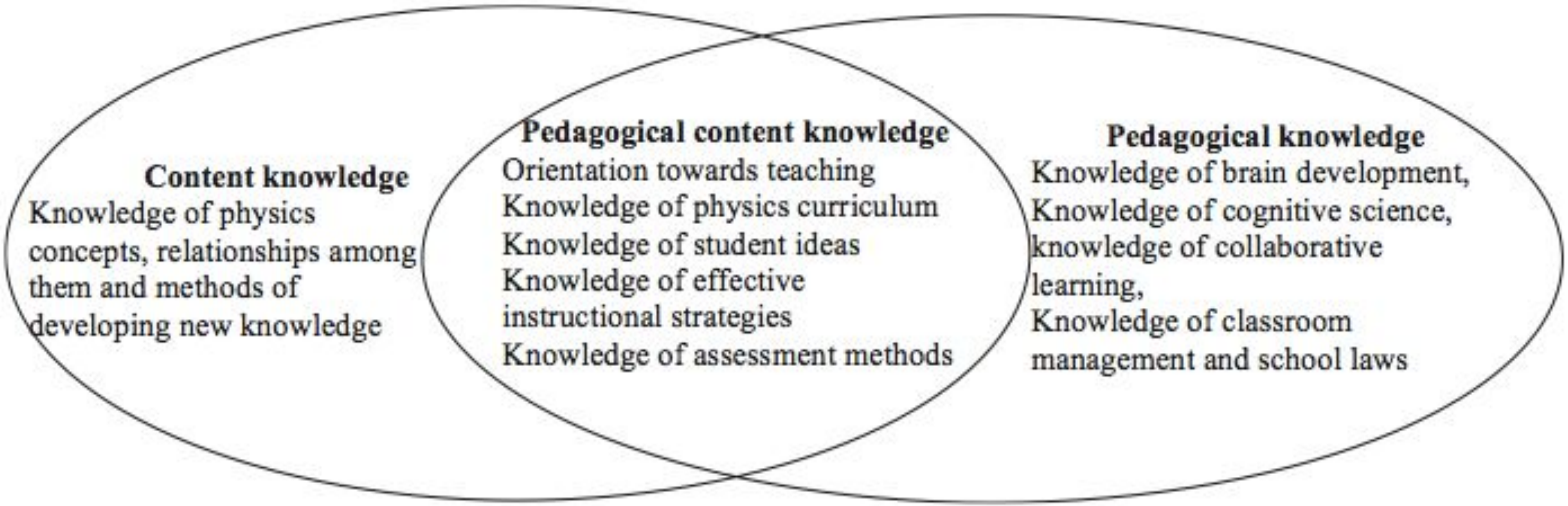
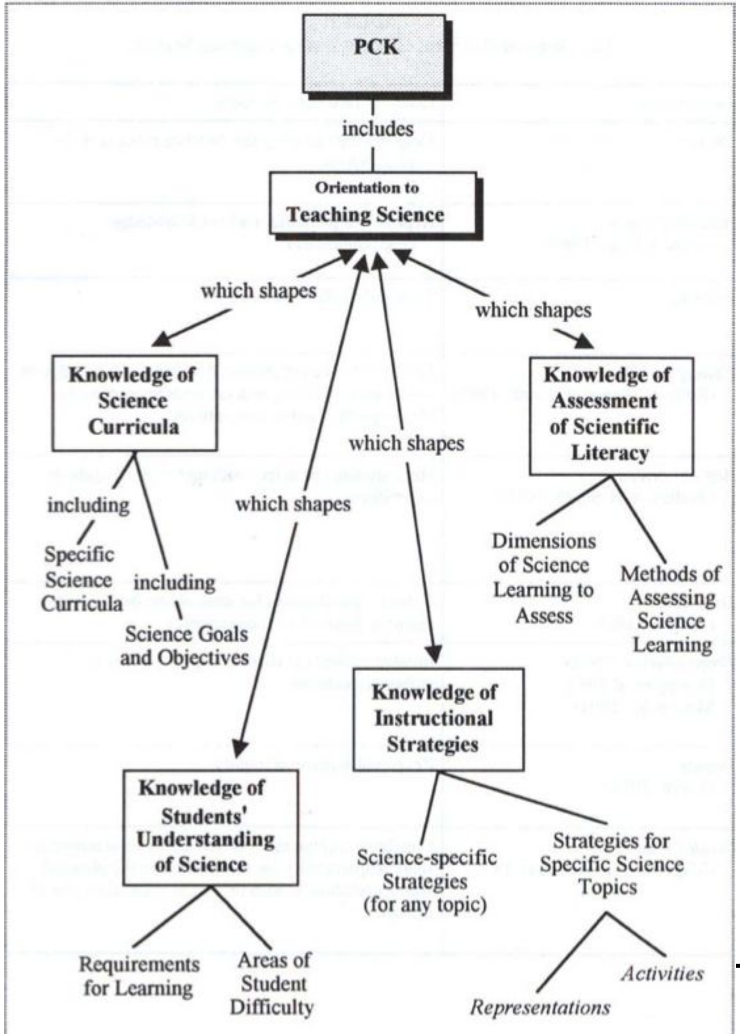
Physics Education Laboratory Lecture 04

Francesco Longo • 02/10/2025

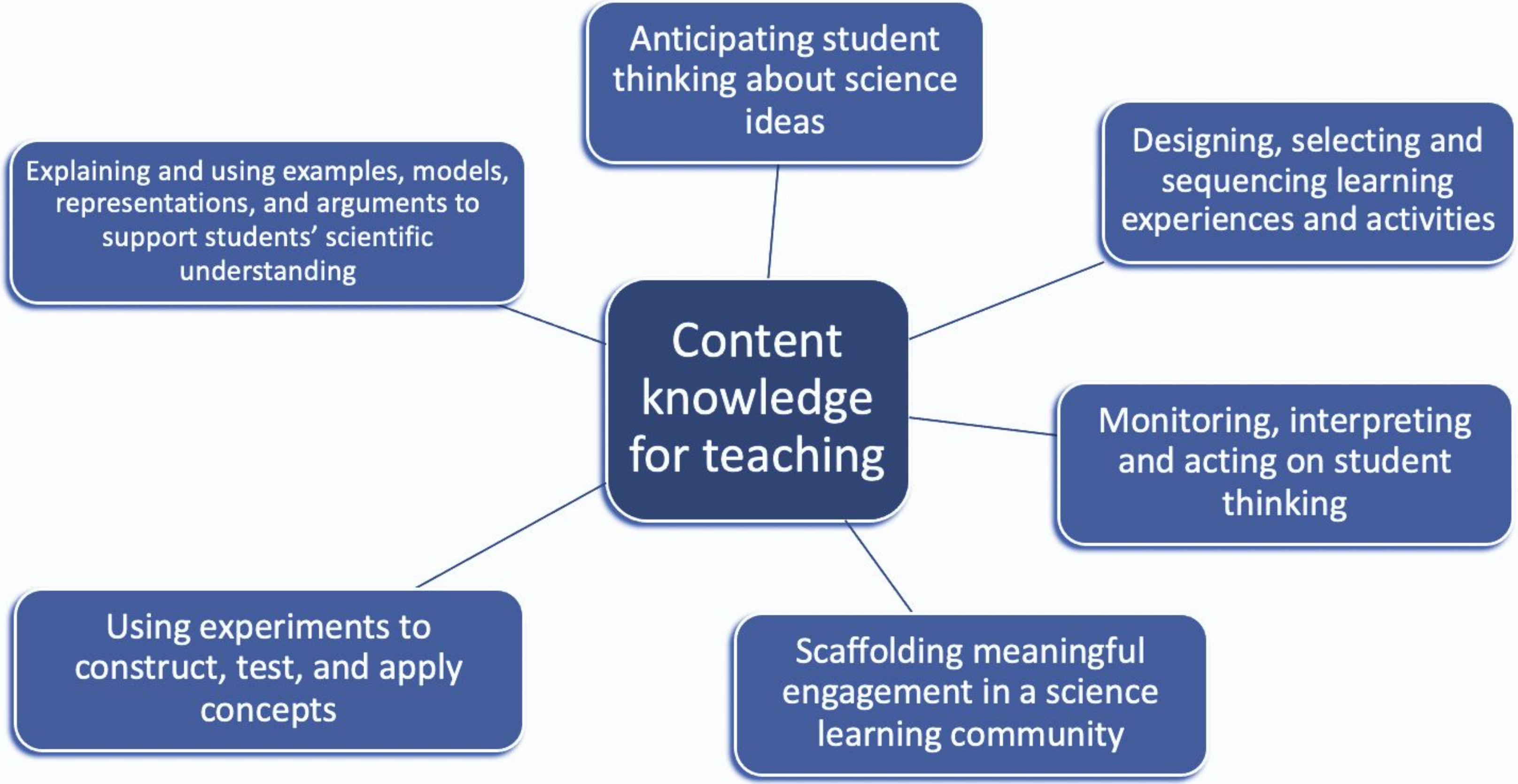
The Structure of Physics Teacher Knowledge

