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## ICT for Education

# An Educational Modernization Initiative: The Ponte dos Brozos Project

*Simón Neira-Dueñas and Felipe Gómez-Pallete Rivas*

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*This article describes the technical solutions adopted by the Amancio Ortega Foundation for the development of an educational change project involving three public education centres in Arteixo (A Coruña, Spain). This is a pilot project. Thus, in terms of its technical, organizational and economic aspects, the final result is an educational modernization model which could be replicated by any public agency or private organization.*

**Keywords:** Education, Educational Change, New Technologies, Pedagogy, Portable Technology, Social Change.

## 1 Introduction

"If we manage to change the way we educate children, the way they face life, we may change the world. Traditional methods are just nonsense". These recent words from Nobel Prize for Medicine winner Rita Levi-Montalcini are an accurate summary of the approach taken by the Amancio Ortega Foundation in the Ponte dos Brozos project. Indeed, the immediate aim of this initiative is to contribute to the modernization of the working methods used in our classrooms.

And we do so in one of the many available ways. Our action serves as a bridge between pedagogical methods and new educational resources provided by the continuous advances being made in the field of information and communication technologies (ICT) (**Figure 1**). This may not be the best possible way, but we are convinced that

to act as a bridge between pedagogy and technology lies at the very heart of an exciting change in the historical cycle: the change from an industrial order currently in its death throes to an emerging information and knowledge society.

Technology and pedagogy multiply rather than add to the necessary process of reform of our education system, both inside and outside the classroom. Because the malfunction or breakdown of either of these factors will inevitably lead to failure; that is, absolute zero,

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not merely a diminished or partial success caused by the absence of one or other of the two elements.

However attractive the presence of information and communication technologies (ICT) in schools may be, the urgent renewal of pedagogical methodologies should not be allowed to take second place. The key to success is to ensure that both technological and pedagogical advances move at the same rate as essential components of "educational change", a change that should be seen as an ongoing process and not as a goal in itself.

Any will to establish a hierarchy (first technology then pedagogy, or vice versa) diminishes the possibilities which arise whenever the mutual or bi-directional dependency of both factors is accepted. Thus each factor, in and of itself, is a necessary but not sufficient condition for educational modernization.

## 2 Identifying Traits of The Ponte dos Brozos Project

The social innovation projects carried out by the Amancio Ortega Foundation, <<http://www.fundacionamanciortega.org/>>, have a number of identifying traits which can be summarized as follows.



Figure 1: The Bridge as A Symbol.

As the actions proposed in the Ponte dos Brozos project are intended for public education centres, the Foundation had to call on the collaboration of the education authorities of the Autonomous Government of Galicia. This is the project's **first** identifying trait: its natural area of activity is the common ground between (a) private initiative and (b) public authorities.

The Amancio Ortega Foundation firmly believes in the enormous potential of this formula: the capacity for innovation of private initiative made available to public authorities. Cooperation, as understood here, does not necessarily mean either privatization or the opposite.

The synergies between the two areas of influence represent one of the most promising avenues for social de-

velopment in the current globalization process.

The education modernization project described in this article has a **second** identifying trait: its promoters firmly believe in the important innovative role played by the introduction of information and communication technologies in all aspects of life in general and schools in particular.

The use of such technologies is a powerful tool for change: change in attitude, in processes, improvement, and, especially in the case of the Ponte dos Brozos project, of efficiency in the classroom; that is to say, the improvement of learning and teaching processes shared by pupils and educators alike.

The **third** identifying trait of this pilot experience has already been mentioned: this is an 'experimental' project; that is, it is an initiative carried out with a view to becoming a paradigm. The Amancio Ortega Foundation believes in the value of paradigms; that is, in the value for society as a whole of doing something and doing it well with the aim of proving its viability and usefulness, and then donating the intellectual property rights of the new invention to society.

It is not possible to embark on the modernization of the educational system as a whole. The degree of complexity involved renders such an ap-

