

Aprendizagem significativa com materiais educativos no ensino inclusivo de física

Meaningful learning with instructional materials in physics inclusive teaching

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Resumo

Este artigo apresenta uma sequência didática com kits multissensoriais que podem servir como materiais potencialmente significativos de acordo com os moldes da Teoria da Aprendizagem Significativa de David Ausubel. Os autores desejam transformar a Física cada vez mais em uma Disciplina Inclusiva.

Palavras-chaves: Materiais Tácteis sensoriais; Leis de Newton; Deficiente Visual.

Abstract

This paper presents a didactic sequence with Multisensory Kits that can serve as potentially meaningful materials according to the molds of David Ausubel's Meaningful Learning Theory. Authors look forward to turning Physics more and more into an Inclusive Discipline.

Keywords: Sensory tactile materials; Newton's laws; Visually impaired.

I. INTRODUCTION

The classroom, remote or physical, constitutes a conducive space for the manifestation of the various aspects related to the Teaching-Learning process and its nuances. In addition to this process, it is an environment that can become a broad field of study and research that is attentive to the various school phenomena that may be linked both to the current regulations that guide the actions of teachers and reflect on the content and their respective approach, such as also in the student's assimilation of the studied themes, or even in the interaction between students and teachers. In this profusion of questions that arise in this context, the difficulties of assimilation of content by students are highlighted, and which has been the object of study by different authors.

Axt (1988) warns of the fact that concepts approached in schools, and which should have supposedly been assimilated by teachers throughout their academic training, have a deficient or incomplete learning. This fact can lead to erroneous concepts, to deformed knowledge, which prevents a good teaching and school learning, since the contradictions found in these teachers and which should have been resolved as graduating, are at the same level as the student. Linked to this poor formation, the author points to the low level of education practiced in schools, due to the low demands of both teachers and students. Anastasiou and Alves (2015) ask whether only the language used by the teacher to communicate with students during the delivery of a standardized Physics class is sufficient for students to absorb the content in a meaningful way. Silva *et al.* (2015) warn of the situations of teachers who have never had direct and in-depth contact with the daily life of the visually impaired, if they encounter classes in which this student is present. On the other hand, the curricular deficit of undergraduate courses in Physics in offering mandatory subjects on the theme of Inclusive Education, specifically visual impairment, has serious consequences for teacher training as well as in the preparation of classes, since many teachers make use an educational method called by Camargo (2016) model "40 + 1". In this model, the class is prepared for the average of forty visionary students, and another is rethought for the visually impaired student. By following this pattern, according to Souza and Ferreira (2019), it is possible to notice that this visually impaired student is not adequately included in Physics classes, since most students in the classroom, the visionaries, are prioritized. On the other hand, the teacher's activities tend to increase due to the need to prepare two different classes on the same subject. The authors draw attention to the fact that the integration of the student in the class via the educational system does not always mean inclusion in the pedagogical process.

Although item III of article 59 of the Law on the Guidelines and Basis for National Education- LDB (Brasil, 1996) argues that students and teachers should be provided with adequate training, this is not the reality of undergraduate courses in Physics, especially undergraduate courses in which is faced with the theme about visual impairment, as pointed out by the works carried out by Silva *et al.* (2015). They warn of the lack of studies on visual impairment in the subjects of the Physics course.

According to the Census of Basic Education of the State of Rio de Janeiro 2019 (Brasil, 2019), there was a 37.3% increase in enrollments for Special Education between the years 2015 and 2019. When compared to the same years for High School, growth jumps to 104%. Unfortunately, these increases do not follow the structure of the Brazilian educational system, because if we select the age group of 4 to 17 years old who are enrolled in common classes and without access to specialized care, between 2015 and 2019, there was an increase of 4% of these students. For those who have access to specialized education, the increase was only 3.3%. These data indicate the challenges to be faced by the bodies responsible for educational policies, especially by teachers who occupy a prominent position in the educational process.

