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Learning Physics Through Online Video Annotations

Aprender la Física a través de anotaciones de vídeos en línea

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ABSTRACT

The support of video in the learning environment is nowadays used to many ends, for either for demonstration, research or share. It is intended to reinforce the space before and after class and introduce a new dynamic and interaction in the classroom itself. Pedagogical Innovation may be achieved by different approaches to motivate students and obtain better results. The Audiovisual didactic content has been in recent years disseminated, in the Physics domain, mainly through YouTube platform. Many aspects of video production activities can increase students' self-esteem, increase their satisfaction with the learning experience, promote a positive attitude towards the subject, provide students with lower level of understanding with a broad individual tutoring, encouraging students to discuss with each other, exchange their opinions, and compare the results of lab activities. On the other hand, video can support research activities, offering the researcher access to a rich data aggregation to investigate the learning processes. This paper presents a revision of the literature about the potential of using video annotation in the education context and, perspectives of teachers' use of collaborative annotation systems, to promote reflection, specifically in the domain of Physics, using an open source annotation tool. The creation of audiovisual references, either for quick access to parts of organized video annotated content by the teacher, knowledge building or revision by and for other students is analyzed. This study is complemented with a testbed, showing the potential of using audiovisual annotated content, within a k-12 context. Students were invited to select video content, annotate, organize and publish the annotations, which could support the learning process in the domain of Physics. Results show that most of the aspects under analysis received a positive evaluation, and students expressed a gain from oral lectures and access to new sources of learning. The only exception relates to the capacity of the approach to motivated students to the study of Physics, as most of the students did not see this methodology too much motivating. The impact of this research relates to alternative teaching / learning methods, within the Physics' domain, using online video annotation, in the support of traditional exposition and memorization methodologies.

Palabras clave:
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Aprendizaje activo
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Anotación de vídeo

RESUMEN

El soporte de vídeo en el ambiente de aprendizaje se usa hoy en día para muchos fines, ya sea para demostración, investigaciones o para compartir. Está pensado para reforzar el espacio antes y después de la clase e introducir una nueva dinámica e interacción en el aula. La innovación pedagógica puede lograrse mediante diferentes enfoques para motivar a los estudiantes y obtener mejores resultados. El contenido didáctico audiovisual se ha difundido en los últimos años en el dominio de Física, principalmente a través de la plataforma de YouTube. Muchos aspectos de las

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actividades de producción de vídeo pueden aumentar la autoestima de los estudiantes, aumentar su satisfacción con la experiencia de aprendizaje, promover una actitud positiva hacia la materia, proporcionar a los estudiantes un nivel de comprensión inferior con una amplia tutoría individual, alentar a los estudiantes a discutir entre ellos, intercambiar sus opiniones, y comparar los resultados de las actividades de laboratorio. Por otro lado, el vídeo puede apoyar las actividades de investigación, ofreciendo al investigador acceso a una agregación de datos rica para investigar los procesos de aprendizaje. Este documento presenta una revisión de la literatura sobre el potencial del uso de la anotación de vídeo en el contexto educativo y las perspectivas del uso de los maestros de los sistemas de anotación colaborativa, para promover la reflexión, específicamente en el dominio de la Física, utilizando una herramienta de anotación de código abierto. Se analiza la creación de referencias audiovisuales, ya sea para el acceso rápido a partes del contenido de video anotado organizado por el profesor, la creación de conocimientos o la revisión por y para otros estudiantes. Este estudio se complementa con un banco de pruebas, que muestra el potencial de usar contenido audiovisual anotado dentro de un contexto k-12. Se invitó a los estudiantes a seleccionar contenido de vídeo, anotar, organizar y publicar las anotaciones, lo que podría apoyar el proceso de aprendizaje en el dominio de la física. Los resultados muestran que la mayoría de los aspectos bajo análisis recibieron una evaluación positiva y los estudiantes expresaron un beneficio de las conferencias orales y el acceso a nuevas fuentes de aprendizaje. La única excepción se relaciona con la capacidad del enfoque de los estudiantes motivados para estudiar Física, ya que la mayoría de los estudiantes no vieron esta metodología demasiado motivadora. El impacto de esta investigación se relaciona con métodos alternativos de enseñanza / aprendizaje dentro del dominio de la Física, utilizando la anotación de vídeo en línea en apoyo de las metodologías tradicionales de exposición y memorización.

1. Introduction

A distinct intellectual advantage of studying new communication technologies is that such investigations provide new types of data and allow researchers to study new variables and theories (Kim & Crowston, 2011; Van de Ven, 2005).

From the perspective of the problems teachers face in applying new technologies in the classroom, Siorenta and Jimoyiannis (2008) state that the need to cover the physics content of the compulsory curriculum and prepare students for exams is one of the main limiting factors. They also identified three distinct groups of teachers: (a) a group of "traditional" teachers whose beliefs are dominated by rigorous presentation of physical content, although they are unwilling to incorporate laboratory and ICT-based activities into their classroom practice; (b) a group of "non-traditional" teachers who are positive about the adoption of ICT-based laboratory instruction; and (c) a third group of "undecided" teachers who combine elements of both belief structures and alternate between traditional and non-traditional approaches.

M.-H. Lee and Tsai (2010) studied how teachers viewed the use of technology in support of their classes, developing a survey to assess teachers' attitudes toward Web learning content (TPCK-W). Alonzo, Kobarg, and Seidel (2012) investigated how video analytics can be used to assess their pedagogical content (PCK) in their interaction with students, identifying three potential characteristics of pedagogical content: flexibility, richness and student centering. Leask and Younie (2013) mention that the allocation of resources to improve the quality of professional teaching knowledge is insufficient, since the knowledge produced and management within the educational sector lack organization and dissemination. De Jesus (2014) reports that one of the problems in the teaching of physics goes through the boundary between the classroom and the laboratory, since experimental data are obtained almost without reflection, which in turn, are presented without a detailed discussion of their meaning and no connection to the theory that could explain them.

This research is based on the hypothesis that video annotations can contribute to the teaching / learning process in the area of Physics. Based on the Clipper (2019) prototype audio-visual annotation tool, the main goal will be to realize the importance that the annotation of video contents plays in the improvement of the educational process.

In relation to the study research questions, they are the following:

- Can video annotations support students in the study of Physics?
- Does the provision of video annotated content contribute to improve the training process by promoting active learning?

The first question seeks to verify if video annotations can help the traditional study by the students as they feel it useful for learning physics. The second question is intended to be comparative-causal, to investigate the relationship between students' video annotation experience and the training process.

The experiment presented in this paper partially answers the two research questions and provides good insights on the use of the described approach.

This paper is organized by the following sections: 1) Literature review concerning learning and teaching with technology; 2) Related work about video and Physics; 3) Testbed with the open access video annotation tool Clipper, among Physics K-12 students; 4) Evaluation process; 5) Annotation analysis; 6) Results, 7) Conclusions.

