The Role of Usability on the Implementation
And Evaluation of Educational Technology

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Abstract
This paper argues that design and usability issues are of
great importance on technology-based implementation
and evaluation programs, as they can have both a
positive and a negative impact on teaching-learning
processes. For instance, the quality of the design can aid
the development of new reasoning skills on the one hand,
and on the other it can affect the understanding of
physical phenomena. From a pilot study conducted with
the purpose of investigating how design and usability
issues impact on the mathematics and science teaching-
learning process in secondary schools in Mexico, we
identify a number of problems that suggest the
importance of considering these issues during the
implementation of educational technology programs and
during the evaluation of its outcomes, as these programs
will ultimately determine the development of, for
example, national curricula and national education
policies.

1. Introduction

In Mexico as in many other countries, the
incorporation of technology into the national education
system is an education policy of primary importance.
There currently exist a number of educational schemes to
incorporate technology into classrooms from elementary
school through university. One of these schemes is the
national project Incorporating New Technologies into
School Culture: The Teaching of Mathematics in
Secondary School funded by the Ministry of Education
and the National Council for Science and Technology in
Mexico (CONACYT)\(^1\). This project is aimed at:
• Incorporating gradually various pieces of technology
into the mathematics and science national curricula at
secondary level.
• Implementing the use of novel technology supported
by a pedagogic model that allows the construction of
learning environments oriented towards the improvement
of teaching mathematics and physics.

\(^1\) Project number: 526338S

Encourage the production of computer environments
that can improve the traditional teaching-learning
methods, i.e., pencil and paper.
The eventual objectives of this program are to raise
education standards, to train teachers in the use of
technology and to broaden the reach of education.
The program started in 1996 and is planned to
conclude in the year 2005. Initially it covered 15 states all
across Mexico including both rural and urban sites, but
has expanded ever since. The software selected for the
project includes:
• In science: Interactive Physics, NIH Image, LXR Test,
  Video Point, as well as Video and CD ROM
  presentations.
• In mathematics: Cabri G om tre, Sim Calc
  Mathworlds, Stella, and Spreadsheets.
The hardware includes Macintosh computers 7300 and
4400, Apple printers 16/8, Optic scanners, Pasco
Introductory Physics Bundle and Smart Pulley (sensors),
TI92 calculators, video cameras, VCRs and network
connections.

In order to achieve the aims above mentioned we
argue that it is essential to investigate how design and
usability impact on the teaching-learning process
particularly in the context of the Mexican users. This is
because usability can have several implications on the
evaluation and implementation phases of the program.
For instance, usability problems can affect the student’s
cognitive processes and the achievement of educational
goals. The latter can consequently influence the
assessment of, for example, the rise in education
standards or the advantages that students gain when
introducing technology into the classrooms.

Moreover, since the ongoing debate between those
who favour the use of computers in education and those
who find them useless, is partly originated by a lack of
convincing evidence on the benefits of using technology,
it can be argued that this lack of conclusive evidence can
be affected by the failure to include the design and
usability variables on evaluation processes.

Thus, we conducted a pilot study aimed at
investigating the impact of design and usability on the
teaching-learning process of mathematics and science in
secondary schools in Mexico [2]. Before analyzing the
design and usability problems that emerged during this
study we will describe it briefly.
2. The Pilot Study

For the pilot study we selected two pieces of the software mentioned above that were previously identified as being problematic i.e., particularly difficult to use by teachers and students:

- Interactive Physics 3.0 (version in English for Macintosh): This is an application used in education to produce and run simulation models of a great range of physical phenomena (see Figure 1).
- Cabri Gomtre II (version in Spanish for Macintosh): This is an application program used in education to help the learner to explore and construct, from the simplest figures to the most complicated geometrical objects in an interactive way (see Figure 2).

The pilot was designed to imitate a school classroom with the purpose of observing usability problems within the different interactions occurring in a real setting, i.e., user-task interaction, user-tool interaction, user-environment interaction, and user-user interaction according to Shackel’s model [11] (see Figure 3). From this model we defined the user as both the student and the teacher. Therefore, we could observe three different types of user-user interaction, the student-student interaction, the teacher-teacher interaction and the student-teacher interaction. With the environment we are basically referring to the immediate environment, that is, school culture school culture has been found to be a major factor influencing the interaction between students and tools [12] but also, we looked at the broader environment, or the culture surrounding school-culture. Finally, with the task we mean, both the different tasks involving the use of the software, and the assignments that the teachers asked the students to complete.

![Image of Interactive Physics](image1)

**Figure 1. Interactive Physics.**

3. Analyzing Design and Usability Problems

From the study described above, we identified a number of problems that can illustrate the importance of including usability testing as standard practice when evaluating the use of technology in education. In order to analyze these problems we will discuss separately those occurring in the user-task interaction, in the user-tool interaction, in the user-user interaction, and in the user-environment interaction.
environment interaction (based on Breakdown Analysis [14]).

