Silent Physics Animation Tasks for Learner Narration

Bjarki Harksen, Matthias Harksen

Science Institute University of Iceland, Dunhaga 3, 107 Reykjavík, Iceland

Corresponding author: Matthias Harksen (E-mail: mbh6@hi.is)

Abstract. We introduce silent video tasks for physics education by providing a practical definition of silent physics animation tasks. The original idea of working with silent video tasks is grounded in social constructivist theories and involves students adding their narration to a ready-made silent animation video. We provide a collection of silent physics animation videos created with Manim and explain their content. We examine and reflect on the results of a pilot-study where we analysed the word-frequency of student narrations.

Keywords: silent video task, animation, narration, verbalisation, Manim

Submitted to: *Phys. Educ.*

1. Introduction

Silent video tasks consist of two complementary activities. The first activity involves the presentation of a short silent video. Students are asked to discuss in pairs as they prepare and record their voice-over to the video. Each video has a clear theme and is meant to illustrate properties or characteristics of physical phenomena, definitions or concepts. In the second activity, the teacher leads a discussion based upon example recorded responses to the task with the aim to deepen and widen students' understanding of the presented topic [1, 2].

The ideology which we adopt in assigning silent video tasks is grounded in social constructivist theories which models the acquisition of knowledge by assuming that it is constructed by each and every learner but socially mediated [3, 4, 5, 6]. In other words, knowledge can not be transmitted it has to be actively built up by each individual knower. A pedagogy centered on a constructivist theory of epistemology is therefore led to conclude that knowledge is dynamically evolving and open to revision. From a constructivist perspective the goal of the teacher should be to facilitate and encourage discussions between all members of the classroom. By engaging in conversations with students the teacher can gauge their understanding and discover particular aspects of their thinking processes. In this framework it is more important to encourage successful thinking rather than necessarily correct answers [7].

The motivation for assigning silent video tasks is to provide a framework in which students can apply their language proficiency of the subject in a controlled environment. The narrations themselves serve as a tool which the teachers can use to gauge which words in the syllabus the learners have adopted and provides an opportunity for discussions. The narrations can help the teacher create a model for each learners particular conceptual thinking structure.

Silent video tasks for physics teaching have been considered in recent works. In [8] learners were asked to record a voice-over to a silent video task showing a ball being thrown inside a car in three different scenarios: stationary, uniform and accelerating motion. The learners responses were evaluated with respect to the SOLO taxonomy created by Biggs and Collis [9]. This evaluation of the learners responses to the silent video tasks was compared with a test score on the same material. The results indicated that there was a weak correlation between performance on examinations and how well a student is able to narrate a silent video. The authors of [8] concluded that this was a sign of the lack of familiarity with such verbalization tasks in which the students express their thoughts using the relevant terminology. A complementary conclusion which might be drawn is that verbalization tasks such as these adhere to an alternative skill set than those of standard examinations.

Similar concepts have appeared in the literature. In [10] the concept of *'silent videoclips'* was introduced. These tasks are intended for prospective physics teachers as a segment in their teacher education. Student teachers use these silent video tasks as practise material for honing their explanatory skills in presenting an experimental demonstration. Unlike science explanation videos these videos do not aim to explain physical content and the recordings serve as a way to sort out the kinks in a monologue which describes the equipment used for a particular experiment rather than as a way to gauge the vocabulary which the students have internalized.

2. A Collection of Silent Physics Animation Videos

We present a collection of 12 animation videos which encompasses the material studied in an algebra based introductory physics course. When we selected the topics suitable for narration in such silent animation videos we focused on visually dynamic physical phenomena. A more detailed account of the topics covered in the animation videos can be seen in Figure 1. The videos are publicly available on YouTube. The code needed to compile the videos is also open-source under an MIT license and available on Github [11]. The code is made with the free and open-source animation engine Manim [12]. In the next section we will describe a pilot study on the word usage in student narrations conducted with one of these animation videos.

