Development of didactic experiment to assist learning in Physics: a study of deformable flat structures

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Abstract

Teaching, in general, undergoes transformations whose main objective is to qualify and streamline learning, in this sense the student's involvement with experimental and computational practices has been shown as a differential for its development. Learning content related to Statics and Body Deformation presents a major challenge for students due to the level of abstraction involved in their concepts and the strong presence of traditional teaching methodologies. The present work addresses the construction and application of a didactic sequence focused on the teaching of Statics and Body Deformation with a methodological approach based on significant learning theory, using reduced models of flat articulated systems and simulations in Ftool software. The sequence was applied to students of the Production Engineering course of a public federal institution, located in southeastern Brazil in the first semester of 2019. A quantitative questionnaire was applied in order to measure student satisfaction with the methodology used. The results showed that the application of teaching methodologies based on a more active posture by the students, through the use of reduced models and also simulations, tends to contribute to the academic development of the student.

Keywords: Meaningful learning, physics teaching, flat articulated systems.

Resumen

La enseñanza, en general, sufre transformaciones cuyo objetivo principal es calificar y racionalizar el aprendizaje, en este sentido, la participación del estudiante en prácticas experimentales y computacionales se ha demostrado como un diferencial para su desarrollo. El contenido de aprendizaje relacionado con la estática y la deformación corporal presenta un gran desafío para los estudiantes debido al nivel de abstracción involucrado en sus conceptos y la fuerte presencia de las metodologías de enseñanza tradicionales. El presente trabajo aborda la construcción y aplicación de una secuencia didáctica centrada en la enseñanza de la estática y la deformación corporal con un enfoque metodológico basado en una teoría de aprendizaje significativa, utilizando modelos reducidos de sistemas articulados planos y simulaciones en el software Ftool. La secuencia se aplicó a los estudiantes del curso de Ingeniería de Producción de una institución pública federal, ubicada en el sureste de Brasil en el primer semestre de 2019. Se aplicó un cuestionario cuantitativo para medir la satisfacción de los estudiantes con la metodología utilizada. Los resultados mostraron que la aplicación de metodologías de enseñanza basadas en una postura más activa por parte de los estudiantes, mediante el uso de modelos reducidos y también simulaciones, tiende a contribuir al desarrollo académico del estudiante.

Palabras clave: Aprendizaje significativo, enseñanza de la física, sistemas articulados planos.

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I. INTRODUCTION

The teaching of physics in contemporary education is outdated in terms of content and technologies, centered only on the teacher, behaviorist and focused on the training of tests [1]. Based on this premise, it is necessary to conduct a learning that can allow the student to build contextualized solutions and, mainly, practical, enabling a meaningful learning and different from traditional methods.

The student education should contain characteristics such as: basic knowledge acquisition, scientific preparation and ability to use different technologies related to her field. Experimental activities become a promising alternative to make teaching more attractive and meaningful to students. In addition, experimentation may assist in the development of practical skills and competences, as well as the meaning of concepts in relation to scientific and social contexts.

The teaching method used in this research is proposed by Ausubel, which shows that the teacher and the student assume distinct and mutually important roles for the teaching-learning process. [2] One of the important roles of the teacher is to diagnose the student's subsumer and to select, organize and elaborate materials that will be presented in the educational process. Thus, the student must be able to capture and assimilate, in a non-arbitrary way, the new information presented to his cognitive structure, organizing and reorganizing it. This educational method puts the student in a more active attitude towards the teaching-learning process, [3] being one of the most efficient models for its cognitive development, because in this way it becomes an agent of the educational process, becoming more attentive and enthusiastic, instead of just memorizing the content.

In the area of education, in general, the use of didactic-experimental techniques broadens the possibilities in the field of pedagogical practice, and this research becomes relevant while it can promote the availability of information to students and teachers, thus facilitating the process building knowledge and providing a better classroom teaching dynamic. The work is expected to allow a better understanding of physical processes and, at the same time, more complex models in the area of deformation of bodies. Studies related to the teaching of physics have been growing over the years, aiming to combine theoretical knowledge with experimental practical activities, mainly due to the criticism of purely traditional teaching, where the student is treated as a content absorber transmitted through the teacher, which do not always relate to the students' prior knowledge. The work aimed to develop a didactic sequence to promote a real vision of how the knowledge acquired in the theme "Mechanics of Deformable Bodies" is implemented in practice and, consequently, to develop prototypes of reduced models for load testing in structures similar to the study. Thus, this work is expected to be contribute scientifically to make teaching more meaningful, in order to add technological and didactic values. It's also hoped that this contribution can overcome obstacles in the learning of scientific concepts, not only by providing interpretations, discussions and clashes of ideas among students, but also by its investigative nature.

