EVALUATION OF COURSEWARE AND LEARNING ENVIRONMENTS IN AN ELECTROMAGNETICS COURSE ENHANCED BY COMPUTER ASSISTED INSTRUCTION

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ABSTRACT

At the University of Twente the first year electromagnetism course has been restructured. A web-based course consisting of different exercises (most of them using a link with Maple) and PowerPoint presentations has been developed to support existing lessons. The aim of these changes is to enhance student's performance, by integrating mathematical knowledge and skills into a Physics course.

The students following the Electromagnetics course were surveyed about their views concerning two main aspects. On the one hand learning environment preferences and effectiveness were evaluated. On the other hand, the courseware was widely surveyed.

Two study patterns can be distinguished: that based on lectures and tutorials, and the self study system based on studying from the book and worked out problems. Attitudes related to computer use can not be significantly correlated with any of the above mentioned study patterns. Most students considered the courseware as a complement to a normal course and not as a substitute. Students think that doing the exercises by means of the courseware resulted in more elaborated and documented work.

The courseware survey found that students are generally satisfied with the user interface and the exercise selection, although half of the students admitted having trouble with the strictness that a symbolic language as Maple requires.

KEYWORDS

Evaluation, Computer assisted instruction, Learning environment , Physics, Mathematics, Electromagnetism, Problem solving.

INTRODUCTION

Students at the University of Twente frequently have trouble with the first year Electromagnetics course. The problems are to a certain extent due to students' lack of both mathematical knowledge and skills [1, 6, 7]. The knowledge and skills are generally assumed by academics to be mastered by this stage of the studies, but often this is not the case in practice. In particular, applying mathematical skills into Physics presents a high degree of difficulty.

In order to reduce these difficulties, the Electromagnetism course is supported by means of computer assisted instruction. The nature of this courseware is discussed in the first section of this article.

The present research has two main goals. The first goal is to know whether or not computer assisted instruction fits with student's preferences for type of learning environment. The second goal is to find out whether or not students are satisfied with the developed courseware. Both studies are based on student questionnaires. First, the design of the survey is discussed. Then the results of the survey are presented in the students' evaluation section.

SUPPORTING ELECTROMAGNETICS WITH COURSEWARE

The Electromagnetism first year course has been modified by means of courseware designed to supplement the current programme. This additional courseware has been developed with different designs, depending on the objectives to be attained. This courseware consists of PowerPoint presentations aiming to underpin the lectures, and computer exercises intending to support the tutorials.

PowerPoint presentations cover some theoretical topics. These presentations are animated illustrations of some Electromagnetics laws and concepts. Moreover, a few mathematical concepts like the divergence theorem are illustrated. These illustrations present step by step how these laws apply in Physics. The PowerPoint presentations are used for illustration in some lectures and they are available on-line and in a CD-ROM that students receive at the beginning of the course.

Two units of computer exercises have been developed. The first unit enhances the learning of mathematical skills used in Electromagnetics [9]. The second unit includes some of the problems of the regular programme that stress applying integrals into Physics. Both units consist of html-pages where a link to Maple has been built. This Maple link enables students to solve the problem symbolically (thus not only numerically), overcoming one of the shortcomings that has so far limited the use of computer assisted instruction in sciences [10]. The design and implementation of these two units is discussed in a previous paper [8]. Both units are available on-line. Students do the majority of these exercises during the tutorial sessions.

Table 1 shows a schema of the modified Electromagnetics course. In brackets is the percentage of the total course. Self-study, plus extra time to finish the courseware (up to 2 hours) are not included in this schema.

Table 1: *Time schema of an Electromagnetics course supported by courseware.*

	Lecture	Tutorial	Courseware
Time in hours	34h (46%)	35h (47%)	5h (7%)

DESIGN OF THE SURVEY

Students following the Electromagnetics course have been surveyed concerning two main aspects. On the first part, students' preferences for type of learning environments (attendance at lectures and tutorials as well as the use of the various offered courseware) and the diverse learning environment effectiveness were assessed. The purpose of this part was to assess whether there are different study patterns, and whether computer assisted instruction can be utilised. On the second part, students were surveyed about the courseware. Students' opinions about the User Interface, learnability and efficiency were assessed. This part of the evaluation aimed to result in an improvement of the present courseware for the coming course (formative evaluation).

