

## Community of prospective primary teachers facing the relative motion and PCK analysis

Marisa Michelini, Lorenzo Santi, Alberto Stefanel, Stefano Vercellati

michelini@fisica.uniud.it, lorenzo.santi@uniud.it, alberto.stefanel@uniud.it, vercellati@fisica.uniud.it

Research Unit in Physics Education of the University of Udine

### Introduction

The first observations of the world done by children are related with motion of objects. Most of the perceptual aspects are activated during primary school and were subject of studies concerning the psychological perception of motion (Johansson 1975, 1985; Bruce, Goldstein 1989). For this reason, it is important to face the physic interpretation of motions already during primary (Michelini 2005; Goldberg et al. 2010; Castells et al. 2010; Ross, Otero 2010; Brussolo, Michelini 2010).

Many learning problems on this subject, as the identification and interpretation of the role of the reference frame, the distinction between trajectory and space-time and velocity-time graph (Sokoloff et al. 1997, 2007; Beichner 1994), the vector nature of quantity as velocity and displacement (McDermott & Redish, 1999), are related to the use of a standard reductionist approach that start with the study of the particular case of the one dimensional uniform motion (Hammer 1989). The construction of a global vision of the physical quantities that describe the motion requires a non-reductionist approach (Karplus, 1977). It provides the opportunity to introduce the vector nature of the kinematic quantities since from the earlier analysis of motions. In fact, even pupils are able to reconstruct step by step the motions through the representation of the displacements done in equal time intervals. In particular, the contexts opened by this approach allow to study the relative motion, composition and decomposition of motion, which often are not enough stressed in the traditional one dimensional approach (Saltiel, Malgrande 1979; Viennot 1996; Castesl et al. 2010). This open a challenge in primary teachers' formation, usually with poor scientific preparation and competencies in active learning strategies.

In this prospective, a specific IBL learning path for primary was designed founding kinematic of motion and relative motion in a non-reductionist framework To allow primary teachers to introduce effectively this approach into their classrooms, a teaching formation course was designed in the prospective of PCK (Pedagogical Content Knowledge) (Schulman, 1987; Magnusson et al. 1999; Abd-El-Khalick 2006). Our research work was done in the framework of PCK, to investigate the research questions presented below.

### Research Questions

With respect of our formative module on kinematic and relative motion, we analyzed the following research questions:

- RQ1 How do prospective primary teachers (PPT) face the conceptual knots related to reference frames and relative motions?
- RQ2 How do PPT proposed to face with pupils these learning knots?
- RQ3 Which are the still open CK and PCK aspects?

### Context, instrument and methods

During the academic year 2009-2010, was held a specific module on kinematics and relative motions in the context of the Physics Education course at the University of Udine –using participated lessons. In this teaching module, the study of motions in everyday contexts was addressed in 2 or 3 dimensions. Using games and visualization tools, the initial formal description of the reference frame and the quantities related to the description of motion are constructed. From

the first formal description of the involved entities: the vector nature of position, displacement, velocity, and acceleration; their mutual distinction and the representation of motions in the physical space or in abstract graphs; the composition and decomposition of motions. The formative module involved 105 prospective primary teachers. The average age was 22 years old.

At the end of the course, a PCK-based post-test was scheduled for the week next to the end of the lessons. To give answers to our research questions, we analyze here what emerge from this post test. The analysis of data was performed defining a priori categories, rearranged a posteriori. In according to qualitative research criteria, for each question we classified the answers of prospective teachers in categories emerging from the data; then the distributions of answers among those categories were analyzed.

## The post-test

The PCK-based test consisted of 7 items: 2 on CK and 5 on PCK end a CK item concerning a specific knots. The post-test proposes situations and specific questions investigating the extension of the concept of the prospective teachers on the specific knot considered. Each PCK item was divided in two part: in the first part (the CK part), a particular situation is proposed to the prospective teachers and they have to analyze it, in the second part (the PCK part), the prospective teachers have to analyze a series of fake students' questions, individuate the conceptual knot(s) which one of them is related and propose a way to face these knots in classroom. The item 2-3-4 reported in Fig. 1 and Fig.2 are typical PCK questions. In the following are analyzed data emerging from these questions.

Item 1 is concerning the role of the reference frame in the description of everyday motion (bus trip), Item 2 is related to the distinction between position displacement and velocity (analysis of a stroboscopic image), Item 3 is about the description of a vertical motion (discussion of the corresponding graphs) and Item 4 is related to the relative motion of an object placed on a medium that is in motion with respect to a fixed reference frame (the motion of a boat driven by a current).


