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A computational application to assist the teaching of physics to visually impaired students

Uma aplicação computacional para auxiliar o ensino de física a alunos com deficiência visual

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ABSTRACT
In response to the needs of including students in the teaching-learning process, we reported our results with Ciência Fácil software. The Ciência Fácil program is a product resulting from work in the classroom to include students with vision pathologies, specifically visual pathology classified as low vision. This software is a technological answer, adapted for cell phones, proposed to assist students in the teaching-learning process of Physics content. Newton's laws comprise the Physics content used in the experiments carried out with our application. The experiments were carried out in the form of questions. Given the answers, we performed the statistical analysis of the results. Before the use of Ciência Fácil, the students presented partial or none knowledge about Newton's Laws. According to experimentation, the use of software helped students in the teaching-learning process. We concluded that the Ciência Fácil application can contribute to the learning of students with low vision.

Keywords: visual impairment, accessibility technologies, Newton's laws.

RESUMO
Em resposta às necessidades de inclusão de alunos no processo de ensino-aprendizagem, relatamos nossos resultados com o software Ciência Fácil. O programa Ciência Fácil é um produto resultante do trabalho em sala de aula para incluir alunos com patologias da visão, especificamente patologias visuais classificadas como baixa visão. Este software é uma resposta tecnológica, adaptada para telefones celulares, proposta para auxiliar os alunos no processo de ensino-aprendizagem de conteúdos de Física. As leis de Newton compreendem o conteúdo de Física usado nos experimentos realizados com nossa aplicação. Os experimentos foram realizados na forma de perguntas. Dadas as respostas, realizamos a análise estatística dos resultados. Antes do uso do Ciência Fácil, os alunos apresentavam conhecimento parcial ou inexistente sobre as Leis de Newton. De acordo com a experimentação, o uso de software ajudou os alunos no processo de ensino-aprendizagem. Concluímos que o aplicativo Ciência Fácil pode contribuir para a aprendizagem de alunos com baixa visão.

Palavras-chave: deficiência visual, tecnologias de acessibilidade, leis de Newton.

1 INTRODUCTION

In the 19th century, in Brazil, the first attempts were made to promote the education of individuals with special needs. At the time, these actions were promoted by residential institutions and hospitals. The educational system had not yet been impacted by the reality of students with special needs. In the 20th century, in the 50s, philanthropic actions implemented networks of schools to meet this demand. In 1970, accessibility became institutionalized, the government increased access to school with the inclusion of special classes in state public schools [1] - [2]. Inclusion in schools is a process that requires specific policies, observing the differences in the school environment to promote the interaction of students with special needs. This process requires a policy of continuing education for teachers, adaptation of the school space and the insertion of methodologies that meet the specific needs of each student.

In 1996, the inclusion process started to be discussed based on the Law of Guidelines and Bases, establishing the inclusion of students with special needs in the school context, guaranteeing the structure and promoting specialized support according to each need [3].

In 2001, with Resolution No. 2/2001, inclusion became mandatory. Resolution Number 2/2001, stimulated change within the school to suit students with special needs, ensuring education for all [4].

The inclusion process in Brazil is being developed by several specialists. Inclusion is a dynamic process, established by the identification of problems as well as in the research and development of techniques to solve challenges found in the insertion of individuals or elements in the school environment. In our work, we highlighted the need to include people with visual impairments in the school context, specifically for teaching Physics. In previous works, some important discoveries and notes on the challenges of helping blind people in the teaching-learning process of Physics were made in [5]. Other efforts are de made in areas as chemistry and the initial and continuing quality training of basic education teachers [6]-[7].