Figure 1. A collection of silent physics animation videos produced with the cross-platform, free and open-source animation engine Manim [12]. The videos are available on YouTube. The code to generate the videos is available on Github [11].

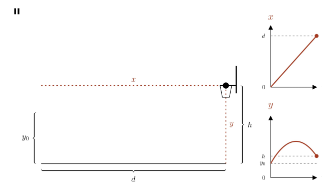
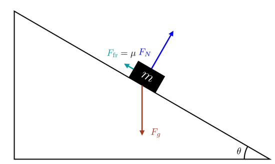
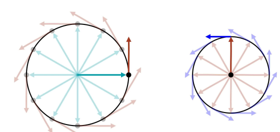
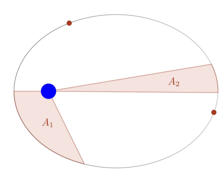
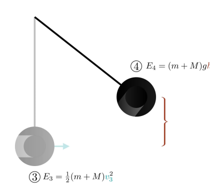
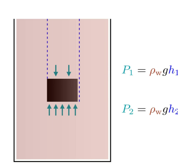
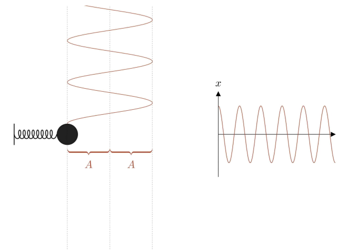
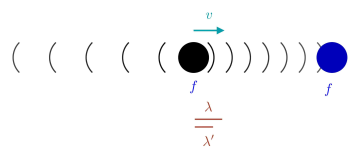
Description of Animation	**Snapshot from Animation**
1. Projectile Motion A ball is thrown in projectile motion towards a basket. Graphs of the position, velocity and acceleration are shown during the ball's motion.	
2. Inclined Plane A block slides down an inclined plane with friction. The vector decomposition of the forces acting on the block are shown. Included is a derivation of the minimum angle of inclination such that the block slides down.	
3. Centripetal Acceleration Derivation of centripetal acceleration by drawing velocity and acceleration vectors at successive time intervals. Based on a description by Landau [13].	
4. Planetary Motion Kepler's laws of motion visualized. A planet revolves in an elliptical trajectory around a star. The area law is shown, and a derivation of Kepler's third law for circular orbits is presented.	
5. Ballistic Pendulum A ball is ejected from a spring from which it impales a ballistic pendulum. The narrative emphasizes the difference between energy and momentum conservation.	
6. Archimedes' Principle The buoyant force acting on the block submerged in a liquid is shown in terms of the pressure acting on the top and bottom surfaces. Condition for whether an object floats or sinks is analyzed.	

Figure 1. (continued)

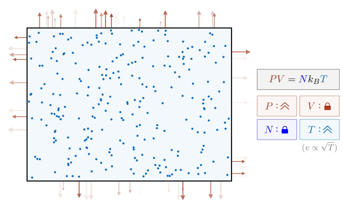
7. Simple Harmonic Motion
A mass attached to the end of a spring is shown. The oscillatory motion is analyzed from the displacement graph. The connection with the spring constant and the frequency of the oscillation is shown.



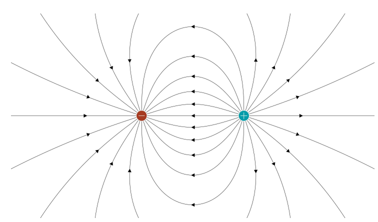
8. The Doppler Effect
A source emitting a sound wave is shown in the case that it moves towards a stationary observer. The shortened wavelength and increased frequency as measured by the observer is explained.



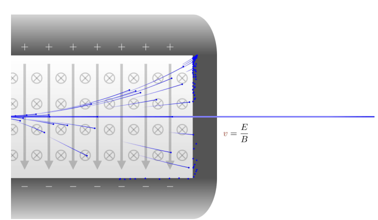
9. The Ideal Gas Law
A box containing particles bouncing on the walls. The gas law in various settings is explained in terms of the pressure, volume, temperature and speed of the particles bouncing inside the box.



