

Analysis of the teaching and learning process of physics content through the use of simulators and user argumentation

ABSTRACT

Historically, in recent decades, the main methodology used by Physics teachers in the classroom is the traditional method, focused on the resolution of exercises and exposure of content by the teacher through a blackboard and chalk. Thus, the Physics Teaching needs to be directed in the search for contextualization and insertion of didactic-pedagogical resources, such as the use of new technologies. In this context, this work has, as a general objective, to demonstrate how computational simulators can favor the teaching and learning process of Physics contents in the classroom, based on this argumentation. To this end, it was developed the first version of a platform called SimulAção, which promotes the use of computer simulators. Initially it was focused on the teaching of content on Mechanical Energy Conservation providing scripts for their use. Through practical experiments carried out on the SimulAção platform, the Toulmin's model was used in order to analyze the students' arguments from the practical activities developed by them; additionally, students and teachers analyzed the usability of the SimulAção platform through a method based on the subjective user satisfaction assessment questionnaire. From the experimental results obtained, it was verified that the use of the argumentation process, provided by the Toulmin's model, led the students to discover the relationships between the simulation elements, enabling the understanding of the physics concepts involved in the proposed activities. Regarding the evaluation of the SimulAção platform, the experimental results proved that the usability of the platform and its services, so far offered, is between the excellent and the best imaginable. The use of computer simulators, as a didactic resource in teaching, seeks to provoke teachers in order to make changes in their teaching methods, arousing interest and promoting the interaction of theory with practice in order to favor learning.

KEYWORDS: Physics teaching. Computer simulations. SUS questionnaire. Toulmin's model.

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1 INTRODUCTION

In recent years, the Teaching of Physics has been the target of much criticism, being considered inefficient and outdated (MORAES, 2009), since the discipline of Physics is usually taught using traditional teaching methods with mechanical repetition of concepts, memorization of equations and display of content simply through the blackboard and chalk (DARROZ; ROSA; GHIGGI, 2015); such methodology makes the student passive receiver of information, making his interaction in the construction of knowledge impossible. Research (MORAN; MASETTO; BEHRENS, 2009; OLIVEIRA *et al*, 2015) show that the active participation of students in teaching activities makes them perform better in relation to learning. Thus, the search for new teaching methodologies and the inclusion of technological resources in the classroom can improve the teaching and learning process, provided that the teacher adequately plays the role of mediator in this process, enabling reflection and investigation by the students in order to motivate them and favor the construction of knowledge.

Thus, the use of educational media, such as animations, videos and computer simulations, provides the teacher with access to a large amount of resources, which can contribute to making the class more interactive, enabling the student to become more involved in the teaching process, as mentioned by Araújo and Veit (2004). In particular, the use of computer simulations in the school context is supported by enabling an interactive environment between the student and the object of study, as well as between classmates and the teacher, making the student an active part of the teaching and learning process, as it can investigate hypotheses, obtain quick answers and enhance skills and competences (COSTA, 2017).

Thus, in this work, the first version of the Simulação platform was developed, which consists of a tool to help Physics teachers, during their classes, in the use of innovative methodologies that can favor teaching and learning; particularly, in this first version, the platform provides free access computer simulators, aimed at teaching content on Mechanical Energy Conservation and developed by PhET-Interactive Simulations and the Educational Portal, and scripts for using them. Therefore, based on the Simulação platform, this article has, as a general objective, to demonstrate how computational simulators can favor the teaching and learning process of Physics contents in the classroom, based on argumentation. For that, considering a simulation of experiments, the Toulmin's model was used in order to analyze the arguments of the students in the practical activities developed by them; additionally, students and teachers analyzed the usability of the Simulação platform through a method based on the subjective user satisfaction assessment questionnaire.

The main contributions of this work are: (a) development of the Simulação platform; (b) establishment of a set of correlated simulators related to the learning of the Mechanical Energy Conservation content; (c) proposal of a teaching sequence involving the established simulators and activity scripts related to them; (d) analysis of the students' arguments during the execution of the proposed teaching sequence; (e) analysis of the usability of the Simulação platform by students and teachers; and, finally, (f) improvement of the teaching and learning process of the content promoted by the Simulação platform.

The remainder of this article is organized as follows. Section 2 presents the works directly related to the main objective of this work. Section 3 presents the Simulação platform. Section 4 discusses the instruments used to analyze the results obtained in the experimentation carried out. Section 5 describes practical experimentation and analyzes the results obtained. Finally, Section 6 presents the conclusions of this work as well as perspectives for future work.

2 RELATED WORK

In order to contribute to learning, technology has gained more prominence in the teaching process, both in the area of Physics and in areas such as Biology, Chemistry and Mathematics at various levels of education; therefore, digital resources, such as mobile technologies, computer simulators, virtual laboratory, gamification and games, have been increasingly used in the classroom and remotely.

As for the use of mobile technologies, Monteiro (2016); Souza (2017); Medeiros, Fonseca Filho and Matos (2018) proposed teaching from the use of cell phones in the classroom, through applications aimed at Physics contents such as Uniform Motion, Accelerated Motion, Wave Phenomena, Magnetism, Newton's Laws and others. The results obtained showed that the use of mobile technologies can contribute to the motivation, attraction and involvement of students during classes.

As for the use of computer simulations, Schweder (2015); Braga (2016); Barbosa *et al.* (2017) showed that they are a favorable option for the teaching of Modern Physics, Energy and Faraday's Law and others, as they enable interaction between students, promoting the teaching and learning process.

