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Francisco Rebelo & Ernesto Vilar Filgueiras

Faculdade de Motricidade Humana, Technical University of Lisbon, Estrada da Costa, Cruz Quebrada, 1495-688 Oeiras, Portugal

Sport Science Department, University of Beira Interior, Rua Marquês D'Avila e Bolama, 6200-001 Covilhã, Portugal

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Ergoshow: a user-centred design game to make children aware of ergonomics and occupational safety and health

Francisco Rebeloa* and Ernesto Vilar Filgueirasab

aFaculdade de Motricidade Humana, Technical University of Lisbon, Estrada da Costa, Cruz Quebrada, 1495-688 Oeiras, Portugal; bSport Science Department, University of Beira Interior, Rua Marquês D’Avila e Bolama, 6200-001 Covilhã, Portugal

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Multimedia has become a part of youngsters’ daily life, although the quality of the current products is not always satisfactory from an educational point of view. Sadly, many multimedia resources are not used as tools for socialising, transmitting knowledge and know-how for improving society. Thus, the aim of the research was highlighting the importance of the user-centred design for developing an educational information system, based on a computer game, for improving knowledge in the ergonomics and occupational safety and health for the children’s domain.

Keywords: multimedia games; user-centred design; usability; occupational safety and health

1. Introduction

Nowadays, teachers often mention that students are not motivated in the classroom and that this could reflect on their learning outcomes. This problem normally occurs in the traditional learning process based on lectures that usually are not very stimulating for young people. An explanation for this might be the fact that children are now familiar with multimedia systems, which are more interactive and exciting. A longitudinal study of 140 low-income children and their use of Internet at home, developed by Michigan State University, reported that gameplay is their primary reason for using computers (Jackson et al. 2005). Gentile and Walsh (2002) showed that American children aged 2–7 play computer games on an average of 43 min/day, children aged 8–12 an average of 56 min/day and teenagers aged 13–17 an average of 78 min/day. The game industry is conscientious of these data, according to ‘The New York Times’ of 23 October 2003 and the investment volume proposed for 2002 for designing multimedia systems in the whole world, either for diversion or training exceeded the investments intended for research in the pharmaceutical industry.

So, one way of keeping the modern student active is to explore the use of information technologies (Dwyer et al. 1991, Negroponte et al. 1997, Muir-Herzig 2004). However, these authors highlight the important role that teachers should have, as it is necessary and essential that they change their forms of teaching. In this context, the new paradigm is that
teachers no longer are the sole holders of knowledge and the only means of transmitting it in a valid and acceptable way.

The research conducted by Knezek (1997) and McFarlane and Latorella (2002) shows that the use of technological information resources for education of children in primary and secondary levels significantly raises the performance achieved by students. The same evidence was related by Nussbaum et al. (1999), mainly in learning mathematics and reading. Other studies showed that educational games offer an environment in which learning is enhanced by stimulating tasks, and skills are developed as a result of playing the game (McFarlane and Latorella 2002). Despite these advantages, Hinostroza and Mellar (2001) show that most current educational software does not offer significant educational situations, especially educational games for mathematics, which emphasise repetitive arithmetic tasks, restricting the focus on resolving problems without introducing them to the context. Murray et al. (1998) confirm this concept and show that it makes the system unattractive and disappointing and may result in an opposite effect. In other words, the emphasis on conceptual aspects in this context results in a low achievement by students, who find no circumstances to develop the skills expected from the use of software, or develop them in the wrong way. In spite of these data, projects for the development of multimedia systems, in most cases, do not involve users in a systematic manner during the development process of these systems (Norman and Draper 1986).

Typically, the emphasis has been given only to the technological aspects, the empirical knowledge of professors, the experience of successful projects or to formal scientific research, all, without considering the end user during the design (Nielsen 2000).

Thus, the aim of this research was to highlight the importance of the user-centred design (UCD) for developing an educational information system, based on a computer game. First, pilot studies will be presented for the validation of this system.

2. UCD in educational games

According to Mandel (1997), one of the difficulties of producing good quality educational software seems to be linked to the fact that in the design process there is a significant difference between representations that designers, programmers and teachers have on the teaching and learning processes. Tchounikine (2002) show that the problems with the majority of educational software seem to be the difficulty between the elements designers have at their disposal and the way in which educators specify their ideas. According to the author, interaction between programmers and educators is a problem due to the difficulty of sharing concepts in different areas.