II. METHODOLOGY

The research methodology used in the creation of the didactic sequence is exploratory, [4] this type of research started through bibliographic survey, interviews with people who had practical experiences with the researched problem and analysis of examples that stimulate the understanding of the phenomenon. It is also evidenced the experimental character that makes up the didactic sequence, which is associated with the direct manipulation of variables related to the object of study.

To construct the reduced models, which were used in part B of the didactic sequence, and which simulate the deformation when loaded, the following materials were required:

- Bamboo toothpick
- PET type bottle (polyethylene terephthalate)
- Scotch tape
- Solid wood blocks
- Riveting rivet

In the construction of the reduced models, the use of PET bottles occurred through their ring-shaped cut, which were later drilled and attached to the riveting rivets at diametrically opposite ends. The rivet attached to the rings was not pulled until its broach broke, but enough so that it was attached to the ring.

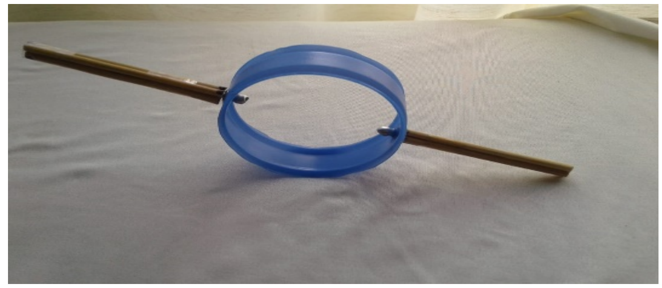

FIGURE 1. Stem with ring tension simulator.

In turn, bamboo sticks were used to construct the rods of the structures. Four sticks were glued together using adhesive tape, forming at the end a rod with a central hole, which fit the rivets attached to the rings, which is shown in figure 2.

The development of the nodes of the structures took place through solid pine wood, where it was built in block format with holes drilled with the aid of the electric drill at angles of 45º and 90º.

FIGURE 2. Rod that makes up the simulator ring.

Allowing the coupling of the rods and subsequent construction of several flat structures as shown in figure 3.

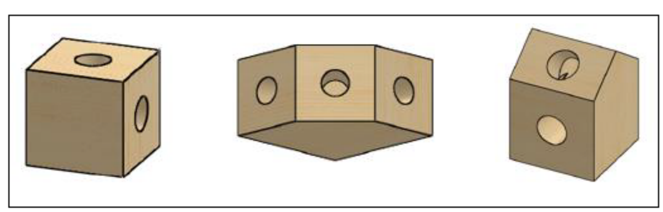

FIGURE 3. Models of the structure nodes.

Figure 4 represents the reduced model of the flat articulated system used in the didactic sequence.

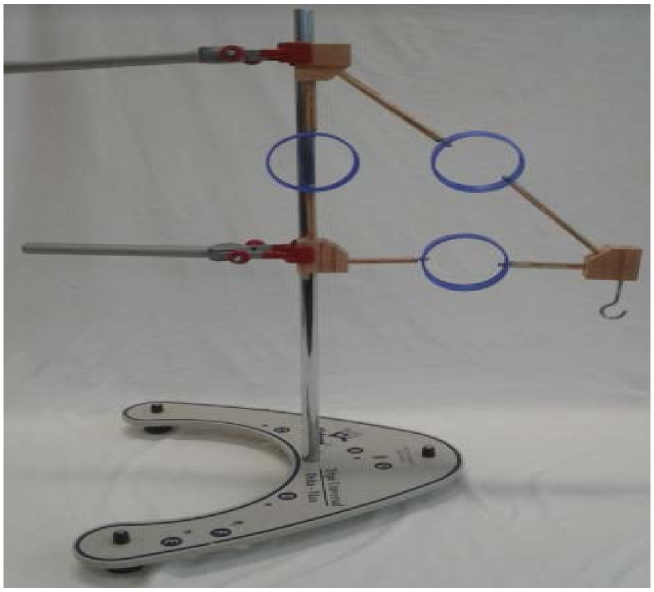

FIGURE 4. Reduced model of a flat articulated system. The following are the steps that make up the didactic sequence.

