Considerations for Designing Educational Software for Different Technological Devices and Pedagogical Approaches

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Abstract. Educational app development enables didatic content to be widely known and enhances the access of professors and students to technological resources, mainly in economically disadvantaged communities. However, building educational applications demands perceptive understanding in the way of approaching desired concepts, so as not to convey wrong information, especially in applications where graphic interface design is essential. This article presents and discusses important factors for the design of graphic educational applications: low-cost technologies, graphic modeling and assessment importance. The considerations presented in this work are based on the design and development of some applications to physics subjects, however they can also be useful for application projects from other subjects.

Keywords: Educational software · Software requirements · Graphic modeling

1 Introduction

Although in developing countries, such as Brazil, especially in public schools, where in one hand teachers and learners have to make do with lower quality and availability of equipment, on the other hand technological evolution has popularized access to a variety of devices with different functions, like sound, image and movement. In other countries, governments continuously invest in hardware and this measure accounts for their education expenditures, which are nevertheless important, but when not linked to development of appropriate educational software, will not meet desired results [1]. In this sense, building applications for low-cost equipment improves access to didactic content in society as a whole, contributing to avoid social exclusion through technology [2, 3].

The main objective of this article is to present considerations for analysis and design of educational software with graphic processing that is a popularization of didactic contents, which are: technologies for educational applications, graphic modeling and importance of tests. These considerations were designed to the experience gained do not

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have the development of several projects designed to popularize access to didactic content to public school students from a region lacking Brazil in the educational context and technology. This work follows a definition of universal access and inclusion in the project:

> “A commitment to universal access rises from the desire to meet the interaction needs of divergent user populations in the information society. Universal access has been characterized as the ability or right of all individuals, in spite of varying levels of ability, skill, preferences, and needs, to obtain equitable access and have effective interaction with information technologies…” (Jacko [4])

Nowadays popularization and diversity of technological devices increases equipment availability, not only via schools, but also via teachers and students themselves. This fact is even more important in developing countries and, that means that the software can also be used in environments other than merely during classes. It is known that the quantity of mobile devices, tablets and smartphones is increasing among the population, and that these devices are becoming better and better, such as image recognition, geolocalization, motion detection, among others. Moreover, video games have a lot of devices with different functions, such as motion sensors and stereoscopic glasses.

The relation among teacher, software and student needs to be considered in order to determine the role of each one in the teaching-learning process. Although the software can be used individually by a student, the role of a teacher as a task advisor can improve the interaction of students with the didactic content. So, the software becomes a tool to bring about topics for discussion, not to draw attention for itself.

Project testing phase consists of a well-established computing practice to determine the system’s capabilities and efficiencies, yet a couple of considerations need to be taken about the educational software. The terms capacity and efficiency do not refer to memory and processing performance, but instead, they express the capacity to include didactic content and efficiency on representing involved concepts. In these tests, human factor influences the results significantly and causes the evaluation process to be hard in quantitative terms, since it is difficult to confirm the results with a new test or to compare the results among methods. Beside this, it is emphasized that usability tests must be performed several times during project development together with teachers and students.

2 Related Work

Software design demands effort when the situation involved manipulates well-defined data. Besides this, when the topic involves didactic content and teacher-student and student-student relationships, the application design requires a user-focused design, which takes into account the user’s effective participation during the analysis and development step.

Software engineering literature is rich in presenting methodologies for the design and analysis of software development, and many of them are suitable for specific cases. Methodologies in software development have evolved from rigid documentation methods to flexible and adaptive methods. Thus, a structured analysis has a series of documents that analysts need to elaborate at the beginning of the project, such as diagrams of classes, data, entity-relationship, among others, [5]. While this allows for full process control, agile methodologies are better suited to modern projects because of team leaders' and users' greater proximity to development and follow-up is concerned [6, 7]. Especially in education, because of a very subjective model along with many variations, the methods are highly recommended for an interaction between developers, teachers and students [1].