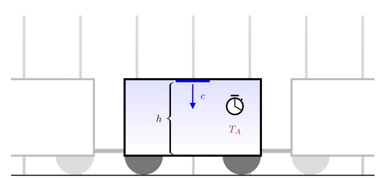
10. Electric Field Lines
The electric field lines of positively and negatively charged particles are shown by considering the forces acting on a test charge. The field lines of an electric dipole are shown.



11. Velocity Selector
A positively charged particle moves inside a parallel plate capacitor in addition to moving in an auxiliary magnetic field perpendicular to the electric field of the capacitor.



12. Time Dilation
Einstein's classic derivation of time dilation is presented by a train thought experiment. Presented from the perspective of an observer inside the train and outside the train respectively.



3. A Pilot Study in Word Usage

A preliminary pilot study on the word usage of student narrators as compared to the teacher expected vocabulary was conducted. Our intention with this pilot study was to see on one hand how many of the words the students used in their narrations and on the other whether across all student narrations they would be able to capture the teacher expected vocabulary. The participants were Icelandic upper secondary school students in their first algebra based course on physics (12th grade). Students recorded a narration on their own phones to the silent video *Inclined Plane* (see Figure 1). In total the participants consisted of 36 groups of two students all of which gave written informed consent to participate in the study and for the results to be published in accordance with the the principles embodied in the Declaration of Helsinki. The audio recordings were forwarded to the examiners without any identifiable personal information.

The examiners first made a list of keywords which they thought were relevant for the narration. Next they proceeded to listen to the recordings of the student groups while keeping track of which of the key-words the student narrators used in their own recordings. The examiners results are showcased in the histogram in Figure 2.