(Fazio, 2010)





- orientations toward science teaching
- knowledge and beliefs about science curriculum
- knowledge and beliefs about students' understanding of specific science topics
- knowledge and beliefs about assessment in science
- knowledge and beliefs about instructional strategies for teaching sciences


Anticipating student thinking about science ideas
Explaining and using examples, models, representations, and arguments to support students' scientific understanding
Designing, selecting and sequencing learning experiences and activities
Content knowledge for teaching
Monitoring, interpreting and acting on student thinking
Using experiments to construct, test, and apply concepts
Scaffolding meaningful engagement in a science learning community

Etkina, 2018

1 PCK FOR SCIENCE TEACHING (Magnusson et al., 1999)

2 PCK FOR PHYSICS TEACHING (Etkina, 2010)
CONTENT KNOWLEDGE FOR PHYSICS TEACHING
(Etkina, 2018)

3 DECLINING PCK FOCUSED ON MATH/PHYS INTERPLAY
(Lehavi et al., 2014, 2017)

Declining PCK for Math-Phys interplay

(Lehavi et al., 2014; 2017)

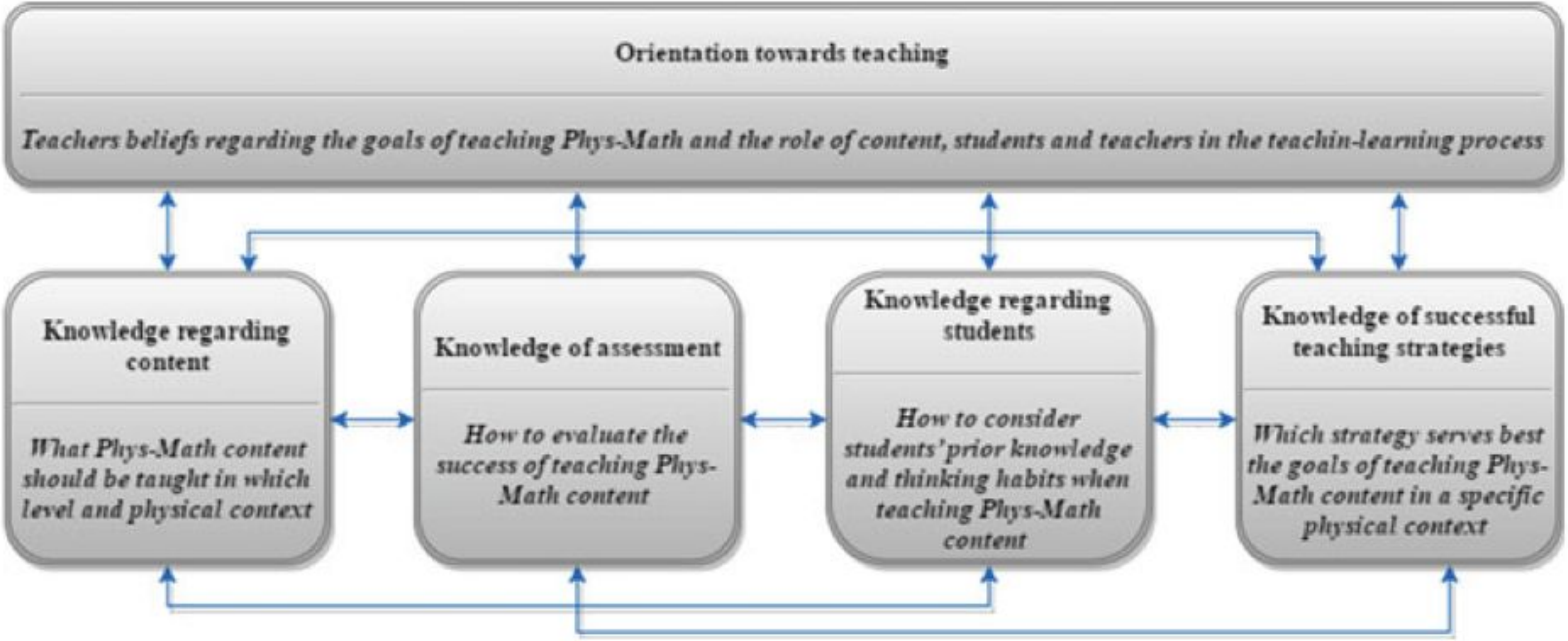


Table 1 Phys-Math patterns, teaching goals and teaching practices (note close relations to goals a-f in the Magnusson PCK model)

Pattern	The teaching goal	The teaching practices
A. Exploration	To demonstrate how phys-math is used to explore the behavior of physical systems	Exploring within math ramifications for the physical system: borders (of validity, of approximation), extreme cases, etc.
B. Construction	To demonstrate how phys-math is used in constructing a model for physical systems	Constructing and developing (from experiments or from first principles) mathematical tools to describe and analyse physical phenomena
C. Broadening	To demonstrate how phys-math can be used in broadening the scope of a physical context	Adopting a bird's-eye view and employing general laws of physics, symmetries, similarities and analogies
D. Application	To demonstrate how phys-math provides aid in problem solving	Employing already known laws and mathematical representations in problem solving

The practice of employing different patterns of the Phys-Math interplay can distinguish master teachers from other expert teachers.

1. Collecting information BEFORE the observations of the lesson activity about teacher’s beliefs, methodologies, physics insights and then about class and students’ skills, attitudes and everything is concerning learning strategies, emerging and recurrent difficulties, assessments.

1. Collecting information DURING the observations of lesson activities, from explanations to evaluation time.

1. Collecting information AFTER the observations of lesson activities from the teachers’ point of view to the students’ self reflection about their performance and learning.

In order to perform a deep investigation of physics teachers’ Pedagogical Content Knowledge our observations consisted in actions and methodologies according to the reported sequence

All information has been collected from interviews, meetings and taking notes during class activities.

Sequence of monitoring

BEFORE

Teachers' monitoring in their lessons planning.

Teachers' interviewing for collecting information about students and class educational trend.

DURING

Observations during class activities in presence and on line (in the first COVID lockdown period) for the extension of a learning module.

In some cases, preparing evaluation tests together with teachers at the end of the learning module, with particular attention to the integration of math and physics languages.

AFTER

Feedback discussions with teachers on monitoring activities.

Test revisions and corrections trying to identify the most frequent mistakes and to classify them in terms of mastery and knowledge of physics languages.

Collecting students' interviews about their difficulties in that learning module and final evaluation test.

We monitored classes at the first year of the curricular physics studies: this is an important point of our investigation, because we would like to find whether difficulties in learning and studying physics arise from a particular teacher PCK adopted at this stage, i.e. at the beginning of high secondary school, when the students’ background is characterized by a basic knowledge of Math.

The main feature of this sample is the age difference among students. It happens that someone starts studying curricular physics at 14 years old and some of them later (16 years). Of course, this is relevant for the stage of cognitive development, in terms of abstraction functions and metacognitive processes. And it also would be relevant in terms of content building processes for successful learning.

We analysed our observations according to the PCK model suggested by Magnusson et al., adapted by Etkina and used in the framework of the content of the Math-Phys interplay by Lehavi et al. and Pospiech obtaining some interesting results.