As for the virtual laboratory, Fonseca *et al.* (2013); Santos, Lopes and Feitosa, (2015); Sena, Silas and Silva (2018) demonstrated that it is an adequate option to approach the abstract concepts of Physics Teaching in an experimental way, promoting students' interest in Physics classes, as they feel more motivated to perform the requested tasks.

Finally, regarding the use of gamification and games, as presented by Silva and Sales (2017); Dantas and Perez (2018); Silva, Sales and Castro (2019), enable the teaching of Geometrical Optics, Imaging in Mirrors and Classical Mechanics and others. Through such digital resources, the results obtained showed that the students showed receptiveness, engagement and motivation, which contributed to problem solving and, thus, to the promotion of learning.

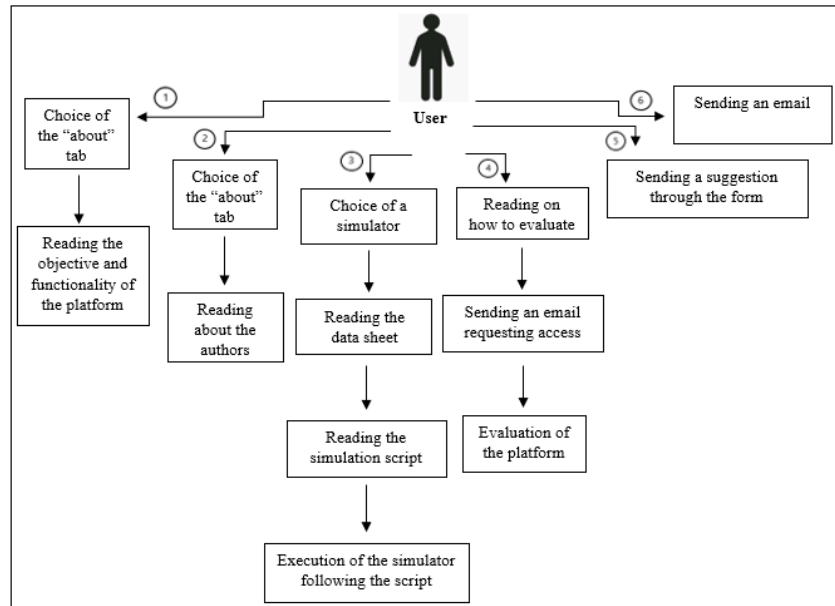
Differently from the works presented, this work analyzes the teaching of Mechanical Energy Conservation, at first, from the use of simulators available on the Simulação platform and the arguments of users. It is noteworthy that the content covered in the Simulação platform can be extended to any area of knowledge, as long as there are simulators aimed at such areas.

3 SIMULATION PLATFORM

One of the contributions of this work was the development of a platform, called Simulação1, which promotes student learning and helps teachers to

diversify and insert innovative methodologies in physics classes. In its first version, as it is aimed at teaching content on Mechanical Energy Conservation, the target audience is 1st year high school students. Figure 1 illustrates the operating architecture of the Simulação platform, which is available at: <https://sitesimulacao.wixsite.com/simulacaoambienteweb>.

Figure 1 – Simulação platform working architecture



Source: The authors (2020).

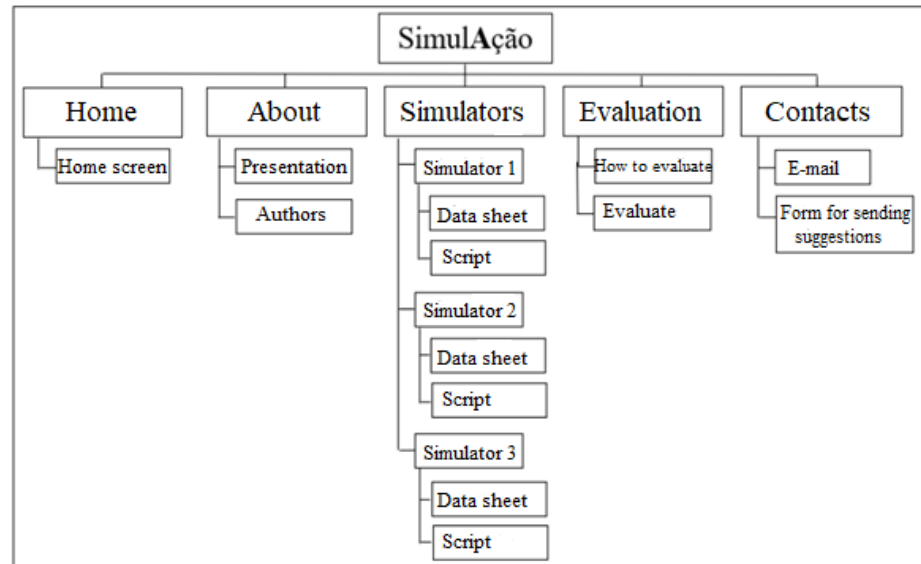
According to Figure 1, functionalities 1 and 2 correspond to the user's action regarding the clarification of the platform, being able to read its objective and functionalities, and information about its authors, respectively. Functionality 3 represents the user's performance regarding the use of simulators present on the platform: the first step is to choose the desired simulator; then read the data sheet and simulation script of the chosen simulator; and, finally, run the simulator following the directions in the script. Functionality 4 corresponds to the user's role in evaluating the usability of the platform: the first step is to read about how to evaluate the platform, if you want to carry out an evaluation; then send an email requesting the password to access the evaluation form; after obtaining the access password, carry out the evaluation of the platform itself. Finally, features 5 and 6 correspond to the user's role in accessing the contact, sending an email or filling out a form sending suggestions, comments and proposals for activities.