To solve this problem, a set of techniques was developed in Scandinavia, intended to manage design with multidisciplinary teams and potential users. The proposed approach named participative design (PD), emphasises the importance of democracy in a work environment, improving work methods, design process efficiency (through users experience and comments) and supporting multidisciplinary teams. From this point of view, the use of PD has brought the following benefits:

1. the company could follow-up and evaluate the project;
2. researchers had a greater understanding and power over the elements, as problems were shared between the directly involved participants. With this interaction, researchers could carry out their theoretical proposals;
3. greater possibility of satisfying the company’s objectives, as they directly took part in the system’s development;
(4) possibility of mutual learning and improving work practices and
(5) greater efficiency and quality.

The involvement of potential users in the project could not be disregarded in any of the
software development phases, even the initial ones, such as the concepts, software
architecture and content development. The users’ cooperation during the whole design
process provided the workgroup with the necessary information.

Besides the PD activities, the resulting system quality is improved due to a better
understanding of the potential users’ accomplished work by combining their knowhow in
the design process (Braa 1996). At present, the involvement of potential users only appears
in the final development stages of a product, making it impossible to produce meaningful
changes. To this fact, we can still add temporal commitments or financial difficulties.
Therefore, by associating the methodologies proposed by the UCD, we are trying to
minimise the distances between the user’s real needs and the technological and didactical
contributions of educational software.

According to ISO 13407, the UCD is a move towards developing interactive systems
with the purpose of developing usable products. This should be a multidisciplinary activity
that combines human factors, knowledge and ergonomic methodologies. Applying
ergonomics in the design of interactive systems improves efficacy and efficiency, improves
conditions of use and avoids possible adverse effects on health, safety and performance.
According to Rieman (1996), the most important role of educational software goes beyond
the promotion of learning. Therefore, it is not only a question of learning how TO DO
something with an interface, but also of learning how to deal with an interface to LEARN
a new concept. In this context, educational interfaces hinder the cognitive development of
users, with an impact on the learning of certain concept areas (Vergnaud 1997).

3. Ergoshow: development methodology and results
Ergoshow was developed for children (8–14 years old) and deals with subjects related to
ergonomics, safety and health aspects. We started by assuming that the consolidation
of the teaching–learning process happens when a youngster understands the ‘reason of
things’, as opposed to being confronted with an ensemble of ‘prescriptions’.

The Ergoshow project team was composed by ergonomists, designers and an architect
and was developed in three phases:

(1) system definition concept;
(2) preliminary and detailed development and
(3) final validation.

In this article and for the reader to better fit into the perspective of UCD applied in
these studies, we will describe the methodologies and results for each one of the previous
phases.

3.1. System definition concept
The Ergoshow project was born from a request of the Portuguese Ministry of Labour
and Solidarity, related to the need of producing didactic resources to raise
awareness of primary education school students about issues related to ergonomics,
safety and health at work. These resources will be used by primary education teachers and
integrated in their usual teaching programme.
The Ergoshow’s concept definition was developed in the following two steps:

- reference situation analysis of the multimedia pedagogical resources related to ergonomics, safety and health at work and
- brainstorming meetings between the project’s team and teachers.

These steps will be described in the following sections.

3.1.1. Reference situation analysis of the multimedia pedagogical resources related to ergonomics, safety and health at work

The reference situation analysis allowed the team to know the contents and explore similar products using heuristics to evaluate the user interface design and the information architecture of the main multimedia resources (Table 1). This exploration was done by two human factors specialists in four computer programs developed to give information about safety and health for young people.

3.1.2. Brainstorming meeting with the project’s team and teachers

In this step, we develop a brainstorming meeting with the project’s team, the primary school teachers and a focus group with children. We involved teachers with the objective of integrating their knowledge about the characteristics of the intended users, the integration of the Ergoshow in the tasks that they will perform in the classroom and the characteristics of the environment in which the potential users will be using the system (particularly related with the hardware).

A brainstorming meeting was set up between the project’s team and two teachers, specialised in the area of safety and health at work. The objective of this meeting was defining the theoretical contents and ways of presenting the information.

