



Repositorio Institucional de la Universidad Autónoma de Madrid

<https://repositorio.uam.es>

Esta es la **versión de autor** de la comunicación de congreso publicada en:
This is an **author produced version** of a paper published in:

Sixth International Conference on Advanced Learning Technologies.
IEEE, 2006. 1055 – 1059

DOI: <http://dx.doi.org/10.1109/ICALT.2006.1652628>

Copyright: © 2006 IEEE

El acceso a la versión del editor puede requerir la suscripción del recurso
Access to the published version may require subscription

Using Adaptive Hypermedia to Support Diversity in Secondary Schools

Félix Muñoz
Computer Science Department,
Universidad Autónoma de Madrid
Tomás y Valiente 11, Madrid, Spain (28049)
Phone: +34914972271. Fax: +34914972235
felix.munnoz@uam.es

Alvaro Ortigosa
Computer Science Department,
Universidad Autónoma de Madrid
Tomás y Valiente 11, Madrid, Spain (28049)
Phone: +34914972271. Fax: +34914972235
alvaro.ortigosa@uam.es

Abstract

Attention to diversity is growing concern in public secondary schools in Spain. This paper presents an approach to support diversity by using Adaptive Hypermedia technology. Three experiences were carried out with an adaptive course on Mathematics to test the effects of this technology on the heterogeneous population of secondary schools. Their results and conclusions are also presented.

1. Introduction

Current social context in Spain, as well as a longer mandatory schooling, promotes a heterogeneous school population. If the goal is a secondary-education system which provides opportunities for everyone, without segregation and without leaving behind students because of their academic results, but being capable of providing actual satisfaction for the educational needs of every student, then the attention to diversity must be a foreground concern.

When dealing with diversity, the fundamental idea is that students are different one from the other and, as a consequence, school must help each one to develop his/her abilities. With this goal, the School has the responsibility to offer to each student at every moment the right answer in order to develop his/her skills and potential at the very best.

A traditional approach to support attention to diversity consists of adapting the classical curricula, where the goals and evaluation methods for every subject are customized for each student. The problem with this approach is that is very difficult to implement due to the number of students, and most of the times a closer and more personalized tutoring is not possible.

In this work, we show how Adaptive Hypermedia [1] can help to solve real problems in secondary education, by providing support to a personalized

teaching. Firstly we present an adaptive course designed to give attention to diversity in a Mathematics course. Secondly, three experiences with 79 students between 12 and 15 years old are presented; the results of these experiences show that AH technology is not only suitable for supporting attention to diversity in a urban secondary school with heterogeneous population, but also its use improves the performance of students.

2. Adaptive course design

Adaptive Hypermedia Systems can be defined as hypertext and hypermedia systems that store user features in a user model and use this model to adapt some aspects of the system to the user. In this work the TANGOW system [2] was used. TANGOW provides a flexible support for the creation of courses with different adaptative features. With the intention of testing the effect of adaptation in this specific context, two courses were developed, one with adaptation rules and the other designed to provide the same contents for all the students. The courses teach the introduction to whole numbers for students of first grade of secondary mandatory education, according to the Spanish educational system.

Analysing what aspects of the course to adapt and what features of the user model to consider, it is needed to take into account the goal of the secondary education in Spain. Due to the heterogeneous population and with the goal of promoting the potential of every student, more important that teaching similar contents to all the students is to provide the conditions for each student to get the most out of the secondary education. In order words, teachers are more concerned with the learning curve of every student than the extent of the knowledge (how much he/she has learnt rather than how much he/she knows).

In this case, what is needed from the adaptive course is the ability to adapt the level of the contents to be

learnt and the corresponding tests to the student knowledge, and to evolve that level accordingly with the student progress. The system should be able to evaluate not only the level of contents acquired, but how much the student has progressed.

2.1. Adaptive features

Considering the goals of the adaptive course, two adaptation methods were designed. The first one consisted of adapting the amount of contents to be learnt: this quantity depends on the student knowledge; more advanced students are presented with more contents, while students with lower level just work a part of those contents.

The second adaptation regards the level of the contents or, more specifically, the level of the tests the students are required to pass. Depending on the student level, tests with different difficulty, including different format, are proposed. Within this adaptation a fundamental ideal is implemented: when a student has a good mark on the exercises of a given level, exercises from the following level are proposed next; on the contrary, when the mark is below a given threshold, exercises of a lower level are proposed.

For example, a student with low level at the beginning of the course is presented with low level tasks. If the student answers correctly, the system will propose higher level tasks. Two different things may occur: if the student goes on answering correctly to the questions, he/she will be able to finish the course in a level higher than the original; if the student fails to pass the tests when the level is raised, the system will decrease again the level, until the next opportunity for level rising is found.