The simulators, belonging to the first version of the Simulação platform, are: The Ramp, The Rollercoaster and the Skate Track, which are available for public use. The A Ramp2 simulator aims to explain the movement of an object on an inclined plane; thus, it is possible to understand how forces act on different bodies and recognize the work of a force even in situations involving frictional forces. The objective of the roller coaster3 simulator is to identify the influence of several parameters on the trajectory covered by a cart on a roller coaster. Finally, the Skate4 Track simulator aims to explain the concept of conservation of mechanical energy, using kinetic energy and gravitational potential energy, and the possible causes of the influence of friction. It is worth mentioning that the use of these

simulators represents a teaching sequence focused on the study of Mechanical Energy Conservation.

To develop the Simulação platform, the Wix5 tool was used due to the fact that this environment has a differentiated, didactic and easy-to-understand design. Figure 2 presents an overview of the Simulação platform interface.

Figure 2 – Simulação platform interface overview



Source: The authors (2020).

According to Figure 2, it is observed that the Simulação platform is composed of 5 main axes, namely: Home, About, Simulators, Evaluation and Contact. The Home axis presents the initial screen of each of the simulators that make up the platform. The About axis presents the objective of the Simulação platform and its authors. The Simulators axis presents, for each simulator belonging to the platform, the simulator itself, its technical file and the script prepared for its use. The Evaluation axis makes it possible to evaluate the services provided by the platform, through a SUS questionnaire. Finally, the Contact axis allows platform users to send suggestions, comments and activity proposals via e-mail.

4 TOOLS FOR ANALYSIS OF EXPERIMENTAL RESULTS

In this section, the instruments used to analyze the results obtained in the experiment carried out in this work are presented. In Subsection 4.1, the Toulmin Model is described, used to analyze the arguments of students in the practical activities developed. And, in Subsection 4.2, the subjective user satisfaction assessment questionnaire is presented, used to assess the usability of the Simulação platform.

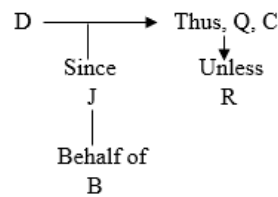
4.1 Toulmin's Model

Toulmin's model is a widely used analysis tool to investigate the "scientific arguments" constructed by students in Science Teaching situations (JIMÉNEZ ALEIXANDRE *et al*, 1998; SÁ; KASSEBOEHMER; QUEIROZ, 2014). To analyze the validity or not of an argument, Toulmin (2001) proposes that the argument must

be represented in a structure or model. This model has the function of pointing out evidence from the construction of statements, associating data and conclusions through hypothetical justifications, in addition to highlighting the limits of a given theory and its support in others (CAPECCHI; CARVALHO, 2000).

According to Toulmin's model (2001), the elements that constitute the organization of an argument are: the data (D), the justification (J), the conclusion (C), the basic knowledge (B), the modal qualifiers (Q) and rebuttal (R). Figure 3 presents the fundamental elements of an argument and the relationships between these elements.

Figure 3 – Toulmin's model for the analysis of an argument



Source: Toulmin (2001).

According to Figure 3, the basic organization of an argument can be composed using three of the elements presented, having the following structure: "from a given (D), since it is justified (J), so it is concluded (C)". However, for an argument to be considered complete, it is possible to determine in which situations the justification indicated is valid or not. Thus, modal qualifiers (Q) can be included in the argument, that is, specifications of essential situations for a justification to be valid. Likewise, it is possible to describe in which situations the justification is not valid or sufficient to support the conclusion. Therefore, a rebuttal (R) of the justification is presented. In addition to the elements cited, the justification, which has a hypothetical characteristic, can be based on a categorical claim or on a law; for example, basic knowledge (B) refers to a claim that supports the justification (SÁ; QUEIROZ, 2007).

The method based on Toulmin's model was used in the experimentation of this work in order to analyze the students' arguments from the practical activities developed through the use of simulators present in the Simulação platform.

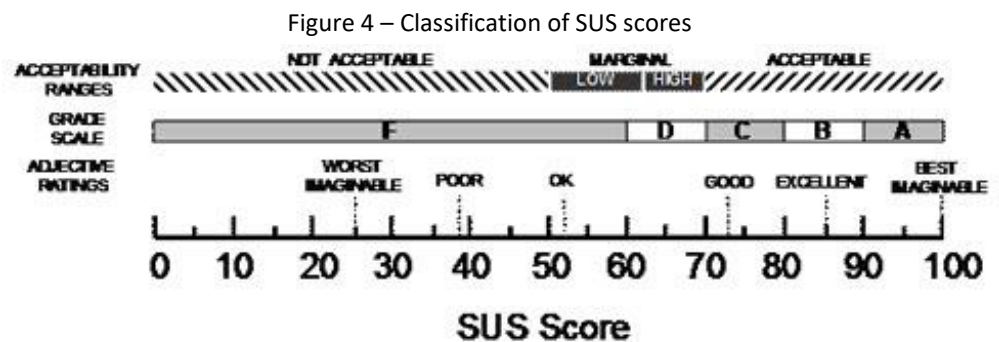
4.2 Subjective User Satisfaction Assessment Questionnaire

The subjective user satisfaction assessment questionnaire or system usability scale (SUS), developed by Brooke (1996), aims to evaluate the usability of products and services such as hardware products, websites, information systems. It has a quick and simple application, being widely used due to its high degree of reliability. It consists of 10 original questions defined by Brooke (1996), which may be appropriate for the context of a particular product or service. For each question, the answer format follows the Likert pattern. A Likert item is usually used to measure the level of disagreement or agreement with a given statement, usually using response levels (BABBIE, 1999) with a scale from 1 to 5, where 1 means "totally disagree" and 5 means "agree totally".

