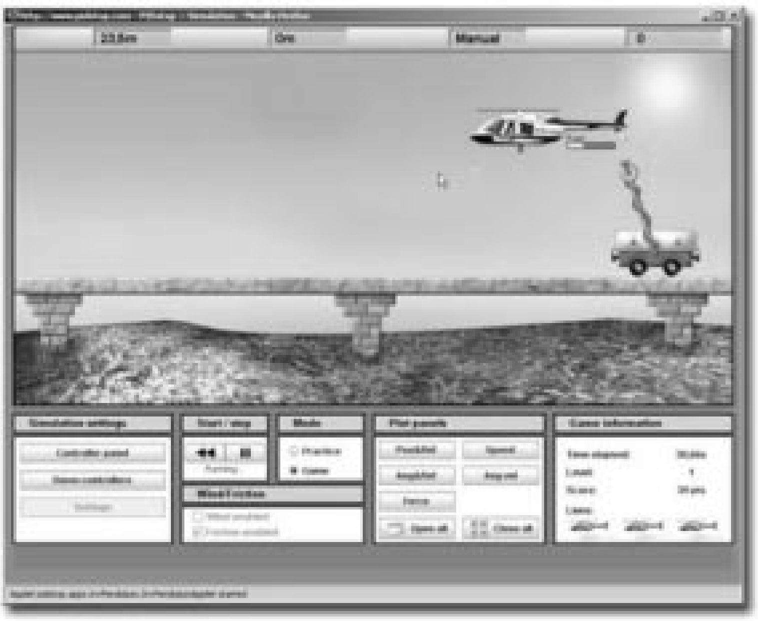

Fig. 3. An inverted pendulum is used in a game setting.

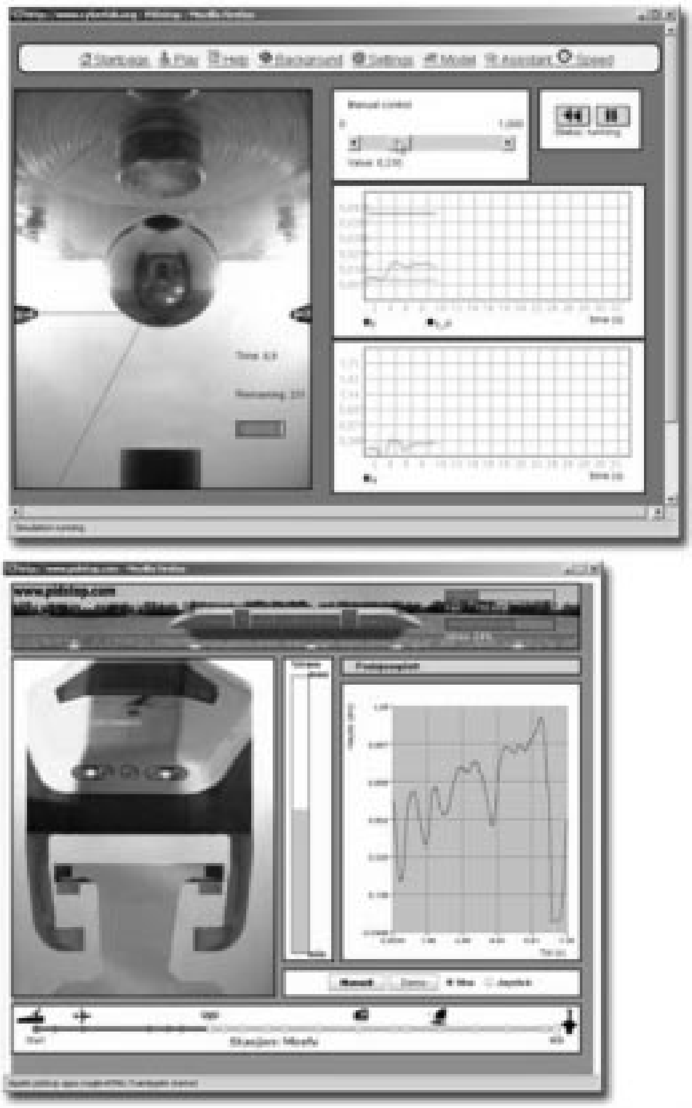

Fig. 4. Magnetic levitation is visualized in two different guises: a magnetic ball balances in an electromagnetic field (left); a magnetic levitation train is used in a game (right).

in a magnetic field, and other learning material, it helps to motivate and maintain the interest of the user through a goal-oriented learning process and the use of competitive features. Further, we claim that these learning resources can be labelled as 'visually pleasing' and realistic, which is critically important as later test results will show.