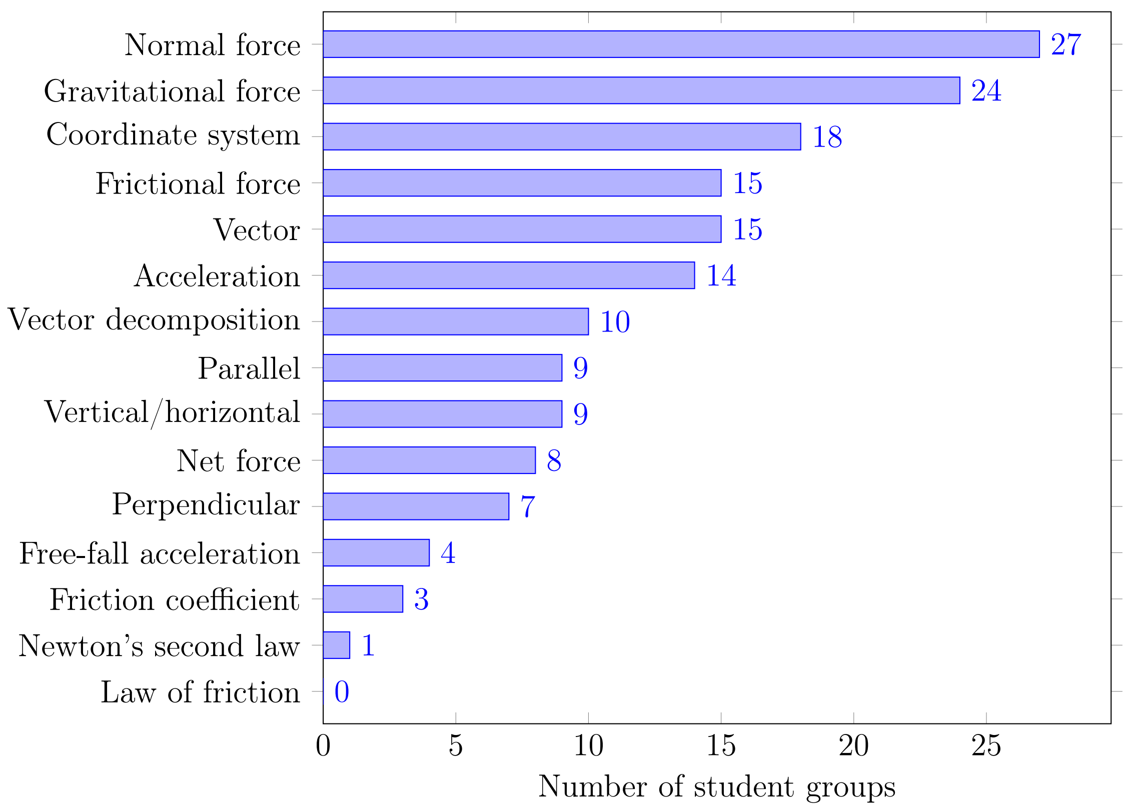


Figure 2. Frequency table of word usage of 36 groups in their narrations.

The examiners remarked that there was a certain disclaimer for these results since during the silent animation video *Inclined Plane* equations are shown throughout. This meant that many student narrators said things like: *"F is equal to m times a"* without specifying that in this silent video F denoted the total force, m the mass of the block and a its acceleration. This was especially highlighted by the fact that very few students specifically mentioned that the symbols g and μ denoted the free-fall acceleration and the coefficient of friction respectively. Another aspect which the examiners felt was not reflected in this analysis of word-usage was the depth of the student narrators explanations of the similar triangles and origin of trigonometric functions in the analysis.

We have transcribed an example student narration (the narration has been translated and filled pauses such as *um, uh* and *eh* have been removed). We have highlighted the first instance of a word which adhered to the examiners word-list as presented in Figure 2. The silent animation video is available here: Inclined Plane.

"Alright. We have this inclined plane which has the angle θ and then we have a block with mass m which slides down the inclined plane. We are going to look at all of the forces which act on the block. First there is the ***gravitational force*** *or the mass times g or 9.82. It is* ***vertical*** *down on the figure. Then we have the* ***normal force*** *which is vertical from the inclined plane or you know from the topside of the inclined plane. Then we have the* ***frictional force*** *which is the* ***frictional coefficient*** *times the normal force and is what is slowing the block down and is therefore away from the block. The* ***total force*** *which acts on the block is therefore all of these forces added together. And if we move the arrows then we can see where the total force is. And it is the small green arrow which goes down since the block goes down. Now if we let the x-axis in the* ***coordinate system*** *be* ***parallel*** *to the topside of the inclined plane then we can see something cool. But there is another rule which tells us that the total force is also the mass times the acceleration and we put these two rules together so that all of the forces are equal to the mass times the acceleration. But now we are going to* ***decompose*** *the gravitational force which is kinda cool so that it is not at an angle but vertical and horizontal. But we see where θ lies and we can place this in our figure and then we see that in the decomposition of the gravitational force then we see where θ is. Then the horizontal gravitational force $mg\sin\theta$ and the vertical $mg\cos\theta$. Then we change the gravitational force to this vector with these numbers which we just found. We do the same for the normal force and it has no direction in x-axis just in y-axis and the frictional force has no direction in x-axis only in. No, it has no direction in y-axis only in x-axis. And the acceleration has only direction along the x-axis. Then we have this kind of a vector equation which is very clever and we can change it to a system of equations and take the zeros and simplify it like this. Then it is very pretty. Now we see something interesting but the normal force is the same as $mg\cos\theta$ then we can place that instead of the F_N upstairs since we do not know what F_N is. Now we can simplify and then solve for a since we see that we know all the variables. Or usually in the problem all variables are given. Or, if the angle is given, then we know everything. Wow crazy. Then we can find a. So we don't even need the mass to find the acceleration, which is very interesting. Yes, we only need the coefficient of friction and the angle. Okay, I don't know why I am talking so much. Amazing. Thank you."*