The main results of this meeting were the following:

- Considering that muscular-skeletal problems related to work are a major problem in the European space. The group decided to introduce two modules: one related to manual load handling and another one with seated work. These contents are also important in the life of the children who manipulate everyday loads (e.g. backpack) and spend much time sitting in the classroom and at home in front of a computer.
- Taking into consideration the need of new strategies for motivating students to those contents, the group decided to format them into a multimedia game.
- To prevent users from jumping between game levels, they need to view all the information from each level before answering a questionnaire and receiving a password to enter the next module.
- The theoretical content of the game must be integrated with real examples experienced by users, as for example, ‘what happens if I’m playing videogames for a long time?’
- The group decided to propose the development of a mascot using an animated skeleton metaphor.
- Related to the language, the group decided to use a mix between formal language with theoretical contents and some breaks with jokes to keep the youngster’s attention.
Table 1. Subjects and main characteristics of five multimedia resources developed to disseminate the contents of safety and health at work for children.

<table>
<thead>
<tr>
<th>Software</th>
<th>Sponsors</th>
<th>Subjects</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>The future adventures of kid safety</td>
<td>US Consumer Product Safety Commission</td>
<td>Platform of online games that involves issues such as safety and accident prevention. It uses simple games as quizzes, puzzles, trivia, hangman, crosswords and arcade games. This online system conveys best practices for the prevention of domestic and urban accidents only through the various types of games that seek to transfer information to the children, without requiring them to obtain previous knowledge for solving various challenges. This formula seeks to awaken the natural interest of children by making it necessary for them to obtain the information from other sources in order to solve problems and overcome the various challenges presented during the games. Based on this system, the Ergoshow team opted to involve the children in a game environment, after each software module</td>
<td>By Internet browser using Java (<a href="http://www.cpsc.gov/Children/Childrensafety/">www.cpsc.gov/Children/Childrensafety/</a>)</td>
</tr>
<tr>
<td>Safer journey: international pedestrian safety awareness</td>
<td>US Department of Transportation</td>
<td>It transmits contents related to the best conduct while crossing roads and crosswalks. It guides the users through a 'virtual tour' where the best procedures are taught using a game with questions and answers. Curiosities and other important aspects related to the theme are also transmitted</td>
<td>By internet browser using Adobe Shockwave® Flash (<a href="http://safety.fhwa.dot.gov/saferyjourney/journey/index.htm">http://safety.fhwa.dot.gov/saferyjourney/journey/index.htm</a>)</td>
</tr>
<tr>
<td>NJPIEAS – interactive lead learning centre</td>
<td>NJPIES – New Jersey Poison Information and Education System</td>
<td>Interactive website containing alerts to the dangers of playing in unsuitable environments. The website classifies the dangers into five groups: park, house, market, doctor and construction sites. In each one of these groups and through a simple system that involves the presentation of balloons, warnings and explanations about the various dangers are presented. These balloons are operated putting the mouse cursor over one</td>
<td>By internet browser using Adobe Shockwave® Flash (<a href="http://www.njpies.org/lead/">www.njpies.org/lead/</a>)</td>
</tr>
</tbody>
</table>
of the elements in each environment. The website presents a simple and easy-to-understand language for the children. This simplicity was added into the Ergoshow by the development team in order to change some theoretical contents from the technical literature in simple and understandable contents for children from 8 to 12 years old.

Napo is an original idea that answers the need for high-quality information products that go beyond national borders in search of different cultures, languages and practical needs of workers. Napo and his friends are lovable characters in fun stories with humour and a relaxed approach. The 'safety with a smile' concept is Napo’s contribution for improving safety and health at work places. Napo’s videos do not have verbalisations; so, in this way, they must transmit ‘good practice’ lessons through the character’s MIME and body language. This concept was incorporated into the Ergoshow where many of the contents were adapted to simple speech, easily understood even without verbalisations.

It is a children’s game that encourages them to put the major internal organs of the human body in a correct position. It is a dynamic game and this application seeks to interest children in the anatomy and physiology of the human body. Based on this online application, the Ergoshow incorporated several challenges that invite children to interact with many elements of the human body.

|------|--------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
Regarding language, the group decided to use a mix between formal language with theoretical contents and some breaks with jokes to retain the youngsters’ attention.

In order to allow accessibility to deaf children, the group also decided to reserve an area where all the verbalisations were written.