The intention behind this design is for the student to go beyond his/her initial level, reaching the highest level according to the potential skills. If a given student does not attain this goal, he/she will be anyway able to finish the course with a good mark, because the contents will be according to his/her level. There will not be students with very high or low marks, as in a traditional educational system, but all the students will get similar marks: in every case they will have a positive grade.

2.1. Implementing adaptation

Courses in TANGOW are composed by tasks and subtasks, and rules triggering their activation. The rules will active some tasks or others depending on given conditions over the student model.

The relevant features of the user model considered in this course are the initial knowledge level (*low*, *normal*, *high*) and the grade obtained in the last task. The knowledge level is set accordingly to previous test marks and knowledge the teacher has about the student

The rules prescribe that whenever a student gets a score above 70% ($\text{grade} > 0.7$), exercises from the next level are proposed. On the contrary, when the score is below 50% ($\text{grade} < 0.5$), exercises from the previous level are presented. For example, next rule will activate *high* level exercises for the “subtraction” task, after the “addition” task, for a given student:

```
(experience == "normal" && task.addition.grade >= 0.7) ||
(experience == "high" && task.addition.grade >= 0.5)
```

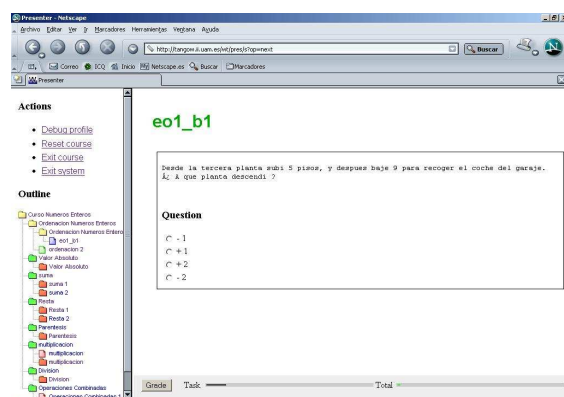


Figure 1. Exercise for *low* level

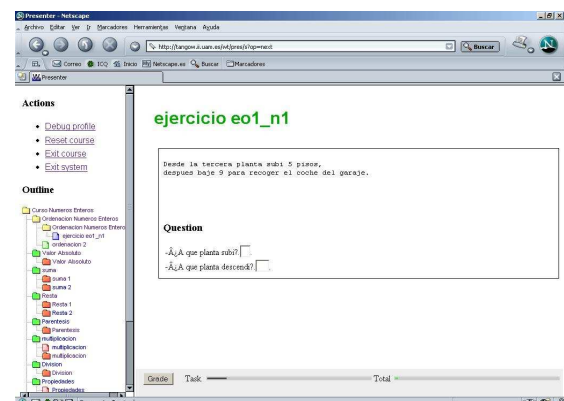


Figure 2. Exercise for *normal* and *high* levels

Not only the difficulty of the exercises is adapted, but also how they are presented and must be answered. Exercises at the *low* level are multiple choice questions, while *high* level exercises only provide text fields where the student should type the answers. Figures 1 and 2 show an example of the same exercise presented differently according to the student level.

3. Experiments

The adaptive system was used by students from the first course of mandatory secondary education of the “*Colegio La Presentación de Nuestra Señora de Madrid*”. In the Spanish educational system, this course is intended for students 12-13 years old, but due to the described heterogeneity of school population, students taking the course were between 12 and 15 years old.

3.1. Experience 1: adaptation at work

The first experience was designed to test whether the basic premise, that adaptation was a valuable tool for supporting attention to diversity, was true. Specifically, the goal was to test if the system helps each student to work accordingly his/her skills. This experience was carried out with a small group (10 students), because more important than extracting statistical conclusions was the personalized tracking the teacher can do of the development of each student.

The results of this first experience were very motivating. As it was intended, all the students got a final mark above 50%. Even students with very low initial knowledge were able to access to the normal level in some points of the course, although some times they were returned to the lowest level because of their low scores at the *normal* level. Students with high initial knowledge were able, in general, to keep the *high* level through the course.

From the teacher point of view the experience was very successful because he could attest that the system motivated each student to do his/her best, and the mark each one got was proportional to the student effort. Regarding motivation, it is important to note that the systems provided stimulus even to some students with serious problems of attention and idleness in traditional classroom.