A. Theoretical Introduction

This stage is characterized by the presentation of conceptual content related to Statics and Body Deformation, and examples that can identify students' previous knowledge, such as testing of materials for construction, rupture of structures such as bridges and buildings, structures that suffer permanent deformation, etc. The class is complemented with problem solving whose objective is to put the student in an active attitude towards the teaching-learning process, in which he she should be led to interpret the problems and suggest possible solutions, in order to enhance their ability to construct. of knowledge.

B. Experimentation

This part of the sequence refers to the use of the reduced models of previously constructed flat articulated systems. During this activity, they put into practice the concepts assimilated during the theoretical introduction, being led to perform a qualitative analysis of the structures. Using the components that make up the reduced structures, students follow an experimental script.

Screenplay - Part I
1. Use the 3 bars with ring type A and 3 nodes to construct the truss model outlined in Figure 1.
2. Attach the truss to a bracket using adjustable snap clamps on the frame nodes to secure fixed supports on the x and y-axes.
3. Observe the stress simulator rings and answer the following questions:
3.1 Is it possible to observe a deformation in the rings?
a) Yes b) no

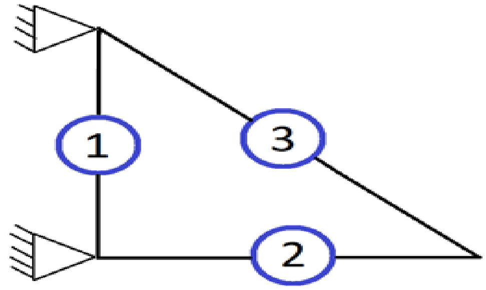

FIGURE 1. Assembly scheme of the first structure.

3.2 How many rings have suffered deformation?
a) One ring b) two rings c) three rings.
3.3 What type of deformation (traction / compression) did the rings suffer?
Ring one: _____________________________
Ring two: _____________________________
Ring three: _____________________________

Screenplay - Part II
1. Use 3 bars with type B stress ring, 2 bar coupling nodes, and 1 hook node to construct the truss model shown in Figure 2.
2. Attach the truss to the bracket using the adjustable snap clips on the frame nodes, leaving the nodes with the hook where the arrow schematic loads will be made, as shown in Figure 2.
3. Start loading with cylindrical masses on the hook attached to the nodes and then measure with the caliper the diameter of each simulator ring that makes up the structure.

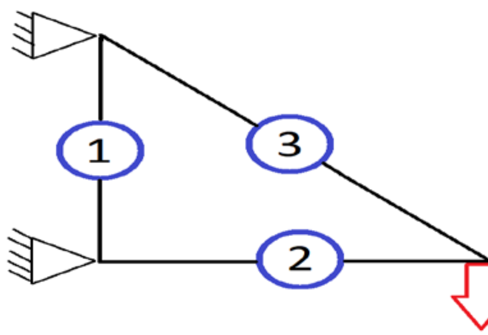

FIGURE 2. Assembly scheme of the second structure.

Repeat this process 5 times.
4. With the results obtained in the previous item, construct a force graph as a function of the deformation of each ring.
5. From the graph F x D, obtained in the previous item, mark:
5.1 What is the mathematical relationship between force F and deformation D for ring 1?
a) Directly proportional
b) Inversely proportional
c) There is no relationship
5.2 What is the mathematical relationship between force F and deformation D for ring 2?
a) Directly proportional

b) Inversely proportional
c) There is no relationship
5.3 What is the mathematical relationship between force F and deformation D for ring 3?
a) Directly proportional
b) Inversely proportional
c) There is no relationship
5.4 Make a conclusion by relating the behavior seen in the graphs analyzed and the type of internal force required in each beam.
5.5 What kind of mathematical function determines the behavior of experimental points?
a) Exponential function
b) Linear function
c) Logarithmic function
d) 2nd order polynomial function
5.6 Looking at the stress-strain diagram, where does the experiment run fit?
a) Elastic
b) Plastic
5.7 Compare the relationship between the result of the experiment and the stress-strain diagram.

C. Software structures simulation

In this final part of the sequence, we used the Ftool-two-dimensional frame analysis tool, version 4.00.04 basic, developed by Luiz Fernando Martha, distributed free. Here, the students simulated a structure analogous to the one they built with the reduced models, and thereafter analyzed which struts of the structure had tensile and compressive stresses and then compared these results with the data collected in the experimental part.
The application of the didactic sequence was performed with 29 students of the Production Engineering course of a public federal institution, located in the southeastern region of Brazil in the first semester of 2019, in the physics and computer laboratories of the institution.