Inserted in the scope of a monograph work concluding a degree course in Physics and concomitantly being one of the central focuses of a research group at UFRRJ focused on Physics Teaching in High School, it was possible to glimpse this educational framework, where several aspects and situations, especially with regard to the visually impaired, are present in the teaching and learning process. Based on this survey, the development of inclusive methodological strategies that can assist both high school physics teachers and students, whether visionary or not, was included in our studies, with a focus on promoting inclusive teaching and learning and valuing the intellectual capacity of the visually impaired student. In this sense, we started the elaboration of a didactic sequence involving a set of Multisensory Kits that can support the Potentially Significant Teaching Units (PSTU) insofar as they are a facilitator for the assimilation of the contents, according to the molds of the Significant Learning Theory (SLT) by David Ausubel (Flores-Espejo, 2013; Moreira, 2012), in addition to valuing and defending Inclusiveness. According to SLT, the apprentice constitutes the fundamental part in the teaching-learning process insofar as he must actively participate in the knowledge construction process and his predisposition to relate the new knowledge to his cognitive structure in a non-arbitrary and non literal way. The teacher is responsible for assuming a teaching methodology based on the use of Potentially Significant Learning Materials (PSLM) to generate new meanings, promoting the anchoring of new information in the student's cognitive structure. One of the first kits to be made is a Sensory Tactile Material (STM), which addresses the study of Newtonian Mechanics Free Body Diagram, constructed with low cost material and where the information will be printed in braille and in high relief characters that can be used by both visually impaired students and visionaries. We hope that at the end of the project, the kits produced and the Potentially Significant Teaching Units (PSTU) proposed in this work will help teachers and students in a classroom, and serve as inspiration for other topics in Physics to be approached in a similar way, as they have enormous potential for inclusion and a powerful facilitator of meaningful learning.

The article is structured in the sections a) Introduction; b) Educational Background of Visually Impaired People in Brazil; c) Projects with Tact Sensory Materials in Rio de Janeiro; d) Free Body Diagram; e) The Theory of Meaningful Learning; f) A Roadmap for Sensory Tactile Materials; g) Discussions; h) Conclusions.

II. EDUCATIONAL HISTORY OF VISUALLY IMPAIRED PEOPLE IN BRAZIL

Formal education for visually impaired people in Brazil began on December 14, 1850 with the return of José Álvares de Azevedo to Brazil. According to Cerqueira *et al.* (2014), Azevedo was a blind boy who, at the age of ten, traveled to France to study at the Royal Institute for the Young Blind in Paris. In 1844, after six years of study at this institute, he returned to Brazil where he began to apply all the knowledge acquired. He taught private classes, lectured at Brazilian courts, wrote articles, activities that took him to Emperor D. Pedro II, to whom he explained his knowledge, his dreams and desires, as well as defending the importance of the braille system. He also proposed the creation of a Brazilian school that resembled the institute at which he had studied in Paris. According to Almeida (2014, p. 9), D. Pedro adopted the bold proposal which led to the inauguration of the Imperial Institute for Blind Children in 1854, currently known as Instituto Benjamin Constant (IBC). José Álvares de Azevedo was unable to attend the inauguration because he would have died months before.

Over the years, other institutes and schools have been created to serve people with visual impairments (Franco, 2020), such as the Antônio Pessoa de Queiroz Institute, which was founded in Recife in 1909, becoming the first institution in this segment in the Northeast and the second in Brazil. In 1926 the São Rafael Institute was opened, based in Belo Horizonte. In São Paulo, with the support of the population and through the ophthalmologist Dr. José Pereira Gomes, the Instituto de Cegos Padre Chico was created in 1928. On the other hand, it was thanks to the pioneering spirit and the realization of the dream of Álvares de Azevedo, today considered a Patron of Education for the Blind in Brazil, that the struggle of visually impaired people in search of legal and educational rights in society began.

