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Proposal and evaluation of didactic materials to support the teaching of Physics

Propuesta y evaluación de materiales didácticos en apoyo en la enseñanza de Física

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Abstract

The teaching of science has always faced multiple adversities for the construction of meaningful learning and the subject of Physics is no exception, however, if we consider that today the educational field has had to change due to the sanitary contingency caused by Covid-19, it has made it clear that the form of teaching must be modified to adapt to current conditions. Hence, the objective of this study was to design and evaluate the impact of a didactic material that contributes to improving the understanding of the learning that are most difficult for students in the subject of Physics III at the Escuela Nacional Colegio de Ciencias y Humanidades plantel Vallejo, through a pilot sample by convenience in which 22 students and 12 teachers participated. For this purpose, a hybrid methodology was used in which pedagogical, disciplinary, and technological aspects were aligned; finding that this is a viable option to improve the student performance. Therefore, it is required that teachers be trained in these topics, since a facilitator with greater variability is needed to adjust his teaching to current requirements.

Learning, Science, Evaluation

Resumen

La enseñanza de la ciencia siempre ha enfrentado múltiples adversidades para la construcción de aprendizajes significativos y la asignatura de Física no es la excepción. Además, si se contempla que hoy en día el ámbito educativo ha tenido que cambiar debido a la contingencia sanitaria causada por el Covid-19, dejando claro que la forma de enseñanza debe modificarse para adaptarse a las condiciones actuales. De ahí que este estudio su objetivo fue el diseñar y evaluar el impacto de un material didáctico que coadyube a mejorar la comprensión de los aprendizajes que más se le dificultad a los alumnos, para la asignatura de Física III de la Escuela Nacional Colegio de Ciencias y Humanidades plantel Vallejo, a través de una muestra piloto por conveniencia en la que participaron 22 alumnos y 12 profesores. Para ello, se empleó una metodología híbrida en el que se alinearon aspectos pedagógicos, disciplinares y tecnológicos; encontrando que esta es una opción viable para mejorar el desempeño de los alumnos. Por ende, se requiere que los docentes se capaciten en estos temas, ya que se demanda de un facilitador que tenga una mayor variabilidad para ajustar su enseñanza a los requerimientos actuales.

Aprendizajes, Ciencia, Evaluación

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Introduction

The teaching of science faces different problems such as the distancing itself from the everyday, emphasizing abstract and unattractive contents. On the other hand, it is especially focused on a propaedeutic purpose and the presentation of an academicist, classical, 19th century science (Araújo & Ballesta, 2019, p.12).

Now, specifically for the subject of Physics,several studies focus on the learning of concepts,leaving aside that it is necessary for students to understand equations or formulas so that they can apply them (Kim, Cheong & Song, 2018). In the same sense, Elizondo (2013) states that the difficulties that students have in understanding physics problems are identifying the relevantdata of the problem, understanding the meaningsof the data, and transcribing them into mathematical language; therefore, it is essential to design didactic materials in accordance with the pedagogical, disciplinary and technological needs that contribute to the achievement of student learning.

In summary, the subject of Physics is considered by manay students difficult and boring perhaps because of the abstract concepts that make it up and/or its relationship with mathematics, and if in a face-to-face modality it was complicated, then how to fulfill the mission of this subject that, according to Duarte, Reyes & Fernandez (2013) is "learning ways of thinking and acting that are effective in describing and predicting thebehavior of the real world" (p.46).

From the above perspective, it is appropriate to point out that to improve some of the situations described above, Riveros (2012) proposes that it is necessary to have materials that encourage reasoning, as well as to write evaluations before teaching the subject, to know what to ask during the class, this proposal is not difficult to understand, since didactic materials have always had a relevant role in the field of education and in the current conditions caused by the sanitary contingency that is being experienced worldwide originated by COVID-19, a series of didactic challenges have arisen, among them the design of educational materials, the planning of activities and the selection of evaluation processes that adjust to an online modality (Lobos, 2021, p.5).

Therefore, didactic materials have become essential tools for the achievement of learning, hence it is essential that the teacher is trained in the planning, design and/or choice of resources that allow the development of a teaching process conducive to scientific training in the learner. Therefore, the situation of confinement is an opportunity to move towards the integration of information and communication technologies in the construction of teaching resources (Burgueño et al., 2021, p.792).