At the end of the application of the didactic sequence, a questionnaire to verify the satisfaction with the use of an active teaching methodology was taken to the participants. In it, questions 4 to 9 were elaborated according to the Likert scale, whose answers vary from 1 to 5, where 1 (one) represents very dissatisfied, and 5 (five), very satisfied. The following are the questions:

1) Have you ever used any software for analysis of articulated flat systems?
a) Yes b) No.
2) Have you ever used a reduced model for articulated plane system analysis?
a) Yes b) No.
3) What are your biggest difficulties in learning the concepts of static mechanics?
a) High level of abstraction required.
b) Complex mathematical calculations
c) Lack of application in practical classes.
d) Content disconnected from reality.
e) Insignificant content.
4) How satisfied were you with working with Ftool software for analysis of rigid structures?
5) Did using Ftool software during class make it easier for you to understand static mechanics concepts?
6) Did the use of reduced models during class facilitate your understanding of static mechanics concepts?
7) Do you believe that by comparing the analysis of the structures in the software with the reduced models, the content abstraction has been reduced, making it easier to learn about static mechanics concepts?
8) Do you believe that being a protagonist in the construction and analysis of structures, both in software and in reduced models, contributed to your learning?

III. RESULTS OF THE STUDY

Before application of the didactic sequence, the authors selected and tested two materials to form the tension simulator ring. Figure 5 below represents the two materials selected.

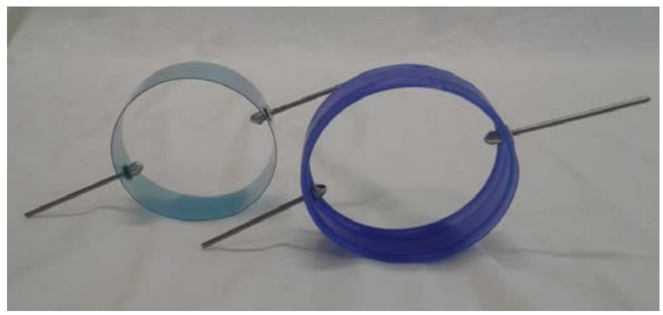

FIGURE 5. On the left the simulator ring A and on the right the simulator ring B.

The first material, called ring simulator A, was loaded with force on it, starting at 0.1 N to 2.0 N, obtaining, for each load its deformation. In Figure 6, there is the result of a loading obtained in this material.

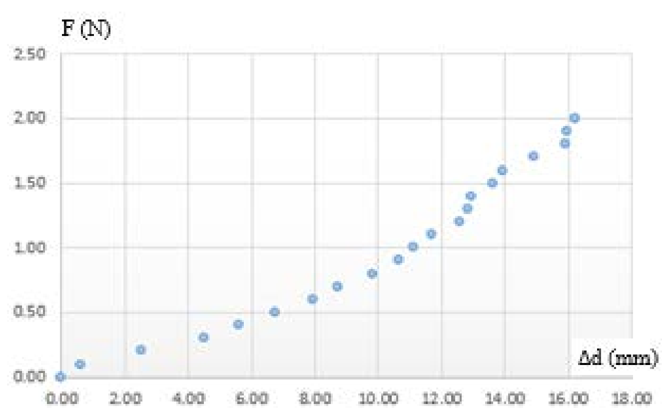

FIGURE 6. Graph of force versus deformation in the simulator ring A.

Table I shows the statistical data related to the simulation performed on simulator ring A.

TABLE I. Statistical data of the flexible ring.

F (N)	*Δd (mm)*	*R*	*R²*	*S*
1.00	9.95	0.973	0.947	5.009

The result of Pearson's correlation coefficient suggested a linear behavior of the data, but when checking the residual graph (Figure 7), he evidences a certain tendency, suggesting that the associated data do not follow a linear pattern. Therefore, the regression line is not a good model for this set. Thus, we can infer that the ring simulator A does not fit as a good material to perform quantitative simulations in linear regime, since it is not entirely in the elastic region of the material in relation to the requested loads. However, it was used in the experimental script at the level of qualitative analysis.

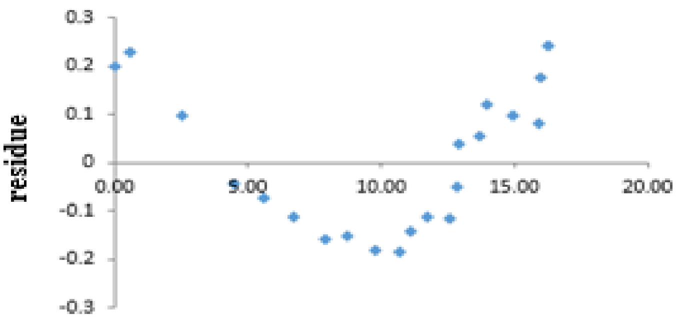

FIGURE 7. Residual graph of the simulator ring A.