III. PROJECTS WITH SENSORY TACTILE MATERIALS IN RIO DE JANEIRO

The inspiration for the construction of Sensory Tact Materials (STM) as materials to support the learning of visually impaired students comes from the observations of high school classrooms, from inquiries related to the difficulties of both students in assimilating content and teachers when teaching a class in which visually impaired students are present, and also due to the knowledge of the existence of some projects that already exist in Rio de Janeiro, of which we will mention two, which have been standing out in the issue of inclusive education. The first is an extension project entitled "Accessible Universe" developed at the Federal University of Rio de Janeiro (UFRJ) and developed in partnership with the IBC. The project brings together a group of students from various undergraduate courses, such as Occupational Therapy, Astronomy and Mathematics, and develops STM as the focus on Astronomy. They built the "Tactile Moon" and the "Tactile Notebooks", among other materials, in order to democratize the access to Astronomy content, since the lack of didactic material adapted for this theme is enormous. Because of this, those responsible for the project build the STM with raw materials that are easy to access and manipulate, such as Styrofoam and papier-mache. In addition, IBC professionals review the material created, as "*as users, they give their opinion on the material produced, they can suggest changes.*" (Martins *et al.*, 2020, p. 72). The second project involving the STM is the "Micro in Touch" (Cesar, 2019) that focuses on the Microbiologist and Immunologist developed at UFRJ. This project, which also has a partnership with the IBC, consists of 3D prints with braille subtitles based on microscopic images of viruses, fungi and bacteria that are part of the theme "Discovering Microorganisms". In addition, there is another activity, which also involves 3D printing, which is about "Oswaldo Cruz and Vaccines". All of these proposals within the project are intended to take knowledge of microbiology to the classrooms in a contextualized, inclusive way and with the use of multisensory. This last aspect is important, as the adapted teaching materials are also insufficient for meaningful and quality teaching to occur. Therefore, it is in this bias that the "Micro in Touch" becomes extremely important to fill these gaps in teaching. However, printing in three dimensions is not a cheap thing to do and having many prints made on each subject, so that students can take it home in order to study, is economically unfeasible. Therefore, 3-D impressions are instruments that assist teachers in presenting content in the classroom. The question of how students will be able to study at home, makes the presence of these easily accessible materials help to expand this project, as the students themselves can reproduce their STM using a flexible and easy-to-handle material.

IV. FREE BODY DIAGRAM

The theme initially addressed in our project was the Free Body Diagram (FBD), inserted within the scope of Newton's law studies. The schematic representation of the DCL with all vectors modeling the forces acting on an object, helps in understanding and solving problems of Newtonian mechanics, and because they require a higher level of abstraction, they can cause confusion in students, such as in the identification of action-reaction pairs or in the indication of the direction of the forces. On the other hand, the entire layout of the FBD is always made from the

reproduction of the figures found in the textbooks of Physics, as in the example of the Figure 1.

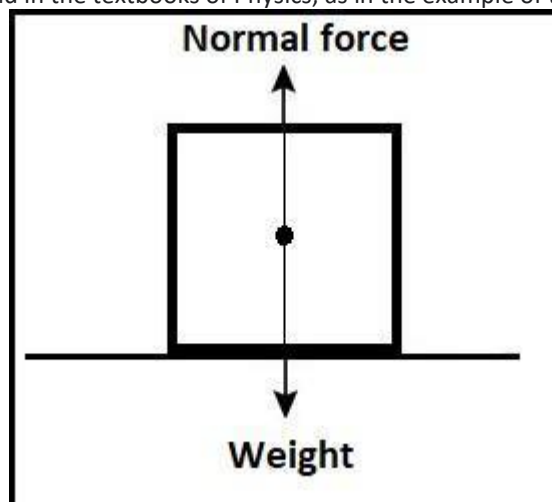


FIGURE 1. Schematic representation of forces acting on a block.