2. Literature review

2.1. Learning and teaching with technology

Since the work of Latour, Woolgar, and Salk (1979) on the central importance of inscriptions in the organization of scientific knowledge, the role of these written supports has become a major focus of research. Instead of reflecting spoken language, these external representations complement it by using the distinctive features of the material world to organize phenomena in a way that the spoken language does not allow. As technology evolved, the use of video and the creation of annotation techniques helped researchers systematize their observations (L. L. Lee, 1974; Retherford, 2000; Rosenblum, Zeanah, McDonough, & Muzik, 2004). These techniques involve the detailed recording of events on paper, specifying features such as durations, classifications / levels and temporal codes (Leadholm & Miller, 1994).

In Roth and McGinn (1998) work, a theoretical perspective on representations is presented, derived from academic studies in science and technology. The approach is around the notion of inscriptions and graphic representations, available through some support. The authors consider two types of writing tools: paper and pen, and computer. They claim at the time that much was to be availed by the use of the computer. We can do the parallelism of the analogical inscription on paper, to the concept of digital annotation that can be used by the members of the community. In an educational context, it may refer to notes made by teachers or students. Marshall (2009) defines annotation as “a tangible demonstration of student engagement with the text,” investigating how readers interact with text. Features such as readability, annotation, and navigation are examined as aspects that e-books have inherited from their print legacy. For Chen and Huang (2014) it is “an active reading strategy where key information is written on the margins of our text, since it gives it a purpose, and the annotation helps to focus while reading, and really helps you learn from the text.”

Digital annotations have clear advantages over paper annotations, as they can be searched, shared, archived and easily manipulated (Shilman & Wei, 2004). Video annotation has a spatial dimension, as in paper annotations, and a temporal dimension, i.e. the time interval in the video in which the annotation is associated. For Burr (2006) the emergence of technology as an auxiliary tool in video annotation has increased reliability, repeatability and optimization of workflow.

The concept of hypervideo (links within the video), has been studied in regard to the use of educational content, specifically audiovisual. In the study by Debevc, Šafarič, and Golob (2008) a prototype was created and evaluated in order to verify if it provides sufficient information, so that students fully understand the subject. The structure of the hypervideo application consists of scenes and sequences of narration. A scene is defined as a set of frames displayed sequentially and relating to the same concept. For example, it could include images showing first all the equipment needed for the experiment and then the experiment itself, for example showing a magnetic ball closest to a plane - this allows observation of the movement of the ball in its own position. A scene can be shared by several narrative sequences, but the context of the scene may change in each one. Narrative sequences represent a potential path or segment through a set of embedded video scenes and synchronized hypertext, sometimes dynamically mounted based on user interaction or in the context of scenes.

The analysis of users (both teachers and students) done by Debevc et al. (2008), identified the following requirements in the use of this type of tools:

- Applications should create a real learning environment with all interactive elements.
- Multimedia applications must be simple and understandable, and video-enabled.
- Systems need to include a navigation template.
- Systems need to include clear segments that users can choose.

As a reinforcement of academic practice through the use of video, Bartholomew (2014) investigated the use of video as an enabling technology for teaching, for research, and for the involvement of stakeholders in curriculum design. In order to establish evidence for the introduction of this technology in this context, two pilot studies were conducted to evaluate if video lectures were effective. The first study related to whether video lectures effectively communicate information to students and facilitate their learning; the second study focused if video lectures are as effective as face-to-face lectures, in communicating information to students and facilitating their learning. Results showed that students, when working in triads, make visible aspects of their cognition through their speeches. On the other hand, when captured with video, it gives the researcher access to a rich aggregation of data to investigate learning processes.

The collaborative knowledge building approach introduced by Scardamalia and Bereiter (2005), based on the CSILE platform, was based on the belief that students represented a resource that was wasted and could be leveraged through network technology. CSILE, according to the authors, "restructured the flow of information in the classroom, so that questions, ideas, criticisms, suggestions, and other similar things were contributions to a public space equally accessible to all, instead of everything given by the teacher or (as in e-mail) passing as messages between individual students. By linking these contributions, students created an emerging hypertext that represented collective knowledge, not just individual knowledge of the participants." (Scardamalia & Bereiter, 2005).

In the literature we find reference to the difficulties in the teaching of Physics (Arons, 1997), namely in the transmission of basic concepts, as well as methodologies of correction in order to mitigate these difficulties. diSessa (1993) points out that one of the problems in the teaching of Physics stems from the fact that students do not feel themselves to be participants in the learning process. It also considers that the use of everyday examples, in the explanation of theoretical concepts, tends to involve students more in the discussion in the classroom, in order to improve their scientific understanding. The learning of physical processes on the basis of everyday objects is viewed by this author as an essential step to make processes acceptable and applicable to a wider range of circumstances. Redish (2003) refers to the problem of students with different abilities memorizing without understanding, despite the most elaborate methodologies of education, and students with reasonable ability to construct a graph, but not be able to understand its meaning. This author refers to several methods and resources that can be used in the teaching of Physics. One good example is the Just-in-Time Physics (JiTT) methodology, based on the interaction between didactic content on the Web and the tasks that are developed in the classroom or laboratory (Novak, Gavrini, Christian, & Patterson, 1999).

In line with this approach one of the hypotheses to support the thesis in progress is that the provision of annotated contents should be able to improve the training process by promoting active learning using audiovisual annotations. This should allow students to practice processes that will have to be applied in the laboratory, or even consolidate concepts of the discipline under study in the improvement of the training process.

The JiTT methodology was initially developed to promote student's learning in the field of Physics by combining modified lectures, group discussion problem solving and Web technology. This approach focuses on two cognitive principles involving students and teachers in the teaching / learning process: the first one states that students learn more effectively if they are intellectually involved; the second mentions that teachers teach better if they understand what their students think and know about the contents (Novak et al., 1999). The implementation of this approach depends, according to the authors, on three factors: 1. a mechanism for delivering questions through the Web and for collecting and visualizing the answers in an appropriate way; 2. a series of exercises designed to allow students to easily understand the contents; 3. a teacher who can understand the difficulties of the students in order to lead the discussion in the classroom.

Inspired by the study of Novak et al. (1999), Simkins and Maier (2010) introduced JiTT into self-taught economics courses, requiring students to answer questions related to the material in the next class, a few hours before class using a course management system online. The results were positive and immediate: students came to class better prepared and reported that JiTT exercises helped to focus and organize their studies outside of class. In addition, students' responses to JiTT questions highlighted gaps in their learning, visible to teachers before class. This knowledge allowed teachers to create classroom activities that directly addressed these learning gaps while the material was still fresh in students' minds - hence the expression "just-in-time" - leading to improved learning. For the authors, the JiTT approach suggests that the classroom is not an assembly line, but rather a learning environment that needs to be adjusted to what students know and bring into the classroom.