Hydrodynamic forces

Hydrodynamic forces are important for all seafaring vessels. An autonomous underwater vehicle (AUV) is the basis for the learning resource shown in Fig. 5. The AUV can be manoeuvred by varying the propeller thrust and the rudder angle. This simulator can be used to study hydrodynamic forces. The movements are observed visually and recorded through time-series plots as shown to the lower right in Fig. 5. The data can, if needed, be analysed offline. This resource does not currently include a game. It is, however, included here because of a feature we have found useful in higher education. Each individual user is assigned a *unique* set of parameters, meaning for instance that the weight of the AUV is different for each user. In the depicted simulator the task is to calculate unknown AUV-parameters, such as its mass, by observing and analysing its movements. The fact that each and every student receives a unique AUV prevents students from copying answers from fellow students. The least they need to be able to do is to copy the procedure for obtaining the answers. The ability to assign unique parameters to individual users is also used in PIDstop games.

RESULTS FROM TESTING

Table 1 gives an overview on the use of PIDstop in five undergraduate courses at NTNU during 2003–2005. The total number of users in these

Fig. 5. A learning resource using an autonomous underwater vehicle to convey and inspire understanding of hydrodynamic forces.

courses was about 1200. External use at exhibitions, in external courses, and for university recruitment campaigns is not included in the Table 1.

In the following, user feedback from three different courses, Calculus 1, Physics, and Control engineering, is presented. All scores are given on a scale of 1 to 6, where 1 is the lowest and 6 is the highest score.

Calculus 1

PIDstop was used in the introductory part of the basic mathematics course for first year students in 2004 and 2005. The compulsory exercise comprised one week's work and consisted of two parts: a traditional exercise and a PIDstop assignment. The PIDstop assignment meant using an interactive simulator as well as the use of a game. The application was the inverted pendulum described earlier. The students, working in groups of three, switched between traditional exercises and PIDstop, and the difficulty of the tasks grew throughout the week. On the last day the students could challenge their competence through the game described in Fig. 3. Feedback from 300 students from two different study programmes is set out in Table 2. Focus will initially be on the Fall 05 data.

The students clearly favoured the combined use of traditional pen-and-paper exercises and PIDstop to a traditional exercise without the PIDstop, as observed by the fact that 95% preferred the combined option. This number is not explicitly included in Table 2. Further, the students experienced the learning effect of the PIDstop learning resource (score of 4.1 out of 6) as somewhat better than the learning effect of the pen-and-paper calculations (score of 3.8). It is interesting to observe that the assignment clearly helped to illustrate the use of mathematics within the students' discipline (score of 5.5). Further, the assignment inspired a significant number of students to learn more mathematics (score of 4.5). The overall impression of the combined exercise received the score of 4.5, a result that substantiates that it was well received by the students. Finally, the results clearly showed that the users experienced the PIDstop learning resource as user friendly and with a very good functionality (score of 5.4).

Comparing the Fall 05 data with the data collected during Fall 04, there is an average improvement of about 0.5. This improvement is substantial, and is probably due to the changes that were implemented as a result of feedback from the Fall 04 data. This data included textual feedback in addition to the scores.

The trials show the importance of providing students with interactive learning resources that are relevant to the problem in hand. It is quite encouraging to observe how students clearly experience the simulator and game as a means of illustrating the importance of mathematics within engineering. This motivational element is important to enhance learning in basic mathematics, a challenge for many engineering education institutions.

Table 1. Summary of the use of PIDstop in five regular courses at NTNU from 2003 to September 2005

Course—code	Department	Semester	No. of students	Level
Calculus 1—TMA4100	Mathematical sciences	Fall 04, 05	2 × 150	1st year
Physics—TFY4115	Physics	Fall 04	2 × 140	2nd year
Energy and environ. physics—TFY4300/FY2201	Physics	Fall 04	30	3rd/4th year
Control introduction—TTK4100	Engineering cybernetics	Spring 04	80	1st year
Control engineering—TTK4105	Engineering cybernetics	Spring 03, 04	2 × 250	3rd year

Table 2. Summary of feedback from 300 students on the inverted pendulum exercise. Data were collected from the Calculus 1 course during Fall 04 (150 students) and Fall 05 (150 students)