Several sources have been considered when designing the survey. Basic concepts were taken from a general guidebook [3]. Further, other surveys in computer science have been taken into consideration: an evaluation of courseware [11] and a comparison between on-line and paper-based evaluation [4].

Both multiple-choice questions and open questions were included into the survey. Multiple-choice questions were used when possible. Most of the multiple-choice questions were formulated either as a positive or negative statement that student had to rate according to the degree of agreement. Open questions can bring to light additional information; however, they are more difficult to analyse in a comparative way.

STUDENT EVALUATION

The 5 page anonymous survey was taken at the end of the course. A book token was given as a reward for filling in this long written questionnaire. 48 out of 60 students (80%) starting the Electromagnetism course returned it.

The questions with summary data are reproduced below, divided into different sections. Median, mean and percentage of respondents giving a favourable answer (or at least what it has been considered to be a positive answer) is given for each question. In most of the cases the mean is not really a meaningful variable since most data are ordinal measures. Despite this, we consider that the mean gives some additional meaning to the median.

PART I: LEARNING ENVIRONMENTS AND THEIR EFFECTIVENESS

1.1 Attendance and use of different study resources

Table 2 shows the attendance records of the student at lectures and tutorials, and the use of the PowerPoint presentations and worked out problems. Performance on the courseware was registered in a database. 53 students (88%) completed both units of the courseware. Students completing the courseware as well as a workshop received 15 of the 100 points of the final mark.

Table 2. *Student's attendance and use of the different study resources. Median and mean scores on a 4 point-scale (1= 0-30%; 2=30-60%; 3=60-80%; 4=80-100%). This is followed by the percentage of respondents giving a favourable answer (3 or 4).*

	Median	Mean	% 3 or 4
Lecture Attendance	4	3.21	81%
Tutorial Attendance	3	2.98	67%
PowerPoint presentations	2	2.23	38%
Worked out problems	3	2.98	65%

Surprisingly, more students attended lectures than tutorials (median 4 and 3, respectively). PowerPoint presentations were generally less used than the rest of the study forms, although some of them were previously shown in the lectures.

The relationship between all the different study forms indicates a significant positive correlation (r=0.664) significant at the 1% level between attendance at lectures and tutorials.

The next stage of the survey concerns the use of the CD-ROM and the on-line study resources (see table 3). The CD-ROM contains PowerPoint presentations, all sheets used during the lectures and some information over order of magnitude in Magnetism. The on-line site comprises the computer exercises and all the information available on the CD-ROM.

Table 3. *Student's attendance and use of the different study resources. Median and mean scores on a 3 point-scale (1= never; 2=sometimes; 3=often). This is followed by the percentage of respondents having ever used this study resource (2 or 3).*

	Median	Mean	% 2 or 3
CD-ROM	3	2.56	94%
Internet site	1.5	1.67	50%

Students preferred working with the CD-ROM. 31% of the students at the beginning of the year and 20% when the Electromagnetics course took place (data referring to the course 1999-2000) did not have an Internet connection at home. Besides, Internet access meant that some of the students had long downloading times, higher telephone bills, and housemates complaining about an always-busy telephone line (according to some students' verbal comments during the Electromagnetics course).

There is a positive correlation (r=0.441) significant at the 1% level between the use of the CD-ROM and solving problems with the help of worked out problems. As expected, the use of the CD-ROM correlates positively with the use of PowerPoint presentations (r=0.411) significant at the 5% level.

1.2. Learning effect: study patterns

In this section, efficacy, efficiency and preferences over the different learning environments are studied. The use of the book [5] was not systematically asked. To start with, the efficacy of the different study resources from the students' viewpoint was surveyed (see table 4).

Table 4. *Usefulness of the different study resources according to students' opinion. Median and mean scores on a 4 point-scale (1= useless; 2= okay; 3=useful; 4= indispensable). This is followed by the percentage of respondents giving a favourable answer (3 or 4).*

	Median	Mean	% 3 or 4
Lecture	3	3.21	88%
Tutorial	3	3.04	75%
Computer Assisted Instruction	2	2.40	44%
PowerPoint presentations	3	2.75	67%
Worked out problems	4	3.48	92%

Studying worked out problems is, according to students, the most effective learning environment, closely followed by lectures. Again, the fact that lectures scored higher than tutorials can be observed. Although merely 8% of the students considered computer assisted instruction as useless (1), only 44% of the students believe that it is a useful study resource (3 or 4). This percentage is significantly lower than for other study forms.