3.1. User-Task Interaction

One of the usability problems that had more impact on completing the tasks in Cabri, was learning to draw with the mouse. When the teacher asked the participants to draw geometric figures, they tended to use the mouse as a pencil metaphor. For instance, they experienced difficulties drawing segments because they moved the mouse from left to right as if using a pencil. However, to construct a segment in Cabri it is necessary to define two end points, which are then automatically linked by the program. In a similar way, when they were asked to construct a triangle they proceed by drawing three different segments (as they normally would do if using pencil and paper) instead of selecting the triangle option in the menu bar. An additional problem is that the figure they came up with, looked like a triangle but did not behave in the same way. As a result, the users experienced problems to conceptualize the two different drawings as the geometrical figure they represent.

Other problem that affected the completion of the tasks both in Cabri and in Interactive Physics was the co-existence of Spanish and English within the same framework. For example, some of the simulation models in Interactive Physics included commands both in English and in Spanish. Also, while Cabri’s version was in Spanish, Mac OS was in English and participants had a number of problems when dialog boxes appeared (they generally needed the aid of the teachers to interpret them). The co-existence of several languages in the same windowing environment is a source of confusion and a major cultural usability problem reported in many intercultural usability studies, c.f. [6, 3, 8].

![Cabri Géomètre.](image)

Figure 2. Cabri Géomètre.
We also observed other cultural usability problems such as the difficulty to measure angles in Cabri. Some children could not understand the teacher’s explanations because they were not able to see an 89.98-degree angle as a 90-degree angle. The latter is presumably because mathematics is taught-learned in Mexico as an exact formal science. According to some studies, this is not the case in other countries. For instance, in a cross-cultural study involving science an mathematics education practices, Sutherland et al [13] point out that while in Mexico teaching-learning approaches use a more formal, top-down approach, in the UK they use a more investigational, down-top approach.

The latter suggests that the consideration of usability testing has great importance when the technology is not originally designed for the cultural context in which it is being incorporated. That is the case of Interactive Physics and Cabri G om tre, which were not originally designed with a Mexican audience in mind. Moreover, since Mexico is far from being a homogeneous country (there are important differences between and within its various regions) the inclusion of usability testing becomes central to evaluate the implementation’s outcomes. For instance, in Mexican rural schools students have to learn Spanish as they generally speak one of 52 different indigenous languages (Otom, Zapotec, Nhuatl, Tzotzil, etc.). Also, it is common to find students from very different ages in the same classroom, who cannot study full-time because they have to work in the field. Education in these rural schools is very different from that in urban schools where students speak Spanish as their native language and in many cases learn to speak a second language such as English. Also, they are approximately the same age, and generally speaking, are able to study full-time. Hence, usability problems arising from these differences can be expected. If culturally determined usability problems are not adequately taken into account, the introduction of the technology into schools may fail despite having a number of educational advantages. In other words, although the technological tool might be accurately designed to meet specific educational goals, if students cannot use it because it is culturally inappropriate, the implementation will fail. If the evaluators are not prepared to take into account this kind of usability issues, and they contemplate exclusively education indicators, such as student achievement, they will probably end up recommending inadequate prescriptions in many of the cases.

Other problem that influenced the user—task interaction was that the technology easily shifted from being an educational tool into being the educational goal itself. At the end of the sessions we asked students what have they learned and the majority answered to use the computer. The latter can be due both to usability and to the novelty of using computers. However, this is an important issue to take into account by designers because the software is not being used as expected and therefore the educational objectives it was designed to meet are not being achieved.

Figure 3. The Pilot Study Set-Up
Finally, in the case of Interactive Physics we observed that although the children were highly motivated with graphics simulating cars and trucks, they also got very distracted from the tasks playing with them. In the case of Cabri they got distracted with the possibility of making their own drawings (once they learned to use the mouse they used the system as if it was a drawing application).

Motivation is an essential requirement in educational software [12]. However, if it is not correctly channelled it may lead to usability problems. That is why, Rappin et al [9] recognize the importance of assessing usability in educational software in a different way from commercial or professional software. This is because learners have different needs from professionals and use software for different reasons and with different skills and motivations [15]. For instance, the aim of professional and commercial software is to help users perform certain tasks better, this is, more efficiently and effectively. In contrast, the aim of educational software is to help users develop certain skills. In other words, to encourage learning while doing rather than just doing and sometimes this can mean that designers will have to preclude the learner from performing some tasks more efficiently. The latter does not mean however, that in professional software learning does not take place. Instead it means that in educational software, learning is the main objective.

3.2. User-Tool Interaction

Breakdowns in user-tool interaction were quite common during the study. For instance, the design elements in the simulations running on Interactive Physics could be moved freely causing the students to get distracted rearranging the layout. In contrast with tools where the student create his/her own scientific model, in computer simulations free manipulation of design items and tools can produce problems in understanding certain concepts or physical phenomena. For example, one of the participants in the study could not understand why the car was still moving when he took apart the road.

In a similar way, we observed that some of the designed objects in the simulation models behaved in unexpected ways. For instance, a vehicle taking off, etc. Some of these behaviors were consistent with reality, but others were not. The latter can affect the understanding of the simulation model and of the physical phenomenon. This is a usability problem that the students (the simulation interface users) inherited from the simulations designers (the educators or teachers).