The students had already been exposed to problems which focused on the inclined plane and similar force diagram concepts. This was reflected in their narrations and word usage. Many of the narrations were meticulously prepared indicating that the students had written down a script before narrating. Other narrations were quite energetic sometimes resembling an excited sports commentator dynamically describing the animation although we emphasise that this did not reduce the quality or vocabulary usage of the narration. Students had a way of bringing their own humour and personality into the narrations, e.g. one student started by saying: *"I hope you are all having a good day. We are in the studio with the guest of the day: Inclined Plane and he has an unknown mass and an unknown angle θ"*. Others tried to put the problem in a real-life setting: *"The block slides down like Marcel Hirscher on skis"*. Many students felt that the video was being played to quickly and solved their problems by saying things like *"Let us pause the video"* and *"Let us play the video again"*. The only word or concept which the student narrators did not use in their narrations was the empirical law of friction nor did they differentiate between kinetic and static friction.

4. Conclusions and outlook

We have provided a definition for silent video tasks in physics education along with providing a collection of animations which may be used freely to assign such tasks (see Figure 1). Furthermore we conducted a pilot study on the word usage of learners in their narrations of one of the animations in the collection. Our results indicate that even though each individual narrator might not be able to capture all of the teacher-expected vocabulary then as a group the learners are able to demonstrate the desired proficiency. This suggests that in a joint group discussion on particular segments of the video the learners themselves will be able to provide most (if not all) of the technical vocabulary without the teacher having to focus attention towards their expected answer.

5. Acknowledgements

We thank Guðný Halldórsdóttir, Johnny Jones, Bjarnheiður Kristinsdóttir and Una Kamilla Steinsen for discussions and insightful comments. Research supported by the Icelandic Educational Materials Developement Fund ÞNS-2023-232672-1601.

6. Bibliography

[1] Bjarnheiður Kristinsdóttir Freyja Hreinsdóttir Z L and Wolff C E 2020 *Research in Mathematics Education* **22** 135–153 [https://doi.org/10.1080/14794802.2020.1722959]

[2] Kristinsdóttir B 2021 *Silent video tasks – their definition, development, and implementation in upper secondary school mathematics classrooms* Ph.D. thesis [https://hdl.handle.net/20.500.11815/2680]

[3] Piaget J and Garcia R 1974 *Understanding Causality* (New York, NY: WW Norton)

[4] Von Glasersfeld E 2013 *Radical constructivism* (Routledge)

[5] Matthews M (ed) 1998 *Constructivism in science education* (Springer)

[6] Tobin K G 1993 *The practice of constructivism in science education* (Psychology Press)

[7] von Glasersfeld E 2012 Questions and answers about radical constructivism *The practice of constructivism in science education* (Routledge) pp 23–38

[8] Gorčáková S and Velmovská K 2024 Knowledge of physics and success in commenting on silent video task

[9] Biggs J B and Collis K F 1982 *Evaluating the Quality of Learning: The SOLO Taxonomy (Structure of the Observed Learning Outcome)* (Elsevier) ISBN 9780120975525 [https://doi.org/10.1016/C2013-0-10375-3]

[10] Schweinberger M and Girwidz R 2022 *'Silent Videoclips' for Teacher Enhancement and Physics in Class — Material and Training Wheels* (Cham: Springer International Publishing) pp 149–159 ISBN 978-3-031-06193-6 [https://doi.org/10.1007/978-3-031-06193-6_11]

[11] SilentPhysicsAnimations 2024 SilentPhysicsAnimations URL https://github.com/SilentPhysicsAnimations/SilentPhysicsAnimations

[12] The Manim Community Developers 2024 Manim – Mathematical Animation Framework URL https://www.manim.community/

[13] Landau L D and Kitaigorodsky A I 1978 *Physics for Everyone - Book 1 - Physical Bodies* (Mir Publishers)