Question (lowest score 1—neutral 3.5—highest score 6)	Average score Fall 05	Average score Fall 04
Did you experience the pen-and-paper calculations as inspiring and motivating?	3.5	2.9
How did you experience the learning effect of the pen-and-paper calculations?	3.8	3.3
Did you experience the use of the PIDstop learning resource as inspiring and motivating?	4.8	4.5
How did you experience the learning effect of the PIDstop learning resource?	4.1	3.8
Did the assignment illustrate the use of mathematics within your discipline?	5.5	4.9
Did the assignment inspire you to learn more mathematics?	4.5	3.9
How did you experience user friendliness and functionality of PIDstop?	5.4	5.1
What is your overall impression of the assignment?	4.5	3.8

The availability of different learning resources, traditional resources as well as online resources including simulators and games, is clearly favoured by the students. An important reason for this is the different preferred learning styles of the students: some prefer an analytical approach while others prefer an interactive learning-by-doing approach. The users clearly rated the PIDstop learning resource as being user friendly. This substantiates the claim that even though higher education institutions cannot compete with computer games in terms visual sophistication, students find simplified solutions fairly acceptable.

Physics

PIDstop was used in two separate compulsory exercises. The topics were the Carnot cycle, or a heat pump, and harmonic oscillations, respectively. The exercises were completed individually or in groups of two students. The harmonic oscillation assignment will be discussed in some detail. The exercise included three parts: undamped oscillations, damped oscillations and forced oscillations as, for example, seen in a grandfather clock where some external force is applied to maintain the amplitude of the oscillations, see also Fig. 1. The students were asked to perform some pen-and-paper calculations as an integrated part of the PIDstop exercise. This exercise did not include a game. The feedback from 280 students is shown in Table 3.

The students typically took 2 hours to complete the pen-and-paper calculations and a little less time was spent on the simulator. However, the time spent on the simulator varied a great deal. On the whole, the results in Table 3 are similar to the results in Table 2. They clearly convey that the students, on average, experience PIDstop as having a positive learning effect. Further, the students found PIDstop's user friendliness and functionality to be good.

Textual feedback from the students shows that the cohort can be divided into two groups. The first group was very enthusiastic about the use of PIDstop and claimed that the use of the simulator clearly improved learning, while the second group had a neutral attitude towards the use of a simulator. These groups seem to be fairly equal in size. The first group emphasized the importance of being able to experiment and to observe the results in different ways, in particular through animation and time-series plots. This indicates that dynamic simulators and simulation-based games support certain learning styles better than conventional learning resources.

The results in Table 3 differ from Table 2 when the results from Fall 04 to Fall 05 are compared. Table 3 shows no improvement from one year to the next, in fact the data show the opposite tendency. The probable explanation is that the learning resource was unchanged from Fall 04 to Fall 05. Correlating this with the finding for the Calculus 1 course indicates the importance of really using feedback from students to improve learning resources on a regular basis.

Control engineering

PIDstop has been used in a control engineering course for third-year students. The results from the Spring semester 2003 are presented here. The assignment was compulsory and based on the cart simulator shown in Fig. 1. The assignment was divided into three parts with increasing levels of difficulty. Further, there were intermediate tests

Table 3. Summary of the feedback from 280 students on the harmonic oscillation exercise. Data were collected from the Physics course during Fall 04 (140 students) and Fall 05 (140 students)

Question (lowest score 1—neutral 3.5—highest score 6)	Average score Fall 05	Average score Fall 04
Did you experience the pen-and-paper calculations as inspiring and motivating?	3.0	3.1
How did you experience the learning effect of the pen-and-paper calculations?	3.8	3.8
Did you experience the use of the simulator as inspiring and motivating?	4.5	4.8
How did you experience the learning effect of the simulator?	4.2	4.3
Did the inclusion of the simulator improve the learning effect of the assignment?	N/A	4.2
How did you experience the user friendliness of the simulator?	4.5	5.0

Table 4. Summary of the feedback from 250 students on a control design exercise. Data were collected from the Control engineering course during Spring 03

Question (lowest score 1—neutral 3.5—highest score 6)	Average score
How inspirational was the assignment ?	4.8
How did you experience the learning effect of the assignment?	4.7
How did you experience the functionality of PIDstop?	4.9
What is your overall impression of the assignment?	4.9

to qualify for a more advanced level. The exercise included a game in which the user, by controlling a DC motor, must catch as many falling balls as possible. If the student is to qualify for the high score list, this requires a well-tuned controller, meaning that the students need to put control theory into practical use.