The latter examples suggest the importance of interface design in the student’s cognitive processes. According to Balacheff and Kaput [1], design can aid the development of fluency between diverse mathematical representations on the one hand, and on the other it can lead to the construction of misconceptions and misunderstandings. Therefore the interface can no longer be considered as a mere superficial layer as in previous decades [1]. They [ibid.] provide a comprehensible review of existing computational technology in mathematics, and describe how differences in design can affect the student’s mathematical experience. For instance, the introduction of direct manipulation (a major breakthrough in usability) has allowed experimentation in domains that previously required a high level of technical skill or background knowledge.

On the other hand, we observed students having several problems with the value bars in Interactive Physics’s simulations. For instance, numeric values were limited and the students could not enter the numbers required to complete the assignment’s sheet. Also, some of these bars presented conceptual contradictions such as the possibility of changing a body’s mass to zero.

These kinds of inconsistencies in the student-tool interaction are as well a problem for the understanding of physical phenomena, and suggest the importance of including the designer as a key participant in the software implementation and evaluation phases. According to Cooper [5], The researcher who wishes to study the genuine, long-term impact of technology-based educational programs must maintain an acute awareness that the instructional effectiveness of an innovation can depend in large part on the continuing presence and involvement of the designer. Including the designer in the whole process of evaluating and incorporating educational software is also important because, as it was pointed out earlier, a system tested to be usable in a certain setting may not necessarily be usable in a different setting. However, according to Clements and Battista [4] testing software with target users is rare and this may account for the low quality of the majority of existing educational applications.

3.3. User-User Interaction

The main type of breakdown that we observed in the user-user interaction (both between students and students and between teachers and students) was that of comprehension [14]. That is when, for example, background knowledge differences lead to failures of mutual understanding, e.g. when one user refers to specific knowledge alien to the other, or when users interpret differently the same information.

Breakdowns of this type included the inability of the participants to understand some of the concepts or terms that the teacher used during the pilot study sessions. In a similar way, we observed how users interpreted differently some of the representations in both the Cabri and the Interactive Physics interfaces. For instance an arrow representation was interpreted as a force by some and as the direction in which the vehicle is moving by others.

The existence of these differences can consequently produce usability problems in the user-tool-and-task interaction. Hence considering this type of breakdowns can be important when assessing the implementation of educational technology.
3.4. User-Environment Interaction

According to Urquijo et al. [14], these type of breakdowns occur when, for example, the user becomes conscious of some intrusive element in the environment. In this particular case, we did not observe a large number of these breakdowns presumably because the pilot was carried out in a controlled environment. Nevertheless, we identified some difficulties. For example, the size of the classroom was small, and the arrangement of the equipment and the participants produced breakdowns. The lack of space between computers and the grouping of the participants in pairs complicated the interaction between students and tools as well as the student-student and student-teacher interactions. Other intrusive elements in the classroom, such as the video-camera and the elevated temperature also complicated interactions or distracted the users.

However, it is expected that user—environment breakdowns will occur more frequently in the case of rural schools, where teachers and students have to cope with, for example, extreme weather conditions and inadequate facilities. Hence, our future research includes the usability testing of the software in various rural schools across the Country.

4. Conclusions

Usability and design should be recognised as very important factors when introducing and evaluating educational technology in schools, since they can in some cases affect, and in others aid the teaching-learning process. The latter is important because, for instance, if usability is omitted from evaluation programs, valuable technology can be seen to fail when other factors, such as educational task design, are actually failing. Failure to detect usability problems and to make adequate prescriptions during these programs can consequently have an impact on the development of national curricula, educational goals, contents, policies, etc.

For example, in a recent evaluation study carried out in Aguascalientes, Mexico [7], it is concluded that there are no sufficient elements to recommend the use of the evaluated software (Geometer’s Sketchpad) in secondary schools in Aguascalientes. However, some of the results that led to this conclusion –e.g., the students attitudes towards the software- could have been influenced by usability problems that were not taken into account during the evaluation and that could have been easily dealt with if properly identified. Consequently, if governing bodies do not see any advantage from using this technology, they may decide, for instance, to buy less computers, or to reduce the number of hours that students spend on computer labs.

In this way, it is important that schools and governing bodies balance the need for usability evaluation with their financial resources. Including interface designers from the beginning, as well as considering usability testing within the original implementation and evaluation plans may reduce costs in the long run. This is because early detection of usability problems can both lead to adequate design solutions and/or to effective implementation approaches (such as training teachers to avoid identified errors or common mistakes produced by low quality interface design). The latter can save time and money to schools and governing bodies and preclude them from investing their limited resources on inadequate tools, or from rejecting valuable technology on the basis of other issues, such as ill-defined educational objectives.

Finally, we conclude that there is a need to develop educational-evaluation models and methodology that include usability testing as a standard procedure capable of determining the success or failure of the adoption of educational technology. The development of such a model and method is a future research aim that we hope to achieve as the program mentioned at the beginning of this paper evolves.

5. References