In the same orientation, Jaímez-González (2019) alludes that teacher require employing diverse pedagogical resources to consolidate the construction of knowledge in the teaching- learning processes, given that didactic materials are employed to promote the development of skills in students, as well as in the improvement of attitudes related to knowledge, without forgetting that these have the quality of being adapt to any learning situation or objective (Morales, 2012).

Likewise, didactic materials serve to develop a quality educational process (Freré & Saltos, 2013), due to the fact that they are a pedagogical tool that supports the teacher's performance and optimizes the teaching-learning process (Vargas, 2017). Additionally, they support the tasks of the teacher in their planning, teaching development and the evaluation of student learning (Area, 2019 and Gabarda, Rodríguez & González, 2021).

In another order of ideas, educational materials can be classified into curricular and didactic, the latter being those that support the implementation of the curriculum, such as reading documents, internet, computer equipment, among others (INEE, 2019), likewise, they are essential elements in education that must evolve with the context and technological advances; whose usefulness is unquestionable, since they have their origin in the interaction of the teacher, the students and the curriculum (Aguilar et al., 2014).

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In another order of ideas, educational materials can be classified as curricular and didactic, the latter being those that support the implementation of the curriculum, such as reading documents, consultation, internet, computer equipment, among others (INEE, 2019), in the same way, they are essential elements in education that must evolve with the context and technological advances; whose usefulness is unquestionable, since they have their origin in the interaction of the teacher, the students and the curriculum (Aguilar et al., 2014).

In summary, it is evident that it is currently required to modify the way of teaching science (Arteaga, Armada & Del Sol Martínez, 2016), which allow students to develop cognitive, instrumental and transversal skills, with the purpose of extending learning to their environment (Drăghicescua et al., 2014).

From the above perspective, it is essential to build didactic materials that are adjusted to the learning that is desired to be achieved with students, according to the curricula and the new normality, that is, to establish teaching for an open learning modality characterized by being synchronous, asynchronous, and interactive (Torres & García, 2019). Additionally, it can be assumed that the importance of implementing methodologies to elaborate didactic materials is that they allow building effective educational resources (Yépez, Sánchez & Zetina, 2021, p.58).

General objetive

Design and evaluate the impact of a didactic material that helps to improve the understanding of the most difficult learning for students in the Physics subject.

Specific objectives

1. Identify the relevant elements and methodologies to be considered for the design of didactic materials.
2. Design and implement didactic materials.
3. Evaluate the didactic material and the results obtained.

Description of the method

El desarrollo de este trabajo se fundamentó en una metodología híbrida constituida por cinco fases y que estuvieron cimentadas por las metodologías de Chunga (2015) y Area (2019), dado que contemplan elementos pedagógicos, disciplinares y tecnológicos para el diseño de materiales didácticos. (Figura 1).

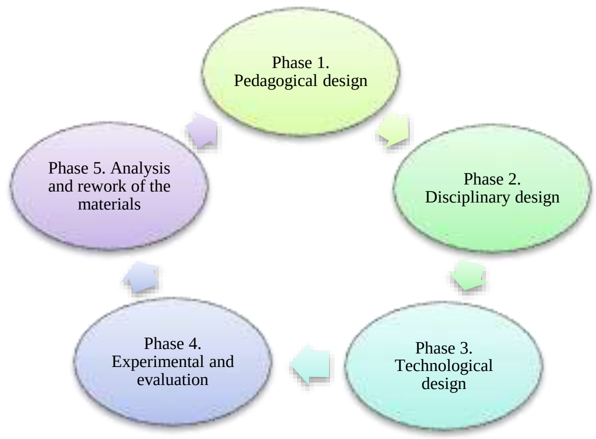

Figure 1 Methodology implemented for the design of didactic materials
Source. Adapted from Chunga (2015) and Area (2019)

It should be noted that the methodology was implemented for the design of teaching materials for the Physics III course, which is taught at the Escuela Nacional Colegio de Ciencias y Humanidades (ENCCH), Vallejo campus.

Phase 1. Pedagogical design

The following aspects were addressed at this stage:

– Determine why and for what the material is to going to be developed.

– Identify the characteristics and prior knowledge of the recipients.

– Construct materials based on the characteristics of the possible users of the material, that is, assessing the age, educational level, learning styles of the students, among other relevant aspects that can influence the construction of learning.