Students were also asked to order these 5 study forms in order of efficiency and enjoyment. Students consider tutorials the most efficient and enjoyable way to study, closely followed by lectures. Studying worked out problems is seen as efficient, although it is not very enjoyable. The study form with the lowest efficiency and fun is, according to students, computer assisted instruction. Whether or not the fact that computer assisted instruction is the only compulsory study form influences students' opinion, requires further investigation.

Study patterns were also checked. Several positive correlations have been found among the different data related to lectures and tutorials (see table 5). Studying worked out problems correlate negatively with both lectures and PowerPoint presentations (see table 6). Computer assisted instruction correlates negatively with both lectures and tutorials (see table 7).

Table 5. *Pearson correlation coefficient and significance level among results related to lectures and tutorials. N varies between 44 and 48 students due to the fact that not all students answered all questions.*

		tutorial efficacy	tutorial efficiency	tutorial enjoyment
lecture efficacy	Pearson Cor.	.451**	.156	.364*
	Sig. (2-tailed)	.001	.301	.015
lecture efficiency	Pearson Cor.	.140	.117	.412**
	Sig. (2-tailed)	.353	.439	.005
lecture enjoyment	Pearson Cor.	.133	.361*	.259
	Sig. (2-tailed)	.390	.016	.089

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

Table 6. *Pearson correlation coefficient and significance level among results related to worked out problems (WOP), lectures and PowerPoint presentations (PPT). N varies between 44 and 48 students due to the fact that not all students answered all questions.*

		lecture efficacy	lecture efficiency	lecture fun	PPt efficacy	PPt efficiency	PPt fun
WOP efficacy	Pearson Cor.	-.117	-.454**	-.132	.071	-.061	.045
	Sig. (2-tailed)	.430	.002	.393	.629	.689	.772
WOP efficiency	Pearson Cor.	-.424**	-.109	-.122	-.381**	-.516**	-.192
	Sig. (2-tailed)	.003	.472	.432	.009	.000	.211
WOP fun	Pearson Cor.	-.467**	-.141	-.074	-.389**	-.408**	-.241
	Sig. (2-tailed)	.001	.362	.631	.009	.006	.116

** Correlation is significant at the 0.01 level (2-tailed).

Table 7. *Pearson correlation coefficient and significance level among results related to computer assisted instruction (CAI), lectures and tutorials. N varies between 44 and 48 due to the fact that not all students answered all questions.*

		lecture efficacy	lecture efficiency	lecture fun	Tutorial efficacy	Tutorial efficiency	Tutorial fun
CAI efficacy	Pearson Cor.	.086	-.033	-.124	-.094	-.167	-.137
	Sig. (2-tailed)	.560	.830	.423	.527	.267	.376
CAI efficiency	Pearson Cor.	-.125	-.459**	-.165	-.391**	-.440**	-.241
	Sig. (2-tailed)	.402	.001	.285	.007	.002	.115
CAI fun	Pearson Cor.	-.047	.008	-.361*	-.185	-.218	-.381*
	Sig. (2-tailed)	.758	.960	.016	.225	.155	.011

** Correlation is significant at the 0.01 level (2-tailed). * Correlation is significant at the 0.05 level (2-tailed).

Students were then asked to explain (using percentages) where they learned the theory, strategic approach for problem solving and mathematical skills. Their learning result should be split among the different study forms offered in the Electromagnetics course (lectures, tutorials, computer assisted instruction, PowerPoint presentations, worked out problems, the textbook [5]) and other subjects. Table 8 shows the mean percentage and standard deviation of each study form per topic. To be observed is the high standard deviation in some of the cases. Students gave as a comment that it was very difficult to answer this question objectively, which can explain the large heterogeneity of answers.