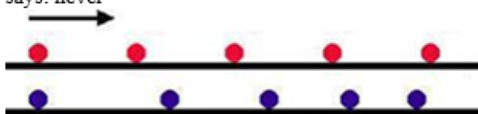
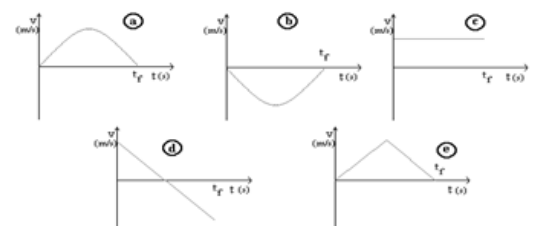
<p><i>Item 1.</i> A bus trip start from Udine. The stops are Cervignano del Friuli, Trieste, Postojna, Ljubljana, Kranj, Klagenfurt, Villach. The map below shows the places touched on the journey. On the maps are represented the wind-rose and scale for distances.</p> <p>1.1 Choose a reference system and it draws on the map          1.2 Represent the position vectors of the different stages: Cervignano del Friuli, Trieste, Postojna, Ljubljana, Kranj, Klagenfurt, Villach          1.3 Represent the displacement vectors for each stage          1.4 The time of travel plan is: Udine: 8.00 h; Cervignano: 8.20 h; Trieste: 9.00 h; Postojna: 10.00 h; Ljubljana: 10.30 h; Kranj: 10.50 h; Klagenfurt: 12.30 h; Villach: 13.30 h</p> <p>Construct the space-time diagram of the motion of the bus.</p>	
<p><i>Item 2.</i> Ex 2) A teacher shows to its students the diagram below where there are represented stroboscopic image of two spheres that go right along two parallel paths. She asks to his students: when the two spheres have the same speed.</p> <p>One child says: only on departure; A girl says, between the second and third position; Another child says: never</p>  <p>2.1 Which is/are the conceptual knot(s) highlight by the answers?          2.2 How could you face it in the classroom?</p>	<p><i>Item 3.</i> A teacher proposed to his students the following situation: A ball is thrown vertically into the air and then take in hand when it returns to the height from which it was throw. Students must choose which of the following velocity-time graphs best describes the motion of the ball. Justify your answers and specify the trajectory followed by the ball.</p>  <p>Discuss each graph.</p>

Figure 1. Items 1-3 of the PCK questionnaire: situations proposed on specific questions to PPT

Item 4. A boat is sailing north at 40 km/h in a sea affected by a current to the east at 30 km/h constant.

4.1. Representing the boat speed and current

4.2. Represent the movement of the boat after 3 hours.

4.3. Represents in a v-t graph the boat and the current speeds

4.4. Explanation of drawing: Explain your choices for performances 4.1 and 4.2

4.5 What kind of motion are followed by boat during the three hours of navigation...

4.5.1 ... compared to the seashore? Explain your answer.

4.5.2 ... compared to the current? Explain your answer.

4.6 To some students are asked to represent the motion of the boat and explain it.

They perform the following considerations

S1: I cannot do represent motion without a compass

S2: If it isn't drawn or indicated the seashore, I don't know how to do

S3: How can I represent time in a drawing of the physical space?

S4: Represent velocity at constant intervals of time is the same than represent the movement

S5: You can not represent the velocities in physical space, I must do a velocity- time graph

S6: Compared to what I have to consider the velocity?

Helping each student, explaining how (what do you say to each student?)

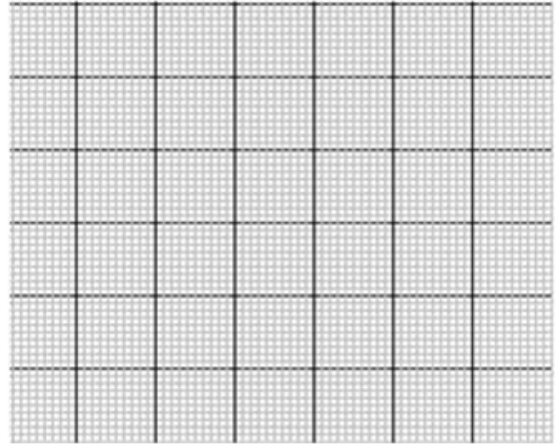


Figure 2. Item 4 of the PCK questionnaire

### Data and data analysis

Item 1. Answering question 1.1 the origin of the reference frame was chosen in almost all of the cases (92%) in coincidence with the starting point of the trip (Udine); in the remaining cases the origin was put in the lower-left corner of the picture (3%) or into the water under Udine (5%). The axes were often indicated (88%), but there was a significant group that drew half-axis (10%) or only one axis (2%). The axis orientations were highlighted by 72%, while (18%) did not highlight the orientation or dual-oriented as the wind-rose (10%). The majority (53%) included the two labels on the axis (E-N 33%; x-y 20%), two marginal groups did not indicate any label (25%) or indicate the complete set of cardinal points N-S-O-E (18%).