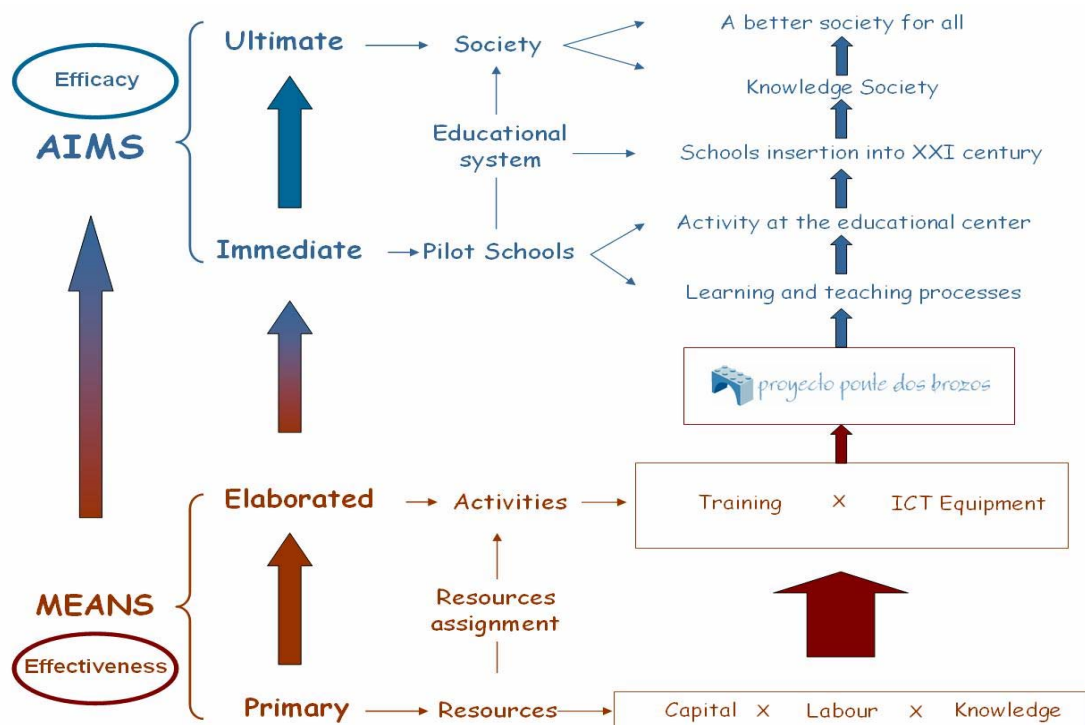


Figure 2: Means-ends Structure.

proach impossible. Thus, to use a much used expression, *we think globally* (as the world is indeed global) *but act locally*, and make our ideas reality in a real world case. In this way we can prove with facts that if it is possible to do it once it must be possible to do it a hundred times at an increasingly lower cost and in an ever shorter time. In no other way can the major problems of our time be solved.

The commitment to society undertaken by the Amancio Ortega Foundation when it initiated the Ponte dos Brozos project was not intended to solve the education problems for the whole of Galicia.

The goal was of a more modest and hence more viable and credible nature: to preach by example by acting end-to-end in specific, real world public centres with a view to proving to the entire education system that this was a viable initiative.

**Figure 2** shows the means-ends structure of the Ponte dos Brozos project.

Funding for the foundation was provided by the founder, which means that the Amancio Ortega Foundation is a private, not corporate, foundation. Thus, as is true of any initiative promoted by this institution, the Ponte dos Brozos project should not be considered as an action intended to improve the image of a for-profit entity, but rather as an expression of the founder's philanthropic desire to contribute to education and progress.

Resources are always assigned so as to ensure the proper development of the project in question. This means that the Amancio Ortega Foundation should be considered as a *service foundation* and not a *financing foundation*, which is the most common model in our environment.

As may be deduced from the chart above, the manner in which the Amancio Ortega Foundation "*commits its means to the achievement of goals of general interest*" (according to the current definition of all foundational institutions) differs from traditional foundations. As a service oriented foundation focusing on projects, the Foundation does not contribute to activities which are currently being carried out, with proven success, by other well respected foun-

dations: scholarship and grant projects, event organization, creation and publication of reports and studies, etc.

### 3 ICT as A Means towards Educational Change

Educators worldwide have developed numerous educational methodologies throughout history, often highly interesting and very different from those usually followed. We refer to methods involving profound changes not only in working patterns but also in the roles played by teachers, pupils, and even their families. Constructivism, learning through projects, problem based learning, etc. are the key words and concepts.

Experts in pedagogy blindly believe in the advantages of these not so new methods: real understanding of whatever is learnt, critical thinking, self-confidence, creativity, teamwork... but, throughout history, they have always been thwarted by the difficulties that teachers encounter when trying to put them into practice in the classroom. These methods require a great deal of effort and time for both educators and pupils. This fact, together with the density and volume of the syllabuses to be covered during the teaching year, makes their implementation unviable and utopian.

But the arrival of new technologies is radically changing this scenario. Computers are bringing a high performance component to our day-to-day work which is beginning to facilitate these modern pedagogical tasks that, with traditional methods, required such a great effort.

It has to be borne in mind that with a laptop, say, you can access the contents of the biggest library in the world (the Internet) at any time and from any place, be in direct contact with teachers and classmates in order to exchange knowledge, and make use of powerful and effective creation, presentation, and knowledge exchange tools.

Thus, new technologies can be used to teach in a different way, and so those of us involved in the Ponte dos Brozos project regard such technologies as a means rather than an end: **we do not want computer literacy to be taught in the classroom; we want better teaching through computers.**

In the following paragraphs we will see how new technologies have been integrated in the classroom as a means for pedagogical change.

### 4 Preliminary Technological Aspects

From a technical point of view, the Ponte dos Brozos project is based on several experiences which have proved successful. To this end, various education centres in Spain, Europe, and the United States have been studied and visited to assess not only such technical aspects as technologies employed, ease of deployment and administration, and cost, but also the degree of acceptance on the part of teachers and pupils, and the appropriateness of such technologies to drive educational change. This preliminary study has led to a number of conclusions.

The first conclusion is that the system should be as flexible as possible for each user: to paraphrase a Spanish saying "*every teacher has his or her own method*" and so, contrary to what happens in business environments, each teacher and pupil tends to use his or her own hardware and software model. This makes it very difficult to reach a consensus throughout the educational community about the use of pre-established software, hardware, or web content. The Internet and communication between teachers around the world encourage the download, exchange, and installation of new software every day, whereupon it is tested for its suitability for use in the classroom.

Hardware such as CD recorders, USB memories, digital video and photo cameras, physical parameter measuring devices connected to computer serial ports, tactile whiteboards, and digital video projectors are widely used on a daily basis.

The download, installation, configuration, and constant use of such software and hardware tools is always the responsibility of the teachers and pupils themselves, which means that other technologies such as *Thin Clients / Terminal Servers* or the numerous Linux 'live' distributions have been ruled out as they require a high degree of effort and knowledge when it comes to installing and configuring new software or devices.