The Active Learning methodology taken in the sense given by Knight (2004) and Hake (1998), is a teaching philosophy where students construct their own knowledge, through interaction with materials and ideas, instead of passive participants in the knowledge process. The implementation of strategies according to this methodology has the following characteristics:

- Students spend most of the class actively involved in doing / thinking / speaking Physics - and not just listening to someone talk about it.
- Students interact with their peers.
- Students receive immediate feedback from their work.
- The instructor is more a facilitator, less a transmitter of knowledge.
- Students are responsible for their knowledge. This includes engaging in activities, text study, and performing tasks.

Allen and Tanner (2005) defined active learning as "seeking new information, organizing it meaningfully and having the opportunity to explain it to others". Researches have shown that the use of active learning methods improves students' learning and their attitudes towards studying (Armbruster, Patel, Johnson, & Weiss, 2009; Chickering & Gamson, 1987; Vygotsky, 1978).

In the spectrum of teachers' perspectives in the promotion of reflection within students, we start to define the concept of reflection to educators, the use of video for teacher reflection, the video annotation for reasoning practices, and teaching practices through technologies in the Physics / Science domain.

The importance of critically reflecting on teaching practices has become increasingly important, as Lawrence-Wilkes and Ashmore (2014) highlights: "Schön (1983) was influential in changing understanding when he described the 'reflective practitioner' in professional practice as a way of developing teaching beyond a technical-rational model. In a fast-changing and demanding 21st-century synchronous and asynchronous learning environments, the teacher's role has become more complex, emerging as social mediator, pastoral supporter, learning facilitator simultaneously with being a reflective practitioner." (p. 12). In line with this studies, Aldahmash, Alshmrani, and Almufti (2017) distinguish between reflection in practice and reflection in action: "(...) reflecting in practice enables teachers to challenge teaching practices and then to perform well in lesson design, curriculum decision-making, class management, and execution of teaching activities. Reflection in action may also help teachers deal with the school and other teaching contexts where it is difficult to find time away from the students to reflect with colleagues." (p. 45).

The literature review presented in this section related to the didactic advantages video annotations can have in the learning process, promoting an alternative study methodology to the traditional memorization practice, facilitating the implementation of active methodologies of teaching and learning, fostering students' reflective attitudes and critical thinking.

2.2. Video in the context of Physics learning

Within the context of video use, Rich and Hannafin (2009) found in their study on the use of videos by trainee teachers, that the collaborative reflection between the trainee and the mentor was fundamental to develop the reflection of the beginning teachers about the practice. Video has specific attributes that facilitate teachers' practice, such as allowing selective and recursive reproduction of any part of a teaching event, and providing auditory and visual references (Boling & Adams, 2008; Es & Sherin, 2010; Masats & Dooly, 2011).

Secondary teacher education programs are increasingly using video recordings of classroom teaching practices, to promote the transformation of professional practice through collaboration and reflection (Juzwik, Sherry, Caughlan, Heintz, & Borsheim-Black, 2012; Santagata & Angelici, 2010; Youens, Smethem, & Sullivan, 2014). The use of videos in teacher training programs provides multiple sources of information to create a rich shared experience, focus attention on specific sequences of behaviours for analysis and discussion, and thus identify practical ways of improving teaching practices (Eröz-Tuğa, 2013; Hixon & Hyo-Jeong, 2009; Marsh, Mitchell, & Adamczyk, 2010; Towers & Rapke, 2011).

A survey was conducted by Tanya Christ, Arya, and Chiu (2017) on how video has been used as a resource in teaching development. It was identified that video is embedded in a variety of contexts, such as video case study discussions, reflective discussions of classroom practices recorded in video of the teachers themselves, and self-reflections about the instructional practices recorded in video of the teachers themselves (Baecher, Rorimer, & Smith, 2012; Calandra, Brantley-Dias, Lee, & Fox, 2009; Tanya Christ, Arya, & Chiu, 2012; T. Christ, Arya, & Chiu, 2015; Fadde & Sullivan, 2013; Long, 2012).

In the context of video annotation, van Es and Sherin (2008) used the "Learning to Notice Framework" to classify teachers' video annotations of their teaching. This framework highlights the importance of interpretation to enable teachers to make informed pedagogical decisions, resulting in actions aimed at improving their practice. The results of the study include the tendency of teachers to focus on their notes, as well as a preponderance of notes focused on reflective practices of description.

In the study of Colasante (2011), the trainees categorized (marked sections), annotated their videos and received comments from colleagues and instructors within the annotation tool. Its use was analysed to determine if this learning environment was effective, to critically reflect and evaluate pre-teaching practice. Results showed that learners appreciated the ability to analyse their videos of teaching practice; to categorise the video and anchor annotations to segments of the video in cycles of notation and feedback.

Ellis, McFadden, Anwar, and Roehrig (2015) examined the social interactions and potential support of a video annotation tool (VideoANT), to promote collaborative interactions for the development of reflective practices. Results indicate the need to give beginning teachers specific supports and scaffolds to further their development as reflective practitioners.

Several video annotation tools have also been compared and discussed in the context of e-portfolio or teacher training (Cebrián-de-la-Serna, Bartolomé-Pina, Cebrián-Robles, & Ruiz-Torres, 2015; Pérez-Torregrosa, Díaz-Martín, & Ibáñez-Cubillas, 2017), and have explored scenarios to help teachers' through video annotation systems (Colasante, 2011; McFadden, Ellis, Anwar, & Roehrig, 2014; Milner-Bolotin, 2018; Nishihara & Yonemura, 2018; Rich & Hannafin, 2009). These studies used as main source the analysis of video recordings of their practice to reflect and improve methodologies of teaching.

In the Physics domain and Science in general, reflection has been studied either to enhance student attention or teaching practices through technology. These pedagogies incorporate extensive formative assessment that is often enabled by modern technologies (Lasry, Guillemette, & Mazur, 2014; Milner-Bolotin, Kotlicki, & Rieger, 2007). Teachers need to have the opportunity to explore these technologies as a mean of reflection (Milner-Bolotin, Fisher, & MacDonald, 2013), firstly, as apprentices of a technology-enhanced learning of Physics and, secondly, to reflect on their own experiences as future teachers. In the study of Milner-Bolotin, Egersdorfer, and Vinayagam (2016), the authors advocate that teachers should be encouraged to reflect on their own teaching, rethink their current pedagogies, and continually consider adapting and adopting new teaching practices. However, reflection should not be limited to self-reflection, since teacher collaboration and mutual support are powerful tools for improving teacher practice. Among the limitations for the implementation of educational technologies, teacher educational programs relate the time required for instructors to learn how these technologies can be implemented, and the lack of opportunities to use these technologies in classrooms during the practice and consequent teaching (Milner-Bolotin, 2015; Milner-Bolotin et al., 2016).