Although this representation present in the various books is a practical and simple way of representing the forces that act on objects, regardless of sizes and shapes, it can be configured as an appropriate aid for the seer student. However, for the visually impaired apprentice, the same practicality and simplicity as with the visionaries does not occur. In this, a new barrier is created between the student and the teacher who did not have an inclusive education, or are still facing for the first time such a problem. A first move in this direction, and one that can assist the teacher in this specific case, was the construction of a sensory tactile material (STM) built with low-cost and easily accessible materials. The raw material used for the vector representation of the forces was cardboard, due to its texture and its malleability and durability. Its preparation followed a previously elaborated mold that can be done manually or digitally. A one-size-fits-all mold was made, but it can be enlarged to represent different strengths of forces depending on each situation. However, in order to facilitate and streamline the construction of the material and also to maintain a standard in braille writing, we opted for a single size model so that these characteristics are highlighted. Figure 2 shows the construction of the vectors in the manner described above.

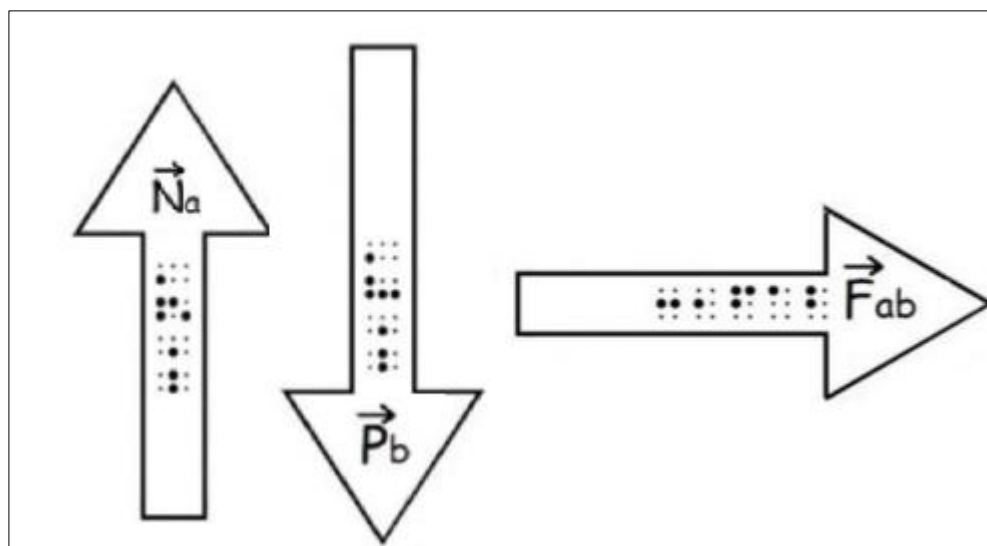


FIGURE 2. Vector representation with usual spelling and braille spelling in ink. Source: Souza and Ferreira, 2019.

Then, on 180g paper, cutouts are made according to the size of the vector made of cardboard. We identified the forces with the usual spelling, but for braille we counted with the help of the Braille Easy software and the clamp and punch for the location and marking of the respective points on the sheet as shown in Figure 2. Next, the cutouts and fixation were made of this paper with the writing on the respective vectors made of cardboard and this way this stage of the project was completed.

Based on the analyzes made and following the same pattern as the making of the force vectors, a software (Paint 3D) was used for digital construction of the cubes, as shown in the Figure 3, so that the initial project takes shape. With the use of the software, we can modify sizes of force vectors, colors and other details, as many times as necessary to reach a satisfactory result, of what we will build physically, because in this way we speed up the construction of the STM