The minimum characteristics of the hardware to play the game are a Pentium II with 200 Hz, 256 MB RAM, graphics 8 MB, 1 GB HD free and Windows 98.

Regarding these results, it is important to emphasise that the contents of the multimedia support came from the UCD methodology and they express the needs of the potential users, children (students) and teachers (who need this kind of didactic materials to improve their work).

3.2. Preliminary and detailed development

The preliminary and detailed development was aimed at developing the previous concept. In a first step, if the team’s group developed solutions for these concepts, then the teachers and youngster’s were involved in focus group meetings to give feedbacks and suggestions about them.

A focus group meeting was set up between the project’s team and three teachers, specialised in the area of safety and health at work. The objective of this meeting was to receive feedback and suggestions about the theoretical contents and the first prototype of the mascot.

Table 2 presents the main results related to the theoretical contents’ hierarchy. It is divided into three modules, each one with three levels.

Related to the mascot designer, we developed a prototype using a metaphor of a funny skeleton was called BONE (Figure 1). BONE is the host in all the software’s stages and phases. It is an adolescent skeleton, designed in live colours, with a hip-hop appearance and cartoon characterisation, and it uses adolescent language.

Some teachers expressed doubts about the use of a skeleton, symbolising death, to expose contents on health and safety. On this subject, it was decided to ask the children’s opinions that will be presented below.

3.2.1. Focus group meetings with the children results

Three focus group meetings with a sample of young people using paper and digital prototypes were conducted in order to check their feelings, opinions and suggestions about the following:

- BONE mascot;
- Ergoshow’s storyboard; and
- identifying interaction problems in the first functional prototype.

About the BONE mascot, the reactions to the skeleton figure (BONE) were very good. Here are some opinions expressed by 20 children:

- It is a beautiful boy. Can I interact with him?
- The mascot is good, but it will be better with other colours.
- It is a good-looking skeleton. Can I have some images?
- The figure is attractive; what is its name?
According to the comments and suggestions given by the children, we changed the mascot’s colours and dress accessories.

In order to evaluate the adaptation of the contents, the Ergoshow’s storyboard was assessed through a focus group with 10 students. The main results obtained were related with a better explanation of some concepts, in a language closer to the one used by young people.

Figure 2 illustrates the storyboard used for evaluating the game’s implementation of a text developed for demonstrating how to manipulate loads.

Based on these suggestions, we carried out a brainstorming meeting with the team to develop a methodology for using language closer to the potential users. The main result of this meeting was the need to listen to young people during their daily activities and

### Table 2. Hierarchy of the theoretical contents.

<table>
<thead>
<tr>
<th>Level</th>
<th>Knowledge</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Module I – Manual handling of loads</strong></td>
<td>1</td>
<td>It explains the concepts related to anatomy, physiology and biomechanics of the spine, which are important for understanding its operation</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Functions of the spine</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Constitution of the spinal unit</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Kinematics of the spine</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>The function of the inter-vertebral disc</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Caution before lifting a load</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Postural procedures to lift a load</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Postural procedures to carry a load</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Care to place a load</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Axial and cutting forces and flexor moments</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>The effect of these forces on the vertebral structures</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>The effect of posture on the intensity of the forces acting on the spine</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>The effect of external loads in the intensity of the forces acting on the spine</td>
</tr>
</tbody>
</table>

| **Module II – Seated work** | 1 | Explains how muscles function | Static and dynamic muscular work |
| | 1 | Mechanism of muscle contraction | |
| | 1 | Factors that explain muscle fatigue | |
| | 2 | Includes recommendations on placing chairs, tables and footrests according to the anthropometric dimensions of users | Adjusting a chair (seat height, backrest, armrest) according to anthropometric dimensions |
| | 2 | Strategies of the sitting posture | Interaction with the desk |
| | 2 | Adjusting a chair (seat height, backrest, armrest) according to anthropometric dimensions | Characteristics of a desk |
| | 2 | Interaction with the desk | Relationship between the chair and desk |
| | 2 | Characteristics of the supports for feet (footrest) | Characteristics of the supports for feet (footrest) |
| | 3 | Includes recommendations on how to position the monitor, keyboard and mouse based on the anthropometric dimensions of users | Adjusting the footrest |
| | 3 | Recommendations for the location and orientation of the monitor on the desk | |
| | 3 | Characteristics of keyboards and computer mouse | |
| | 3 | Recommendations for interaction with the keyboard and computer mouse | |
adapting the explanation of concepts, with the introduction of a language that they normally use.