In line with these studies, the concept of Deliberate Pedagogical Thinking with Technology presented by Milner-Bolotin (2018), emphasizes not only teachers' knowledge but also their attitudes and dispositions about the use of digital tools to support student learning. The tool used was CLAS (Risko, Foulsham, Dawson, & Kingstone, 2013), an open access online collaborative platform, which allows upload, share and comment videos stored on the system, while permitting to make general and specific comments throughout the video.

From the teachers' perspective there are factors that limit their activity with students, as it is reported on TALIS (OCDE, 2014), being that the teacher's workload increased because of the extra responsibility for extracurricular activities, making it difficult to fully involve them in improving the quality of teaching.

In this section we focus the importance of the use of video recordings and video annotation tools by teachers, to promote student attention and enrich teaching practices in the Physics domain. This research identified several issues related to the learning / teaching of Physics, which can be mitigated by presenting active methodologies to both students and teachers, allowing in one hand to present alternative resources to study (through online video annotations) and optimize and complement teaching practices due to curriculum time constraints.

Although all these experiences provide relevant conclusions on the use of audiovisual content in the teaching / learning process in the domain of Physics, there are still some open questions that can be raised such as: a) students' involvement either on the annotation process itself or in the consultation of annotations to enrich their traditional study; b) the type of annotation analysis that could be made through the type of online video chosen to annotate; tagging annotations to promote workflow within a teamwork set-up annotation task;

3. Testbed

3.1. Annotation Tool

Clipper (2019) is a free web-based tool that allows users to create a catalogue of video annotations and share individual annotated clips or clips that are within a specific list of clips.

This tool allows the user to specify a section of the video, hereinafter referred to as a segment or clip, directly from the player's timeline of the video imported by the user, identified through the video URL (for example, a YouTube URL). These segments, identified by the initial and final playback instant, are anchored so that the user can view the clips identified by the user instead of having to view the entire video. On the other hand, the user can insert text annotations and keywords that accompany each of the user-created segments.

Once the application provides all the functionalities required for the intended experiment, it was selected as the tool to be used within this testbed.

3.2. Application Scenario

The testbed was fully implemented in a class of 20 k-10 students who selected the videos to be annotated, used Clipper to annotate selected videos and built a website for publicizing the annotated content.

In the first stage of the project, the students reviewed the curricular goals of Physics and Chemistry A curricular program, specifically concerning the contents of Physics. A list of all the contents of the curriculum that could be complemented by annotated videos to assist their study was built. The students recalled the organization of the k-10 Physics curricular by domains and subdomains: the first domain, titled "Energy and movements", has 8 subdomains; the second, entitled "Energy and electrical phenomena", is composed of 7 subdomains; and the third, "Energy and thermal phenomena and radiation", is composed of 10 subdomains. This organization of the contents was always kept during the project to facilitate the attribution of the selected videos to the contents of the program.

A web search for videos of relevant content that may prove useful for studying the concepts of physics in each domain and subdomain was done. This research was performed by the students involved in the project, who selected almost 200 videos. After a more detailed analysis and later validation by the teachers, 95 videos were identified to be annotated with the Clipper tool, as they are potentially useful in the study of several concepts of the different topics.

The video annotation stage was divided into three phases:

1. tutorial session for the students.
2. student familiarization with the tool through a hands-on session with example videos.
3. annotation of the 95 videos.

In the first phase, the students were assisted in using the tool to create annotations. At this stage, it was exemplified what is meant to be an annotation and some exercises of annotations were done with illustrative videos in a large group.

In the second phase, the students performed several annotation tasks and some doubts were overcome.

In the third phase, the students annotated the 95 videos, segmenting them into clips that pointed to the most relevant content and added a summary and some illustrative keywords. The annotation review was done in pairs.

To enable a broader disclosure of the work done, so that it could be of benefit to a larger group of students, a website was created ("Aprender Física com o Clipper," 2018) and promoted within the group of students, either those beginning the k-10 and those already attending the k-11, so they could use the contents to review some concepts.

This process was documented in video ("Clipper in Portugal," 2018) and shared between the Clipper developer team and community.

3.3. Evaluation Process

The evaluation process included two aspects:

1. The teacher in charge analyzed the output of the annotation process and classified each group according to a set of pre-defined parameters (appendix 3);
2. Each student answered a survey.

The teacher's evaluation focused on four topics of the learning process:

1. Clarity in the presentation (organization of video clips)
2. Creativity / originality (what kind of videos was chosen)
3. Subject agreement (if the clip was in accordance with the topic)
4. Content (annotation quality)

To measure the students' perception about the annotation process, a 4 point Likert scale was used, to evaluate six statements related to the annotation experience. The goals were:

1. To assess the pertinence of this type of study methodology.
2. To verify if this kind of study motivated the students.
3. To understand the usefulness of annotations in the understanding of contents.
4. To ascertain whether the fact of video annotation being carried out in a group is an advantage or disadvantage.
5. Based on the possibility of the annotation platform making it possible to work with the same account by several users, it is intended to assess the advantage of this functionality in the context of group work
6. To determine if the group work facilitates the mutual aid in the annotation, three open questions were asked:

   a) What aspects did you dislike in this annotation work?
   b) What aspects did you like in the annotation work?
   c) Comments or ideas to help improve the application?

These open questions served as feedback to troubleshooting and improvement either in the teaching methodology and the technology itself. This information proved to be valuable for the developers of Clipper, in detecting bugs unnoticed within learning context use.

3.4. Annotations Analysis

We now present some examples in relation to the types of contents / experiments from the annotated videos, the type of the annotations (only tagged or with descriptive text), and how videos were selected and assigned by the teacher to be annotated by the students.

Types of annotated videos:

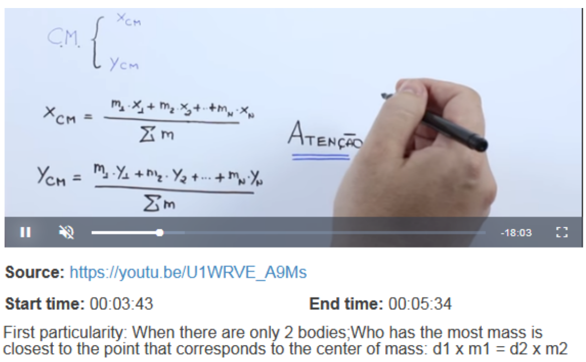

Figure 1. Formulas

Figure 2. Drawing

Figure 3. Simulation (3D)

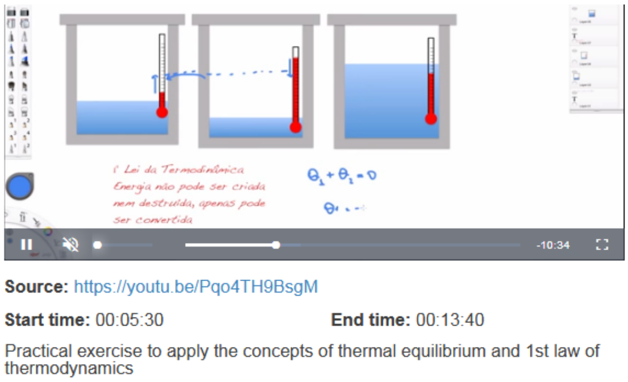

Figure 4. Animation (2D)