Prevalent pattern of Math/Phys Interplay

→

Application and Formulas Manipulation

At the first curricular year of Physics study

Prevalent patterns of Math/Phys Interplay

Application and formulas manipulation

Model building

Exploration and broadening

At the last curricular year of Physics study in the high secondary school

Main results from the observation analysis

Where the lack of math competencies is relevant, the teacher adopts strategies converging to the strong use of observative/descriptive language for conceptualization.

If the teacher is aware of students difficulties in Math, or of the absence of Math-Phys interplay, he/she tries to support their learning process focusing on mathematical languages.

This causes a large use of math in the demonstration of physics laws and a great number of math exercices applied to physics phenomena, with the consequence that even the evaluation tests seem to be mathematically rather than physically oriented.

Main results from the observation analysis

On the other side some teachers try to resolve the students difficulties in Math using improperly the different language structures (formulas, graphs...) making a conceptual reduction of Physics, separating what comes from mathematics results and what corresponds to a physical phenomenological observation.

This kind of approach tends to amplify the distance between the two disciplines instead of favouring their interplay and integration also in a form of interdisciplinarity to be thought and taught.

(Bologna & at., 2022) https://iopscience.iop.org/article/10.1088/1742-6596/2297/1/012034

Keep in mind

1. **Exploration**
   Exploring within math ramifications for the physical system: borders (of validity, of approximation), extreme cases, etc.

2. **Construction**
   Constructing and developing (from experiments or from first principles) mathematical tools to describe and analyse physical phenomena

3. **Broadening**
   Adopting a bird's-eye view and employing general laws of physics, symmetries, similarities and analogies

4. **Application**
   Employing already known laws and mathematical representations in problem solving

Which pattern is prevalent?

https://www.youtube.com/watch?v=wEQ69qW8Q6I Fisica Fast moto parabolico

https://www.youtube.com/watch?v=qK3tIupN_Xw Step by step

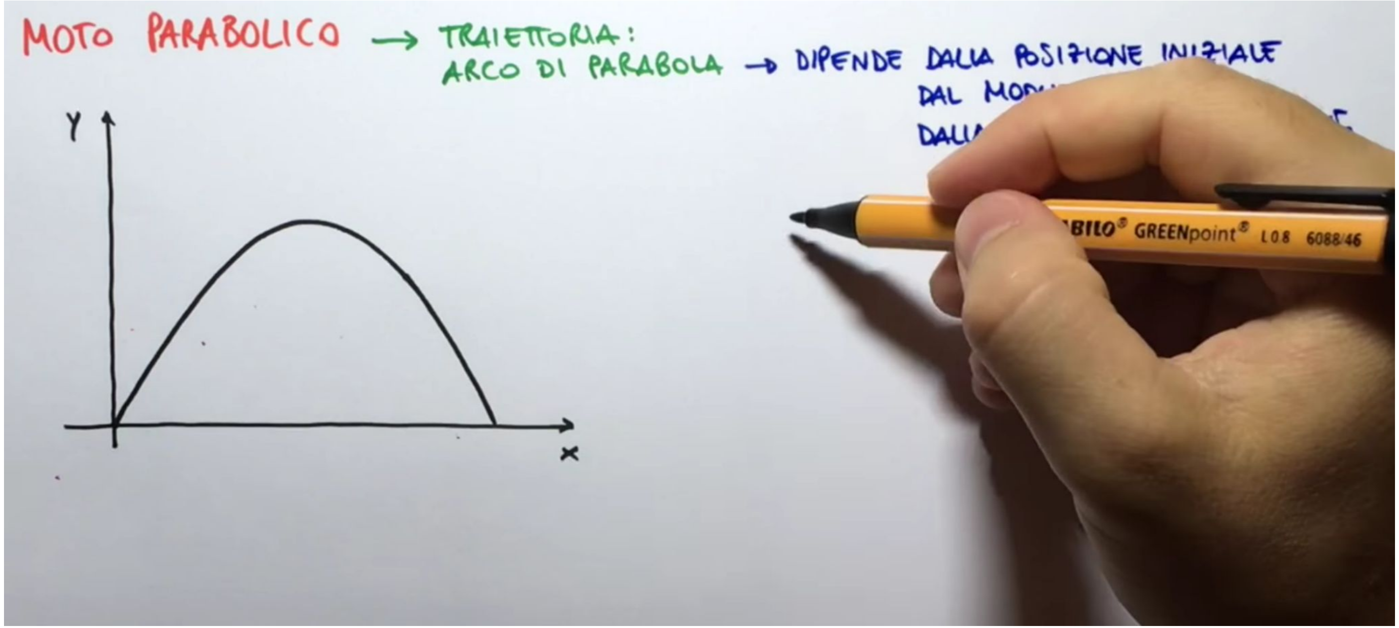
https://www.youtube.com/watch?v=xZ0WN8z3cD0 Moto di un proiettile

https://www.youtube.com/watch?v=xxFWe1JI6b8

La Fisica Che Ci Piace - Lezioni di Fisica Live! Caduta Libera

Which pattern is prevalent?

PCK for Math/Phys Interplay



Fisica Fast:
https://www.youtube.com/watch?v=wEQ69qW8Q6I

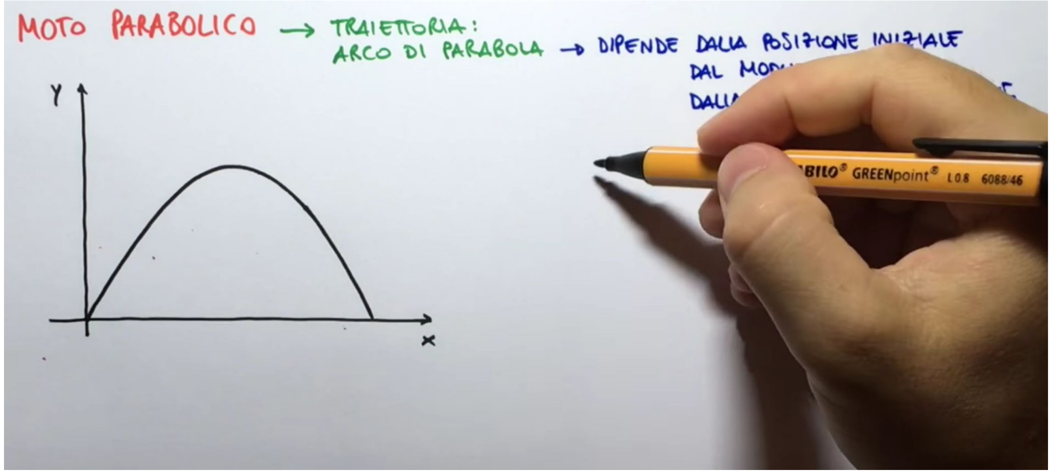
PCK for Math/Phys Interplay - Group 01

Mainly 4 - Application. Usage of mathematics to solve physical problems, with a section specifically about an application (range of a projectile). Knowledge of mathematical preliminaries is necessary to understand the video.

A bit of 2 - Construction. Precise mathematical proof of the intuitive idea of the trajectory of a projectile. Proof that it is indeed a parabola. However, the physical reason why acceleration is a constant is not discussed.

General lack of examples, which could be used not only as applications, but also as foundational experiments (2 - construction).