As expected, theoretical concepts are learned basically either from lectures or the book (M=34.74 and M=28.30, respectively). Tutorials and PowerPoint presentations seem to play also a role on this learning process. Strategic approach is mostly learned in tutorials and by doing worked out problems (M=30.89 and M=32.83, respectively). Computer assisted instruction seems to make also a contribution (M= 11.89). Finally, to be observed from table 8 is that most mathematical skills are learned by following other subjects (M=39.09), although tutorials, lectures, and worked out problems also have a rather important contribution (M=20.06, M=10.56 and M=10.70, respectively).

Table 8. *Mean percentages and standard deviation about where general concepts and skills (theoretical concepts, strategic approach to solve problems and mathematics skills in general) were learned.*

	Lecture		Tutorial		CAI		PPt		Worked out problems		Book		Other subjects	
	M	St	M	St	M	St	M	St	M	St	M	St	M	St
Theory	34.74	18.54	11.00	9.15	5.26	5.59	9.57	12.07	8.34	10.28	28.30	20.56	3.00	7.49
Strategic approach	7.68	6.56	30.89	19.80	11.89	11.12	5.38	10.43	32.83	22.81	8.28	11.81	3.04	5.36
Math. skills	10.56	12.91	20.06	15.82	7.50	11.66	3.98	6.26	10.70	11.61	8.11	10.46	39.09	28.82

Learning of both mathematical skills and concepts has been divided into the most used topics in Electromagnetism. Since similar results were found to the mathematical skills in general (see table 8), the findings will not be explicitly presented here. To be observed is that almost in all topics the influence of other subjects is much higher than initially considered (table 8), although, in all cases, remains the first learning resource. Lectures, tutorials, self-study from the book and computer assisted instruction have a substantial effect on some of the topics. However, some differences can be observed among the mathematical topics.

Some correlations are found among the topics:

1. There are again rather strong positive correlations among topics related to lectures and tutorials.
2. On the one hand, learning from the book correlates negatively with lectures. On the other hand, both some positive and some negative correlations among topics related to learning from the book and tutorials have been observed.
3. On the one hand, learning from worked out problems correlates in several topics negatively with learning from both lectures and tutorials. On the other hand, learning from the book correlates in some topics positively with learning from the worked out problems.
4. Learning from computer assisted instruction show positive correlation with lectures, tutorials and worked out problems, although in most cases it is between topics that have a low mean, and therefore not really significant. No correlation either positive or negative could be found with the learning from the book.
5. Learning from PowerPoint presentations presents both some positive and some negative correlations with both learning from lectures and worked out problems, some only negative correlations with tutorials, and strong positive correlations with computer assisted instruction.

PART II: COURSEWARE SURVEY

2.1. User Interface

Results on the user interface are given in table 9. In this case, there were positive and negative statements. Positive and negative statements are indicated with a “+” or “-”, respectively, on the percentage field. Respondents giving a favourable answer to a positive statement resulted in a 4 or 5 (agree or strongly agree), while respondents giving a favourable answer to a negative statement resulted in a 1 or 2 (strongly disagree or disagree).

Table 9. *User Interface. Median and mean scores on a 5 point-scale (1= strongly disagree; 2=disagree; 3=neutral; 4= agree; 5=strongly agree). This is followed by the percentage of respondents giving a favourable answer (1 or 2 [4 or 5] for negative [positive] statement).*

	Median	Mean	%
Computer exercises are easy to use	4	3.71	64.6 (+)
Navigation is intuitive	4	4.08	81.2 (+)
Control buttons are adequate	4	4.06	78.7 (+)
There is too much text on a page	2	2.00	87.5 (-)
Graphics are clarifying	4	4.09	82.6 (+)
Speed of presentation was too slow	2	2.65	54.2 (-)
There was too little interactivity	3	2.60	42.6 (-)
I had little trouble filling in the answer in a Maple compatible format	3	2.90	37.5 (+)
There was enough flexibility to write the answer (in Maple format)	2	2.30	14.9 (+)
Help pages are easily accessible	4	3.56	54.2 (+)

Students were in general satisfied with the user interface. Only the use of Maple presented some problems. Students think that Maple is not flexible enough. During the supervised computer assisted instruction and looking to the database (where students' answers were registered) it was observed that students are not accurate in their notation. Students may know the right answer but they do not reproduce it correctly in Maple compatible format (missing brackets, product instead of a division, etc.), therefore these answers were consider to be wrong (and they are as a matter of fact incorrect). In our opinion, this lack of accuracy may have influenced students' opinion about Maple's flexibility.