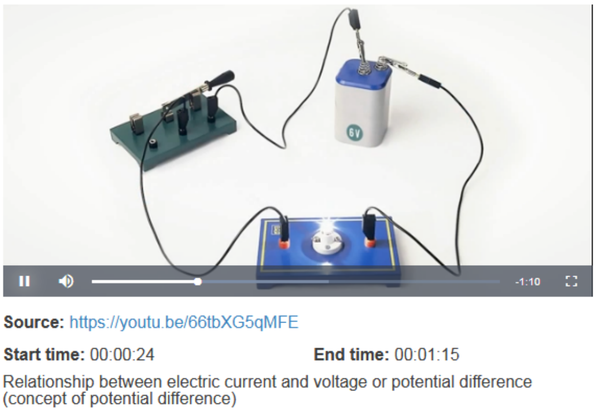

Figure 5. Demonstration

Figure 6. Graphics

The typology of videos presented in figures 1 to 6, exemplify the range of techniques in the production of lecture videos (blackboards, 3D, photography), relating to distinct topics: mass density written formula (Figure 1), draw differentiating the rotation and translation motion (Figure 2), gas energy compression simulation (Figure 3), animation on how to apply the concepts of thermal equilibrium (Figure 4), concept of potential difference demonstration (Figure 5), and energy efficiency graphic (Figure 6).

In relation to the process of annotation, different styles were found: from simple annotation containing a brief description with no tags, to elaborated annotations explaining the processes related to the video along with tags, as exemplified in figures 7, 8 and 9. The advantage of using tags along with the annotation is the ability to find faster a group of clips in separate cliplists, but containing similar characteristics such as the duration of the clip or to be part of a new cliplist ("clips under 30 seconds").

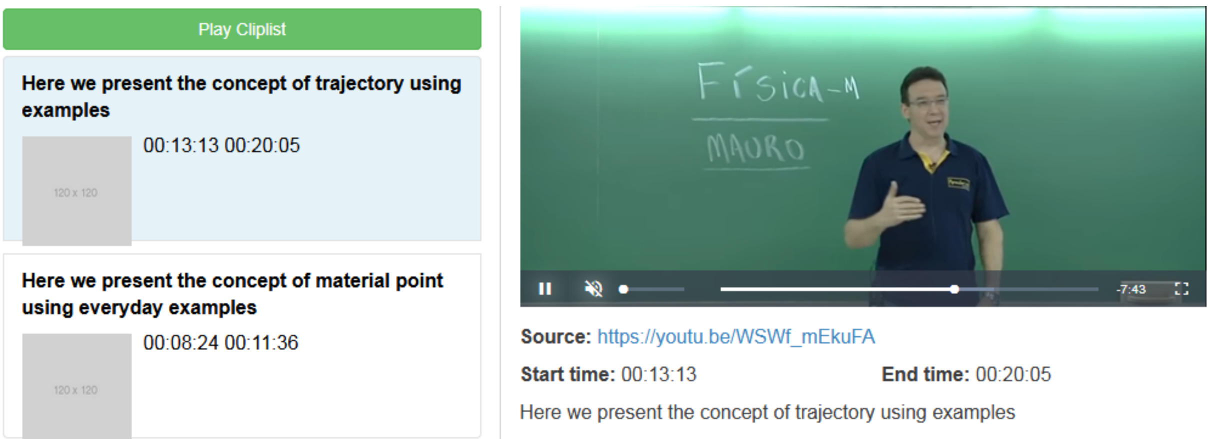

Figure 7 – Simple annotation without tag

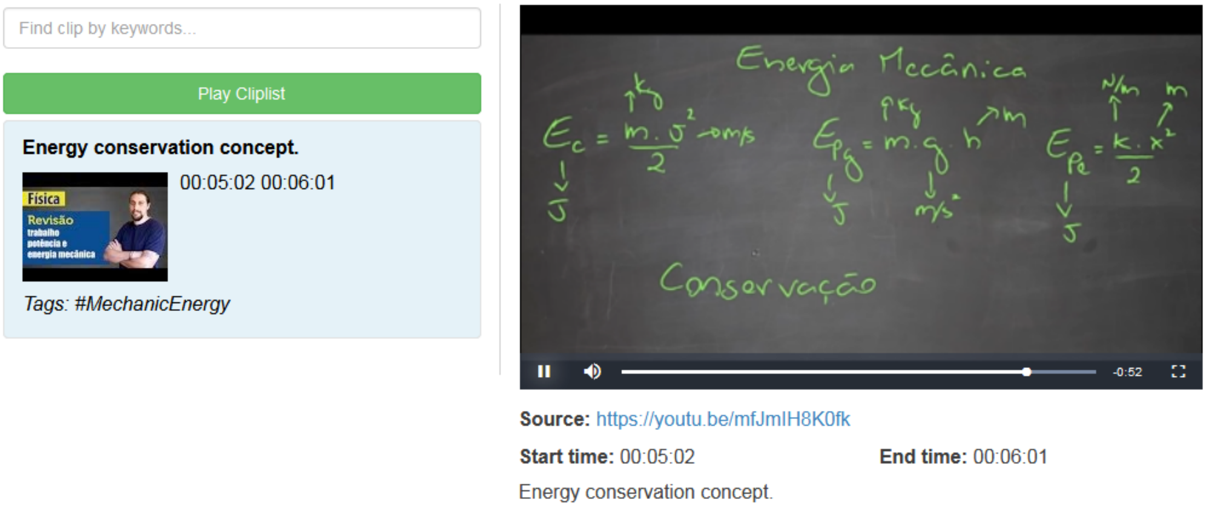

Figure 8. Simple annotation with tag (allowing for keyword search)