According to the Brazilian Institute of Geography and Statistics (IBGE), in 2010, the sense brought the information that in Brazil, approximately; 6.5 million people are visually impaired. Among these people, 528,624 are blind, 6,056,654 have low vision. Still, 29 million Brazilians have some pathology of vision [8]. In the context of developing new tools to assist the teaching-learning process. We created a technological tool to assist in teaching physics to the visually impaired. Our proposal allows for easy access to didactic material, such as the contents of Newton's laws and for that, we used mobile software. The target audience is 9th grade students in elementary school where the theme is dialogued with experience, since the definitions are born and are, practically, at least for most students, the first contact with the theme with regard to structured form in the curriculum. We seek a methodology that facilitates the learning of visually impaired students.

2 MATERIAL AND MÉTHODS

Below we presented the theoretical foundation of Newton's laws and the computational tools for the development of the Ciência Fácil software. As far as Newton's laws are concerned, we have no ambition to talk about any novelty, limiting the results presented solely for the theoretical basis at the core of Ciência Fácil software, found in the vast literature of the physical sciences. Some of these are duly cited at the end of the account of Newton's laws.

2.1 NEWTON LAWS

Before the mathematical principles of dynamics were launched by Galileo and Newton, the Greeks, Aristotle, Euclid, Archimedes, Eratosthenes, were part of a school that had their own conceptions about the movement of bodies. The Universe system accepted by them was the one built by Ptolemy. Although not Greek, Ptolemy built a geocentric system formed by two main spheres. The terrestrial sphere, where the beings of the earth live, and the celestial sphere where the planets move. The Greeks were responsible for building a great scientific revolution that, in the Renaissance, influenced the works of Galileo and Newton.

In his book “Dialogue on the Two Main Systems of the World”, Galileo first formulated the law of inertia for the first time, describing it for a sphere launched on a perfectly polished horizontal plane and neglecting air resistance. The movement would not have a negative or positive acceleration: without forces in the horizontal direction, the described movement is straight and uniform. Aristotle, in turn, to describe a moving body and keep it in this state requires the action of a force. This experience, in particular, agrees with the daily experience of an object sliding on the ground tends to stop if we stop pushing it.

Isaac Newton built postulates about the movement of bodies that, experimentally proven, became physical laws. Newton's laws are:

- 1st law: A body at rest or in a state of uniform rectilinear motion, remains in this state, unless this state changes under the action of forces printed on it;
- 2nd law: A body under the action of a force, moves in such a way that the rate of time variation of the linear moment is equal to the force;
- 3rd law: a If two bodies exert forces on each other, these forces are equal in magnitude and opposite in direction.

The first law occurs when the resulting force is zero. A particle under such phenomenological conditions is called a free particle. The second law expresses that the force is related to the rate of change of the linear moment. The linear moment is described by

$$\vec{p} = m\vec{v} \qquad (1)$$

where $\vec{p}$ is the linear moment, m is the mass and $\vec{v}$ is speed. The relationship between force and linear moment is made mathematically by

$$\vec{F} = \frac{d\vec{p}}{dt} \qquad (2)$$

bringing the information that the force numerically equals the rate of time variation of the linear moment.

The third law is not a general law of nature. The conditions for its validity occur when the following condition of symmetry is satisfied: the force that an object exerts on another is parallel to a line that connects them, this line is an abstraction that, by construction, defines an imaginary line secant to the center mass distribution of objects; for this characteristic, such interactions are called central forces. Examples of central forces are the gravitational force and the electrostatic force. In our deductions, for simplicity, we will focus on the particular case in which the mass distributions are approximated to point masses.

Using Newton's third law it is possible to derive an appropriate definition of mass. Consider an isolated system composed of two bodies, one of mass m_1 and another one of mass m_2, interacting.