3.2. Experience 2: adaptive vs. non-adaptive

Being aware of the needing to evaluate the use of adaptive hypermedia technology, an empirical evaluation [3] was designed to test whether the proposed adaptation makes a real difference on the way the students learn. The experiment followed the traditional between-subjects design [4], with an experimental group working with the adaptive course and a control group working with a non-adaptive version of the course. This non-adaptive course was developed based on the *normal* level of the adaptive version, being the only difference between them the

lack of rules for changing the level of the material and exercises proposed to the students.

The experience was carried out with 47 students from the secondary school, which have no previous knowledge about the contents studied through the course. The students were assigned to the experimental and control group randomly, only testing that both groups have no apparent difference in previous knowledge. Students were no aware of the experiment goal; actually, they were not told there were adaptation rules being used at all.

After they finished the course, either adaptive or non-adaptive, the students were required to pass an exam, the same for all of them. The grades the got in this exam (control mark) was then compared against the mean of each student in previous Mathematics courses (reference mark).

A summary of the results are shown in table 1 (marks are given in a 0-10 scale, being 5 the minimum required to pass the exam). The mean difference refers to the differences between control and reference marks, while the standard deviation refers to deviation of these differences.

Table 1. Results from experience 2

	Non-adaptive	Adaptive
Total students	23	24
Reference mark mean	5.79	5.77
Control mark mean	6.13	7.4
Mean difference	0.33	1.63
Standard Deviation	1.73	0.98

As can be seen, students using the adaptive course exhibited a mean improvement of 1.63 points (28%), while students using the non-adaptive course improved an average of 0.33 points (5%). Although the sample for the evaluation is relatively small, the results described are statistically significant ($p < 0.05$).

It should be noted that previous performance on Mathematics course was very similar, in average, for both groups. These figures suggest that additional reasons like intelligence, previous knowledge and good attitude towards learning can be disregarded as possible causes for the better performance of the experimental group.

Another remarkable result is that both groups increased the grades. Moreover, the number of students with marks below the minimum required (50%) was reduced from 8 to 2 in the experimental group (75%) and from 8 to 6 in the control group (25%). This improvement on the performance of both groups is supposed to be related with the use of technology in the

classroom. Generally, students are more motivated for the novelty of learning through the computer.

However, this result does not mean that using only the computer to teach the students would produce better results in the long term. In this case, students will grow bored and the final results would not be as expected. The best situation is to use technology as a complementary support to the work developed in traditional classrooms. Experience 3 aims to find results supporting this statement.

There is one last result derived from experience 2 to be analyzed: the marks obtained by the students within the own system. In this case, comparisons between groups are not possible, as the tests presented to the students of the experimental group were adapted to their level; therefore, they may be different from the tests presented to students in the control group. Nevertheless, it can be noted that the number of students with marks below 5 is 50% greater in the control group, and the standard deviation is also slightly greater (30% against 22%). This result is consistent with the goal of the adaptive course of having less variability among the marks of student with different knowledge level.

3.3. Experience 3: students with previous knowledge

The third experience was oriented towards testing whether the adaptive course would have the same effect on students with previous knowledge on the topics being studied, that is, when it is used as a complement to traditional lessons.

In this case 22 students from the first cycle of secondary education (between 13 and 15 years old) were part of the empirical evaluation, designed similarly to experience 2. The courses they used were the same than in experience 2, but in this case the goal of the learning process was reinforcement of previous knowledge. The reference mark used was the grade the students got in a previous exam about the same topic (Whole numbers). An important remark is that students participating in this experience were required to review the contents because of their low grade in the first exam. The control mark was obtained through an exam harder than the exam used for students in experience 2. The results of third experience are shown in table 2.

In this evaluation the observed difference between experimental and control group are not statistically significant. This is due to the small sample and the high variance of means, mainly in the control group. Nevertheless, it seems that the tendency observed in experience 2 still applies in the case of students with

previous knowledge, as the students in the experimental group improved their performance by 89%, while students in the control group improved by 60%.

Table 2. Results of experience 3

	Non-adaptive	Adaptive
Total students	10	12
Reference mark mean	2.45	2.69
Control mark mean	3.92	5.08
Mean difference	1.47	2.39
Standard Deviation	2.41	1.49

3.4. Experience 2 vs. experience 3

When comparing results from experience 2 and 3, the advantages of using the system with students having previous knowledge become clear. Table 3 shows the results when considering the whole set of students, while table 4 shows the results when considering only the students that used the adaptive version.