According to Sousa, Travain and Assis (2019), to calculate the final score of a SUS questionnaire, after filling it out, the following rules are used. For odd questions (questions related to positive points about the use of services), the

question score is equivalent to the scale (position) of the answer selected by the user minus 1. For even questions (questions related to negative points about the use of the services services), the question score equals 5 minus the scale (position) of the answer selected by the user. Thus, to obtain the final score (SUS Score) for filling out a SUS questionnaire, the scores resulting from each question in the questionnaire must be added up and multiplied by 2.5, thus generating the value of the usability level.

In an experimental process of evaluating a product or service, after obtaining the final score produced for each SUS questionnaire completed by a user participating in such process, it is possible to establish the general usability score through the average of the final scores produced. Thus, from the value obtained for the overall score, it can be concluded about the usability of the product or service evaluated by the user, following the acceptability ranges and adjective classifications defined by the study by Bangor, Kortum and Miller (2009), as seen in Figure 4.



Source: Bangor, Kortum and Miller (2009).

Thus, according to Figure 4, as an example, for a given product or service rated by a user with an overall score of 80, it is possible to say that the usability of such a product or service for such a user is acceptable and is in accordance to with the adjective ratings between good and excellent.

For prior knowledge, the method based on the SUS questionnaire was used in the experimentation of this work in order to additionally evaluate the usability of the Simulação platform according to Bangor, Kortum and Miller (2009).

5 EXPERIMENTAL ANALYSIS

In this section, the description of the experiment is carried out (see Subsection 5.1) and the obtained results are presented and analyzed (see Subsection 5.2).

5.1 Description of the trial

From the practical use of the Simulação platform, it was possible to verify the results generated by the use of simulators, both in relation to teaching and learning content on Mechanical Energy Conservation, as well as the general use of the platform itself, regarding its operation and its usability. The platform simulation of experiments was carried out with two groups of users, namely: a group of non-specialist users, consisting of 30 students, aged between 15 and 17 years, from a morning shift class of the 1st year of Education High school in a state public school;

and a group of expert users, consisting of 12 physics professors and 2 students from the 8th period of a Physics Degree course. It is worth mentioning that this research was approved by the CEP/UFOP Research Ethics Committee, nº 3.294.785.

The non-specialist users group carried out the simulation of experiments involving the use of the three simulators (that is, the complete teaching sequence), through their proposed activity scripts, and the application of the SUS questionnaire, aiming at evaluation of the usability of the Simulação platform. To analyze the written records obtained from such scripts the Toulmin model was used, resulting in the evaluation of the users' argument processes; for that, the texts and speeches were restructured based on the elements proposed by Toulmin's model. It is worth mentioning that the experimentation activities were carried out in the school's computer lab and that users were divided into groups of three. However, it appears that, in Toulmin's models built from the transcripts of the activities, there are speeches from students from different groups: despite the definition of three students per group, due to the proximity in the laboratory between the groups, students from different groups gave suggestions on the activities of a particular group, thus contributing to the development of the argument. Considering the interaction between the pairs that ascended during the activities, an excerpt of the experimental results obtained from the application of the activities involving each of the three simulators will be presented: the analysis of the Toulmin's model was performed only for some groups, since the results were similar and, in some transcripts, noises that are considered equal responses appeared.

As for the group of expert users, the experimentation was carried out based on the dissemination of the Simulação platform via e-mail and social networks, in order to obtain the greatest possible reach. For those who are interested, a Google Docs form was created in which the consent form and information regarding the Simulação platform were presented. After acceptance, the access link to the platform was disclosed to the participants, where, after browsing the platform in the desired and free way, they answered the SUS questionnaire and registered their opinion regarding the use of the platform.

5.2 Analysis of results

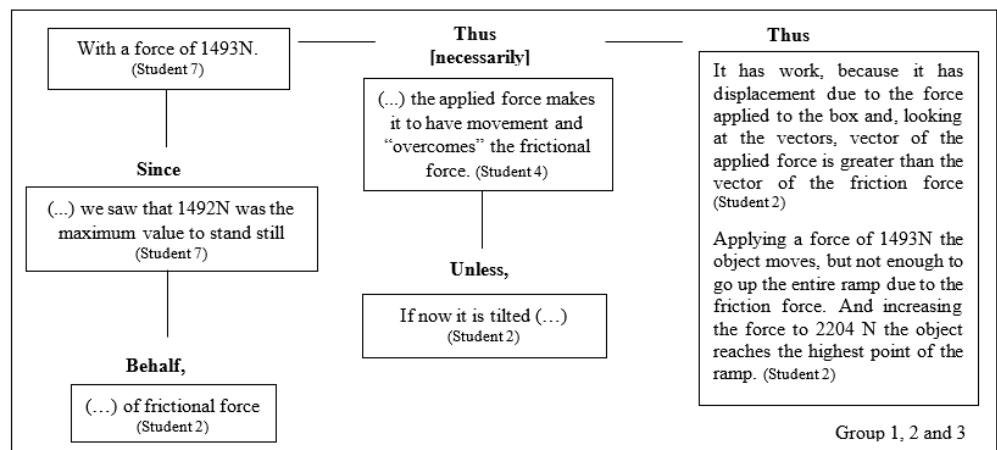
The analysis of the experimental results obtained by non-specialist and expert users took place in different stages. For non-specialist users, the transcripts made for the simulation of experiments referring to the simulators were analyzed based on the Toulmin's model, as well as the answers regarding the questions in the SUS questionnaire. As for the specialist users, the considerations made by some participants regarding the use of the platform were discussed and the answers regarding the questions in the SUS questionnaire were analyzed. Thus, in Subsection 5.2.1, the Toulmin's model for the simulation of experiments, referring to the simulators, performed by non-specialist users are presented. In Subsection 5.2.2, the considerations made by some expert users regarding the use of the platform are discussed. Finally, in Subsection 5.2.3, a general analysis of the results related to the SUS questionnaire, generated by non-specialists and specialists, is presented.