By the third law, we formulated the interaction as follows:

$$\overrightarrow{F_1} = -\overrightarrow{F_2} \qquad (3)$$

and using equation (2), we obtained the relation by the formula of the rates of variation of linear momenta

$$\frac{d\overrightarrow{p_1}}{dt} = \frac{-d\overrightarrow{p_2}}{dt} \qquad (4)$$

as the masses are temporal invariants, the previous relationship can be approximated by

$$m_1 \frac{d\overrightarrow{v_1}}{dt} = -m_2 \frac{d\overrightarrow{v_2}}{dt} \qquad (5)$$

thus, we obtained that the ratio of the masses of object 1 to object 2 is quantitatively equal to the ratio between the acceleration modules of object 2 and the object, respectively. This relationship is numerically equal to

$$\frac{m_1}{m_2} = \frac{-|\overrightarrow{a_2}|}{|\overrightarrow{a_1}|} \tag{6}$$

where the negative sign indicates that the two accelerations , $\overrightarrow{a_1}$ e $\overrightarrow{a_2}$, have opposite directions. Therefore, mass is a positive quantity and equation (6) describes a constant ratio.

Still considering the system above, we will carry out the phenomenological description inferring specific conditions on the space, as to the core of its nature. Let's assume that the space is homogeneous (equal everywhere) and isotropic (there is no preferred direction). Therefore, following a quantitative description via Newton's second law

$$\frac{d\overrightarrow{p_1}}{dt} = \frac{-d\overrightarrow{p_2}}{dt} \tag{7}$$

it follows, by the principle of overlap, that

$$\frac{d\overrightarrow{p_1}}{dt} + \frac{d\overrightarrow{p_2}}{dt} = \frac{d(\overrightarrow{p_1}+\overrightarrow{p_1})}{dt} = \frac{d\vec{p}}{dt} \tag{8}$$

pertinently calling $\overrightarrow{p_1} + \overrightarrow{p_1} = \vec{p}$, we rewrote equation (8) as follows

$$\frac{d\vec{p}}{dt} = 0 \tag{9}$$

where the linear moment is $\vec{p}$ it is an invariant of the movement for arbitrarily small rates of time variations. We concluded that a binary system of point masses under the hypotheses of homogeneity and isotropy of space, isolated and interactions of the central type, the total linear momentum is conserved [9] - [12].

2.2 SIGNIFICANT LEARNING OF AUSUBEL

Facing the Theory of Meaningful Learning (TAS), developed by David Ausebel (1918 - 1994), themes such as Developmental Psychology, Educational Psychology, Psychopathology and Ego Development, became prominent in the educational bias, therefore, our interest is to address Newtonian mechanics laws seeking reference in Ausebel's educational theory.

Meaningful learning involves information or new knowledge and its relationship to the learner's cognitive structure. The relationship between the new information and the learner's cognitive structure must occur in a non-arbitrary and non-literal way, also called substantive. For Ausubel [13]; acquiring, storing ideals and knowledge according to their representations in the different fields of knowledge is the mechanism called meaningful learning [13]. Non-arbitrariness and substantiality are the fundamental characteristics of meaningful learning.

Non-arbitrariness means that pre-existing knowledge in the cognitive structure communicates non-arbitrarily with potential new knowledge. These are called subunits, i.e., the knowledge that serves as a matrix for the learner's cognitive structure for the incorporation of new knowledge.

Substantivity means that the substance is incorporated into the cognitive structure. The same idea can be expressed in different ways with equivalent meanings. Therefore, meaningful learning is not dependent on the use of specific signs [13-20].

2.3 PRESENTATION OF THE EDUCATIONAL PRODUCT

An application was developed to assist students in the teaching-learning process of Physics. The application was named Ciência Fácil, a prototype with the objective of helping students with visual impairments in learning basic physics. In this version, we only implemented the Newton's law module.

Ciência Fácil application was developed for the Google Android platform. Support for Smartphones version 5 or higher. Its version requires a memory space of 12 megabytes (MB). This prototype is not available for download from the Play Store (Goolge App Store). The application is available at the link referenced by [21].

In figure 1, we showed the application's presentation screen, displayed in the immediate moment of the application's execution, followed by the main screen, figure 2, where a menu of options for the contents of Physics areas is available, namely: Mechanics , Thermology, Optics, Wave and Electromagnetism.