A second conclusion is centred around the standardization of the technologies used. The exchange of information and educational material among teachers in the same or different centres around the world over the Internet, intranets, or by physical means is a daily and constant reality. In order to reach a consensus among all parties, standard and popular formats, tools and protocols are used so that anyone can read and modify them anywhere in the world. MSWord, HTML, Excel, PowerPoint and PDF documents; JPG images, mp3 audio files, MPG, AVI or WMV video files, SMTP format e-mails, mail lists, commercial instant messaging tools, Clic and Hot Potatoes activities, flash files, USB memories, CDs and DVDs, SMB protocol based file exchanges ... these are examples of standard and common technologies that need to be supported if we want fluent communication between teachers worldwide so as to encourage mutual training and the creation and sharing of educational materials.

The creation of digital material for daily activities in the classroom is no easy task if all the syllabus is to be covered. But the creation and sharing of such material is necessary to avoid duplication of effort (it is very normal for a teacher in Pamplona, Spain, to take advantage of class material produced by another teacher in the USA). Hence the importance of world wide standardization in digital communication methods. This fact has caused several closed, albeit widespread, technologies, such as e-Learning or content publishing platforms, to be ruled out.

Another good reason to use these popular technologies is continuous



Figure 3: The Computer Corner.

vocational training. It is important for both teachers and pupils to have access to such technologies in all aspects of life so as to become accustomed to using them in an easy and effective manner. This means that the equipment they use in their education centre should be similar to what they use in their homes, in their friends' and family's homes, in offices, cyber-café's, mass media, in other education centres, in companies...

In Spain, now and for the last 12 years the technology most commonly used is the common or garden PC with multimedia capacity, Internet, and a Windows operating system (if we were in the USA we would also be talking about Mac technology).

Finally, it is important to stress the need to introduce computer literacy in the classroom rather than giving computer literacy courses. It has been proved that for the use of new technologies to have a positive impact on educational processes, and not just be mere "computer courses", access to computers needs to be constant, just like any other classroom tool. The use of computer classrooms necessarily means that the use of new technologies is occasional, leading to the loss of training time due to having to move from one classroom to another, the loss of personalized user profiles for teachers and pupils and, above all, the loss of focus on didactic aspects as the occasional nature of this form of training draws pupils' attention to computers and their software, distracting them from the content that they ought to be learning.

### 5 Ponte dos Brozos Project Technology from The User's Point of View

After analysing the abovementioned experiences, and taking the best parts from each one and rejecting the worst, it was decided to provide teachers participating in the project with the following technological equipment.

For infant and first cycle primary education (children from 3 to 7) classrooms were equipped with what are commonly called "computer corners" (Figure 3). These consist of two desktop multimedia computers connected to the centre's intranet and installed in

a corner of the room. All children in the class have access to this corner, in pairs and for equal length turns. Normally, each computer is shared between two children so that they learn to self-organize, share, and work in teams.

In these corners, teachers and children use software that varies depending on the teacher or on the topic of the lesson. Some teachers use commercial educational software which suits their specific needs and that they have previously tested. Others who cannot find suitable solutions on the market develop their own programs with author tools such as Clic, Neobook or even PowerPoint, and use image editing applications, sound edition, scanners, and digital cameras. Other teachers even teach the first steps towards reading and writing using simple text processors with surprisingly good results. In this first phase of the educational process the goals attained by using new technologies include memory exercising, spatial vision, logic, colours and shapes, first letters, first sums...

For teachers, access to Internet on classroom computers provides access to the experiences of other teachers around the world, experiences from which they can learn. It also provides access to an endless list of software applications and audiovisual material which may be of great use in the production of their own classroom material. The education centre's Intranet also allows teachers from different classrooms to share their materials and knowledge on a real time basis.

In the near future it is also planned for teachers to communicate with their pupils' parents by e-mail or by publishing, say, the material being used in the classroom or photographs taken in the classroom during the week on the centre's web site.

For second cycle primary education (8-9 years) the same philosophy is applied as for the previous courses (computer corners) but moving towards what is known as 1:1 technology (one computer per pupil).

This involves the occasional use of computer classrooms, video projections for all pupils at the same time as activities performed digitally by teachers and pupils, and resources obtained



**Figure 4:** AlphaSmart, A Transition Technology.

from Internet, plus the introduction of a new tool: the AlphaSmart word processor (**Figure 4**).

AlphaSmart is a small keyboard with a small LCD screen which acts as a word processor. The idea is for it to be an introduction to laptops, the tool that pupils will use in the future courses, but which children at that age are still too young to operate. AlphaSmart, however, offers a similar tool but one which is much easier to use, cheaper, and more resistant to dropping. It also covers one of the main classroom objectives for that age group, text writing, with excellent results from what we have seen in the USA and the UK.

Pupils can even take these keyboards to the library where they can gather data as a research exercise and, back in the classroom, download it onto the computer through a USB port where they can edit and improve their texts using any word processing software. In the CEIP Ponte dos Brozos there are 2 shared trolleys with 30 AlphaSmart each, to be distributed among classrooms according to specific needs.