5.2.1 Analysis of the argumentation processes of non-specialist users

In this subsection, the argumentation processes of non-specialist users are presented and analyzed, according to the proposal of the Toulmin's model, based on the simulation of experiments carried out for each simulator.

The A Ramp simulator, as already mentioned, describes the movement of an object on an inclined plane, making it possible to understand how forces act on different bodies and recognize the work of a force even in situations involving frictional forces. For example, from the transcripts made, Figure 5 presents the analysis based on Toulmin's model for activities 2 and 3 of the script; these activities seek to analyze the influence of forces and the performance of work on a moving object, under a horizontal plane (activity 2) and under an inclined plane (activity 3).

Figure 5 – Toulmin's model for activities 2 and 3 of the A Ramp simulator

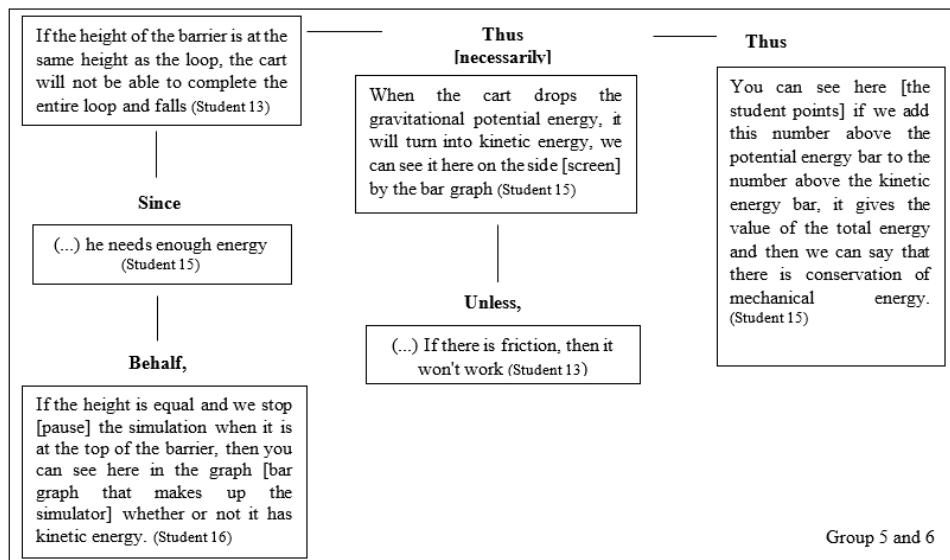


Source: The authors (2020).

As shown in Figure 5, it can be observed that Student 7, belonging to Group 3, when mentioning “with a force of 1493N”, he presents his hypothesis for the problem, a given (D); when stating “(...) we saw that 1492N was the maximum value for standing still”, he points out the evidence, his guarantee (Q). Then, relating hypotheses and evidence, students from different groups reach a shared conclusion (C). It is also noted that Student 2, belonging to Group 1, contributes to the construction of the argument by mentioning “[Unless] if it is now inclined (...)”, presenting a rebuttal (R). Thus, according to the interaction during the experiment, it was found that the use of the A Ramp simulator can be a mechanism that aids learning, making it possible to discuss the relationship between applied force and the displacement of a body to conceptualize work.

The roller coaster simulator, as already mentioned, identifies how different parameters can influence the trajectory taken by a cart on a roller coaster. For example, based on the transcripts made, Figure 6 presents the Toulmin model for activities 2 and 3 of the script, in which students conclude on the Conservation of Mechanical Energy by modifying parameters such as initial and central barrier, initial speed, radius of loop and cart mass.

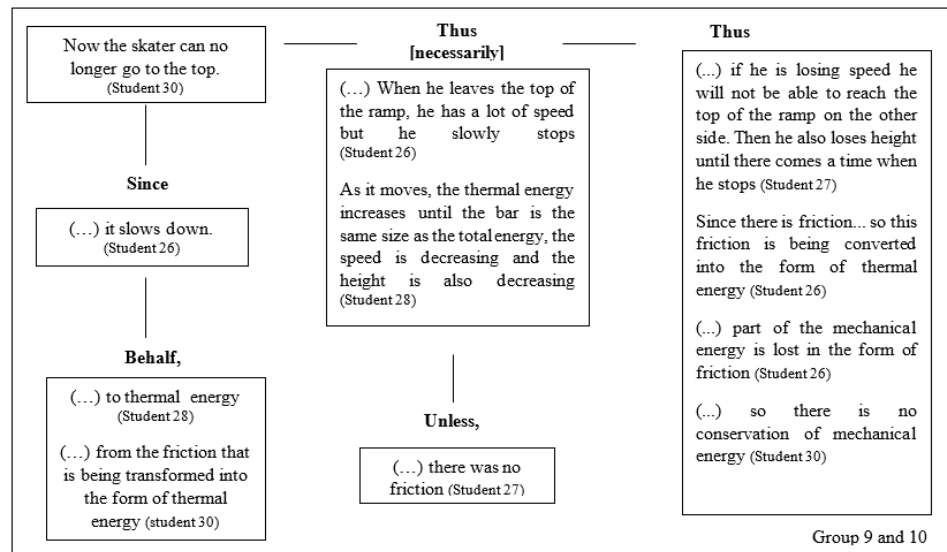
Figure 6 – Toulmin’s model for activities 2 and 3 of the roller coaster simulator



Source: The authors (2020).