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Based on all of the above, it was considered that the material has a propaedeutic purpose, since it was directed towards high school students between the ages of 17 and 19, but most of them will study a career related to the area of physics- mathematics, since this is an elective subject that is designed, for young people to acquire the conceptual, procedural and attitudinal knowledge required in the first semesters of the career at the bachelor's degree level.

It should be noted that at the beginning of each learning process, diagnostic evaluations were proposed that consisted of drivers questions, small tests, CQA charts (what I know, what I want to know, and what I learned), questionnaires, concept maps, among others. These evaluations were designed so that the teacher could identify the present and absent knowledge of his students.

It is worth mentioning that in addition to carrying out initial diagnostic evaluations, specific evaluations were also carried out in some subjects, with the purpose of correcting some conceptual or procedural deficiencies that prevented the construction of new learning.

It is necessary to highlight that at the beginning of the didactic material an evaluation instrument of learning styles designed by Alonso, Gallego & Honey (1997) was attached, which consists of 80 items and determines four preferences (active, reflective, theoretical and pragmatic) that are classified each in three levels (high, low, very low) and where young people have two possible answers to choose (a positive (+) if they identify with the situation or a negative (-) if they disagreed with the question posed).

The purpose of this activity is for the teacher to implement activities that strengthen each of the styles that can be found in a classroom, since the strategies should be randomly interspersed, in such a way that they involve the largest number of learning styles, in order to strengthen the learn to learn (Gutiérrez, 2018).

Phase 2. Disciplinary design

– This material was designed according to the Physics III syllabus of the ENCCH, which is made up of two units, the first one titled rigid body systems and the second unit called fluid systems, giving a total of 19 lessons to be covered in 64 hours.

– Subsequently, the contents were selected and organized in such a way that they were distributed by degree of difficulty. It is convenient to indicate that preference was given to developing different types of activities for those very difficult or difficult learning, for this the data of the Academic Diagnostic Exam (EDA) were reviewed, which is an internal instrument used in the ENCCH and has the objective of evaluating the achievement of the learning of the subjects of the Curriculum (Gaceta CCH, 2020).

– The resources were designed with an educational intentionality, that is, that the appropriate didactic characteristics were recognized to facilitate learning (Real, 2019), in this case emphasis was given to the stimulation of mathematical skills necessary for the subject of Physics III.

– It should be noted that most of the proposed materials were audiovisual, in other words, they contain audio, text and video. In addition, some activities such as word search, videoquiz, crossword puzzles, hypervideos, among others, were chosen. However, it is essential to emphasize that these were built from active methodologies such as gamification or the flipped classroom, to promote the continuous participation of students.

– Likewise, evaluation criteria and exercises were developed through co-evaluations, heteroevaluations and self-evaluations.

Phase 3. Technological design

The following points were considered in the technological design phase:

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- Prospecting of digital resources, materials and similar projections, in order to serve as a parameter and to detect limitations.

- Review of free and easily accessible technological resources, including Sway, Stream, power point, Microsoft Teams, simulators, YouTube videos, Geneally, web pages, among other resources.

- Choice of graphic environment, links, icons, among others.

Phase 4. Experimental and material evaluation

At this stage, an experimental prototype was developed as explained below:

- A two-week pilot test lasting 40 hours was conducted both asynchronously and synchronously. At the end, students were provided with an evaluation instrument to measure the quality of the designed material, also at the beginning and end of the course they were provided with another evaluation format to determine the level of understanding reached by the students.

- In addition, the material was peer reviewed by means of a course designed for the evaluation of the material, which lasted 20 hours in a synchronous and asynchronous modality and not only had the purpose of evaluating the quality of the material, but also to disseminate it among teachers so that they could use it in their classes.

Phase 5. Analysis and rework of the material

This stage consisted of adjusting and modifying the material designed according to the results obtained in the previous phase, therefore, the actions carried out consisted of the following:

- Analysis of the results collected from the previous phase.

- Redesign of didactic and technological dimensions.

Participants

The sample was by convenience and non-probabilistic, specifically it was a purposive sampling, that is, it was not aimed at choosing subjects at random to be representative, but participants were selected who met certain characteristics according to the needs of the research (Argibay, 2009, p.19).