In general, upon the development of educational software, there are additional factors to be observed. First, which educational content will be made available by the tool or the teacher, and how they will be presented to students – whether on websites, desktop applications, mobile applications, interactive media, or others. Moreover, many educational software programs converge on the mechanisms of communication between the teacher and the students, and also with the students' activities' evaluation process, particularly in distance learning courses [8].

In many of these softwares, the didactic content per se will be presented in the form of texts, videos, audios, questionnaires, forums, and other mechanisms, and so the teacher must use an existing material or build his own, a task which requires to be knowledgeable about publishing in popular software [9]. Much work has been done in this direction and the volume of generated content is huge, but the interactivity of this user is smaller when compared to applications that involve some graphic processing, which are the concern in this article.

The graphic representation of didactic contents allows a better understanding of the concepts under discussion. Neither casting aside the students' ability nor the stimuli that a teacher provides to be imagined as more diverse situations, a virtual environment that models an object of study allows a greater interaction between teachers and students. In addition, graphical environments stand themselves as quite interesting ways to capture and captivate people's attention, especially younger generations, as with games for example.

3 Educational App Technologies

In Brazil, and possibly in developing countries, private schools can afford the modernization of a school environment, and are able to fill their activities with didactic content adapted for all kinds of technological devices. Since technological advancement has popularized electronic devices, adapting didactic content templates for low-cost equipment make applications more accessible for society in general, also favoring public education, and this is a way to improve education technologically.

It is noteworthy that the acquisition of these devices does not depend on public investment, although it could be of some use, since these are being acquired individually by teachers and students. This way the technological evolution in education would be occurring effectively through teachers and students, and educational applications would help in this process.

Evolution occurs in most diverse gadgets, such as in motion sensors of the device itself (accelerometer, georeferencing and gyroscope), data capture (cameras and touch) and data reproduction (sounds and images), as well as processing and memory features.

This has also enabled the creation of virtual reality environments (3D glasses) and augmented reality, among others.

While the quality of these features makes it possible to create interesting, complete, and complex interface applications, one's should stick to the relationship between the primary purpose of the application and the intended learning content. This means that these resources should be used wisely, while keeping the attention of their users in the studies involved.

In the sub-sections below it is presented some sensors and their characteristics that enhance their application in educational softwares.

3.1 Motion Capture Sensors

The evolution of video-game peripherals brought along a more natural way of capturing users movements, increasing interactivity and immersion. For many of these peripherals, it is possible to connect them to personal computers directly or through small adapters, and use them in applications via libraries made available by manufacturers.

The use of these peripherals is quite common due to the large number of people who play video games. Many benefits have been observed by the use of these peripherals in health projects [10–12] and education [13–15]. However, there is a wide variety of peripherals in terms of shapes, functionalities and data capture mechanisms.

Some peripherals detect parts of the human body through some sensors that do not require to stay in close contact with the body, such as Kinect and Leap Motion. Others require the user to hold them, such as Wii Remote and Playstation Move. Finally, Wii Fit and steering wheels equipped with force feedback need to be pressed.

3.2 Mobile Device Sensors

Technologies applied to smartphones and tablets in recent years have also contributed to user interactivity with applications. Sensors that can be found on these devices include gyroscope, GPS, accelerometer, touch screen, camera, microphone, among others. These sensors pick up signals of some sort and transform them into digital data, which can be processed. In addition, they are being very well accepted by people for their ease of use, as can be observed with the touch screen.

In [16] the mobile device accelerometer was used to input data on variation of the acceleration during a quite small time interval to demonstrate the occurrence of impulsive forces. The Lablet [17] application, in turn, uses the accelerometer to record gravity acceleration and the microphone to pick up the beep, within a concept where the application is an experiment lab. In addition to this, MobTracker [18] and VidAnalisys [19] use the camera to capture movements of an object while the experiment occurs.

3.3 Graphic Processing Capacity

The quality of the images rendered by electronic equipment (TVs, monitors and mobile devices) strongly contribute to users immersion in the activity performed, so much so that the industries seek better definitions of colors and resolutions. The graphics processing capability also influences immersion because it renders more realistic images and in shorter times within 2D or 3D.