From Figure 6, it can be seen that Student 13, belonging to Group 5, when mentioning "If the height of the barrier is at the same height as the loop, the cart will not be able to do the entire loop and falls", he presents his hypothesis for the problem, elaborating a data (D); thus, Student 15, belonging to the same group, when stating "(...) he needs to have enough energy", points out an evidence, his justification (J). Student 16, belonging to Group 6, based on basic knowledge (B), mentions "If the height is equal and we stop [pause] the simulation when it is at the top of the barrier, then you can see it in the chart [bar graph that makes up the simulator] whether or not it has kinetic energy". From this, modal qualifiers are presented to validate the justification (J) when Student 15, belonging to original Group 5, specifies "when the cart goes down, the gravitational potential energy will turn into kinetic energy, you can see it next [screen] by the bar graph"; in addition, Student 15 himself proposes a rebuttal (R) "(...) if there is friction, it won't work". In this case, the students were able to observe that, if there is friction in the system, the gravitational potential energy and the kinetic energy will change and the mechanical energy will not be conserved. In this way, based on the arguments of both Group 5 and Group 6 students, it was possible to reach a conclusion as mentioned by Student 16, belonging to Group 5, "you can see here [student points] if you add this number in above the bar [energy value provided by the bar graph] of the potential energy with the number on top of the bar [energy value provided by the bar graph] of the kinetic energy gives the value of the total energy and then we can say it has conservation of mechanical energy". In this sense, the use of the roller coaster simulator and the teacher's mediation actions favored learning, enabling a quantitative study on Mechanical Energy and its conditions for Energy Conservation to be carried out, and to problematize, contextualize and systematize the concepts related to Work and Mechanical Energy.

Figure 7 – Toulmin’s model for activities 2 and 3 of the Skate Track simulator



Source: The authors (2020).

From Figure 7, it can be observed that Student 30, belonging to Group 10, when mentioning “now the skater can no longer go to the top”, presents a hypothesis for the problem, a given (D); from this, Student 26, belonging to Group 9, points out evidence, justifying (J) “(...) decreases its speed”; therefore, Student 30, belonging to Group 10, relies on basic knowledge (B) when arguing that, “(...) of thermal energy. From the friction that is being transformed into the form of thermal energy”. In addition, Students 26 and 28, belonging to Groups 9 and 10 respectively, by mentioning that “(...) when he leaves the top of the ramp he has a lot of speed [analysis based on the representation of a speedometer that makes up the simulation] more gradually it stops. (...). As it moves, the thermal energy increases until the bar [of the graph] is the same size as the total energy, the speed decrease, so does the height”, so the presence of modal qualifiers (Q) can be noted. In view of this, the Student 27, belonging to Group 9, presents a rebuttal (R) for the justification mentioning that the skater loses speed due to friction, by mentioning unless “there was no friction”. Finally, Students 27, 26 and 30, belonging to Groups 9 and 10, from the arguments, come to the conclusion (C) “(...) if he is losing speed he will not be able to reach the top of the ramp of the other side. Then he also loses height until there comes a time when he stops. (...) As there is friction... so this friction is being converted into the form of thermal energy. Then part of the mechanical energy is lost in the form of friction. (...) so there is no conservation of mechanical energy”. Thus, it is noted that, from the processes of argumentation, questioning and mediation, students were able to reach conclusions about the content of Conservation of Mechanical Energy.

It is important to emphasize that, during the application of the activities, the teacher accompanied them, promoting mediation to resolve the issues and proposing new situations caring not to interfere in the activities, even when the student used a term/concept mistakenly. In this way, the interaction process through argumentation was developed between the students and the teacher and between distinct groups of students. In the experimental proposal of this work, the interrelationship that was promoted between the groups was not expected; however, naturally, the students felt more comfortable to participate in the

discussion of other groups, since, for example, the idea of an explanation for a scientific data had emerged in the dialogue of a colleague external to their group, evidencing the exchange experiences between groups of students. Based on the activities carried out, the domination of concepts by some students was observed; however, depending on the activity, external aid is more present. For Vygotsky, it is in the way of these two points, between what the students already know and what they can learn through interaction and exchange of experiences between their peers (in this case, contributions between distinct groups of students), that it is possible the development of learning (VYGOTSKY, 1978).

It is known that the discussion provoked by the interlocution of a teacher favors the development of learning, in a situation which students think together, providing opportunities for those who have "more experience" to interact with those who have "less experience" causing the development of the Zone of Proximal Development (ZPD), as described by Vygotsky (1978). In the simulation of experiments proposed in this work, from the interaction between those involved, the clear exchange of knowledge was observed, since, during the experimentation meetings, the teacher was concerned with playing the role of mediator following what Vygotsky's (1998) theory proposes for the learning stimulus situation. The students were guided through the mediation and interaction of the subjects (students) with the simulators, in this case, an object of knowledge. As difficulties arose, students received guidance from the teacher; thus, in many cases, they sought the interrelationship between the partners themselves, that is, the discussion on the physical sciences content covered between student-student and student-teacher. In this way, students progressively acquired control and responsibility in solving activities, promoting the cognitive development of those involved in this process.