PCK for Math/Phys Interplay



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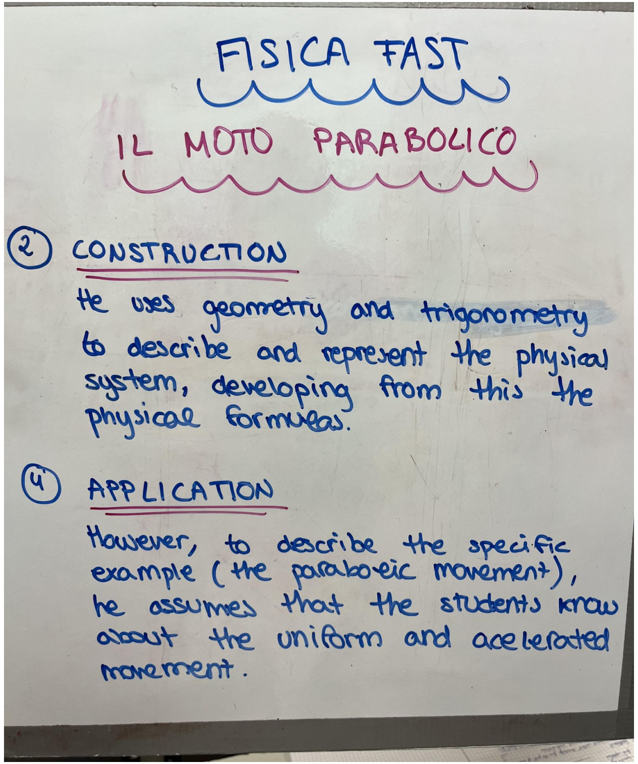
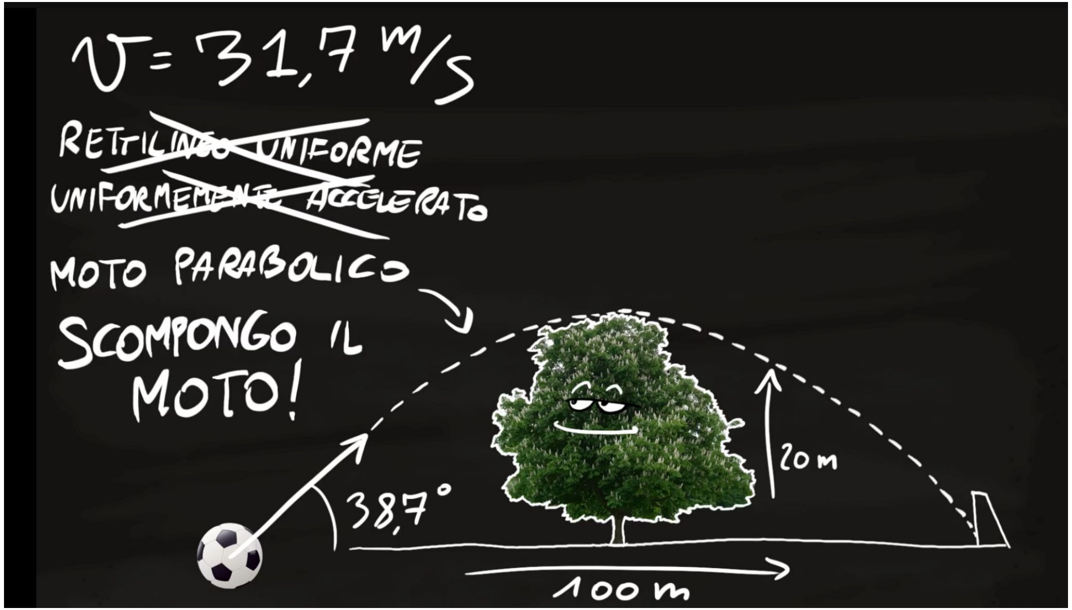


PCK for Math/Phys Interplay



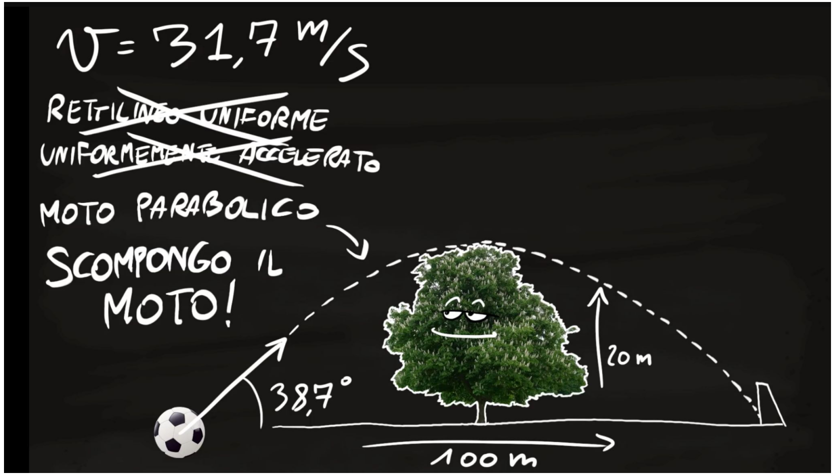
Step by step:
https://www.youtube.com/watch?v=qK3tIupN_Xw

PCK for Math/Phys Interplay - Group 02

1. APPLICATION: non deriva le formule ma le utilizza per svolgere l'esercizio proposto.
2. CONSTRUCTION: costruisce la base dei modelli fisici a partire dalle formule matematiche date per scontate nell'application

Non generalizza l'utilizzo degli strumenti matematici ma si limita ad applicarli ad un caso specifico (fa solo esempi numerici), per questo motivo non abbiamo trovato utilizzo di BROADENING e EXPLORATION.

PCK for Math/Phys Interplay



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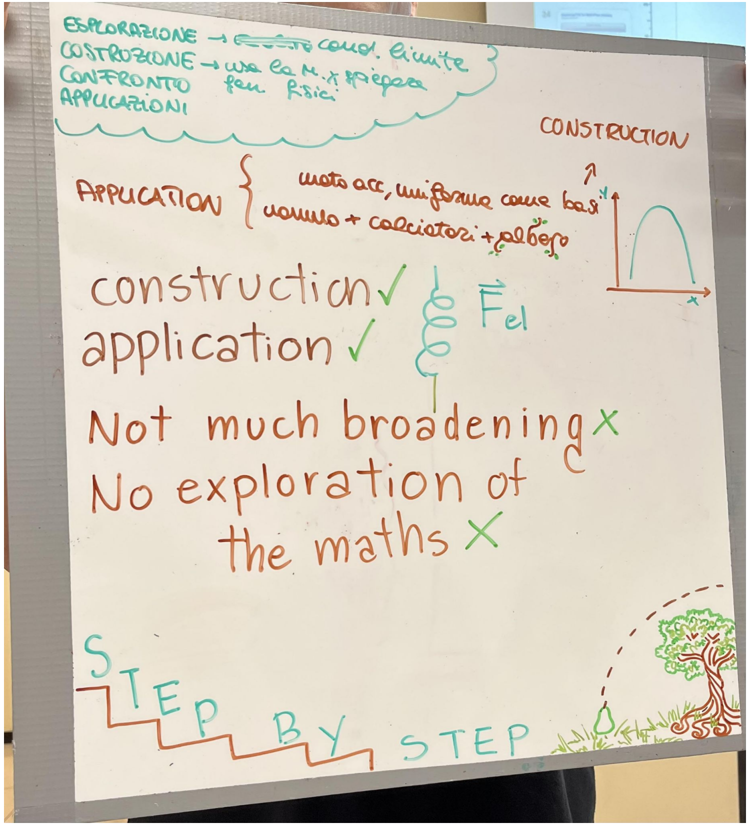
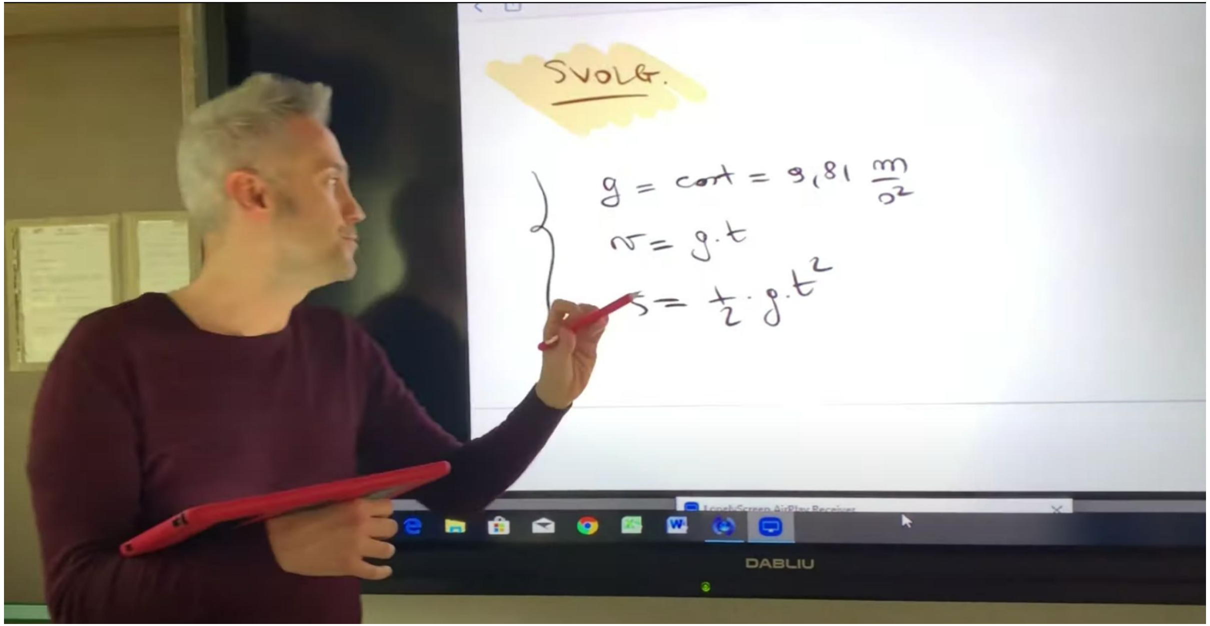