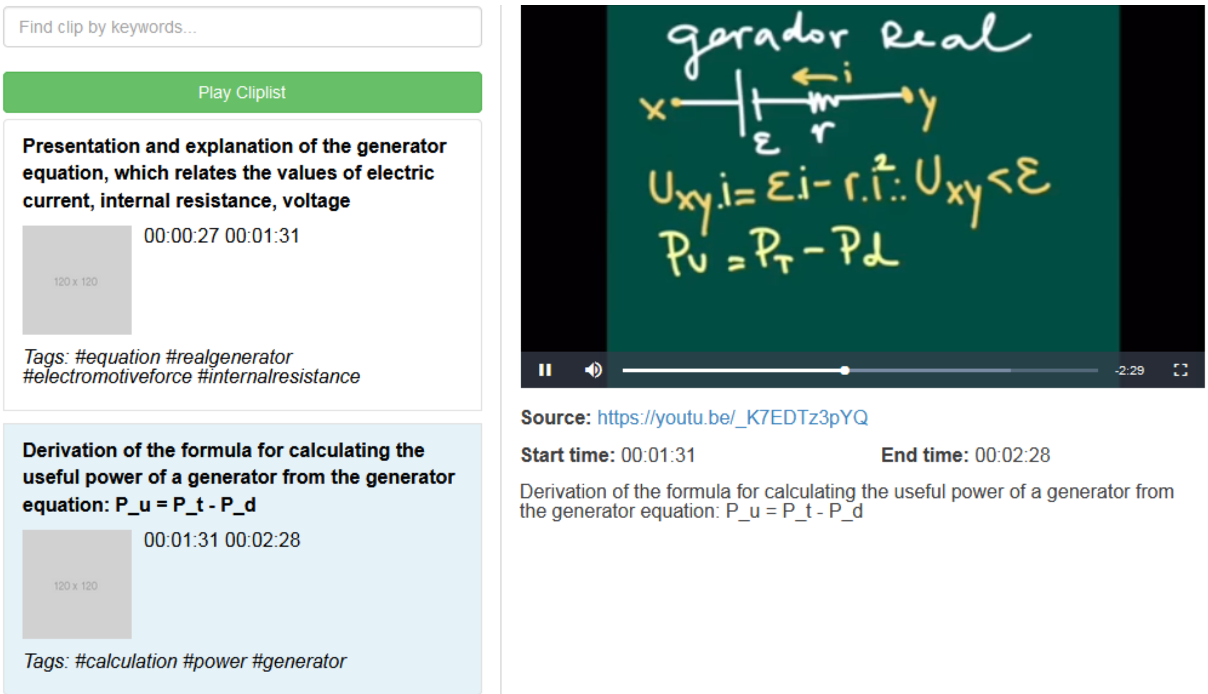

Figure 9. Descriptive annotation with tags

The selection and assignment of videos was done by the teacher. Each student assigned 5 videos to annotate, each video focused on a single topic, avoiding different students to annotate the same topic. All the videos in total comprised 12 hours duration and 458 annotations were created from the 100 videos assigned.

From this preliminary analysis we verify that annotations are used in distinct ways. The different types of video lecture representation can support multiple perspectives from the same didactic content. We developed with the Physics' teacher a baseline to which future teachers could adopt the same annotation methodology.

In the next section we present the results from the testbed.

4. Results

Table 1 presents the collected results to the 6 scaled questions of the 20 students' pool. The weighted mean and standard deviation values are also shown.

1-totally disagree, 2-disagree, 3-agree, 4-totally agree	Scale					
Question	1	2	3	4	Mean	SD
Taking notes in the videos helped me understand concepts in physics.	1	5	14	0	2.65	0.57
When taking notes, I became more motivated to study physics.	3	12	5	0	2.1	0.62
The video annotations provided by colleagues allowed a better understanding of the concepts.	0	4	16	0	2.8	0.4
The collaborative process of video annotation has contributed to a quicker understanding of content.	1	4	15	0	2.7	0.55
Creating the clip list contributed to improving the collaborative annotation process.	1	5	11	3	2.8	0.74
Group annotation work make the annotation process easier.	1	6	13	0	2.6	0.58

Table 1. Results from survey applied to the students

The three open questions also gave some clues about what could be improved either in the tool or in the process. Although the tool was considered adequate for the annotation purpose, a set of functionalities to be included in a future upgraded version were identified. The most relevant are annotations could be more intuitively perceived if they were overlapping the video content instead of being presented in a separate area; navigation functionalities within the annotations should be improved. In the following we present some comments/ suggestions of students that fundament their perspective:

> Student #1: *Enable export / import of cliplists into other projects in and out of the same Clipper account*.
> Student #2: *To be able to select multiple clips to move, delete, or copy.*
> Student #3: *In the annotated clips query mode, through the generated link, only allow access to the set clip time, without having access to the total length of the video, should the annotated clip be interrupted at any time.*

The open questions also contributed to strength the conclusions from the scaled questions as students highlighted the ability of the approach to help consolidating the subject and helping to acquire knowledge. They also mentioned this could be an interesting complementary study method.

> Student #4: *It is good to consolidate the subjects and helps to acquire knowledge*.
> Student #5: *The project and cliplist system is much more productive*.
> Student #6: *Search hard to find the right videos.*

Overall, students expressed that the main benefit of this time-based annotations was to enable them to optimize their study by watching summarized versions of the content instead of reading and watching long videos.

Most of the aspects under analysis received a positive evaluation. The only exception relates to the capacity of the approach to motivated students to the study of Physics as most of the students did not see this methodology as motivating. One factor that may have contributed to this result is the fact that, because it was their first hands-on experience with the Clipper platform, these students were not familiar with the tool and therefore faced some problems in its use. Tasks such as sorting the videos in the "playlist mode", pausing videos when playing and cropping the time, were not easily implemented. This resulted in extra time devoted to a working process which may have influenced their perceived benefits.

One could argue that this approach for teaching with "fast, easy to consume" contents, can carry risks over the knowledge acquisition process – "simplification of the message" vs "teaching how to think". Martín-Ramos, Gomes, and Silva (2018) address the study of pendular movement and head-on elastic collisions through an open source video analysis application, using a smartphone / tablet, and demonstrate that theory and practice can be integrated using standard class devices such as Newton's balls. Online video didactic content could be cross-referenced through video annotations of in-class video data acquired experiments, comparing data and building knowledge through analysis of each learning source. Teachers could present an experiment scenario using several YouTube videos, from which students would elaborate through video annotation, the results obtained from the YouTube video and the in-class experiment.

The student's interpretation of a specific experience will be different from that of the teacher, because the teacher is relating it to a different set of previous experiences. (Choi & Johnson, 2005). From that premise, comparing students' and teachers' perceptions of video annotation-based learning / instruction and traditional text-based practices, implies that context-based on video annotation has the potential to increase student retention and motivation. A similar approach was conducted by Yuh-Tyng (2012), in which students could easily hyperlink a particular video segment they needed so as to reduce student's extraneous cognitive load, and simultaneously concise textual and pictorial learning elements which could benefit to reinforce their learning.

5. Conclusions

We presented a study based on the premise that online video annotation can complement the study of Physics' students. The literature review encompasses several domains regarding video as an educational tool: representation of annotations (analogue / digital), hypervideo, collaborative knowledge building, difficulties in the teaching of Physics, Just-in-Time Physics / Active Learning methodology, teacher's perspectives in the promotion of reflection within students (either with video analysis, video annotation or technology) including in the Physics domain. To support the pertinence of our study, we researched factors that hinder teachers' activity with students and, scenarios to help teachers' through video annotation systems.