The quality of the latest generations of smartphones allows users to immerse users in applications with virtual and enhanced reality, the latter allied with the ability of câmera capture. Currently, several devices (3D glasses) are smartphone-friendly and are able to create virtual stereoscopic environments in which users really feel within the modeled environment. These resources are still little explored in education, considering that this an area with great potential to be explored.

4 Graphic Modeling and Its Implications

Not all didactic content needs to be modeled within an application, or modeled on graphics application. But there are many didactic contents where its graphic modeling is strongly recommended due to the difficulty and complexity of its representation. In many cases, a 2D or 3D virtual environment provides freedom and ease during the time of study. By "freedom", we mean the amount of interactions as possible with the graphic models, and by "ease", it is meant for the amount of different images that can be obtained in a short time interval.

A content is suitable for modeling when the amount of graphic elements to be represented is large enough to be demonstrated by other means, rendering the process way too long, difficult or unfeasible. In this analysis it is noteworthy to find graphic elements - colors, figures and movements - consistent with the information to be represented so that the modeled concept does not lead to misunderstanding or induces unreal behavior. A classic examples is the "double jumping" from action game characters where, after jumping from the ground and, still in the air, the character gets a boost to get even higher with no help from a foothold whatsoever.

The application should also deliver the user a modeled environment to interact with, by modifying the parameters of the modeled objects and their viewing angles, as well as adding a variety of options. In this way, the teacher can build classes with more autonomy and more interactive activities.

Types of software that use graphic modeling are presented in the sub-sections below: serious game, graphic simulator and data capture tool.

4.1 Serious Game

A serious game direct towards a playful way of interacting with the player (user) to keep their attention, and that is not necessarily fun, although desirable. Thus, usually a theme is chosen to introduce and intermediate the discussion whereas a well-known basic structure from gaming experiences may be applied, such as phasing to address sub-themes, punctuation for player engagement, personification and feedback for hits and misses situations [20].

The subject chosen must appropriately meet the didatic content to avoid addressing wrong concepts or in the wrong way. A good choice also avoids later adaptations and allows a good connection between what has been studied and reality.

CineFut [13, 14] software, Fig. 1, was created for the parabolic cinematic motion theme, a very important subject physics education area. Although this content is very much present in games, its objectives are not the teaching-learning process in itself and its adaptation to a study environment requires a great effort from the teachers, both to adjust the discussion and to maintain its focus. In addition, it is common to find conceptual physics mistakes in games, given that they are focused in entertainment, such as characters jumping far beyond their real capabilities or changing direction during jump when a joystick is used. At CineFut the models were came alive with proportionally real dimensions, where the dimensions of the character, the distance to the goal, the size of the barrier and the movement of the ball can all be checked, as part of the pedagogical activity.

Fig. 1. (a) Select stage and options, (b) message of feedback, (c) graphic objects: parabola, speed vectors and coordinate system.

The CineFut features a character aiming to kick a ball to the goal, and to do that one's should set the angle and initial speed of the ball. Thus, the Kinect motion sensor was chosen as the motion capture equipment due to its conventional features and also because it also delivers a better user-player interaction. The very user adjusts the ball launch angle and kick speed [21]. The angle is determined by raising the right arm from the horizontal line of the body and the kick speed is discovered considering the gap of time between the right foot moving from backwards to forwards position. This way, an understanding of physical magnitudes is enhanced by the user's movements. By raising the left arm is possible to pause an animation at a desired point.

The CineFut was divided into 4 stages approaching 4 kinematics: maximum range, obstacle transposition, complementary angles and effects from gravity. A goal must be achieved by the students at each stage, which requires an understanding of a concept. Messages are displayed after every kick, as feedbacks for hits or misses. Unlikely most of the games, stages can be played in any order, so lesson plan is up to the teacher's will.

2D environment was adequate to approach the subjects of each stage, specially the animation created for the ball parabola, since the third axis would cause difficulty of visualization because it depends on the positioning of the 3D scene observer. This could be of some use to address the physical phenomena of dynamics and external forces upon it, such as ball rotation, altitude and resistance and air pressure.