PCK for Math/Phys Interplay

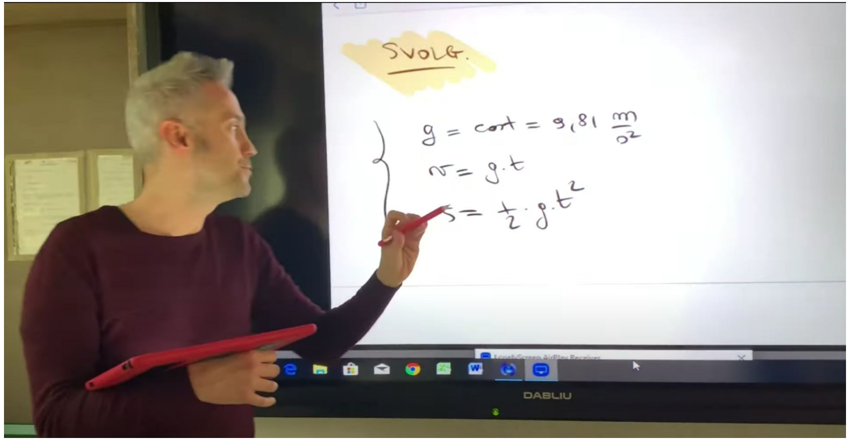


La Fisica Che Ci Piace:
https://www.youtube.com/watch?v=xxFWe1JI6b8

PCK for Math/Phys Interplay - Group 03

CONSTRUCTION: è partito da concetti già noti relativi al MRU, MRUA per costruire un parallelismo tra il MRUA e il moto di caduta libera. vengono utilizzati esempi della vita quotidiana per applicare i modelli matematici.
APPLICATION: esercizi svolti assieme agli studenti per applicare le leggi spiegate in precedenza

PCK for Math/Phys Interplay



La Fisica Che Ci Piace:
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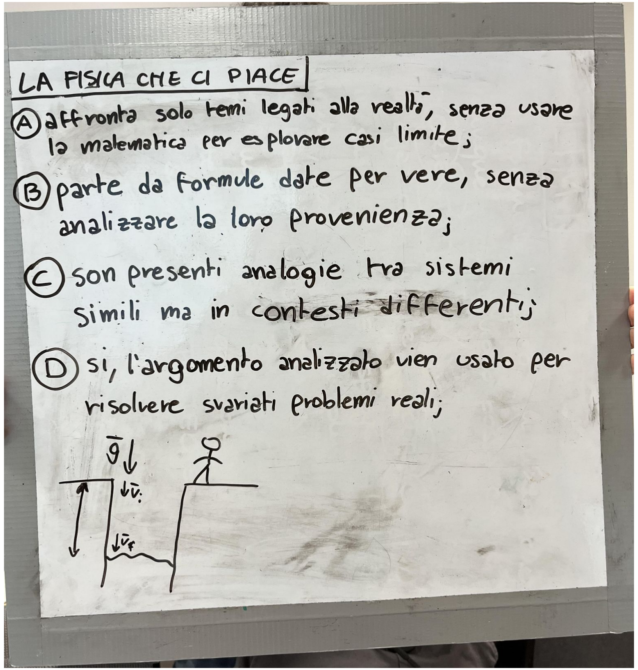
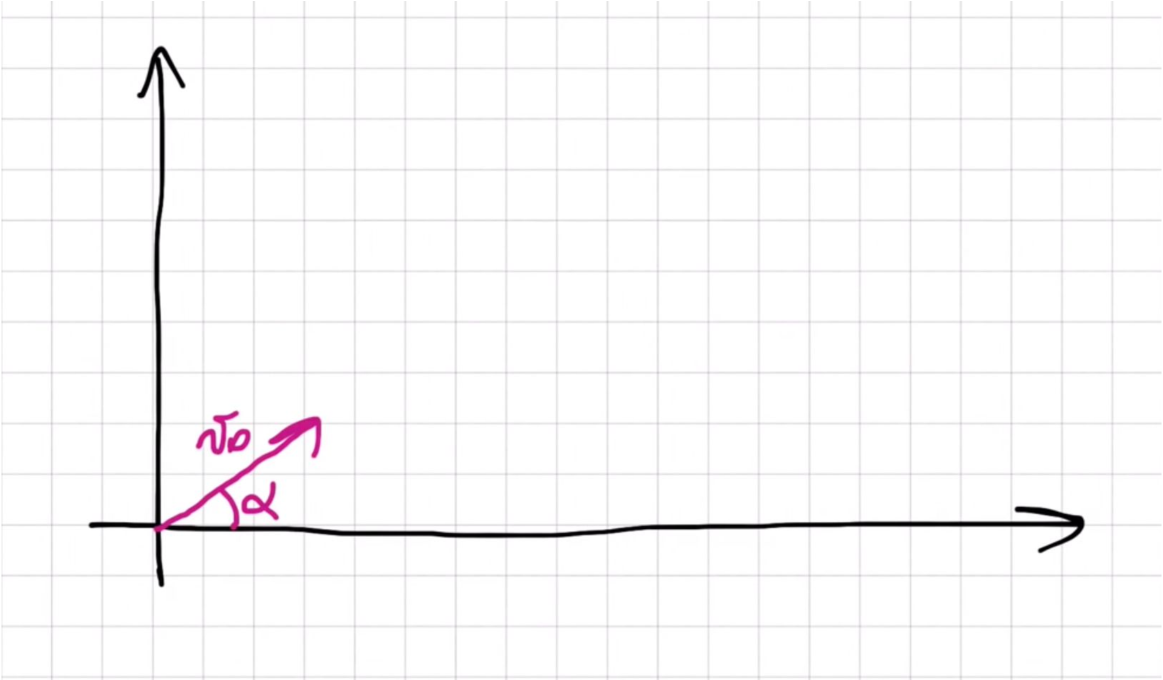


PCK for Math/Phys Interplay



Moto di un proiettile:
https://www.youtube.com/watch?v=xZ0WN8z3cD0

PCK for Math/Phys Interplay - Group 04

1. CONSTRUCTION

   scrittura matematica del problema fisico. Utilizzo del grafico, scomposizione vettoriale.