As of third cycle primary education (10-11 years) computer corners are no longer used; instead there is full commitment to 1:1 technology. It has been demonstrated that the introduction of 1:1 technology in the classroom for daily use helps to bring about educational change, which is one of the objectives of the project. Fixed desktop computers on classroom desks is an option, but this reduces pupils' visibil-

ity and working space and hinders both mobility and teamwork. Moreover, they require major cabling for data transmission and power supply. The alternative used in the Ponte dos Brozos project is laptops connected to the centre's network through wireless technology. This system allows the classroom layout to be changed to encourage teamwork and the use of new educational technologies.

Laptops not only allow children to solve exercises from web pages and Clic or HotPotato activities by digital means, but they are also a valuable research tool thanks to Internet access and the content posted on the web by teachers or other pupils, either on the centre's web site or file servers. The production of research-based materials by pupils is another strong point for portable computers. Text processors, spreadsheets, or presentation edition programs such as PowerPoint are also

powerful tools for the production of class-work. All the above, together with the versatility of laptops for working anywhere, and the efficiency of communication via e-mail, instant messaging, or file servers, encourages pupils to work in teams and helps teachers to monitor their work and provide ongoing tutoring. The digital content created by pupils from their initial research is presented, shared, and discussed using video projectors, web page publishing, and simple mail lists.

As the responsibility of looking after a portable computer is too great for this age group, it was decided that the equipment would be kept in and be the property of the centre. Computers are stored in metal trolleys with wheels, shelves, and plugs which are taken from classroom to classroom as needed (**Figure 5**). Each trolley has a capacity for 25 computers, the batteries of which are recharged en masse once the class is over.

For Lower Secondary, Upper Secondary, and Vocational Training (students aged 12 years and over) the approach described in the preceding paragraphs is maintained. Laptops are used as integrating tools for research, creation, exhibition, communication, and discussion activities (in short, for learning – **Figure 6**) but pupils take the computers home once the classes are over. This allows pupils to work and keep learning any time and anywhere. In the classroom, on field trips, in the library, during breaks, at home, on the bus, during holidays... Physical and time barriers disappear thanks to this tool.

Another advantage of this tool is the unlimited creative and explorative



**Figure 5:** Trolleys.



**Figure 6:** Pupils Preparing a Presentation Using Laptops.

possibilities offered. It is capable of motivating and attracting any pupil, even those hyperactive ones who normally fail at school.

In order to make access to portable computers easier for pupils and families, the Foundation has established the following procedure.

The Amancio Ortega Foundation provides initial funding equivalent to 50% of the cost of the equipment for all families taking part in the programme.

The Arteixo town council provides further funding for the remaining 50%. The final amount of this funding is determined by the local council according to their own criteria. If there is any residual amount not covered by the two funding sources – which in practice tends to be, on average, 25% of the cost of the computer – the families themselves have to provide it.

Finally, families may have a third source of financial assistance provided by a number of financial entities collaborating in the project on a non-profit basis: Banco Pastor, Banco Gallego, and Caixa Galicia, in the form of a 0% loan to be paid back in monthly instalments. The number and amount of the instalments depends on the time that each pupil has to spend in school to complete his or her training cycle.

The Foundation, the town council, and the financial entities are responsible for the ongoing coordination of their respective resources and working methods in order to prevent any pupil from being excluded from this programme for economic reasons.

This programme of funding and

loans goes far beyond the advantageous economic conditions offered to parents. The main achievement of this programme is, as we involved in it tend to say, "to build community", an aspect of the Ponte dos Brozos project of which we are particularly proud. The programme is the result of combining the efforts of a number of very different institutions: a town council, several banks, a foundation, the governing bodies of two local public schools, a computer manufacturer, the pupils and, of course, their families.

### 6 Other Equipment

In addition to the computers used in the classroom and the personal laptops of the teachers and pupils, there is additional equipment available to pupils and teachers working at the centre: laser network printers installed in common areas such as libraries and staff-rooms, high-powered multimedia computers, video and CD-DVD recorders for performing complex multimedia tasks such as digital video, colour ink jet printers, scanners, video projectors, interactive digital whiteboards, video and digital photo cameras (**Figure 7**).

### 7 More Specifically: The Network

The computer network covering the three education centres which make up the experimental field of the Ponte dos Brozos project is similar to that found in any business environment.

All desktop computers are interconnected by a switched Fast Ethernet network with category 5e copper ca-

bles. In each Infant and Primary classroom there are 4 network access sockets and another one close to the ceiling for use as an interconnection point for the wireless network. In Lower Secondary, Upper Secondary, and Vocational Training, there is only one access point per classroom since desktop computers are hardly used in the classroom.

Buildings in a centre are interconnected via multimode fibre through underground ducting. Thus, nearby centres are interconnected via monomode fibres permitting server and Data Centres (DCs) to be shared so as to save on system administration costs and effort.

DCs in each centre (or group of nearby centres) have a rack containing a number of UPS protected servers. DCs are connected to the Internet link (ADSL 2Mbps) provided by the Education Ministry of the Government of Galicia (*Consellería de Educación de la Xunta de Galicia*). Although, as mentioned earlier, client devices use Windows technology, the servers are GNE/LinuxDebian which, despite the initial complexity of installation and configuration provides for ease of replication, script-based remote administration, security, and stability.

A first server acts as a firewall and proxy. In this network, in which any person is allowed to install any program, it is essential to prevent the entry of viruses, worms, and trojans, and also to protect the limited bandwidth available for Internet use, which is nowadays rather saturated due to the use of peer to peer (P2P) programmes. Hence, the firewall is totally closed by default and only allows outbound traffic for certain POP3 mail servers and anti-virus and Windows update services. A web proxy and File Transmission Protocol (FTP) has been installed in the firewall, which acts as cache, anti-virus, and content filter and is managed by the teachers themselves through a simple web interface tool. This means that access to certain web pages or internet files can be allowed or restricted depending on users, groups or class times.