Figure 1: Cover of the Ciência Fácil application.

Figure 2: Main application menu.

In figure 3, the function menu icon, located in the upper right corner of the main menu, is shown, where the content of the Support Material is made available. In the supporting material, bibliographic references, the purpose of the computational application and authorship of the application can be found.

Figure 3: Menu with application information.

In the application the module for Newton's laws was developed, having an expandable list with the content related to the main topic.

Figure 4: Selection in the Main Menu of the link to Newton's laws.

In the button Newton's Laws, figure 4, a historical description of the fundamentals of Newton's Laws with audio is available. For example, when selecting the option Newton's first law, an explanation of the content is displayed. After the explanation of the content, the presentation of multiple choice exercises follows. When selecting an alternative, a message and / or audio is displayed informing the result.

Figure 5: Newton's Laws menu.

In figure 5, we showed the Newton's laws button, where a historical description of the fundamentals of Newton's laws is available with audio included. When selecting the option Newton's 2nd law, an explanation of the content is displayed. After explaining the content, there is the presentation of exercises of the dichotomous type: true or false. When selecting an alternative, a message and / or audio is displayed informing the result.

Figure 6: Newton's Laws Menu - Principle of Inertia

In figure 6, the content of Newton's 3rd law is displayed. When selecting the option Newton's 3rd law, an explanation of the content is displayed. After explaining the content, the presentation of multiple choice exercises follows. When selecting an alternative, a message and / or audio is displayed informing the result.

Additional examples of the content available in the application are shown in figures 7 and 8. In figure 7, content about the principle of dynamics is provided. In figure 8, the principle of action and reaction is displayed.

Figure 7: Newton's laws menu - Principle of Dynamics.

Figure 8: Newton's laws menu - Principle of Action and Reaction.

3 RESULTS AND DISCUSSION

We carried out experiments with the Ciência Fácil application. Eight users have tested the app. Users were subjected to a battery of questions. Answers were collected and statistical analysis was performed. The questions that are part of the interview are:

1. What assistive technologies did you use throughout your student career?
2. Have you used any accessibility software throughout your student career? What software? How was the experience?
3. Students tend to have a lot of difficulty with the exact sciences as was their experience with these subjects, was it really more difficult to deal with these contents mainly Mathematics and Physics?
4. Accessibility software in general is more efficient for handling text, have you used any software specifically for exact sciences or numbers for example?
5. Nowadays cell phones are quite common and are in the hands of practically all students, have you ever used any kind of application focused on accessibility, with the exception of “Talkback”?
6. The application to be tested was developed to help you learn Newton's laws, how do you assess your degree of understanding of these laws? Don't you know, know little, know at least one or know all three?
7. After using the Ciência Fácil app, what were your first impressions, your first thoughts about the app?
8. After using Ciência Fácil application, how would you reassess your knowledge of Newton's laws? Don't you know, know little, know at least one or know all three?
9. From 0 to 10, how do you evaluate the tested application?
10. What suggestions would you give to improve the tested application?

In response to question 1, 2/8 of the students claim not to have used any assistive technology, while 6/8 have had access to at least one technology during their student career. In question 2, 1/8 of the interviewees have no experience with accessibility software, while 7/8 used some type of accessibility software. According to the answers to question 3, 3/8 reported ease in learning the subjects of Physics and Mathematics, while 5/8 reported having difficulty in both subjects. In response to questions 4 and 5, on the use of software related to exact sciences and the use of accessibility software, 100% of the students declared that they had never used any computational tool for these purposes. Question 6 deals with the students' previous understanding about the knowledge of Newton's laws. Among the participants, 3/8 claim to know the three laws of Newton, 1/8 claim to know two, 3/8 know one and 1/8 do not know the three laws. Before answering question 7, the interviewees made use of the Ciência Fácil application, 100% of the participants expressed the experience as positive, beneficial or effective for learning. Observing question 8, 100% of students declare to understand Newton's three laws. In question 9, the students evaluated the application, assigning grades in the interval [0, 10], with an average of 8.3. Suggesting criticism from the students, question 10, we found that 3/8 did not make any observation, 3/8 suggested the improvement in audio, 1/8 reported the need to add more alternatives in the questions and 1/8 suggested adding an title for each question.