5.2.2 Analysis of expert users' considerations regarding the use of the platform

As for the considerations made by expert users regarding the use of the Simulação platform, this subsection presents the analysis and/or adjustments to the platform, which show a synthesis of the suggestions, problems identified by the expert users and consequent adequacy needs.

After analyzing the considerations made by the expert users about the use of the Simulação platform, it was observed that several positive occurrences were made related to the research developed in this work, showing the importance of the Simulação platform as a tool that can help the teacher during classes and improve the teaching and learning process. The following occurrences were also observed:

- two occurrences that suggest adjustments in relation to the available scripts, one being specifically directed to the questions proposed in the activity scripts and one related to the way of accessing the online scripts;
- two occurrences about the type of application used as an extension in the simulators;
- an occurrence about the existence of inconsistency regarding the type of browser used to access the Simulação platform;

- a negative occurrence in the sense that the use of simulators can make it impossible to manipulate the experiments in a concrete way.

Considering the observations listed, the following adjustments were made:

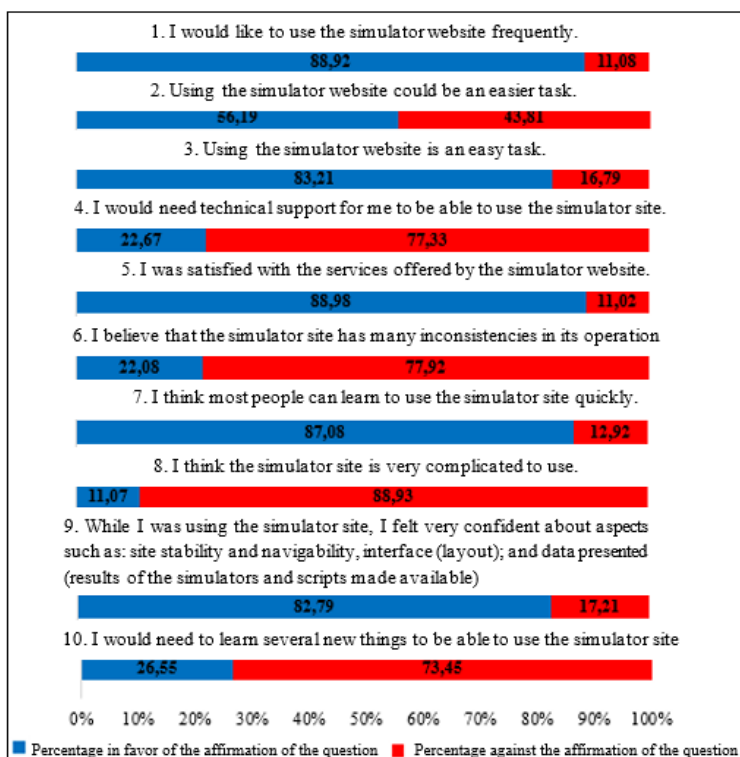
- in the data sheet of each simulator, adding an item, called Web browser characteristics, with the function of recommending the type of browser and specifying which type of application is used as an extension in the simulator in question;
- alteration of some activities in the simulator's scripts according to the indicated guidelines, in order to further promote student learning;
- We emphasize that the use of computer simulators constitutes an additional resource that can favor learning, aiming to complement teaching and not replace theoretical and/or experimental classes in laboratories.

5.2.3 Analysis of the SUS questionnaire applied to non-specialist and specialist users

In this subsection, the results obtained from the responses of non-specialist and specialist users regarding the SUS questionnaire are presented in general form considering all users. According to the definition presented in Subsection 4.2, from the values related to the answers chosen by a given user for the 10 questions of the SUS questionnaire, the final score (SUS Score) is obtained. Based on the final scores generated, the overall score related to the methodology proposed by the SUS questionnaire for usability analysis is presented.

In general, considering the 44 non-specialist and specialist users, the overall score obtained regarding the use of the SimulAção platform, was 82.72, which represents, according to the classification of Bangor, Kortum and Miller (2009), that the Usability of the SimulAção platform is acceptable, regarding the acceptability ranges, and it is between the excellent and the best imaginable, regarding the adjective classifications. Figure 8 shows the overall score obtained, separately, for each question proposed by the SUS questionnaire.

Figure 8 – Overall score obtained for each SUS question



Source: The authors (2020).

Considering the result presented in Figure 8, it is noted that only question 2 did not reach the adjective classification above as good. According to the classification of Bangor, Kortum and Miller (2009), what implies that the implementation of the Simulação platform, in general, may have been a little complicated for users, as they are not used to using this type of tool. On the other hand, the score for question 3 shows that users had no difficulty in using the platform, demonstrating a contradiction between such scores. Thus, it is not possible to affirm, through these two questions, what users think about the ease of use of the platform. For the other usability issues, the results were very favorable to the use of the Simulação platform.