The students who answered to questions 1.2 and 1.3 (78%) drew the position vectors. Among these, 58% indicated the displacement vector, while 12% represented only a segment; the remaining 8% drew only the positions of the stops or the traveling as a segment or the position vectors. In question 1.4, concerning the construction of the space-time diagram: the 61% choose to represent the graph of the distance from the origin of the journey; 22% interpreted the delivery constructing the time-space diagram by representing on the y-axes the linear distance traveled by the coach; 9% represented the space-time graph considering equidistant one leg of the journey to the next one; the remaining did not reply.

Table 1: Categories of Item 2	%
<b>HIGHLIGHT A KNOT</b>	<b>65</b>
Def. Of velocity	25
Difference: velocity – acceleration	17
Local vision of the motion	14
Diff. between velocity and trajectory	6
Do not justify	2
And did the CK analysis	1
<b>EXPLICIT A LEARNING GOAL</b>	<b>7</b>
<b>DO A CK ANALYSIS OF THE PROBLEM</b>	<b>5</b>
Rectilinear uniform motion	4
While $Ds/Dt$ are equals	1
<b>NR</b>	<b>23</b>

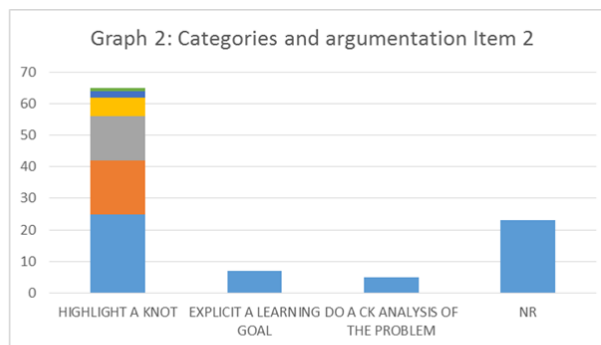


Figure 3. Answers categories and argumentations to Item 2

*Item 2.* The 77% of the PPT replied to this item as shown in Fig. 3: 65% focalize on only one learning knot, 7% explicit just one learning goals, 5% do a CK analysis of the situation without referring to the pupils answers. Between them 57% proposed an active intervention as games or practical activities centered on the highlighted knot (16% explicit how they are related to the specific knot, 19% describe only the activity and 22% give only a vague description of the way in which perform the proposed activity), 18% described an activity that involves learning knots that are different from the individuate one, 3% suggested to construct the space-time graph of the motion. It emerge the attitude to analyze the problematic situation in a single dimension prospective highlight the need to construct a multi-dimensional analysis of situations both on the subject matter perspective and relate to the educational one.

*Item 3.* The correct graph (d) was identified by 11%, while the main distractor was the graph (a) chose by 47%, which represents the right space-time graph. The distribution of the other answers is shown in Fig. 4. The difficulties in the reading of the graph was highlighted also by the 32% of the students who did not replies.

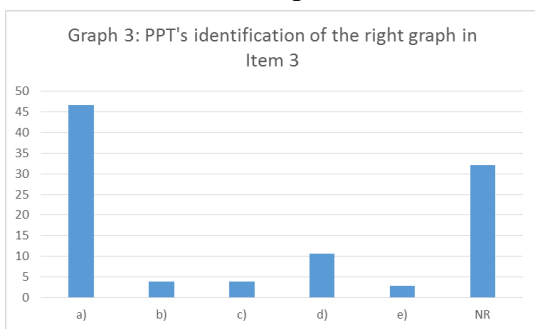


Figure 4. Graph individuate as right in Item 3 by PPT

A significant group (40%) analyzed the graphs doing references to the ascent and descent motions of the ball, in the remaining 52% described the individual graphs or did not reply (8%). Despite the approach that they used, mostly students described the graph in terms of acceleration or change of velocity (28%+15%). In some cases, some PPT did not distinct between trajectory and graph (16%+24%), or between space-time graph and velocity-time graphs (4%+1%) – Fig.5. This result could be related to the well-known problem related to the multi-representation of motions and, in particular, to the distinction between  $v-t$  graph and trajectory.

*Item 4.* Concerning questions 4.1-4.4 related to the description of the motion of the boat driven by the current: 85% of the students do a composition between the velocity vectors and 59% explicit the way in which the compose them, but only half of the students take in consideration the entire length of the motion (51%). One third of the students (32%) represent also the reference frame, showing how strong is the attitude of PPT to leave implicit the reference system.

As concern question 4.5.1, 49% replied that the motion of the boat is rectilinear and uniform; 13% described the motion as uniformly accelerated (because the distance between the boat and the seashore continuously increase); 5% said that it depends by the seashore location; 2% did not specify the type of motion but highlight only that a composition between the two motion is needed; 31% did not replay to this question.