2. APPLICATION

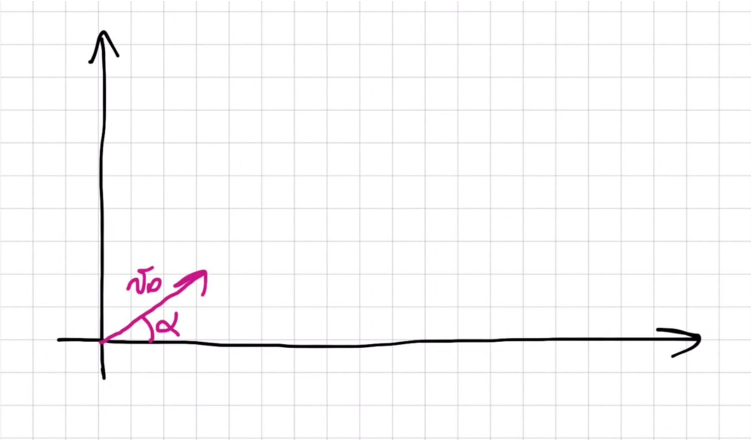
   utilizzando le formule già note agli studenti (leggi orarie) le adatta al sistema preso in esame

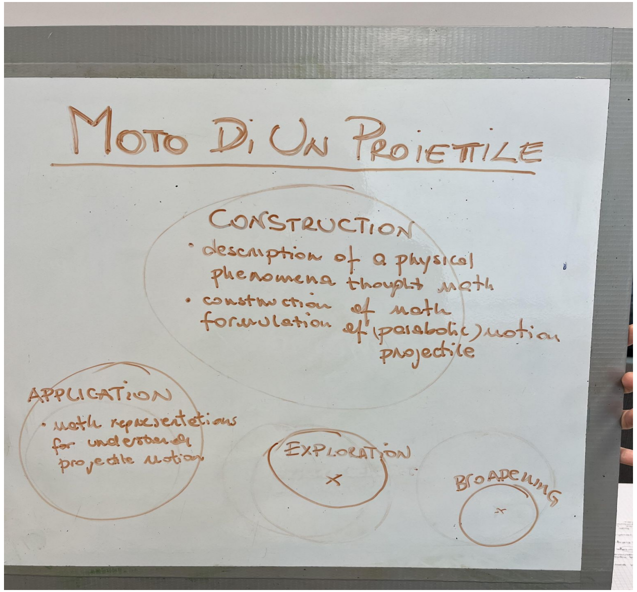
PCK for Math/Phys Interplay - Group 05

EXPLORATION: Calcolo altezza massima e gittata

APPLICATION: Utilizzo della trigonometria per la scomposizione del moto, utilizzo delle leggi orarie per ricavare le coordinate della posizione

PCK for Math/Phys Interplay





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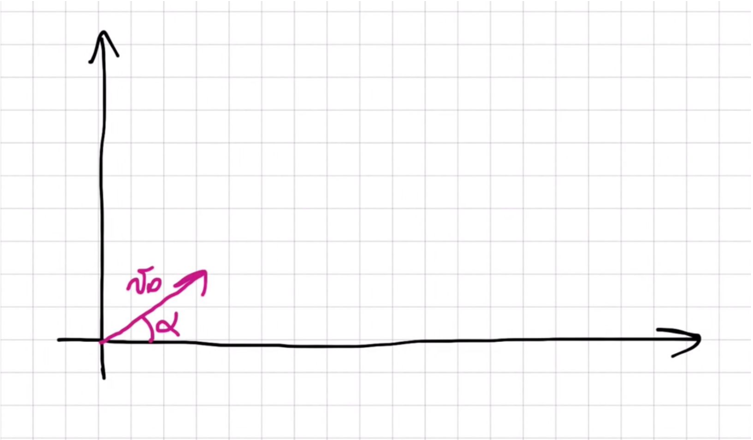
PCK for Math/Phys Interplay



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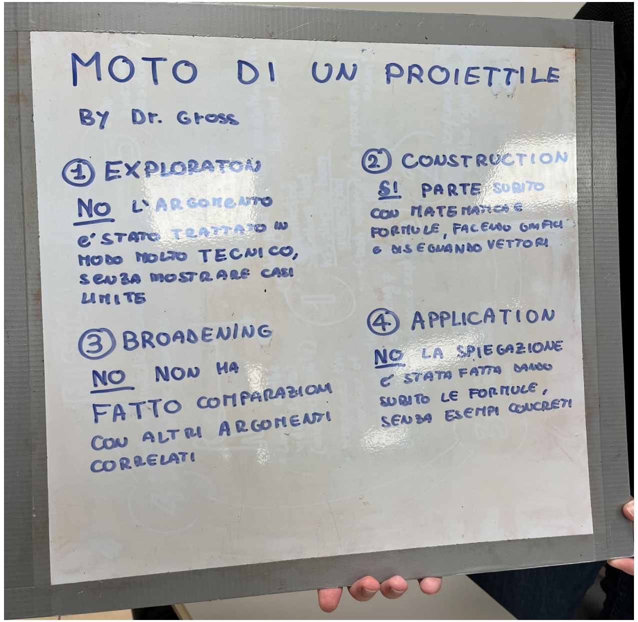


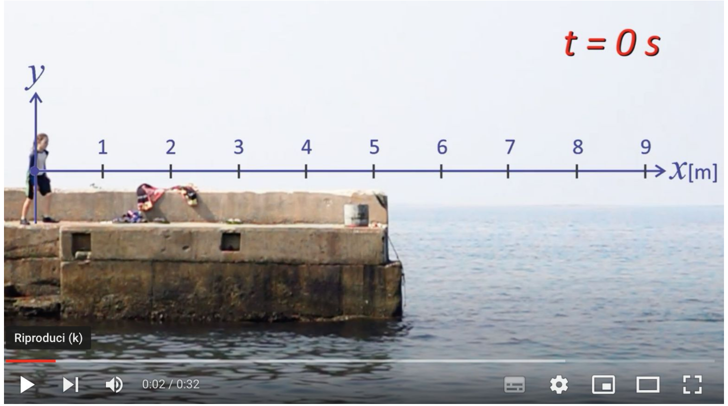
SAME TOPIC,
DIFFERENT PERSPECTIVES!

MATHS PERSPECTIVES
VS
PHYSICS PERSPECTIVES

EXERCISE FOR REASONING

https://www.youtube.com/watch?v=_sCp1igJ3j8

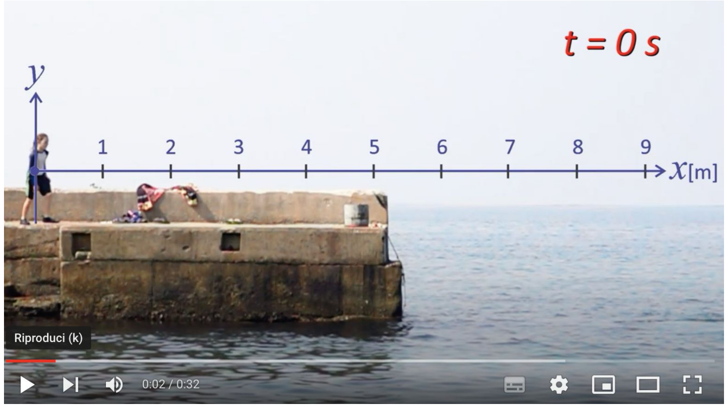
Horizontal Jump

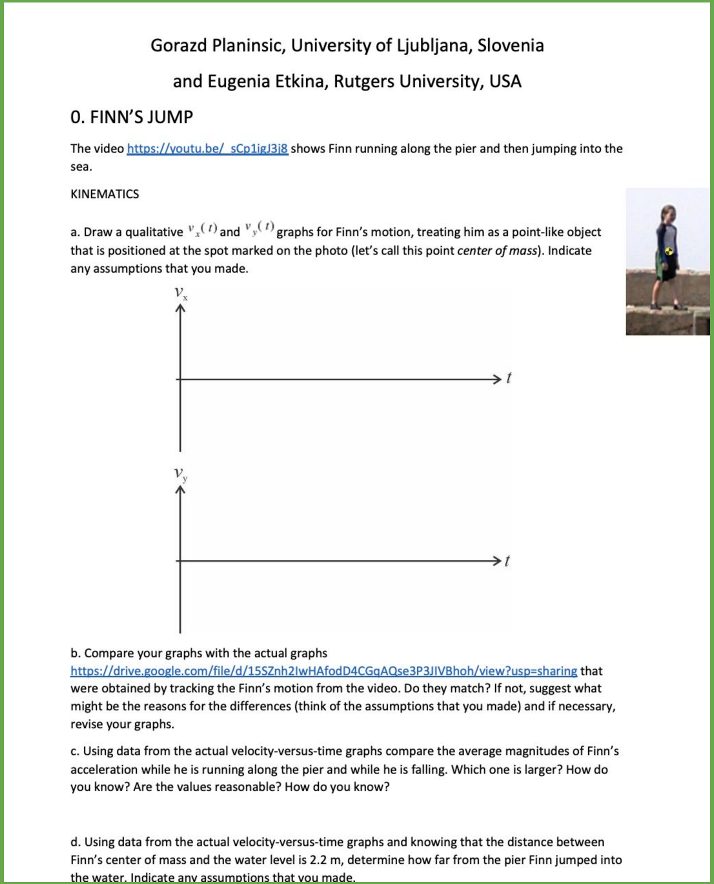


EXERCISE FOR REASONING

https://www.youtube.com/watch?v=_sCp1igJ3j8

Horizontal Jump





Gorazd Planinsic, University of Ljubljana, Slovenia

and Eugenia Etkina, Rutgers University, USA

0. FINN'S JUMP

The video https://youtu.be/_sCp1igJ3j8 shows Finn running along the pier and then jumping into the sea.