6 CONCLUSION

From the practical experimentation carried out, according to the Toulmin's model applied only to non-specialist users, from the analysis regarding the simulation of experiments involving the three simulators, it was possible to understand the argumentation process developed by the students during the activities. The activities related to the content of Mechanical Energy Conservation, which were analyzed from the students' arguments, proved to be a resource that benefited the understanding of this content. The activities enabled students to manipulate and test their hypotheses in conjunction with the teacher's interventions and mediation. From these interventions and mediations, students were led to perceive some relationships and characteristics about the studied content. In this sense, the practice of argumentation presented itself as a method that contributed to the understanding of the physical concepts studied. The

activities developed in the simulators allowed students to share ideas and identify the scientific phenomena involved in the experiments carried out, also enabling the development of arguments from the discussion promoted by students from the same group and belonging to other groups. The use of the argumentation process, in the course of solving the proposed problems, led the students to discover the relationships between the simulation elements, enabling the understanding of the science concepts involved in the proposed activities.

Furthermore, among the argumentative processes triggered by the teacher's questions, the discussion of scientific phenomena observed experimentally through Toulmin's argumentation enabled the construction of knowledge and the development of learning between the partners involved. Based on the ZPD theory proposed by Vygotsky (1978), the exchange of experiences between less experienced and more experienced students enabled the less capable students to mature.

As for the SUS questionnaire method, applied additionally, considering all users in general, it was possible to verify that the Simulação platform presented an overall score of 82.72, indicating that the usability of the platform and its services, so far offered, it is acceptable, lying between the excellent and the best imaginable. According to the SUS questionnaire method, the platform satisfactorily met the criteria efficiency, satisfaction, ease of learning, ease of memorization and minimization of errors.

As perspectives for future work, there are: (a) application of some data mining technique and/or machine learning in the experimental data obtained, in order to find significant patterns; (b) review and improvement of the Simulação platform in terms of its usability; (c) insertion of other simulators and activity scripts in the Simulação platform, aiming at new teaching sequences.

ANÁLISE DO PROCESSO DE ENSINO E APRENDIZAGEM DE CONTEÚDOS DE FÍSICA POR MEIO DO USO DE SIMULADORES E DA ARGUMENTAÇÃO DE USUÁRIOS

RESUMO

Historicamente, nas últimas décadas, a principal metodologia utilizada por professores de Física em sala de aula é o método tradicional, voltado para a resolução de exercícios e exposição de conteúdos pelo professor por meio do quadro negro e de giz. Desta forma, o Ensino de Física precisa ser direcionado na busca pela contextualização e inserção de recursos didático-pedagógicos, como a utilização de novas tecnologias. Neste contexto, este trabalho possui, como objetivo geral, demonstrar como simuladores computacionais podem favorecer o processo de ensino e aprendizagem de conteúdos de Física em sala de aula, a partir da argumentação. Para tanto, foi desenvolvida a primeira versão de uma plataforma, denominada SimulAção, que promove o uso de simuladores computacionais voltados, inicialmente, para o ensino de conteúdos sobre Conservação da Energia Mecânica, e disponibiliza roteiros para utilização dos mesmos. Por meio de experimentos práticos realizados na plataforma SimulAção, foi utilizado o modelo de Toulmin com a finalidade de analisar os argumentos dos alunos a partir das atividades práticas desenvolvidas pelos mesmos; adicionalmente, alunos e professores analisaram a usabilidade da plataforma SimulAção por meio de um método baseado no questionário de avaliação de satisfação subjetiva do usuário. A partir dos resultados experimentais obtidos, verificou-se que o uso do processo da argumentação, provido pelo modelo de Toulmin, conduziu os alunos a descobrirem as relações entre os elementos de simulação, possibilitando a compreensão dos conceitos de Física envolvidos nas atividades propostas. Quanto à avaliação da plataforma SimulAção, os resultados experimentais comprovaram que a usabilidade da plataforma e seus serviços, até o momento oferecidos, encontra-se entre o excelente e o melhor imaginável. A utilização de simuladores computacionais, como recurso didático no ensino, busca provocar os professores a fim de realizar mudanças em seus métodos de ensino, despertando o interesse e promovendo a interação da teoria com a prática de forma a favorecer a aprendizagem.

PALAVRAS-CHAVE: Ensino de Física. Simulações computacionais. Questionário SUS. Modelo de Toulmin.

NOTES

1 For more details about the Simulação platform, visit: <https://br-ie.org/pub/index.php/sbie/article/view/8751>. Access on: Feb. 20th, 2021.

2 Open access simulator, provided by PhET-Interactive Simulations and created by authors Wendy Adams, Tris Lobelina, Kathy Perkins, Sam Rei, Carl Wieman and Danielle Barlow. Available at: https://phet.colorado.edu/pt_BR/simulation/legacy/the-ramp. Access on: Feb. 20th, 2021.

3 Free access simulator, provided by Portal Educacional and without specification by the authors. Available at: http://www.educacional.com.br/Recursos/ConteudoMultimidia/scorm/06_080/06/01/Principal.htm. Access on: Feb. 20th, 2021.

Note: *Flash* application activation is required for it to work. For this, for example, considering the Google Chrome web browser, select: "Settings" - "Extensions" - "Open Chrome Web Store". On the page that will open, search for Flash Player 2021. Then select: the extension itself - "Use in Chrome" - "Enable extension".

4 Open-access simulator, powered by PhET-Interactive Simulations and created by authors Ariel Paul, Noah Podolefsky, Sam Rei, Michael Dubson, Bryce Gruneich, Patricia Lobelina, Emily B. Moore, Kathy Perkins, Sharon Siman-Tov, and Amanda McGarry. Available at: https://phet.colorado.edu/pt_BR/simulation/energy-skate-park-basics. Accessed on: Feb. 20th, 2021.

5 <https://editor.wix.com>. Access on: Feb. 20th, 2021.

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