The second material, called simulator ring B, had its load test performed in the same way as simulator ring A. The results were satisfactory regarding the desired linear behavior in the work. Next, in Figure 8, we have the loading data obtained for the simulating ring B.

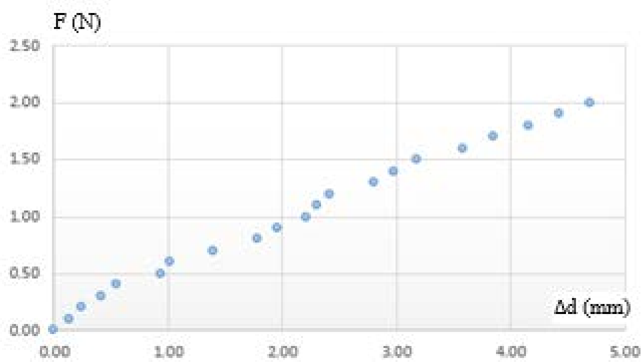

FIGURE 8. Graph of force versus deformation in the simulator ring B.

The result of Pearson's correlation coefficient, as shown in Table II, was 0.996, which suggests a strong linear correlation between the data.

TABLE II. Statistical data of the rigid ring.

F (N)	*Δd (mm)*	*R*	*R²*	*S*
1.00	2.14	0.996	0.993	1.491

When a graph of stress versus strain is obtained, the material is in elastic deformation regime; in other words the material is linearly elastic [5]. In order to confirm the adequacy of the linear regression model to the load test, the graphical analysis of the residuals has been made, as shown in Figure 8, this did not show any tendency, with the points being randomly scattered around the x axis, thus suggesting that the regression equation associated with it is a good model to represent the sample data set.

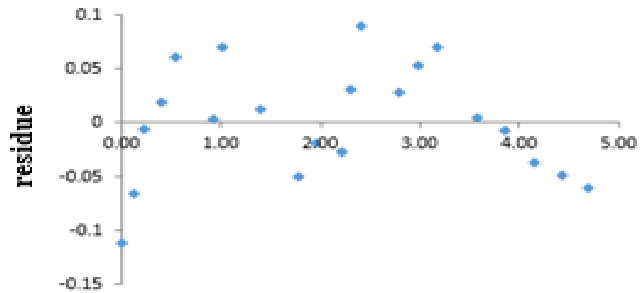

FIGURE 9. Residual graph of the simulator ring B.

Thus, because the material presents linear elastic deformation in the loading range (0-2 N), the simulating ring B was chosen for use in the experimental part II of the didactic sequence, which analyzes quantitatively.

In the application of the didactic sequence the students started the work with the reduced models of flat articulated systems, following the script Parts 1 and 2. In the Figure, the students can be visualized manipulating the developed structures of the articulated flat models.

The students were able to verify in which rods of the structures there were traction or compression requests.

FIGURE 10. Students using the developed framework.

And they also used the data obtained to construct a force graph as a function of the deformation of each stress simulating ring, which suggested that the rods of the structure should were under linear elastic regime.

Using the Ftool software, the students simulated structures similar to the reduced models used in the previous step and compared the results of the software with those previously collected by the experimental analysis. By crossing the obtained information with the physical models and the simulations, the students were able to develop an analysis about the phenomenon, suggesting a learning that went beyond the simple memorization of the information delivered by the teacher, possibly significant, transforming them into active agents of the teaching-learning process and their ability to analyze and solve problems, concluding that the rods that the simulator described were under traction and compression were the same pointed by the rings of the reduced models. [6]. This procedure is satisfactory and from the visualization of the evolution of a phenomenon in simulators that students can understand how the behavior of the different quantities related to this physical phenomenon is. It is also considered that there is a need for a continuous process of reflection and to explore to what extent the inclusion of these technologies enhance and optimize certain training processes [X].

Regarding the analysis of the answers of the satisfaction verification questionnaire, of the 29 students who answered, it was evidenced that 83% of the students had never used any software for analysis of articulated flat systems and that 89.6% never worked with some kind of reduced model. These results suggest that the use of traditional methodologies composed only of lectures, static content and body deformation still predominates in the classroom.