This first testbed allowed to test the Clipper tool and refine the application methodology to future students and teachers. Overall the results were positive, considering that this was the first time this tool was tested in educational context and adjustments and improvements are needed.

In relation to the limitations in this study, we highlight that although there were several initial opportunities in testing the application and the methodology, setting-up a large pool of students at the same time revealed challenging, mainly because of the involvement of potential students in other research projects.

Other online annotation platforms have been explored within the education context, specifically a web-based video annotation game which relies on a collaborative process and on gamification mechanisms to engage users on the tagging process, developed by Viana and Pinto (2017). The gamified approach used in that platform used pre-selected video content from the archive of the national TV broadcaster (RTP), involving the mechanism of time to annotate the right tag in the video segment, and also rewards as motivation strategy. The annotation process in Clipper is based in a knowledge building methodology through the selection and annotation of YouTube clips.

Future work includes making similar experiments in a larger pool of students and focusing on the teacher's use of video annotations to support the teaching practice.

Several questions will be designed to survey teachers' experience with Clipper, such as: 1. Improvement in the learning process; 2. Involvement of students; 3. Preparation of lessons; 4. Ease of personal use / implementation with students; 5. Application to scientific areas other than physics; 6. Average note length; 7. Type of video content that best explains the contents; 8. Another type of use of annotated video content;

Visualizing qualitative phenomena in addition to the standard numerical exercises, is one of the areas where students' gaps and misconceptions can be detected, as Arons (1997) highlights: "(…) one must visualize the details of effects that cannot be seen directly; they transcend direct sense experience. Such exercises are essential in building up students' capacity for abstract logical reasoning and for using concepts as a basis for understanding more complex phenomena." (p. 329). Online video annotation can be an enhancement to these exercises, within a customized workflow to capture, segment, annotate, organize, share and visualize.

There may be several ways of using video annotation tools that may also be exploited. This will depend on the teaching strategy of each teacher to prepare students for the assessments or, for example, in the construction of a "recorded bookmarked video library" that can be used by other students at the beginning of a curricular topic.

Comparing students' and teachers' perceptions of online video annotation-based learning / instruction and traditional text-based practices is the next phase from this research.

In a future experiment several aspects can be also explored and improved, such as: evaluate which type of annotations receive more engagement, and a set-up refinement from which students should elaborate their work. If tags help students search within the annotated videos, and given that not always students used them, in the future we will give instructions on how to improve the use of tags.

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APPENDIX 1. List of videos

Table 2 presents the list of videos according to domain and sub-domain of physics contents.

Physics Contents – K-10 – 100 videos – 458 Anotations – 12 hours – ESCOLA GLOBAL		
Domain	Sub-domain	Videos to annotate
1. ENERGY AND MOVEMENTS (6H.)	Kinetic energy and potential energy; internal energy (31 min)	1_1_A - https://youtu.be/Ft4p6hDWh_A 1_1_B - https://youtu.be/Ht-a2_yNuec 1_1_C - https://youtu.be/INL19TNCoHA
	Mechanical system; system reducible to a particle (center of mass) (72 min)	1_2_A - https://youtu.be/9vCW7uPs05A 1_2_B - https://youtu.be/U1WRVE_A9Ms 1_2_C - https://youtu.be/FQlSnNW55kM 1_2_D - https://youtu.be/WSWf_mEkuFA 1_2_E - https://youtu.be/ImEQigZV3vo 1_2_F - https://youtu.be/jT-Tm7tZ9dY
	Work as a measure of energy transferred by forces; work done by constant forces (50 min)	1_3_A - https://youtu.be/MiDrO9R8vV8 1_3_B - https://youtu.be/x-XrstCAS-w 1_3_C - https://youtu.be/HjDhps5zP9Q 1_3_D - https://youtu.be/_jBZkHFOD28 1_3_E - https://youtu.be/IaetD5LjGvM 1_3_F - https://youtu.be/w4QFJb9a8vo
	The Kinetic Energy Theorem (56 min)	1_4_A - https://youtu.be/0Lm4KpaGV24 1_4_B - https://youtu.be/Ht-a2_yNuec 1_4_C - https://youtu.be/94VcVNIPPNk 1_4_D - https://youtu.be/-2pPayrmmPI 1_4_E - https://youtu.be/CsT-XEH0xSE 1_4_F - https://youtu.be/-mAgCDv-Mc0
	Conservative and non-conservative forces; weight as a conservative force; work done by weight and variation of gravitational potential energy (33 min)	1_5_A - https://youtu.be/dBI0iQ1HzcE 1_5_B - https://youtu.be/7ew40UGhLh8 1_5_C - https://youtu.be/Pu2NO8Mlfhg 1_5_D - https://youtu.be/Y948c2WdV2U 1_5_E - https://youtu.be/v60vQVxGEek
	Mechanical energy and conservation of mechanical energy Non-conservative forces and variation of mechanical energy (62 min)	1_6_A - https://youtu.be/E7HS2FlhfiE 1_6_B - https://youtu.be/LaMbPbNEZEU 1_6_C - https://youtu.be/9RghIP9LNSY 1_6_D - https://youtu.be/Pu2NO8Mlfhg 1_6_E - https://youtu.be/hce4pncZlI4 1_6_F - https://youtu.be/h8jWm5IzNYs
	Power (24 min)	1_7_A - https://youtu.be/G5KJZmG9-Uk 1_7_B - https://youtu.be/mfJmIH8K0fk 1_7_C - https://youtu.be/waSbtOYNuUs 1_7_D - https://youtu.be/RpbxIG5HTf4
	Energy conservation, energy dissipation and yield (42 min)	1_8_A - https://youtu.be/KJh-OIguTIg 1_8_B - https://youtu.be/Pu2NO8Mlfhg 1_8_C - https://youtu.be/LaMbPbNEZEU 1_8_D - https://youtu.be/bdoPOeL8Yiw 1_8_E - https://youtu.be/ueS9IiFhLSw