In order to evaluate the interaction problems and give potential solutions to improve the computer game, we used observation and ‘think aloud’ methods. A sample of 10 students interacted with the program (Figure 3) to perform a task related with vertebral

Figure 1. The evolution concept of the mascot – BONE, select by focus group and interviews with real users. A, anatomy concepts; B, cartoon characterisation; and C, hip-hop and street costume (317.5 × 177.2 mm²).

Figure 2. Storyboard used to evaluate the game implementation of a text (189.5 × 117.3 mm²).

However, there are other situations in which our muscles strength but do not produce movement. It happens when someone holds an object or even when seated.

If the load is placed close to the floor, the focus is on the back, in this way the back should be kept straight and bend the legs until to place the cargo at the right place.

You should not put heavy objects in extremely high places, especially above the level of your shoulders.

The cutting forces are responsible for the sliding of one vertebra over another. In an extreme case, the cutting forces can even cause rupture of the vertebra in this area that you can see.

Before holding the load you should see if it’s too heavy. If you are not able to carry it alone, the better is to ask for help from a colleague.

You can also use an appropriate equipment, such as a trolley or other mechanical device that facilitates your work.

Another thing to remember is that you must always keep your back straight when carrying a load.

After to feed muscles, the blood returns to the heart carrying the degradation product and also carbon dioxide.
column functioning and at the end answered five multiple choice questions. We measured the errors made during the interaction, the performance with the questions and the ‘think aloud’ comments while they interacted with the program.

All participants were informed that the goal was testing the program and not the participant’s performance, so they should be honest in their comments. The results of this test were very positive and we developed a simple and clean user interface that would cause no problems to children. Another positive aspect was that the children showed that they would like to have the final version of the program, repeatedly asking where they could purchase it. These results motivated the team to continue this project using the same described methodologies and strategies.

### 3.3. Interface Description

For a better understanding of the user interface, we will describe the main aspects of the interface. The items were grouped in one of the following four functional areas (Figure 4):

1. **Top toolbar**: on this toolbar, we can find the software’s control elements as well as the system user’s situation and reference indicators.
2. **Host area**: on the left side, there is an area set apart for the host. In this area, the mascot performs several movements without interfering with the Animation table’s elements.
3. **Animation table**: this area is characterised by a white board, in which animations described by ‘BONE’ are posted and where all the animations, films and also questionnaires appear. On the top of the animation table we can always see a text about the subject being viewed.
4. **Lower toolbar**: directly below the animation table is a bar designed exclusively for subtitling. The prime objective of this area was to make the contents accessible to hearing-impaired people, thus broadening the number of possible users of this program.

### 3.4. Final validation

The validation of the first prototype was developed to explore the aspects of a multimedia game’s interface (sound, graphics, interaction, technical language, everyday language and the possibility for reviewing), most appreciated by children (Rebeiro et al. 2008). In this part of the study, we used a sample of 36 students from two 4th grade classes, 19 male and
17 female students, divided in four groups (three groups of 10 students and one group of six with one computer for each student).

Regarding the test results, the Friedman Analysis of Variance for repetitive measures shows that the importance is not identical for the six interface components. This means that the students award different degrees of importance to each one of the studied groups (sound, graphics, interaction, technical language, everyday language and the possibility for reviewing).

To explore which one of the groups is more important for the proposed activities, we applied a multiple comparisons test and we verified that for the Ergoshow ‘Module I, Manual handling of loads’, significant differences existed between:

- sound and graphics;
- graphics and the possibility for reviewing;
- interaction and the possibility for reviewing;
- technical language and the possibility for reviewing and
- everyday language and the possibility for reviewing.

When observing the ranks’ means corresponding to each one of the groups, we conclude that the possibility for reviewing is the group that obtained the most significant value.
Regarding the Ergoshow game’s ‘Module II, Seated work’, we verify significant differences between the following:

- sound and technical language;
- technical language and the possibility for reviewing and
- everyday language and the possibility for reviewing.

When observing the ranks’ means corresponding to each one of these groups, we concluded that the possibility for reviewing is, also in this module, the group that obtained the highest score regarding technical language and everyday language.