Figures 9-16 show the quantitative graphs of each student's percentage performance. We analyzed the students' performance, counting the sets of errors and successes when answering the questions made available in the Ciência Fácil application. The issues were related to Newton's laws. Student E scored 42%. Student G scored 50%. The performance of student C was 58%. Students A, B, D and H scored 75% and, finally, student F scored 100%. The following shows the individual performance of each of the participants in relation to the sets of hits and errors in pie charts.

Figure 9: Student performance A.

Figure 10: Performance of student B.

Figure 11: Student performance C.

Figure 12: Performance of student D.

Figure 13: Student performance E.

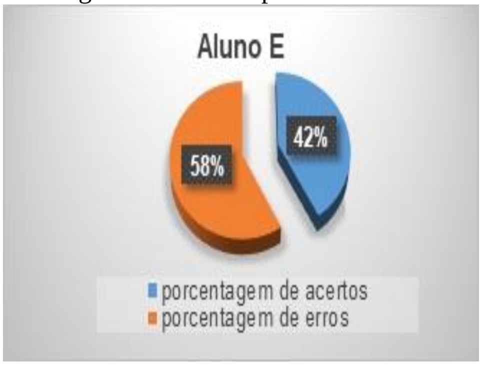


Figure 14: Student performance F.

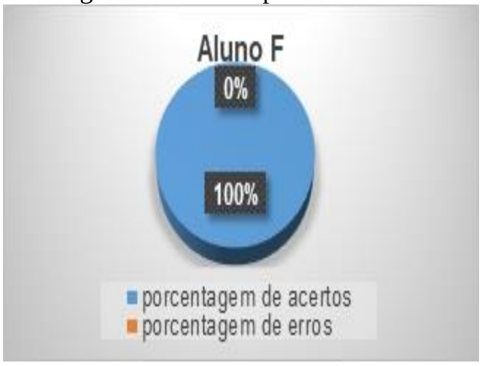
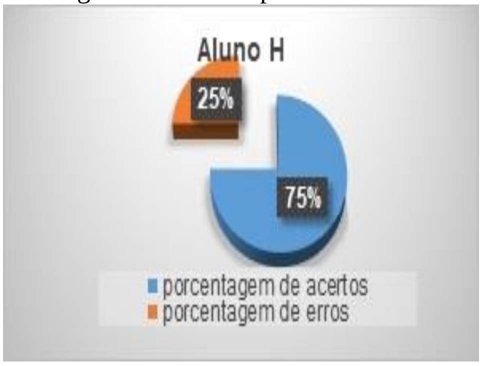


Figure 15: Student performance G.

Figure 16: Student performance H.



4 CONCLUSION

We carried out the implementation, application and statistical analysis of the results of the responses of students from the 9th grade of elementary school to the use of the Ciência Fácil application. In the implementation phase, we described the technological tools used to write the application, its purpose and characteristics. We conducted an opinion survey with students of elementary school through a questionnaire based on the criteria of usability and accessibility for the visually impaired made available by the Brazilian Ministry of Education, in partnership with the Secretariat of Professional and Technological Education, through the Virtual Accessibility Project. The number of respondents who claim to know Newton's laws increased in percentage after using Ciência Fácil application. Analyzing the results of the students' responses, highlighting the performance when answering the questions in the application, we noticed that 3/8 of the users had a performance below 60% of correct answers, ½ had a performance above 75% and 1/8 had 100% correct answers of the questions. Our results indicate that the computational tool can assist in the teaching-learning process of students, especially those with some type of visual pathology, since the dynamics of the software with auditory resources performs this role.

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