A second server, configured as an active-passive cluster, offers disk, printing, user directory, and back up



Figure 7: ICT Equipment.

copy services. For disk services it uses Samba technology, emulating an NT domain. In all clients the following network drives, which have a daily back-up copy service and virus scan, are mapped:

- Private Drive: each user, whether teacher or pupil, has a private network unit where he or she can safely store his or her personal data;

- Public teachers' drive: teachers may share their common files within a theme based file structure;

- Public teachers and pupils' drive: as above, but with access for pupils too. This unit is structured in a hierarchical manner, corresponding to classrooms or pupil workgroups;

- Media library: read-only network drive where project coordinators may leave materials, content, and software of general interest.

Users properties and passwords are stored in an OpenLDAP server where users are authorized to access the network, to access Internet, or to access the wireless network, as explained below.

The last server in the network's DMZ acts as web server for teachers' and pupils' personal pages. Each user

has a file in their private network unit where they can insert information to be immediately published on the Internet. This system makes amending or uploading a web page from any HTML editor immediate; no FTP type tool is necessary for uploading or updating contents.

As far as the wireless network is concerned, coverage of the relevant centres is practically total. Due to the high density of access points it was not easy to distribute them: in principle, with two access points at maximum power a full centre could be covered.

However, in an education centre with wireless technology where there could eventually be 200 to 400 clients connected at the same time with the consequent saturation of the shared environment offered by an access point 802.11g with 54 Mbps bandwidth. We therefore need one access point for every one or two classrooms to avoid a drop in performance. This gives rise to another problem: we only have 3 radio channels which do not overlap one another with which to configure our access points and we will have dozens of access points coinciding in a small space. The way to solve this

problem is to "play" with the transmission power of each point, to separate them as much as possible, and even to use directional antennae so as to avoid overlaps.

Security of the wireless network is crucial, as, based on experience, the natural tendency of young users is to play at being hackers and try to access all their school mates' and teachers' data as it circulates on the airwaves by using one of the many utilities available in the Internet for that purpose.

For this reason we decided against the popular but fragile WEP (Wired Equivalent Privacy) encryption and to use the WPA (Wi-fi Protected Access) system, authenticated against a Radius server using the user name and password as in the network. WPA is not 100% reliable either, so we will be on the lookout for future standards to plug this vulnerability.

## 8 Maintenance

A technological environment such as the one we have in the Ponte dos Brozos project, where, to date, a total of 8 buildings have been computerized and where there are more than 500 computers and a thousand users (figures which will grow in the future) is not so very different from the technological environment found in a major company.

To ensure that all this infrastructure is properly maintained requires a great organizational effort among all members of the education community: teachers, parents, and pupils in cooperation with the Foundation's IT team. Thus, it is essential to establish clear limits to each party's responsibilities.

On the one hand, the Education Ministry of the Government of Galicia is responsible for ensuring that Internet access is operational as well as administering the router, the central e-mail account server, and the content publishing platform.

A specialized team formed by professional Fundación Amancio Ortega staff, and personnel from the Arteixo local council and external companies is in charge of primary maintenance of ICT infrastructures through remote access: this includes network electronics, access points, and servers. In addition, a itinerant computer specialist

deals with any hardware and software problems that the personnel in the education centre are not capable of solving, in cooperation with the technical post-sales services provided by the equipment suppliers.

However, it is the teachers and pupils themselves who are responsible for the lion's share of maintenance work. It should be realized that a network such as this, where everyone has administrator privileges over his or her equipment, where software and hardware may be installed at the user's discretion, and where equipment is used by children and youngsters, there is a high risk of software problems of all kinds, including viruses and destabilized operating systems.

For this reason there is a teacher in each centre, trained in basic computer skills and in direct contact with the Foundation's technical department of the Foundation who coordinates a group of pupils interested in computing who, during their spare time (mainly break-times and out-of-school hours) devote some time to troubleshooting for pupils and teachers. They may offer support on the use of a certain application, reinstall or configure the operating system, liaise with the computer supplier's technical service, etc...

One essential tool for an efficient maintenance of such a large and potentially troublesome network is a hard disk image server. In our case we use Rembo.com. At the slightest problem of instability in the operating system or its configuration, in a matter of minutes the computer automatically reinstalls and configures itself with a template image through the network. Several times during the school year model-computers are generated using the most up to date versions of the software that users most commonly employ, together with the very latest operating system patches and service packs. The hard disk images of these computers are kept in the server and transmitted through the network to any other computer having problems. Even in extreme situations, for example when all computers are having a problem (due, for example, to a virus attack) these images may be transmitted in parallel to all computers using

multicast. In this way all computers can be repaired in minutes.

In order to avoid data losses during this process, it is the user's responsibility to make back-up copies of all his personal data in the disk server. For desktop computers, this is made automatically by using users' profiles. It is also the user's responsibility to reinstall all uncommon software not contained in the centre's official images.