Table 2: Categories to Item 3	%
<b>DESCRIBE THE GRAPHS</b>	<b>52</b>
Description in terms of variation of velocity	28
No distinction Trajectory, v-t graph	16
uniform accelerated motion	4
No distinction v-t, s-t	4
<b>ANALYZE THE MOTIONS OF THE BALL</b>	<b>40</b>
No distinction Trajectory, v-t graph	24
Description in terms of variation of velocity	15
No distinction v-t, s-t	1
<b>NR</b>	<b>8</b>

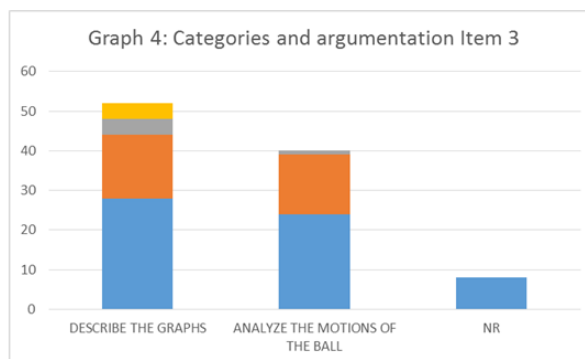


Figure 5. Categories and argumentation for Item 3

As concern question 4.5.2 about the description of the motion of the boat with respect to the current, the number of the correct answers decrease: 35% identified the motion as rectilinear uniform, 10% as rectilinear uniformly accelerated, 48% did not answer to this question, and 7% replied “perpendicular to the current”.

Concerning the discussion on the fake students’ answers 4.6.SX, 75% of PPT emphasized the importance of the definition of a reference frame, however often they did not describe which reference frame they consider. In fact, commenting 4.6.S1, PPT assured that the compass is not needed (68%) and, commenting 4.6.S2, that the seashore position is not important (52%). Aspect that highlight a particular critical point in the PPT formation. The problem of the definition of the reference frame, and, moreover, the formulation of a description it, is one of the main problem in literature (Sokoloff et al. 1997, 2007) and it is pivotal that PPT will be able to face it with their students to understand the role of the reference frame into the description of the motion. In analogy with the Item 3, it emerges from the 4.6.SX questions how PPT, by facing of the PCK analysis of the fake students’ answer, highlight the same difficulties shown in the CK part and how there is no more an investigation of the learning knots, but the PPT attitude is toward the expression of a judgment about the correctness (or not) of the students’ answers.

## **Discussions and conclusions**

For what concern the CK part, PPT face the conceptual knots related to reference frames and relative motions (RQ1) it emerge how: A) PPT are able to setup a well-defined reference frame even if there is a remaining tendencies to use a local approach into the definition of the reference frame origin and in the axes labeling [Item 1]; B) the multi-representation of the motion is still a problem in particular for what concern the distinction between trajectory and space-time and velocity-time time graphs [Item 3]; C) in many cases, PPT can apply in an effective way the step by step construction of the motion by mean of displacement vectors [Item 4].

Looking at the PCK aspects (RQ2): A) when they had to face a PCK activity of a well mastered content, almost all of the PPT individuate one of the main knots behind the proposed question and is able to propose a specific activity that, in the majority of the cases, is effectively focused to address in classroom the knots individuated [Item 2]; B) when they consider a question concerning a not well mastered content, PPT tend to judge the correctness of the pupils answer instead of looking for learning knots and analyze their origin and, in such a situation, they tend to propose generic learning activity [Item 4]; C) in some cases, also when they evidence CK competencies, do not link the activities proposed to address with student the specific knot considered, not going beyond the generic indication “with experiments”, “with games”, or proposing specific games and building activity but not focused on the knot identified [Item 2].

For what concern the still open aspects related to teachers CK and PCK (RQ3) we can summarize them as follow: A) the main problematic CK aspects for the prospective teachers are the construction of a system of arbitrary reference frame in a given context (referring to different systems, or not related to any specific system) [Item 1], the reference to manage multiple reference frames in relative motion on with respect to the other [Item 4], the handle of the physical multi-representation [Item 3]; B) the main PCK open aspects are the difficulties in the recognition of different learning knots included into the students’ sentences [Item 2, Item 4], in the construction of a set of activities (and not just one) that can be used to propose to students a same aspect form different point of view, or face on a same experiment the different knots involved [Item 2,].

As indication on how improve our formative module, emerge from one side the need to put attention on the study of relative motion and emphasis on the construction and the role of the



reference frame. For what concern the PCK aspects, it emerge the need to integrate in the education laboratory of part devoted to design co-projected single activities as well micro learning path. The results of the research presented to indicate that the formation CK is a precondition for being able to build significant PCK. At the same time, the actual construction of PCK also requires an extensive analysis of proposed activities to be able to watch the same phenomenon from different points of view, or with a variety of alternative proposals. In addition, the skill of being able to focus on a teaching of a concept called a node requires a specific design tasks.

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