4. Analysis

The study presented in this article had the merit of involving potential users during the whole development process of an information system. We contextualised this methodology in the design of an educational software ensemble, in game format, for adolescents from 8 to 14 years old.

The involvement of the potential users in the various development phases of this information system allowed for:

- answering doubts about the use of a skeleton mascot and improving it according to the needs and potential expectations of the users;
- improving the game format and the level of difficulty of the questions;
- verifying if the examples complied with the future users’ everyday realities;
- identifying and changing small problems of the first graphic and navigational environment proposal and
- evaluating the language used and introducing some expressions used by adolescents, without damaging the thoroughness of the transmitted information.

In synthesis we need:

- a better adjustment of the Ergoshow to the users’ mental model, their needs and expectations;
- the possibility to identify mistakes that would be difficult to correct at the end of the project; and
- reducing expenses, as corrections at the end of the project would mean added costs.

Regarding the use of PD, we became aware that applying these kind of techniques and others, originating from organisational psychology and management areas, is extremely important for managing the development of educational products, for controlling each one of the development stages and reinforcing individual competencies of each one of the involved persons.

The UCD has brought enormous benefits to the project. Only by frequent enquiries in each of the product’s development phases, is it possible to adjust, in the best possible way, what designers think of the project regarding imagination and expectations of the target population, mainly because imagination varies according to Mauss (1990), regarding the following:

- culture of the analysed people;
- age group of the target population and
- gender.
It was surprising to observe that the system attracted the attention of individuals outside the proposed age group, mainly adults, with different kinds of profiles and cultural levels. Therefore, this product generated the interest of some companies that requested it for training their staff in the area of safety and health at work.

Information technologies have been used in school environments for over 20 years, with most of its development taking place in the 1980s, when personal computers emerged (Hinostroza and Mellar 2001). An important reason that justifies applying information technologies in this environment is the capacity to improve student’s learning, by giving the student an opportunity to develop different kinds of competencies.

5. Discussion

Despite this, we recognise that the application of the UCD method could restrict all the potentialities of ergonomics and fields of intervention and we think that the final work was closer to the needs and expectations of the children. Being aware of this problem all along the presentation of the Ergoshow subjects, we highlight the importance of ergonomics in the other fields of intervention.

Compared to methods that do not take into account the overall involvement of the potential users in the early stages and the definition of concepts, this study showed many advantages by using UCD procedures in the development of tools for education. This approach allowed us to avoid the academic tendency to set concepts and theories based on our need of making the importance of ergonomics and its fields of intervention known. Apart from the content, the implementation of the UCD methodology allowed us to find the most attractive format for children to be exposed to ergonomic contents in an easier way. The format of a game with the specificity referred by potential users, confirmed many of the observations of other authors and without them we would naturally be led to consider the exposure of the contents in a less attractive way, with the possible consequences for motivating children (Nussbaum et al. 1999, Hinostroza and Mellar 2001, McFarlane and Latorella 2002).

The results obtained with potential users were satisfactory regarding performance, motivation and learning expressed by the children. This fact can be confirmed by the insistence of many children (who participated in the meetings and in the evaluation of the project’s different phases) to know how their parents could buy a full version of Ergoshow. These results lead us to believe that this process, in spite of demanding more time and financial resources in the development process, will meet the needs and expectations of potential users more easily. In conclusion, this project proves that it is a welcome tool for transmitting information about ergonomics and occupational safety and health.

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References


About the authors

Francisco Rebelo received his PhD in Ergonomics from Faculty of Human Kinetics at the Technical University of Lisbon in 1996. Since 1991 he was a faculty member in the Department of Ergonomics at the same University and now is Associated Professor. He is Director of the Ergonomics Laboratory of the Ergonomics Laboratory at the same University. His main research interest is usability and ergonomic design methodologies to improve the human being and system efficiency.

Ernesto Vilar Filgueiras is Industrial Designer (specialist in ergonomics) and has the Master’s degree in Production Engineering at Federal University of Pernambuco (Brazil). He is a PhD candidate in the Faculty of Human Kinetics at the Technical University of Lisbon (Portugal). His research investigates the ergonomic design methodologies to improve the human being, system efficiency and Ergonomic Design. Currently he teaches and researches on ergonomics at the Beira Interior University (Portugal).