### 9 The Ponte dos Brozos Project in Figures (May 2005)

3 centres:

- CEIP Ponte dos Brozos (Infant and Primary education)
- IES Pastoriza (Lower Secondary Education)
- IES Sabón (Upper Secondary and Vocational Training)
- 130 teachers
- 1,600 pupils
- 1,300 households
- 105 desktop computers (125 planned for 2007)<sup>1</sup>
- 355 laptops (1,000 planned for 2007)
- 16 servers
- 32 Wi-Fi access points
- 17 network printers
- 20 video projectors (30 planned for 2007)

Ratios in the classroom involved in the project:

- Computers / teachers: 1:1
- Computers / Infant and 1<sup>st</sup> Cycle Primary pupils: 1:12
- Computers / 2<sup>nd</sup> and 3<sup>rd</sup> Cycle Primary pupils: 1:2
- Computers / Lower Secondary pupils: 1:1
- Computers / Upper Secondary pupils: 1:1
- Computers / Vocational Training students: 1:1

*Translation by Luis Fuentes Núñez*

<sup>1</sup> Computers used in computer classrooms and school administration facilities are not included.

# On The Superiority of Internet-Based Mass Enrolment to High Schools over Traditional

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*Fairness in educational enrolment means that a student with better previous educational results is preferred to a worse student in every school they apply to. In this paper we show that in the case of mass enrolment it is difficult to make it entirely fair. This observation has lead us to the design and implementation of a client-server enrolment system working over the Internet. We make an attempt to formally prove that computer support is necessary to achieve fair mass enrolment. First, we formally define enrolment and its fairness. Second, we formally criticize mass enrolment performed with the use of traditional methods, and third, we introduce algorithms coordinating computerized mass enrolment coordination and prove their correctness.*

**Keywords:** algorithms, combinatorial problems, e-Government, e-Education, educational enrolment, enrolment fairness

## 1 Introduction

Fairness in educational enrolment means that a student with better previous educational results is preferred to a worse student in every school they apply to. This is a fundamental rule, which should be fulfilled in the name of maximizing educational results and democracy.

However, in this paper we show that it is difficult to make mass enrolment entirely fair. This observation made in practice in 2002 (see Section 3.1) has lead us to the design and implementation of a client-server enrolment system working over the Internet (see Section 3.2). In this paper we make an attempt to formally prove that computer support is necessary to achieve fair mass enrolment (see Section 3.3). In Section 4 we formally define enrolment and its fairness. In Section 5 we formally criticize mass enrolment performed with the use of traditional methods, while in Section 6 we introduce algorithms coordinating computerized mass enrolment and prove their correctness. The paper concludes with Section 7.

## 2 Basic Background

In Poland we have the following types of schools:

- primary school (6 years),
- junior high school (3 years) – called "gimnazjum",
- high school or vocational school (usually 3 years).

In this paper we focus on high school or vocational school enrolment, which in Poland has a unified framework. For this reason we will use the term 'schools' to denote both high schools and vocational schools.

Moreover, we will use the term 'students' to denote schoolchildren who graduated from junior high school and apply to a high school or a vocational school.

## 3 Motivation for This Work

### 3.1 Dramatic Event as A Motivation

Since the early seventies of the previous century, Polish schools have been enrolling new students on the basis of their school certificates only. Each school can have slightly different rules to compute the number of points from the grades on the certificates. From all the applying candidates each school admits no more than the number of openings and chooses the candidates who have the highest number of points.

In 2002 the Polish Ministry of Education changed the rules of school enrolment by allowing the candidates to apply to an unlimited number of schools at the same time (before that the applicant was allowed choose just one school). In that year it led to a total chaos in the enrolment process in many schools in Poland, especially in big cities, where thousands of students applied to hundreds of schools and many of them tried to enroll to as many as ten schools simultaneously. The best students were admitted to every school they applied to and consequently blocked places, which pre-

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vented some of the other applicants from being accepted even in one school. It took long weeks full of frustration before they finally found a place while the better students gradually unblocked places by deciding which school to choose.

### 3.2 Our First Solution at A Glance

Those events has immediately led us to the idea that a centralized information processing system for all enrolling schools at least from one entire metropolitan area would solve the problem. In the beginning we thought that the main engine could be a simple sorting algorithm working on data containing the number of points and the list of preferences for each student. It should be noticed that the students had to specify an ordered list of schools starting from the most desired one (in the traditional decentralized process the students chose an unordered set of schools they applied to).

However, we soon had to modify our first draft of the enrolment algorithm to take into consideration the different algorithms the schools used for ranking the candidates on the basis of their certificates.

We implemented a demo system using the modified algorithm on a notebook computer September 2002 and made presentations following which the educational authorities of our metropolitan area expressed interest. In cooperation with educational experts appointed by the local authorities we created a detailed specification of a computerized mass enrolment system, which was implemented by the Poznan Supercomputing and Networking Center – all in six months. Contrary to the previous year's chaos, the subsequent enrolment in Poznan in 2003 was a great organizational success. Students could submit their certificates and preferences until Friday afternoon and received the final results the following week – on Tuesday morning. On Sunday before the Tuesday a super-committee of all school principals worked together and modified their school's offers in order to improve compliance with students' preferences. As a result, each student was admitted to one educational place at most. More than 90% of students found places in this phase of enrolment. The rest did not because the preference lists they had provided proved too short.

### 3.3 Need for A Theoretical Justification

Our enrolment coordination algorithms and systems are mostly viewed as a solution to a specialized problem in a case-specific organizational environment. However, we believe that they can have several more global applications.

For this reason we have decided to focus on objective formal methods, to criticize traditional methods used in mass enrolment and prove that computer-oriented algorithms overcome these difficulties.