KINEMATICS

a. Draw a qualitative $v_x(t)$ and $v_y(t)$ graphs for Finn's motion, treating him as a point-like object that is positioned at the spot marked on the photo (let's call this point *center of mass*). Indicate any assumptions that you made.

v_x — t

v_y — t

b. Compare your graphs with the actual graphs https://drive.google.com/file/d/15SZnh2IwHAfodD4CGqAQse3P3JIVBhoh/view?usp=sharing that were obtained by tracking the Finn's motion from the video. Do they match? If not, suggest what might be the reasons for the differences (think of the assumptions that you made) and if necessary, revise your graphs.

c. Using data from the actual velocity-versus-time graphs compare the average magnitudes of Finn's acceleration while he is running along the pier and while he is falling. Which one is larger? How do you know? Are the values reasonable? How do you know?

d. Using data from the actual velocity-versus-time graphs and knowing that the distance between Finn's center of mass and the water level is 2.2 m, determine how far from the pier Finn jumped into the water. Indicate any assumptions that you made.

https://drive.google.com/file/d/1wZ71m7GWmmDTsh9dWkPoPxZ4qcLk7Go6/view?usp=sharing

EXERCISE FOR REASONING - Group 01

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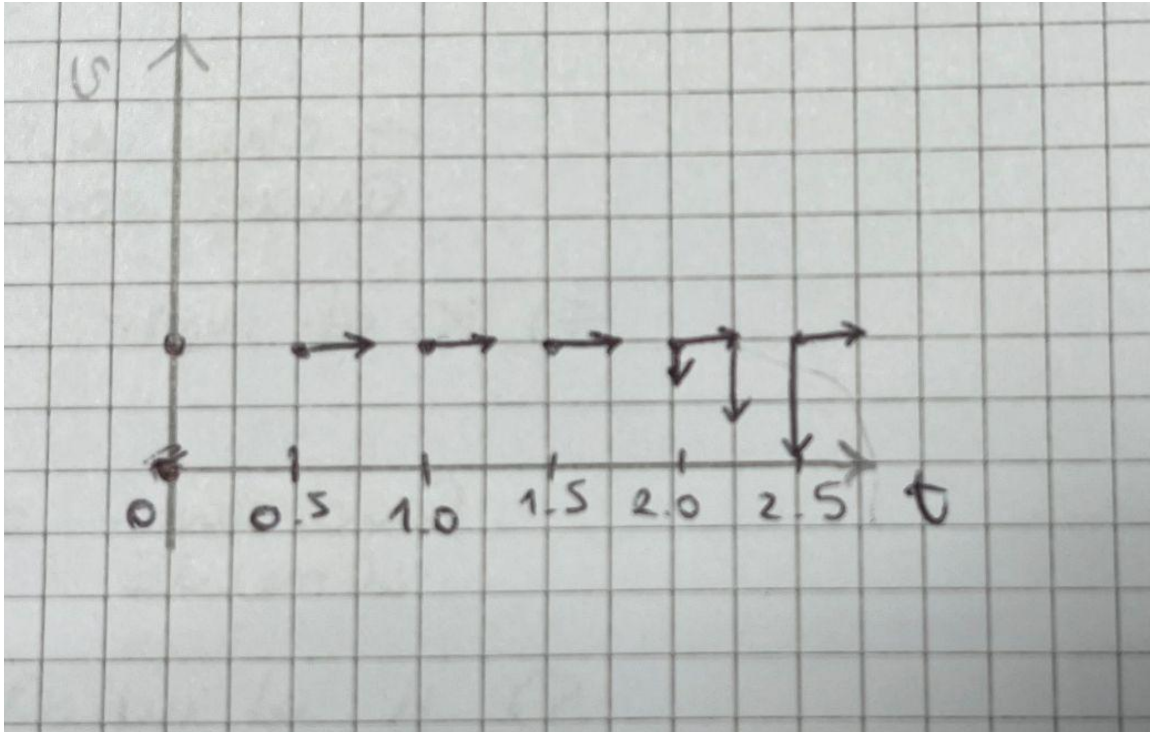
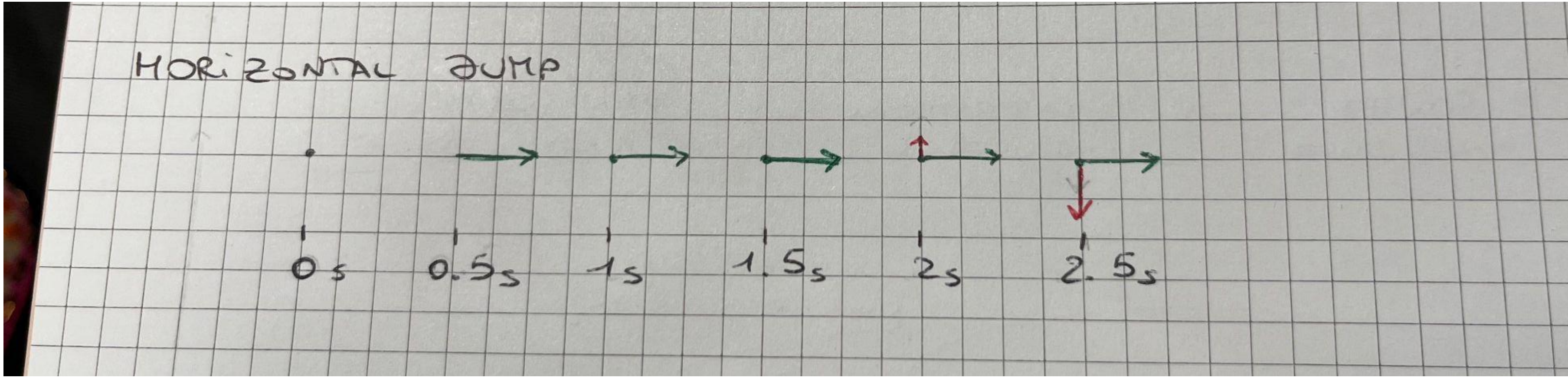
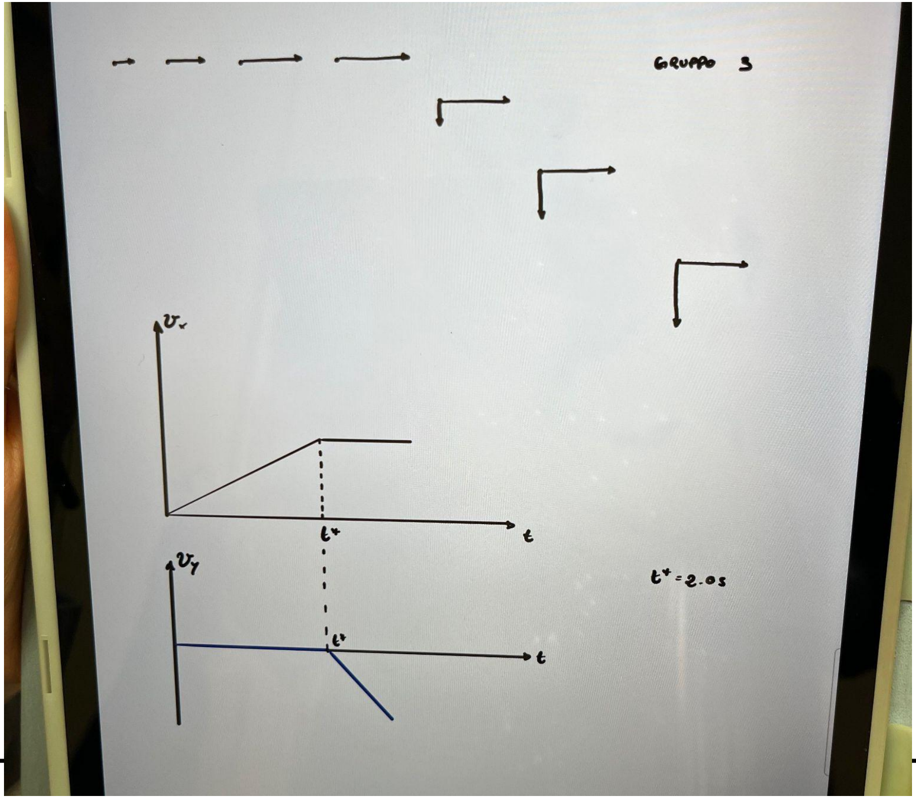