Table 3. Comparing experience 2 and 3

	First time	Reinforcement
Total students	44	22
Reference mark mean	5.78	2.58
Control mark mean	6.76	4.55
Mean difference	0.98	1.97
Standard Deviation	1.54	1.97

Table 4. Comparing experimental groups

	First time	Reinforcement
Total students	23	12
Reference mark mean	5.77	2.69
Control mark mean	7.4	5.08
Mean difference	1.63	2.39
Standard Deviation	0.98	1.49

In this analysis the results showing a greater increment in the performance for students with previous knowledge are statically very significant ($p < 0.01$). However, it should be noted that this result may be affected by the fact that students participating in the third experience had an initial level much lower than the students from experience 2. Thus their control marks were compared with lower reference marks. Nevertheless, the control exam was harder for this group, and one can expect that students participating in experience 3 would have get much better results is confronted with the same control exam than students from experience 2.

The results shown in tables 3 and 4 affect both the adaptive and non-adaptive versions of the course. When analyzing whether students with or without

previous knowledge take out more benefits from the adaptive features, it seems that there is practically no difference.

4. Related work

There are two works especially relevant when considering previous reports about usage of adaptive systems in secondary schools.

John Anderson [5] reports an experience of several years using intelligent tutorials at Mathematics courses in Pittsburgh Public Schools. He claims that the fundamental contribution of intelligent tutors in that context is the increment they promote on the time each student devotes to studying Mathematics, as well as a better use of that time. In our case, benefits derived from the use of the adaptive system are mainly due to the extra encouragement it provides to the students.

Anderson also remarks the value of working together with the teachers in order to codify what their conception is of the Mathematics curriculum. In this sense, the course used in this work was developed by the teachers themselves.

In a follow up report [6], Koedinger and Anderson describe how the project evolved and took advantage of the design of a new curriculum for algebra in Pittsburgh urban high schools, especially suitable for providing computer-supported teaching. Differently, the goal of our work was to improve current situation at secondary schools, trying to maximize the opportunities for every student, in a context where Mathematics curriculum were not designed considering the use of computer tools in the classroom.

Following a different approach, Bajraktarevic et al. [7] make use of the Learning Style Model proposed by Felder and Silverman to adapt the contents of a geography course for secondary school students. Even if this work does not deal with Mathematics contents, it extends results found mainly in the university educational level to secondary schools. They also show the benefits of applying personalized contents to secondary students.

5. Conclusions

In this work the use of Adaptive Hypermedia for supporting attention to diversity in secondary school was presented. Three experiences designed with the goal of evaluating the impact of their application in a Mathematics course were also described.

Analysing the results, it is clear that AH enhances student performances by taking care of individual

differences, a growing need in the current social context of public schools in Spain.

Another important conclusion is that computer-supported learning, and particularly AH technology, produce their best results when combined with traditional classes. Students that improved the more were those that used the learning system to reinforce contents already studied in previous years.

Additional benefits can be obtained by taking into consideration more aspects of the user model, like learning style and cultural background, for example. Further work it is needed in this direction.

In order to consider a wider use of AH in secondary schools a lot of work remains to be done, especially regarding tools and techniques to make easier the elaboration of educational material by the teachers.

6. Acknowledgments

We thank to the students of the Colegio La Presentación de Nuestra Señora de Madrid, who patiently helped us in the development of the experiments. We also thank to the school teachers who helped in the experiment organization.

This work has been funded by the Spanish Ministry of Science and Education, TIN2004-03140.

7. References

- [1] P. Brusilovsky, A. Kobsa and J. Vassileva. "Adaptive Hypertext and Hypermedia". Kluwer Academic Publishers.
- [2] R.M. Carro, E. Pulido and P. Rodríguez. "Dynamic generation of adaptive Internet-based courses". *Journal of Network and Computer Applications*, Vol.22, pp. 249-257. Academic Press. 1999.
- [3] D. Chin. "Empirical Evaluation of User Models and User-Adapted Systems". *User Modeling and User-Adapted Interaction* 11: 181-194, 2001.
- [4] C. Gena. "Methods and techniques for the evaluation of user-adaptive systems". *The Knowledge Engineering Review*, Vol. 20:1, 1-37. Cambridge University Press. 2005.
- [5] J.R. Anderson. "Intelligent Tutoring and High School Mathematics". *Proceedings of the Second International Conference on Intelligent Tutoring Systems*. Montreal. 1992.
- [6] K. Koedinger, J. Anderson. "Intelligent Tutoring Goes To School in the Big City". *International Journal of Artificial Intelligence in Education* (1997), 8,30-43
- [7] N. Bajraktarevic, W. Hall, P. Fullick. "Incorporating learning styles in hypermedia environment: Empirical evaluation". *Proceedings of AH2003*, at 12th World Wide Web Conference, Budapest, Hungary, 41-52. 2003.