### 4 The Enrolment Problem and Its Fairness

In order to define the enrolment problem, we assume that each candidate provides an ordered list of schools starting from the most desired one.

**Definition 1.** *The enrolment problem*

#### Input

$p$  – preferences,  $p_{ij} = k$  means that  $k$ -th school was ranked  $j$ -th by candidate  $i$

$q$  – quality of a student,  $q_{i,k} = v$  means that student  $i$  in the opinion of school number  $k$  is valued at  $v$  (in this paper we assume that each student has a different quality value), if the value does not depend on the school (each school has the same opinion) we omit  $k$

$s$  – maximum school capacity;  $s_k = l$  means that school  $k$  can take in not more than  $l$  new student

$n$  – number of students

$m$  – number of schools

#### Output

$r$  – enrolment result,  $r_i = j$  means that student  $i$  is assigned to his preference number  $j$ -th or 0 if there is no school for student  $i$

#### Problem

Find integer  $r$  such that:

1.  $\forall_{i \in [1, n]} 0 \leq r_i \leq m,$
2.  $\forall_{k \in [1, m]} s_k \geq \left| \left\{ p_{i, r_i} = k \mid i \in [1, n] \right\} \right|.$

Our Definition 1 does not describe all required solution properties. We would also like our enrolment to be fair.

#### Definition 2. Fair enrolment

If student  $i$  is admitted to school  $r_i$  and student  $j$  is not, although he/she would like to,  $i$  should have better quality than  $j$ .

$$\forall_{i, j \in [1, n]} \exists_{k < r_j} (p_{j, k} = p_{i, r_i} \Rightarrow q_i > q_j).$$

Definition 2 describes a rule which could be easily checked on publicly available lists of admitted candidates.

### 5 Traditional Distributed Enrolment

Traditionally, each school performs the enrolment independently of the others, and the process is not coordinated by anyone. We distinguish two variants of such enrolment: with strongly limited and unlimited number of schools the student can apply to at the same time.

#### 5.1. Limited Number of Schools The Student Can Apply to

The most common limit set by different countries throughout the years is between one and three.

##### Algorithm 1

Each school performs its individual enrolment process at the same time. No school can recruit more students than the number of available places.

**Theorem 1.** *Algorithm 1 is not fair.*

**Proof.** We can easily imagine a situation where a student with fairly good results applies to very popular schools and is not admitted anywhere in the first stage of the enrolment process because of too many better applicants. Had he or she chosen a less besieged school, he or she would have been admitted straight away. The algorithm is not fair because the results of enrolment depend on the student's ability to predict a school's popularity in a given year.

## 5.2 Unlimited Number of Schools the Student Can Apply to

The great inconvenience and disadvantage of this method lies in the fact that the organizers of enrolment have to force students to make hasty decisions. Moreover, in practice the process appears to be very long and inefficient. However, in this paper we discuss its fairness only.

### Algorithm 2

Each school starts its enrolment at the same time. After the application submission deadline, students who are potentially admitted are required to confirm their enrolment within a few days or else they are deleted from the list. Candidates who were rejected at first are now added to the list of admitted students to fill in the empty places, but again they are given some time to confirm their enrolment. The process continues until the lists contain confirmed enrolments only. What is more, each student can confirm his or her enrolment in one school only, which means that the decision has to be final.

**Theorem 2.** *Algorithm 2 is not fair.*

**Proof.** Not fair, because it requires students to make risky decisions in a short period of time. A good but nervous student will probably confirm the first offer, although he or she had a chance to get a better school, providing that he or she waited patiently until better students confirmed their enrolments and unblocked places.

## 6 Centralized Coordination of Mass Enrolment

In the previous section we have proved that traditional distributed mass enrolment is not fair. When we discovered this in practice (see Section 3), we introduced central computerized mass enrolment coordination, fairness of which we will prove in this section. We will separately discuss several variants applied in different circumstances.

### 6.1 Coordination Algorithm for a Unified Criteria Problem

The unified criteria problem is the simplest one, but still useful in practice (see [3] for examples). It assumes that all schools use the same student ranking methods and therefore it is enough to compute one quality value for each student.

#### Algorithm 3

Sort the student records by their educational results starting from the best student. Take the first student from the list and let him choose any school which still has openings. Remove the student from the list, and repeat the operation for the next student.

**Theorem 3.** *The sorting algorithm is fair for the unified criteria problem.*

**Proof.** Fairness rule from Definition 2 will be fulfilled, because only a candidate with better results can steal another candidate's dream place in a given school.

### 6.2 Cloned Applications Algorithm for Different Ranking Criteria in Every School

The following algorithm was first implemented on a notebook computer in 2002 and used to build the first enrolment system in 2003 (see Section 3). It is almost the same as the traditional Algorithm 2, but all decisions are made "inside the computer" (student preference lists are used instead of asking the students for confirmation in the course of the process), which makes work much faster, and which makes the results fair because it does not require risky and hasty decisions from students.

#### Algorithm 4

**Step 1:** For each school there is a queue of candidates:

$$\forall_{k \in [1, m]} C_k = \{i \in [1, n] \mid p_{i,j} = k\},$$

$$\forall_{k \in [1, m], i, j \in [1, n]} |C_k| \geq i > j \Rightarrow q_{c_k, k} < q_{c_k, k}.$$

Each student is cloned to appear in the queue of every school he or she included on his or her preference list.