2.2. Content

The content of the computer exercises is evaluated in this section. Results of some open questions which were asked is presented.

90% of the students consider all computer exercises suitable. Reasons given by small percentages students who consider them inappropriate are:

(a) Exercises where too much Maple has to be used are not suitable
(b) Some exercises are spoon-fed
(c) One of the exercises is messy

19% of the students missed some exercises. The topics they mention are magnetism, electromotive force, special techniques (chapter 3, Griffiths [5]), induction, dipoles, dielectrics and, insight into the divergence and curl concepts. There are some students willing to tackle more computer exercises.

81% of the students consider that the computer exercises provide a good insight into the problem. Problems or remarks that students mentioned are:

(a) Explanation of the solution route
(b) Because of Maple, I loose insight into the problem
(c) You do everything (correctly), but you don't really get what you are doing
(d) Sometimes it is too easy
(e) Computer exercises are too spoon-fed
(f) Good background over how and why. Computer exercises are too intuitive
(g) With pen and paper I have a better insight
(h) Sometimes I had the impression that I didn't know anymore what I was doing

(i) For some reason doing written exercises is a better preparation for the examination

Then some positive and negative statements referring the content of the courseware were analysed. Some of the statements do not relate directly to students' opinion on the computer exercises but to the starting-points in the design of the courseware. The summary data is reproduced in table 10.

Table 10. *Content. Median and mean scores on a 5 point-scale (1= strongly disagree; 2=disagree; 3=neutral; 4= agree; 5=strongly agree). This is followed by the percentage of respondents giving a favourable answer (1 or 2 [4 or 5] for negative [positive] statement).*

	Median	Mean	%
Content of the page is well-organised	4	3.75	72.9 (+)
It's clear what to do	4	3.67	66.7 (+)
It's clear why should I do it	4	3.40	54.2 (+)
Looking at a page, I lose the link to the rest of the exercise	2	2.67	54.2 (-)
Exercises should be solved in a symbolic form (not numerically)	3	2.98	37.5 (+)
Analysis is not important	2	1.70	91.5 (-)
Estimating order of magnitude is not important	3	2.90	41.7 (-)
Checking units is not important	2	2.42	60.4 (-)
Considering limit cases is not important	2	2.15	70.8 (-)

Looking to these results it can be observed that students are pleased with the organisation of the content in the pages. Most students know what to do (66.7%), but fewer know why they should do it (54.2%). Half of the students (54.2%) think they do not lose the overview with the rest of the exercise when looking to a particular page; however, 33.4% say they do.

Surprisingly, merely 37.5% of the students think that exercises should be solved in a symbolic way, although 29.2% do not really have either a positive or negative opinion about this statement. Students starting a university course are used to solve problems numerically. Results show that this practice seems to be difficult to change.

Students consider the analysis of the problem to be the most important (91.5%). This is followed by studying limit cases (70.8%) and checking units (60.4%). Estimating the order of magnitude is considered as largely less important for students (41.7%).

2.3. Feedback

This section reproduces the survey's results about the feedback students get on their answers (see table 11). Again, there are some statements about some of the starting-points of the courseware design.

Most students appreciate having a hint when their answer is wrong (85%), although more than half of them also would like to get the solution quickly. Less than half of the students (45.8%) likes to get extra information when they answer correctly, while 31.3% disagree with this statement.

About half of the students (41.7%) do not either agree or disagree with the statement that feedback gives helpful hints, while 35.5% are positive about it.

Table 11. *Feedback. Median and mean scores on a 5 point-scale (1= strongly disagree; 2=disagree; 3=neutral; 4= agree; 5=strongly agree). This is followed by the percentage of respondents giving a favourable answer (4 or 5).*

	Median	Mean	%
If my answer is correct I want some more explanation rather than knowing only that it is right	3	3.25	45.8
If I can't find the solution I would like to receive a hint	4	4.17	85.4
If I can't find the solution I would like to get the right answer quickly	4	3.25	52.1
Feedback gives helpful hints	3	3.17	35.5

2.4. Maple Help function

75% of the students used the Maple help function at least once. 66.7 % of the students who used this help consider that their needs were satisfied. Non-satisfied students' commented that this help is not well-organised and clear.