Based on the above, 22 students participated in this study, 54.54% of whom were women and 45.45% men, who were taking Physics III at the ENCCH Vallejo campus, between the ages of 17 and 19 years old; it should be noted that we worked with students who had not passed this subject or who were at risk of failing it. Likewise, to review the material, we worked with 12 teachers (58.33% women and 41.67% men) who teach this subject at the School; in order to provide feedback on the didactic material.

Evaluation instruments

The evaluation instrument to measure the level of understanding reached by the students was very similar to the one applied to them in the EDA test. In this case, the exam had 27 items with three response options, it should be noted that the questions included conceptual and procedural aspects of the subject, in which nine learning difficult to assimilate by young people were addressed and which are presented in the Table 1.

Difficult learning	Items
Determine the mass of the body that generates the gravitational attraction from Kepler's third law.	3
Calculate the center of mass of a system.	3
Apply angular displacement, velocity and acceleration to problem solving.	3
Identify the similarities of linear parameters with angular parameters.	3
Calculate the moment of inertia of different systems or solid bodies.	3
Identifies the characteristics of gauge pressure.	3
Prove Bernoulli's equation with Torricelli's theorem.	3
It uses Bernoulli's equation in its general form and in its particular cases.	3
Identify Bernoulli's equation with the law of conservation of mechanical energy.	3

Table 1 Learning difficult to achieve by students according to the Physics III study program in the period 2019-1
Source: DGCCH (2016)

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It should be added that two other evaluation instruments (survey) were designed and applied in phase 4, the first one for students and the second one for teachers. The criteria evaluated in the instrument implemented with the students are presented in Table 2.

Criteria evaluated	No. de items
Motivation	10
Understanding instructions	5
Understanding the content	10
Material quality	10
Level of difficulty of the activities	10
Total	45

Table 2 Criteria evaluated in the survey applied for students
Source: Adapted Aguilar et al. (2014)

The survey applied for teachers was designed based on the criteria of González, Guzmán & Barrera (2014) shown in Table 3.

Criteria	No. de items
Consistency	10
Transferable and applicable	10
Interactive	10
Aesthetic design	10
Significant	10
Valid and reliable	10
Functionality	10
Total	70

Table 3 Criteria evaluated in the survey applied by teachers
Source: Adapted from González, Guzmán & Barrera (2014)

It should be added that in all cases they were applied through a Google form, through non-probabilistic sampling of the intentional or opinionated type, since according to Arias (2012) the elements are chosen with respect to the research criteria. In the same orientation, the survey was self-administered since the interviewer did not participate in filling out the survey.

For the quantitative analysis, an assessment was established for each item according to the Likert scale, which indicates the frequency with which they identify with the situation described in the item. Where, the weighting is 1) Strongly disagree, 2) Disagree, 3) Undecided, 4) Agree and 5) Strongly agree. To identify the most relevant items, the mean frequency was obtained by means of equation 1.

$$\bar{x} = \frac{A(1)+B(2)+C(3)+D(4)+E(5)}{N} \tag{1}$$

Where, the values 1, 2, 3, 4 and 5 are obtained from the Likert scale and the letters A, B, C, D and E are the individual index of subjects and N is the total number of individuals by groups.

Results

Throughout this study, reference has been made to a fundamental aspect that refers to the evaluation of materials by the two main actors in the educational process, since it must be considered that resources help to conceive different ways of understanding teaching (Cepeda, Gallardo and Rodríguez, 2017).

On the previous bases and the results obtained, Table 4 is presented, where it is shown that the evaluation of the material by the students was positive, since in most of the criteria average frequencies ≥ 4.0 were achieved, except for two which were the motivation and the level of difficulty of the activities.

Criteria evaluated	$\bar{x}$ Average frequency
Motivation	3.90
Understanding instructions	4.55
Understanding the content	4.33
Material quality	4.22
Level of difficulty of the activities	3.23

Table 4 Average frequency obtained from the students' evaluation of the material

It should be noted that in relation to the results obtained in the case with the students, the aspect with the lowest average frequency was the level of difficulty of the activities, since they state that the tasks should be simpler and perhaps this is one of the possible reasons, why the motivation category also had an average frequency lower than 4.0. Probably, this is caused because the tasks requested are designed to promote reflective thinking in the learner, that is, the student must analyze, investigate to propose a solution to a certain physical phenomenon and not just memorize a concept or procedure; consequently, they must dedicate a greater number of hours to carry out their activities.