The exercise was used by 129 groups from four different study programmes, and the students spent on average 3.5 hours on the exercise. The evaluation was designed as a single page evaluation form with 20 questions and the option of including textual remarks. The feedback from 250 students is shown in Table 4. The results are again encouraging and in line with the results from the assignment in the Calculus 1 and Physics courses. The students also responded to the question 'Do you think you learnt more or less by using this type of assignment compared with traditional assignments?' with 74% choosing the category 'We thought we learned more, or a lot more', meaning that the students felt that this exercise was beneficial from a learning viewpoint. The reason for this is the observation that many students prefer an interactive learning-by-doing approach. In particular they favour having complementary learning resources spanning from traditional analytical exercises to interactive dynamic simulators and games. Further, students prefer learning resources that clearly show how theory and methods can be applied in practice. This latter issue seems to increase in importance. Finally, students report learning resources applying game-world elements as 'cool'!

DISCUSSION AND CONCLUSIONS

The results presented in Tables 2–4 are also representative of the feedback from the other courses listed in Table 1, i.e. 'Energy and environmental physics' and 'Control introduction'. The discussion therefore implicitly includes feedback from these courses.

The actual learning effect of PIDstop as applied in this study can be measured in both a quantitative and qualitative way. There has been no quantitative study on, for instance, the final grades of students using PIDstop compared with those of students not exposed to these learning resources. The learning effect is measured qualitatively and hence indirectly through the students' perceived learning experience.

The trials substantiate the hypothesis that dynamic simulators combined with educational games provide a useful supplement for online learning resources within the engineering domain. The data consistently support this hypothesis. Moreover, there is a considerable breadth in the trials. First, there is a spread in the students' background, ranging from first-year to third year-students. Second, the educational resources are tested on students from four different engineering study programmes and, finally, the total number of students is quite large.

One finding is that students clearly prefer a diverse set of learning resources, especially traditional exercises combined with interactive dynamic simulators and games. A probable reason is that students prefer different learning principles. A closer analysis of our data reveals that one group of students claim that the use of PIDstop-like learning resources clearly improves their learning, while a second group had a neutral attitude towards the use of these educational games. These groups seem to be fairly equal in size. As mentioned earlier, the first group emphasizes the importance of learning-by-doing and observing the results in different ways, in particular through animation and time-series plots. Further, these users clearly favoured the combined use of a traditional exercise with a highly interactive learning arena such as PIDstop, as opposed to a traditional exercise by itself.

To further substantiate that PIDstop-like resources create diversity in terms of learning styles, [18] identifies 36 learning principles in video games and simulation. Many of these are relevant for the e-learning resources studied here. Examples are the 'probing principle' focused on learning by exploring, the 'self knowledge principle' where the student creates an understanding of the limitation of his or her knowledge based on experience, and the 'design principle' where the students design the learning process while learning.

The educational resources are all based on a dynamic simulator that reproduces the behaviour of some system. The use of a simulator is a key concept in order to develop motivating and highly interactive e-learning resources for the selected subjects. Student feedback supports our claim that learning resources based on dynamic simulators are highly relevant for engineering education.

The educational resources include a mix of interactive dynamic simulators and games. The games are fairly simple. They do, however, include well-known game features: The user has a number of lives available; there is a highscore list, a high degree of interactivity, and multiple views. In addition, a higher knowledge level will, on average, improve the score. Feedback shows that the use of games is important to motivate and maintain interest from the students. Another helpful feature is the observation that users are stimulated by the immediate feedback through intermediate tests and game-like features such as the ability to elevate from one level to a more advanced level.

Today's computer games have very high standards when it comes to functionality, user friendliness and graphics. This is a challenge since the user of educational games will compare the learning resources with commercial computer games. Hence, to provide a fair comparison it is critically important to design learning resources that are visually pleasing and with good functionality. User feedback as seen in Table 2–4 shows satisfaction with the functionality and graphics of the learning resources. This implies that somewhat simplified solutions in terms of graphics and user friendliness are acceptable to students. We do, however, expect that there is a lower tolerance level in terms of user friendliness below which the learning experience deteriorates rapidly. Our findings indicate that recognizable visual elements and the use of humour improve the learning experience. The graffiti-inspired image in Fig. 1 is an example of a visual element that was well received by the users.

A limitation of the study is the fact that only engineering education is targeted in this work. This restriction implies that the findings are, to some extent, limited. On the other hand, engineering education is a large and important sector in higher education. Furthermore, the results are positive. Hence, they do at least also show promise for other sectors in higher educations.

As a conclusion, the study shows that dynamic simulators combined with educational games, as defined in this study, have a positive learning effect on a substantial number of students in engineering programmes. In particular the users favoured the combined use of a traditional exercise with an interactive learning arena, as opposed to a traditional exercise by itself.

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