2.5. Help function (content)

This help function gives additional information over the content of the exercises. If necessary, there are also some hints to solve the problem.

6% of the students never used the help pages. 83% looked at them sometimes. The remaining 11% used it on a regular bases. The three students who did not use it gave different reasons for this (no need, did not know of its existence, and it takes too much time plus it is not interesting)

Students were surveyed about the use they made of the help pages. Merely 4.5% used them before answering the question. 42% used them in case their answer is wrong. 49 % used them when their answer was wrong several times. The remainder, 4.5%, gave other reasons like not having any idea how to solve the problem.

The content of the help pages was satisfactory. The needs of 91% of the students were satisfied. The rest found that in some cases the information was not suitable to their problem. One student also mentioned that the pages do not help in case of an input mistake, but this is not really the goal of this help.

2.6. Results and efficiency

This sections aims to compare computer assisted instruction with doing exercises on paper. Besides few other questions related to efficiency and fun were again checked in a slightly different way. Results are shown in table 12.

To be observed from table 12 is that students consider that computer assisted instruction results in a more elaborated way of solving problems than paper based. However, the result concerning the units is largely less favourable. This is the consequence of a wrong formulation of the question. Students who thought that they were not forgetting it before answer this question negatively, but this does not mean that they do not use units.

Computer assisted instruction is mostly seen as a complement of the course and not as a substitute, which was the desired outcome when introducing the courseware.

Finally it turned out that in spite of the fact that students think that they learn using the courseware, they do not consider it to be very effective or fun.

Table 12. *Results and efficiency. Median and mean scores on a 5 point-scale (1= strongly disagree; 2=disagree; 3=neutral; 4= agree; 5=strongly agree). This is followed by the percentage of respondents giving a favourable answer (4 or 5).*

	Median	Mean	%
I learned a lot with CAI	3	3.40	47.9
I did CAI more elaborated than on paper	4	3.67	70.8
I did a better analysis than on paper	4	3.69	66.7
I did a better check of the answer than on paper	4	3.52	54.2
I'm now used to not forgetting the units	3	2.77	18.7
CAI has been very effective in relation to the invested time	3	2.85	31.2
I see CAI as a substitute of tutorials	2	2.23	18.7
I see CAI as a complement of the course	4	3.60	64.6
CAI is fun	3	3.17	39.6

CONCLUSIONS

An Electromagnetics course was enhanced by courseware to integrate mathematical knowledge and skills into Physics. Students were surveyed about the courseware and preferences for type of learning environments. The main conclusions are listed here:

Students prefer working with a CD-ROM rather than using Internet for practical reasons. Availability of better connections in the future could lead to a change of preferences.

Two study patterns can be distinguished: followers of both lectures and tutorials, and self study enclosing studying from the book and worked out problems. Attitudes related to computer use can not be significantly correlated with any of these study patterns. On the one hand, computer assisted instruction correlates both positively and negatively with the study pattern which encloses lectures and tutorials. On the other hand, computer assisted instruction does have some positive correlations with preference for worked out problems, but not with preference for learning from the book. Besides, preference for PowerPoint presentations show no correlation with any of these study patterns.

According to the students' opinion, courseware contributes to enhance mathematical knowledge and skills with a percentage comparable to the time spent on learning from this environment. Besides, courseware enhances strategic approach for problem solving. This encouraging result is in accordance with findings by De Bruijn [2] for studying from worked out problems on the Internet.

Courseware is positively evaluated as a whole. However, one point was really negatively evaluated, against what it was expected. The use of a symbolic language as Maple was considered not to be flexible enough. However, it was observed that students do not work accurately, and therefore they easily feel frustrated. Another topic that can be related to this fact is that students considered not receiving a helpful hint when they made such mistakes. Besides, some students considered the help page for Maple not well-organised.

Computer assisted instruction results in a more elaborated and documented work in making exercises than the paper version, but it involves therefore extra time. Probably because of this, computer assisted instruction is seen as less efficient than tutorials and learning from worked out problems. Computer assisted exercises prompt students to invest more time and to elaborate extensively the exercise, what can be considered as an advantage.

Correlation among the results of this evaluation and the results on examination could not be studied because the survey was anonymous.

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