A crucial point for the development of new pedagogical practices is to understand the students' difficulties regarding certain content. Regarding the teaching of Statics and Body Deformation, it can be seen from the result of Figure 10 that 59% of the students interviewed indicate the high level of abstraction required as the main difficulty for their learning, followed by the lack of application in practical classes, with a percentage of 55%, it is noteworthy that in question 3 of this satisfaction questionnaire, the student could mark more than one alternative. This reinforces the hypothesis of the presence of traditional teaching methodologies in the analyzed content, which are little focused on the students' learning process and more focused on presenting the content mechanically, often ignoring their previous knowledge and its subsequent. knowledge building. [8] The use of classroom experiments, which aim to lead the student to a deeper investigation of physical phenomena and at the same time, the student confronts the experiment with the theory already learned, and Thus, meaningful learning has a great chance of becoming effective, creating a harmony between what he has as life experience in the search for the absorption of knowledge.

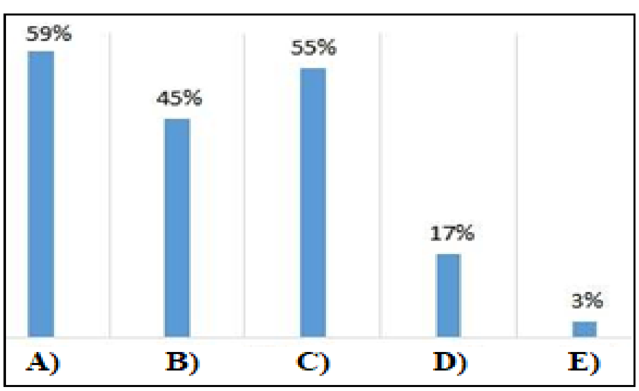

FIGURE 11. Answers to question three.

Understanding student satisfaction not only reveals their attitudes toward teaching, but also reflects their work performance. [9] Students in the classroom interpret physical phenomena, often only through problem solving, and such problems, for the most part, are viewed by students simply as exercises. .Satisfied students have a high probability of academic success, so as a formal “needs assessment”, student satisfaction assessment is an essential part of any comprehensive assessment of higher education institutions, helping the teacher adjust and optimize your strategies [10]. The results show that all answers to questions 4 to 8 obtained the maximum satisfaction level of the Likert scale above 50%.

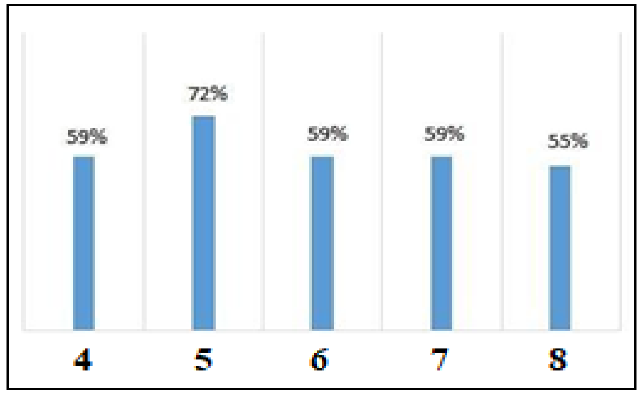

FIGURE 12. Result for level five answers.

For a satisfaction questionnaire to be valid, it is necessary to measure its degree of reliability. For this, the questionnaire applied to the Alpha Cronbach coefficient was submitted, obtaining a result equal to 0.85. Cronbach's alpha coefficient is an inherent property of the response pattern of the population studied, not a scale characteristic itself, ie the alpha value changes according to the population to which the scale is applied [11]. The minimum acceptable value for alpha is 0.70, below which the internal consistency of the scale used is considered low. Already above 0.90, one can consider that there is redundancy or duplication, ie several items are measuring exactly the same element of a construct; thus, redundant items should be eliminated. Thus, it is concluded that this measuring instrument showed high reliability in the environment in which it is applied.

IV. CONCLUSION

The results of this study showed that active teaching methodologies based on achieving meaningful learning can have a major impact on student satisfaction during the cognitive development process. Students were widely accepted with the use of potentially significant materials, such as reduced models of flat articulated systems and software simulations, for the learning of deformable body statics. This contributed to the process of learning construction of students, stimulating curiosity and the ability to analyze and solve problems, which consequently develops a more effective teaching-learning process. In addition, through the analysis of the questionnaire responses, we also highlight the strong need to develop pedagogical practices increasingly focused on an active attitude on the part of students, abandoning the methodological characteristics that seek to teach the contents mechanically.

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