4.2 Graphic Simulator

In turn, the graphical simulator models a problem to present its data in the most realistic way possible. Generally, the modeled data does not correspond to the real world and uses a graphical form that can be easily understood by its users, such as coordinate systems and vectors used in exact sciences. However it is imperative that the movements and animations produced are based on systems of equations provided by science, because the accuracy is elementary for a correct understanding of the concepts involved.

Astron 3D software [22] consists of a graphic simulator to render the apparent motion of the stars to any place on the globe and any time on the time scale. The apparent motion

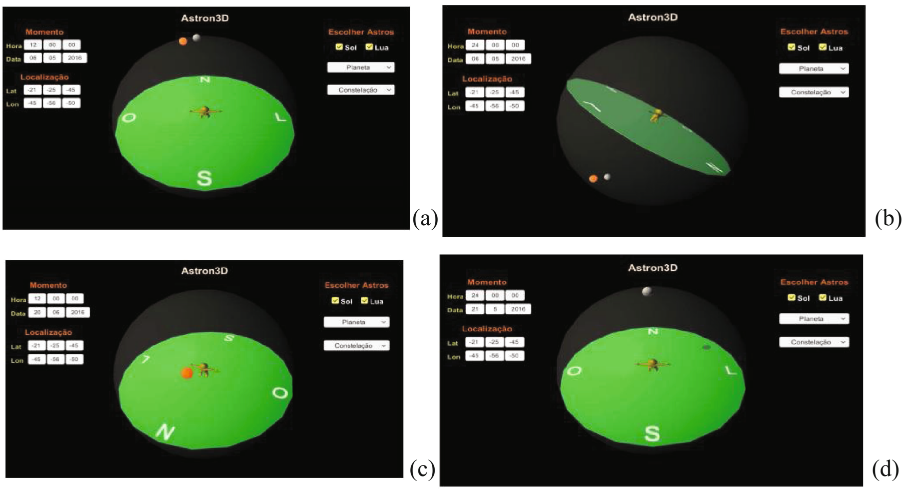

Fig. 2. (a) e (b) Screens with simulations of the moon and the sun during a new moon, from different points of view, (c) position of the sun on the day of the summer solstice and (d) representation of the position of the moon during the full moon [22].

is defined in astronomy as the movement of the perceived star in a half sphere above the observer, which is positioned at its center. Stellarium, Celestia and Cartes du Ciel softwares also render the stars with lots of information and have versions for mobile devices. Although they can be used in education, Astron 3D was designed specifically for this intent, and for that purpose it has a third person view of the celestial dome model, Fig. 2.

Astron 3D offers no challenges to be achieved nor sends feedback messages to users. For being a graphic simulator, the parameters, location, time and stars should be adjusted initially to render the models. The location will be adjusted to the length and latitude of a location, or a previously configured city. The time will be set in day, month, year, hour, minute and second. The stars can be selected from the sun, the moon, some planets to some stars.

The calculations in Astron 3D produces accurate images and avoid incorrect understanding of the physical phenomena involved. However, the focus of the application are the movements of celestial bodies and not their dimensions, because the representation of the stars in scale would reduce their sizes to some pixels of the screen causing difficulties of visualization. Thus, the construction of a model should focus on the simulator main objective, which, for education is favoring the teaching-learning process.

4.3 Data Capture Tool

In the data capture tool some device sensor obtains real-world information that is transformed into data that can easily be stored. In these tools the user defines the way to obtain the data, and can manage how the results will be made available, which, in most cases is done in tables, graphs and databases.

Physical experiments in school environments require capturing of data to understand the studied phenomena, which is usually performed with traditional instruments such as rulers, timers, protractors, among others. Its use brings expenses with its purchase, storage and maintenance, and the generated data is usually inaccurate and more time consuming to obtain. MobTracker software [18] can retrieve data from previously recorded videos or at the time of the experiment.

MobTracker does not recognize objects in the scene, it allows the user to mark the object at specific instants of the video, generating Cartesian data as a function of time. This form of interaction was designed so that the student participates in the data collection process, thus experiencing the behavior of the observed object, not worrying about the technical adjustments of the experiment.