However, when the young people viewed their tests, they considered that the material helped them understand various topics that had been difficult for them up to now.

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The results of this test are shown in table 5, considering that these were positive, since it was observed that 100% of the reagents had an increase in the percentage of students who answered correctly, this could be caused by two possible reasons, the first refers to the fact that the learning material was potentially significant and the second that the learner presented a predisposition to learn (Encinas et al., 2016).

Difficult learning	Item	Percentage of students %	
		Before	Final
Determine the mass of the body that generates the gravitational attraction from Kepler's third law.	1	50	81.81
	2	36.36	86.36
	3	22.72	59.09
Calculate the center of mass of asystem.	4	68.18	100
	5	54.54	90.90
	6	27.27	95.45
Apply angular displacement, velocity and acceleration to problem solving.	7	40.90	86.36
	8	45.45	77.27
	9	36.36	81.81
Identify the similarities of linear parameters with angularparameters.	10	18.18	90.90
	11	22.72	95.45
	12	22.72	95.45
Calculate the moment of inertiaof different systems or solid bodies.	13	45.45	95.45
	14	50	86.36
	15	50	86.36
Identifies the characteristics ofgauge pressure.	16	27.27	100
	17	27.27	95.45
	18	18.18	100
Prove Bernoulli's equation withTorricelli's theorem.	19	40.90	95.45
	20	31.81	100
	21	36.36	90.90
It uses Bernoulli's equation in its general form and in its particularcases.	22	27.27	68.18
	23	31.81	77.27
	24	31.81	72.72
Identify Bernoulli's equation with the law of conservation of mechanical energy.	25	9.09	59.09
	26	18.18	63.63
	27	22.72	77.27

Table 5 Percentage of students who answered each item correctly before and at the end of the course

With respect to the results emanating from the evaluation of the material by teachers 100% obtained an average frequency > 4.0 as shown in Table 6, therefore it can be deduced that the results were positive given that, according to Aguilar et al., (2014) states that the quality of a learning object should be contemplated in a comprehensive manner, in other words, all aspects evaluated must achieve a positive perception by the users.

Criteria	$\bar{x}$ Averege frequency
Consistency	4.56
Transferable andapplicable	4.78
Interactive	4.12
Aesthetic design	4.25
Significant	4.09
Valid and reliable	4.23
Functionality	4.34

Table 6 Average frequency obtained from the evaluation of the material by teachers

In addition, it should be noted that the criterion with the lowest average frequency evaluated by teachers was the item of meaningfulness, which according to González, Guzmán & Barrera (2014) consists of reflecting whether "the contents make sense in themselves, represent something interesting for the addressee and are presented progressively" (p.11).

After the above, and based on the evidence gathered, some activities were redesigned, whose changes consisted mainly in incorporating some resources that favored interdisciplinarity so that students could observe that the subject of Physics is not an isolated subject with respect to other disciplines and the experiential context of young people. Therefore, projects were integrated with the purpose of providing solutions to some of the problems raised in the didactic material.

Conclusion

With respect to the evidence obtained in this research, it can be inferred that in order to improve some of the aspects in the teaching of Physics, a viable option is the construction and choice of materials, hence it is required that teachers are trained in methodologies that allow the design of resources that contribute to the achievement of the construction of new knowledge and in a change of the paradigm that Physics is difficult.

It is important to clarify that pedagogical, disciplinary, and technological elements must be considered in an integral manner when designing materials, since they lead to results that would not be achieved in isolation; hence the importance of developing materials from a systemic approach, that is, visualizing all the factors that intervene in the educational process.

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Based on the above, the student is the center of the teaching and learning process, however, it requires a facilitator with a high level of disciplinary, technological and pedagogical training that allows him/her to have a greater variability that helps him/her to adjust his/her teaching to the needs and characteristics of his/her students and the context.

Finally, it should be noted that a limitation of this work is that it was a pilot test with students who owe the subject or who were at risk of failing it, so it can be inferred that perhaps a possible reason for their commitment during the course is due to the need to pass the subject, Therefore, it is contemplated as a future work to implement this material to a group studying Physics III for the first time and evaluate the results to make decisions in the redesign of the proposed didactic material.

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