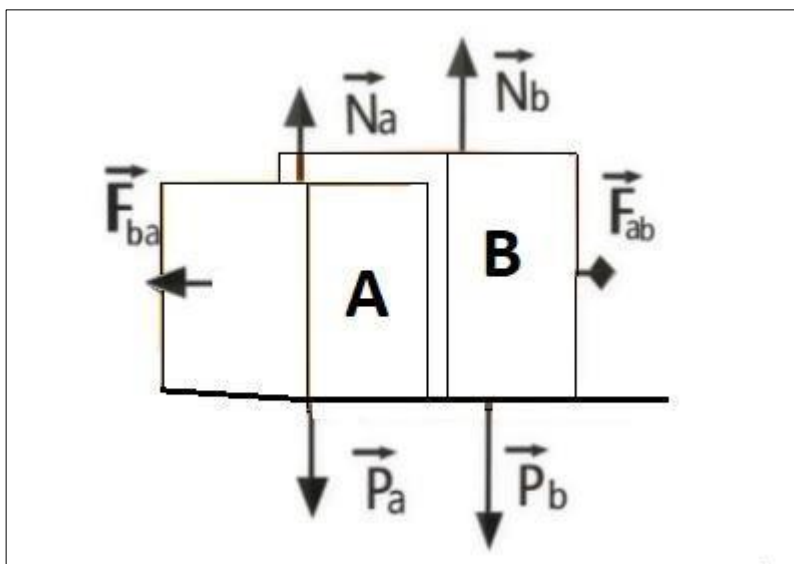


FIGURE 3. Schematic representation of forces acting on two blocks.

With the cube already assembled, it will be necessary to reinforce its structure in order to obtain an even firmer object, as the intention is to manipulate the cubes it is possible that they fall to the ground over time and thus be damaged. Therefore, to increase its durability, newspaper strips are used that are glued throughout the object through a mixture of school glue and water increasing the durability of the material. In addition, the use of the newspaper adds texture to the STM, which is important for the students' senses. Finally, for the identification of the cubes, the letters A and B were glued to their faces according to a digital design. Instead of differentiating them using the representation of the letters in ink only, a mold was made out of cardboard, as shown in Figure 4, of the letters to give relief and texture so that the cubes could be differentiated in a tactile way. In addition, distinct and vivid colors were used to cover the cubes in order to contrast with the identification letters, as shown in Figure 4, and thus enable the perception and differentiation by students with low vision, in addition to drawing the students' attention seers. The colors used for the cubes were orange and yellow. Black was used for the letters.



FIGURA 4. Painted and identified cubes. Source: Souza and Ferreira, 2019.

V. SIGNIFICANT LEARNING THEORY

The theory that underlies our work is Ausubel's Theory of Meaningful Learning (TML). According to Moreira (2012), meaningful learning occurs through a process of conceptual assimilation, where new information is related to the cognitive structure of the recipient and is carried out in a non-arbitrary and non-literal way. That is, non-arbitrariness means that the new information received will be specifically related to the previous knowledge that the recipient has in order to corroborate the implementation of the new information in its cognitive structure. Ausubel designates this prior knowledge of the subsumer that plays the role of being an anchorage for fixing new ideas and that from this interaction, new subsumers are being formed. The non-literalness of the new information means that it can be incorporated into the cognitive structure in several ways, which is important since the understanding of information varies from person to person. This idiosyncratic aspect is relevant in this theory as learning becomes significant, since this new information interacts with the subsumer present in the student's cognitive structure, modifying it and at the end of the process a new subsumer ends up replacing the old one. Thus, the teacher is configured as a fundamental piece assisting the teaching and learning process, because according to Flores-Espejo (2018) when this teacher assumes a teaching methodology, making use of Potentially Significant Learning Materials (PSLM) new meanings are generated, promoting the anchoring of new information in the cognitive structure, in order to leverage the level of abstraction of students where learning becomes even more significant. The author adds that

In order to promote meaningful learning, it is necessary to generate a negotiation of contextualized meanings between the teacher and the students through potentially significant learning materials that have a logical meaning, so that the scientific meanings can be assimilated through an active construction, the which allows the student to build psychological meanings within the acceptability of the community of users who validate them and are able to apply them in new problematic situations. (Flores-Espejo, 2018, p. 6)

Another relevant aspect of SLT is the student's predisposition to be an active agent for the construction and assimilation of knowledge. It is necessary that the student is willing to learn in a meaningful way, because *"the attitude of meaningful learning is a necessary and influential condition in the process of construction of meanings."* Flores-Espejo (2018, p. 20).