Graphic elements are added on the video to reference the capture of the desired values, Fig. 3. First, the origin of the coordinate system is placed anywhere in the video and with any orientation of the axes. Second, two markers are positioned to determine a scale. After that it is determined how many points will be collected in the video, either by the number of points or by the interval of time between the collections, finally, data collection is performed manually.

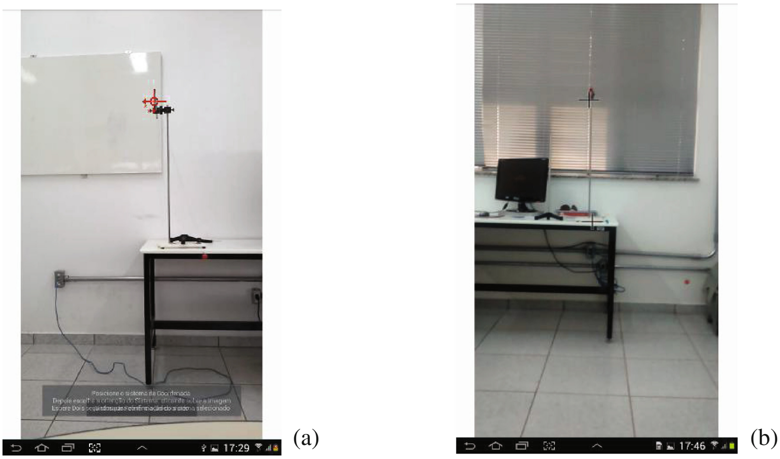

Fig. 3. (a) Two-dimensional graphic object from the coordinate system used to mark in the scene the origin of the system, (b) two-dimensional graphic objects used to point scales in the scene

This approach is already known from other papers, the Tracker software performs the same operations, but runs on personal computers [23, 24]. VidAnalysis [19] and Lablet [17] softwares work on mobile devices and use the graphical interface to support with data collection. Each of these applications performs the environment settings differently, but all use graphical interface to improve data collection and visualization.

Data capture tools streamline the process of obtaining data and optimize the time of class so that the teacher and students can focus on the results obtained, not only in the capture process, for a better understanding of physical concepts. The simplicity of these applications allows the leaner to conduct experiments outside the classroom environment, which contributes to the autonomy and independence of students with the concepts studied.

5 Testing Relevance

There are types, ways, and test styles that can be run during software development. In tests of usability, the aim are operation reactions, iconographic representations, sequences of operations, among others.

As “user” one must understand 2 different profiles, teacher and student, since each one has its way of interacting with the application. Thus the iconographic representation must be intuitive and compatible to the didactic content, mainly to avoid student’s misinterpretations. The sequence of operations, in turn, can affect the autonomy of the teacher to create his own didactic sequence, for example, if the teacher adopts a serious game with well defined and linear phases, his didactic sequence will practically be defined by the phases.

In application tests, advances and disadvantages between the methods are compared, and statistical tools are widely used to validate the results obtained. But in education several factors hamper an objective analysis of the results:

- teacher training: each teacher adopts different methodologies and tools in their classes for different classes;
- didactic sequences: teachers can create numerous ways of approaching didactic content, for different classes or not;
- student profile: numerous and uncontrollable factors define learning facilities or difficulties of a student, and even more of a class of students, which makes it impossible to use statistical tools to compare the tests performed.

Thus, qualitative analysis is more recommended in applicability tests and better expresses comparisons between the methods studied. Although the results obtained with the students are crucial to determine the efficiency of the application, the opinion of the teachers is better prepared because it is the teacher himself/herself who is knowledged in the field of didactic sequences that can be used with the application.

6 Conclusion

For the aspects described in this article it is easy to observe that the development of educational software needs particular considerations when compared with software for other purposes. Even more so when graphic modeling is an essential element to address didactic content. This concern tends to gain ground as the quantity and quality of available technology resources is increasing and the focus on teaching content should not be lost.

The success of a didactic application depends on the appropriate choice of equipment, how the didactic content will be represented graphically and what results will be expected from the tests. This success contributes to the teaching-learning process and improves access to education through low-cost equipment, especially in underprivileged communities or in undeveloped countries, where there is no due attention by governments to education.

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