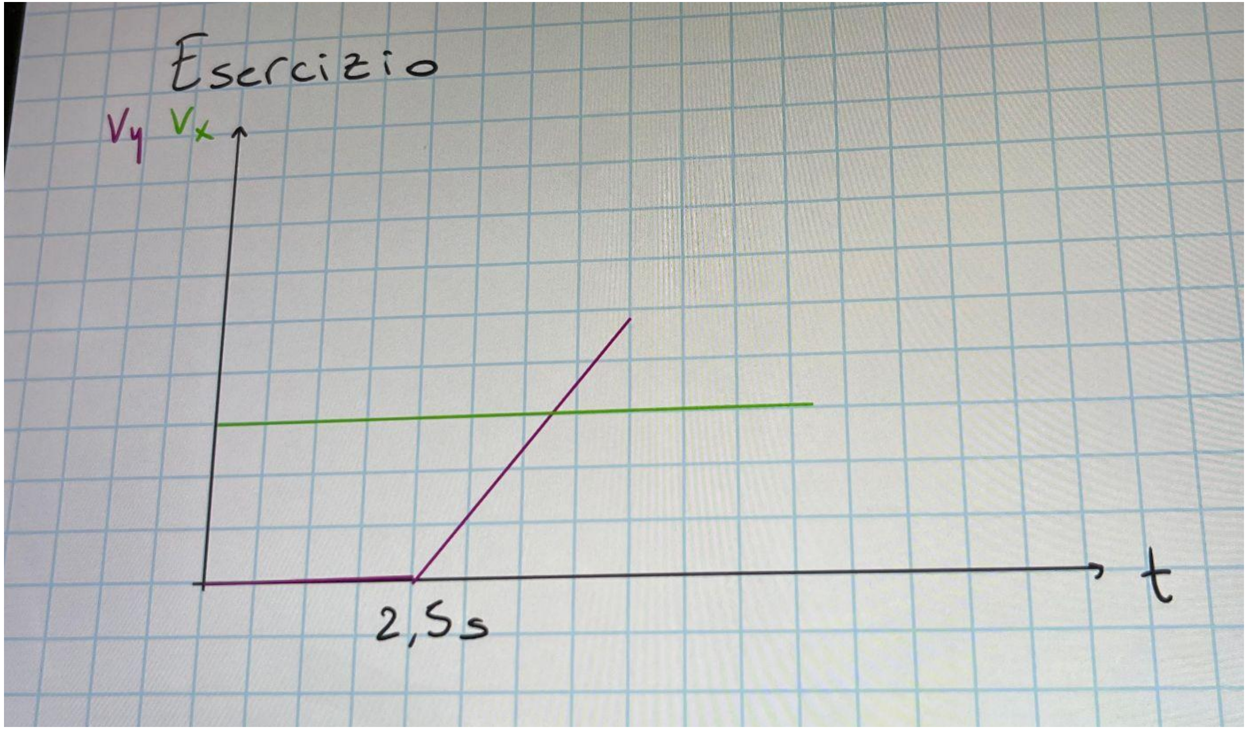
EXERCISE FOR REASONING - Group 02



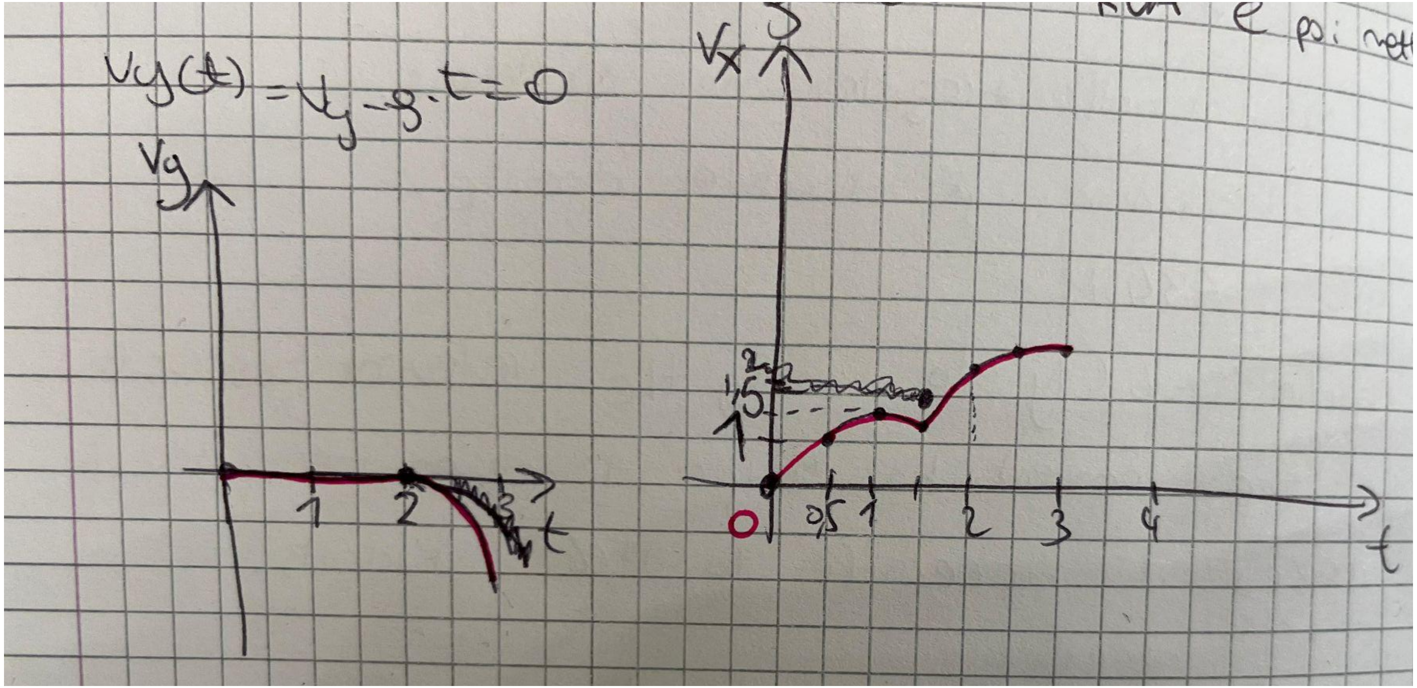
EXERCISE FOR REASONING - Group 03



EXERCISE FOR REASONING - Group 04



EXERCISE FOR REASONING - Group 05



Developing new patterns for integrating Math/Phys Interplay

REFLECT on the EXERCISE FOR REASONING!

WHICH PATTERN IS PREVALENT?

Which are student specific target?

Which are the tasks that the teacher has in mind while teaching in the CKT frameworks?