**Step 2:** Queue  $L$  of potentially admitted students is created and initially assigned:

$$L := \{i \in [1, n] \mid \exists_{i \in [1, s_k]} c_k' = i\}.$$

**Step 3:** A subsequent student with number  $i$  is taken from  $L$  and removed from it.

**Step 4:** We are looking for a minimum value of  $mj$ , where

$$p_{i, mj} = k \wedge \exists_{i \in [1, s_k]} (c_k' = i \wedge i \leq s_k).$$

**Step 5:** For all  $j$  greater than  $mj$  we remove  $i$  from a corresponding  $C_k$ .

**Step 6:** Add to  $L$  students who moved above the admittance border in any  $C_k$ .

**Step 7:** If  $L$  is not empty, then go to Step 3.

**Step 8:** All  $C_k$  contain a list of admitted students (on positions from 1 to  $s_k$ ).

**Theorem 4.** *Cloned applications algorithm is fair.*

**Proof.** 1. The property of fairness is guaranteed in Step 1, which enforces the right student order in each school. This order is not changed in subsequent steps and only superfluous entities are removed in Step 5.

2. Algorithm finds a solution in a finite number of steps, because each entry from  $C$  is added and removed from  $L$  only once.

However, some colleagues found that this algorithm behaves strangely in some cases and thus is not entirely fair [3].

#### Definition 3

For at least two students  $i$  and  $j$  of whom one has  $p_{i,1} = 1$  and another  $p_{j,1} = 2$ : if a given algorithm assigns them in a reversed order, i.e.  $r_i = 2$  and  $r_j = 1$ , we call it a paradox of crossed preferences.

**Theorem 5.** *Algorithm 4 has the property of a paradox of crossed preferences.*

**Proof.** Assume that we have only two students and two schools with only one free place in each one. Preferences are as follows:  $p_{i,1} = 1, p_{j,1} = 2, p_{i,2} = 2, p_{j,2} = 1$ , and quality factors:  $q_{i,1} = 100, q_{j,1} = 200, q_{i,2} = 200, q_{j,2} = 100$ . It is easy to notice that Algorithm 4 will find results  $r_i = 2$  and  $r_j = 1$ .

### 6.3 Moving Applications Algorithm for Different Ranking Criteria in Every School

When one thinks about a new generation of enrolment systems one thinks about something extremely flexible. When we analyzed the enrolment problem for the first time, we thought about agent-based systems [1, 2]. However, existing environments are not ready to be used in such sensitive applications. Today's agent-based environments do not implement persistent systems [2]. Nevertheless, our experiments on agent-based systems resulted in creating a simple and elegant algorithm, which could also be implemented traditionally:

#### Algorithm 5

```

proc AddToSchool (t:Student, k:School);
     $C'_k = \{i \in C_k \cup \{t\}\}$ 
    For a school k queue of candidates is updated:
         $\forall_{k \in [1, m], i, j \in [1, n]} |C'_k| \geq i > j \Rightarrow q_{c'_k, k} < q_{c'_k, k}$ 
    if  $|C'_k| > S_k$ 
    then begin
        AddToSchool("last student from  $C'_k$ ", "next school on his/her preference list");
        RemoveLastFrom  $C'_k$ ;
    end;
end (* AddToSchool *);

begin
    for all t from all students
        AddToSchool (t,  $p_{t,1}$ );
    end;

```

Of course, this algorithm is fair. We have

**Theorem 6.** *Moving applications algorithm is fair.*

**Proof.** Algorithm 5 works on the basis of a rule "better removes worse". Each student tries to apply to the first school on his preference list. If there are already no openings there, the student moves to the next preference, but even if the algorithm leaves someone with his or her first or next preference, the place is not guaranteed and can change in subsequent steps. This is a direct application of the fair enrolment rule (Definition 1). What is more interesting is that it does not allow for a paradox of crossed preferences, because we have:

**Theorem 7.** Algorithm 5 does not have the property of a paradox of crossed preferences.

**Proof.** Assume we have only two students and two schools with only one free place in every school. Preferences are as follows:  $p_{i,1} = 1, p_{j,1} = 2, p_{i,2} = 2, p_{j,2} = 1$ , and quality factors:  $q_{i,1} = 100, q_{j,1} = 200, q_{i,2} = 200, q_{j,2} = 100$ . It is easy to notice that Algorithm 5 will find the correct results  $r_i = 1$  and  $r_j = 2$ .

### 7 Conclusions

In our first paper [3] we sketched a much wider area of applications for enrolment systems including internal (already implemented and used in practice at Poznan University of Technology since 1998) and external enrolment at Universities. Our next step should be to refine our algorithms or even find more sophisticated ones, so as to make the enrolment process as efficient and fair as possible.

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### References

- [1] Mazurek, C., Stroinski, M., Urbanski, A. P., A Client-Server System for Mass Recruitment to Secondary Schools in a Metropolitan Area, in: *eAdoption and Knowledge Economy* (Eds.: Cunningham, P., Cunningham, M.), IOS Press, Vienna 2004, 1801–1808.
- [2] Plóciennik, M., *Solving Recruitment Problems in Agent-Based Environment*, M. Sc. Thesis, Faculty of Computing Science and Management, Poznań University of Technology, 2004 (in Polish).
- [3] Urbanski, A. P., Nawrocki, J., Algorithms for fair and efficient educational recruitment, Conference on EDI-EC, Łódź 2003, *Acta Universitas Lodziensis, Folia Oeconomica* 167 (2003), 429–442 (in Polish).