In general, being an active student and learning knowledge through SLT, regardless of its specificity. However, new demands and methodologies of teaching and learning that are inclusive are necessary for students with visual impairment to reach their academic goals, achieving an apprenticeship in Physics in an autonomous, didactic, inclusive and meaningful way. Because of these demands and taking as a principle an inclusive Physics class based on ausubelian aspects, it is necessary to explore the important components for the elaboration of a robust methodology that serves all students. In this way, we highlight the seven elements described by Flores-Espejo (2018) as being practical criteria that help the teacher in the elaboration of teaching and evaluation strategies in meaningful learning. With this, we extend these elements to the methodological study of a regular class that involves the presence of visually impaired students. The first element refers to the Domains of Meaningful Learning related to the construction of learning where the domains of thought, sentimental, acting, conscious and contextual are included. The second focuses on Learning Variables and addresses ausubelian aspects that undergo changes throughout the learning process due to what was initially programmed. In other words, an example is the student's cognitive structure that undergoes changes during meaningful learning. The third is the Learning Principles that refer to the theoretical foundations that guide changes in cognitive structure according to meaningful learning. Theoretical examples are integrative reconciliation and progressive differentiation that together can be interpreted *"as instructional programmatic principles that potentially facilitate meaningful learning."* Moreira *et al.* (1997, p. 37). The fourth element is the Learning Criteria, which are the sources belonging to the learning variables that undergo progressive changes and serve to indicate the best path to follow along the learning process according to the SLT. The fifth domain, the Learning Indicators, reveals through evaluative methods how significant the student's learning is. The sixth element, the Learning Items focus on the practical way of data collection made either through dialogue between student and teacher, using SPLM, or through the teacher's observations, among other means that materialize meaningful learning and that points out the indicators. Finally, we have the Evaluation Formats, which are the instruments used to assess whether the anchoring of new concepts was done in a meaningful way. In this topic there are no restrictions on how the assessment should be made. The important thing is not to be limited to the traditional means of evaluation and that the method chosen is based on SLT, where the elements mentioned above are taken into account.

The aforementioned domains interact with each other to form meaningful and demonstrably effective learning. For this work, we highlight the sensory tactile materials (STM) that will be used as the SPLM pointed out by Flores-Espejo (2018) considered as instruments of conceptual assimilation for the teaching and meaningful inclusive learning. In this, our proposal presents, in a first stage, the elaboration of Potentially Significant Teaching Units (PSTU) with the

use of STM, and “they are theoretically grounded teaching sequences, focused on meaningful, non-mechanical learning, which can stimulate applied research in teaching, the one directed directly to the classroom” (Moreira, 2011, p. 2). In addition, we intend to use the elements described above in order to monitor and assess whether significant learning has been achieved. These teaching units are intended for a high school class that contains a visually impaired student and whose theme will be the free body diagrams inserted in Newtonian mechanics. The description made below follows the basic script model that can serve as guidance to the teacher and aims to contextualize and use an STM in the classroom.

VI. SCRIPT FOR SENSORY TACTICAL MATERIALS (TEACHING KIT)

Below we describe the basic script model that can serve as guidance to the teacher regarding the contextualization and the use of an MTS in the classroom. Possible changes and adaptations are at the discretion of the teacher. The script was developed from the MTS proposed above, where the theme focuses on FBD, for a total of 3 to 6 class hours:

1. Initial situation: survey of the students' initial subsumer through conversations and the exploration and analysis of sensory tactile experiments with objects that may fall, which suffer displacements due to pushes, examples from everyday life. Presentation of Previous Organizers: situations that involve actions of forces, whether through reading newspapers and texts, including texts in Braille, reports and dialogues related to the theme. obtain written comments from students;

2. Problem situations: to use for discussion mediated by the teacher some examples, such as: a) two books on the table, one on the other. When pushing the bottom or the top (in different directions of the force), for example, what happens? b) the books on the table being in contact, side by side, when pushing one of them in the most different directions, what is observed?