2. ENERGY AND ELECTRICAL PHENOMENA (2H.37M.)	Electric quantities: electric current, electric potential difference and electric resistance (64 min)	2_1_A - https://youtu.be/66tbXG5qMFE 2_1_B - https://youtu.be/jyssHo42eaI 2_1_C - https://youtu.be/0UX11WbhD8w 2_1_D - https://youtu.be/JIjXbTnsGiA 2_1_E - https://youtu.be/vvilhEiMGQE 2_1_F - https://youtu.be/APh1zKtb1vM
	Direct current and alternating current (19 min)	2_2_A - https://youtu.be/dfNmTe9mqPQ 2_2_B - https://youtu.be/6lSvbmri-M4 2_2_C - https://youtu.be/dfNmTe9mqPQ 2_2_D - https://youtu.be/VhsUgiLcrgo 2_2_E - https://youtu.be/vN9aR2wKv0U
	Resistance of filiform conductors; resistivity and variation of temperature resistivity (15 min)	2_3_A - https://youtu.be/YhyykO8pjnw 2_3_B - https://youtu.be/w-kEIyFwf4I
	Joule effect (10 min)	2_4_A - https://youtu.be/ZKhS3lmp_OM 2_4_B - https://youtu.be/2JyKS-m5vwg 2_4_C - https://youtu.be/LZUMnFel-6I
	Direct current generators: electromotive force and internal resistance; characteristic curve (29 min)	2_5_A - https://youtu.be/llqco9mV728 2_5_B - https://youtu.be/3VcqkGWyrU0 2_5_C - https://youtu.be/9r3Xgd79MFw 2_5_D - https://youtu.be/_K7EDTz3pYQ
	Associations in series and in parallel: difference of electric potential and electric current (37 min)	2_6_A - https://youtu.be/jyssHo42eaI 2_6_B - https://youtu.be/XPf1ucOJK9E 2_6_C - https://youtu.be/x2EuYqj_0Uk 2_6_D - https://youtu.be/v1a629-Ryjc
	Conservation of energy in electrical circuits; electric power (43 min)	2_7_A - https://youtu.be/EJQpBpQxQn4 2_7_B - https://youtu.be/twxaAW9HQ_w 2_7_C - https://youtu.be/XXqsZx-D9yg 2_7_D - https://youtu.be/n7ELjY3BnZ4 2_7_E - https://youtu.be/-gSEv4HimKE

3. ENERGY, THERMAL PHENOMENA AND RADIATION (3H.)	System, border and neighborhood; isolated system; thermodynamic system (24 min)	3_1_A - https://youtu.be/BEWer66NS3Q 3_1_B - https://youtu.be/V_KFfv3hS-8 3_1_C - https://youtu.be/eHeQAaVCyeE
	Temperature, thermal balance and temperature scales (37 min)	3_2_A - https://youtu.be/TDLKzHMCxlQ 3_2_B - https://youtu.be/Pqo4TH9BsgM 3_2_C - https://youtu.be/NuLZf0zWUgE 3_2_D - https://youtu.be/UNOuh4r48JU 3_2_E - https://youtu.be/ibmubP26R9M
	Heat as a measure of energy transferred spontaneously between systems at different temperatures (13 min)	3_3_A - https://youtu.be/tZe5Cn9vf3Q 3_3_B - https://youtu.be/BEWer66NS3Q
	Radiation and irradiance (15 min)	3_4_A - https://youtu.be/XxM6Q7YP0cI 3_4_B - https://youtu.be/MTnlsiv3ic0
	Mechanisms of energy transfer by heat in solids and fluids: conduction and convection (8 min)	3_5_A - https://youtu.be/Gyj444FK0zs 3_5_B - https://youtu.be/rL3MEVO15bA 3_5_C - https://youtu.be/Gyj444FK0zs
	Thermal conduction and thermal conductivity (18 min)	3_6_A - https://youtu.be/bBIIGpjwEaU 3_6_B - https://youtu.be/Hb-C2JUinVU
	Thermal capacity (11 min)	3_7_A - https://youtu.be/Nz9Soy59DBY 3_7_B - https://youtu.be/MafSCjXmHK0 3_7_C - https://youtu.be/2Mb6mbabwmk
	Variation of melting and vaporization enthalpy (13 min)	3_8_A - https://youtu.be/ZEpOIMOwqdg 3_8_B - https://youtu.be/Z3EfGLXGe_4
	First Law of Thermodynamics: Energy Transfers and Energy Conservation (14 min)	3_9_A - https://youtu.be/ImEQigZV3vo 3_9_B - https://youtu.be/pUIHqpzQL6M 3_9_C - https://youtu.be/kurO_LiwrRM 3_9_D - https://youtu.be/Hs0WmivIVRU
	Second Law of Thermodynamics: energy degradation and yield (33 min)	3_10_A - https://youtu.be/O59pXDYLljI 3_10_B - https://youtu.be/yep0qXKwuLE 3_10_C - https://youtu.be/9f_db8Z1Hhc 3_10_D - https://youtu.be/mXwhVmg8e6I

Table 2. Videos selected by domain and sub-domain of physics contents

APPENDIX 2. Annotation assignments

Table 3 presents 5 of the 20 videos for work annotation assignments.

N.º	Aluno	Domínio | Subdomínio	Vídeos
1	Student 1	D1 – 2	1_2_A - https://youtu.be/9vCW7uPs05A 1_2_B - https://youtu.be/U1WRVE_A9Ms
		D1 - 8	1_8_B - https://youtu.be/Pu2NO8Mlfhg 1_8_C - https://youtu.be/LaMbPbNEZEU
		D2 - 7	2_7_A - https://youtu.be/EJQpBpQxQn4
2	Student 2	D3 - 4	3_4_B - https://youtu.be/MTnlsiv3ic0
		D3 - 5	3_5_A - https://youtu.be/Gyj444FK0zs 3_5_B - https://youtu.be/rL3MEVO15bA
		D2 - 7	2_7_D - https://youtu.be/n7ELjY3BnZ4 2_7_E - https://youtu.be/-gSEv4HimKE
3	Student 3	D1-2	1_2_C - https://youtu.be/FQlSnNW55kM
		D1-4	1_4_A - https://youtu.be/0Lm4KpaGV24 1_4_B - https://youtu.be/Ht-a2_yNuec
		D3-10	3_10_A - https://youtu.be/O59pXDYLljI 3_10_B - https://youtu.be/yep0qXKwuLE
4	Student 4	D1-2	1_2_D - https://youtu.be/WSWf_mEkuFA
		D1-1	1_1_A - https://youtu.be/Ft4p6hDWh_A
		D1-6	1_6_A - https://youtu.be/E7HS2FlhfiE 1_6_B - https://youtu.be/LaMbPbNEZEU
		D3-8	3_8_A - https://youtu.be/ZEpOIMOwqdg
5	Student 5	D1-6	1_6_C - https://youtu.be/9RghIP9LNSY 1_6_D - https://youtu.be/Pu2NO8Mlfhg
		D2-4	2_4_A - https://youtu.be/ZKhS3lmp_OM
		D3-1	3_1_A - https://youtu.be/BEWer66NS3Q 3_1_B - https://youtu.be/V_KFfv3hS-8

Table 3. Video annotation assignments

APPENDIX 3. Annotations' Evaluation Framework

Table 4 presents the Annotations' Evaluation Framework.

GG (Groups' grade) CG (Classes' grade) TG (Teachers' grade)		**Evaluation: (PR) Presentation (10%) (CR) Creativity (40%) (OB) Objectives (10%) (CO) Content (40%)**				
Domain	**Students | Final Grade**	**PR**	**CR**	**OB**	**CO**	
1. ENERGY AND MOVEMENTS	Student 1, Student 2, Student 3…	10	35	10	35	GG
	85	10	37	10	35	CG
		10	35	10	30	TG

Table 4. Annotations' Evaluation Framework