3. Teach an Expository-Dialogued class; Contextualize the phenomenology of the concept of Force and its relationship with the movement (describing in detail the representations and schemes used relating to the Previous Organizers); Introduce Newton's Laws. Raise pertinent questions for students about what has just been taught;

4. Present the STM (didactic kit) as a significant complement to the theme; Kit Title (STM): Name the material used; Make students aware of the composition of the material; Procedure: Describe in detail the operation of the material allowing students to handle the kit; Practice: Stimulate student participation through questioning and physical hypotheses that involve actions between bodies through the use of material;

5. To lead the visually impaired to understand the abstract concept of vector, its meaning and intensity through the representation of tactile arrows made of cardboard. The sighted student can help the visually impaired by simulating small pushes or pulls of small objects on the table by applying different intensities of forces, either by the direct use of the hands or using ropes or any other easy-to-handle material, so that this student will understand the intensities involved. After this step, they start to manipulate the cardboard arrows in order to understand the forces applied in the step previously developed. In this we believe that we are promoting interaction, the inclusion of students with visual impairments, in addition to the actual approach to the topic addressed;

6. Summative assessment: Activity scheduled and communicated to students in advance in which the understanding of the subject addressed should be freely expressed. There may be figures that can guide them;

7. Expository class with final integrative dialogue: Guide the discussions between students asking them to present their opinions on the practice performed; to remedy the difficulties, to reinforce the use of the scientific terms of forces, their actions;

8. Assessment of Learning at SPTU: From the materials delivered by the students, from the observations made, from the summative assessment;

9. Conclusion and Evaluation of the SPTU: Pay attention to possible changes in alternative conceptions and initial subsumers. From this stage, add or rethink the next activities.

VII. DISCUSSION

Due to the difficulties faced by teachers in a classroom, the idea arose to create material that could help this teacher throughout the teaching of the contents, and that had a direct impact on the students' significant learning, especially on visually impaired students participating in a high school room. Several authors contributed with reflections and new proposals for the solution of the considered problems. Concomitant to this, we realize that there are actions by professors and students from other Universities who constantly work to include inclusion in their respective disciplines, as has already been happening in the projects already mentioned. These are works that involve the

creation of tactile materials made in different ways, but with the same objective that it is to teach, to visually impaired students, subjects that were previously inseparable from visual representation.

In our work, we aim to build an STM in which we follow all the necessary adaptations and make use of multisensory, texturing and Braille spelling in order to meet the demands of visually impaired students, as well as visionary students. To meet the requirements of the Physics discipline, we based on Ausubel's SLT, in the works of Moreira (2011) and used the concepts and ideas described in the works of Flores-Espejo (2018) to build a meaningful teaching sequence using PSTU that assist the teacher in the teaching of Newtonian Mechanics concepts, especially FBD, using STM to fix the content. Therefore, our proposal to create a tactile material based on meaningful learning theories and based on proven practical facts come to help the Physics discipline to be inclusive with the use of STM for application in the classroom as a methodological support.

VIII. CONCLUSION

In this work, we proposed a didactic unit (DU) that bets on the use of STM, built with low-cost and easy-to-handle material, and that uses braille language to facilitate communication with these students, especially non-seers. We believe that this Didactic Unit with the STM, being potentially significant, will assist both the visionary student and the visually impaired student, in addition to supporting the teacher in his teaching, and preventing the duplication of his work. Although the DU could not be carried out in a classroom due to the current pandemic moment in which the world finds itself, we believe that this proposal can bring new reflections to the degree courses in Physics, and that aim at necessary changes in the training of this teacher. In addition, with all the theoretical background derived from our studies, we hope that the proposal presented for the construction of the STM on the FBD will achieve the same objectives and the same results achieved by the projects in other areas that have been mentioned here. In this way, we can teach Physics from the perspective of SLT by exploring all the functionalities of tactile materials, which includes multisensory and the use of braille, as it is a powerful teaching tool. Therefore, and according to Souza and Ferreira (2019, pp. 15-16), we will approach the contents proposed by the discipline in a broader and dissociable way visually, generating discussions among students and contributing to the enrichment and construction of their knowledge. We hope that the future results involving these STM will reflect on the changes in the curricular structures and that there will be relevant transformations in the subjects of the Physics degree courses, in the formation of this teacher, turning Physics increasingly into an Inclusive Discipline.

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