A transversal educational proposal for prospective primary teachers: the theme of Time

IOP Conf. Series: Journal of Physics: Conf. Series **1287** (2019) 012042 doi:10.1088/1742-6596/1287/1/012042

A transversal educational proposal for prospective primary teachers: the theme of Time

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Abstract. Time is a transversal topic that plays a fundamental role in our every-day experience and represents a natural conceptual bridge between common sense ideas and scientific knowledge. Two classes of Prospective Primary Teachers (PPTs) at the Universities of Udine and Verona were introduced to the theme of Time in a formative intervention organized into a) the discussion of various educational and multidisciplinary approaches aimed to deal with different aspects of Time and b) the exploration/experimentation of various instruments for time measurement. In this work, we study and compare the learning outcomes in terms of planning and implementation of educational projects built by PPTs following two different Rubrics.

1. Introduction

Up to now, one of the main problems in Prospective Primary Teacher (PPT) education is how to produce Pedagogical Content Knowledge (PCK), in particular as regards scientific education [1-2]. The lack of reference materials (textbooks, good practices, research based proposals) increases the difficulties of this task. As a wide research literature documented and underlined [3-5], the need to integrate different areas of knowledge requires specifically dedicated time and activities [6]. Our research has been focusing on this problem for a long time, looking on how to develop in PPTs the necessary professional competences starting from their weak preparation on the different scientific subjects included in primary school education combined with a too much amplified general emphasis on pedagogical, psychological and social aspects [7-8]. The model that we developed, based on the discussion of educational proposals on different themes analysing how the various aspects of a subject are addressed in their rationale, is now implemented on different topic areas [10-15] and in the design and analysis of the learning processes. Specific results give us confidence on how to face some conceptual problems in scientific learning. What is particularly relevant is the personal involvement of PPTs in planning and analysing research based educational proposals for primary school and in experiencing and practicing in classroom the intervention modules after discussion [6,16]. The transversal perspective is another problem that needs to be solved: it requires the competences of integrating different cultural approaches in a given context and of taking the opportunity, from the situations that can emerge during the activities and from of the curious questions of the children, for a wide flexible perspective in introducing basic transversal concepts. To this respect, Time is a comprehensive, naturally transversal topic, which offers many educational opportunities to deal with different kind of experimental and exploratory activities, since it is part of common experience [17]. Time is also naturally linked to the real world and represents a conceptual referent to bridge common sense ideas to the scientific ones in a multidisciplinary perspective [16]. However, Physics education for PPTs in Italy does not include multi- disciplinary activities (which

are offered only as initiative of scientific area university teachers) and transversal topics such as Space and Time are rarely treated, even if they are fundamental in PPTs professional work. This implies that the lack of scientific competence that PPTs need to solve is not correctly addressed [4-6], [18], [19]. In the theoretical framework of the Model of Educational Reconstruction (MER) [20-21], by means of Design Based Research intervention modules we developed three different educational proposals on the topic of time, implemented in five different primary schools [22]. In this paper, we present a research-based teaching intervention module focused on the personal engagement in exploration and planning on the topic of Time involving PPTs of the Italian Universities of Udine (120) and Verona (30). PPTs were introduced to a presentation of various possible approaches to the topic of time and invited to discuss together in the context of more than 100 hands-on experiments in the GEI (Games, Experiments, Ideas) exhibition [23] to explore possible educational proposals. PPTs were later asked to plan a short educational path for children by means of two different Rubrics. Here we analyse and discuss the learning outcomes of PPTs and the relative fall-out.

2. Sample

The sample of the present research is made of 29 PPTs who participated to the same formative intervention module of 8 hours about the theme of Time including presentation, exploration of educational materials and experiments, and discussions about planning an educational path. These activities were proposed as part of the Physics Education course (8 cfu) and Lab (1cfu) offered during the III year of the combined Bachelor + Master Degree Course in "Primary School Education", after the courses of pedagogy, psychology, anthropology, social sciences and Math education (300 cfu), including apprenticeship (about 200 hours). The Physics education course in both universities includes in a different order the discussion of Content Knowledge (CK) and the discussion of educational paths on each topics (PCK), using the same reference materials for PPTs formation.

3. Instruments, Methods and Research Questions

The present study is an investigation of the learning outcomes in terms of educational projects built by PPTs following two different Rubrics but starting from a common formative experience.

The formative intervention was proposed in Udine to all the involved PPTs and included: 1) a discussion on the concept of Time (1 hr); 2) a presentation of three experiences of educational paths with the corresponding instruments and methods explained as part of their rationale and discussion of the chosen strategies and methods (3hrs); 3) exploration of GEI experiments [8-10] and analysis of the corresponding explanation sheets according to the principle "I see, I do, I understand" (2 hrs); 4) a discussion divided by groups to compare possible educational paths (2 hrs).

All PPTs were requested to build in a synthetic form an educational project on the theme of Time (Rubric A). In addition, the PPTs of Udine University were invited to choose a theme among those treated during the course for a detailed project (Rubric B) followed by an experimentation in classroom with the pupils. Eight of them chose the theme of Time. Rubric A is made up of the following items: A1) list of the founding nuclei of the treated argument; A2) conceptual knots and difficulties (list and motivations); A3) rationale of the proposal and conceptual map; A4) table of Inquiry Based Questions with the associated activities in the proposed path. Rubric B is divided into three parts. Part B1 – detailed educational proposal, including: B1.1) cultural, educative and social motivation for the topic; B1.2) approach, strategy and methods; B1.3) conceptual map; B1.4) rationale and detailed path with description of the proposed activities. Part B2 – revision of B1 according to the school work implementation with pupils of path B1, after discussion with the responsible of the course and peers. Part B3 – monitoring of pupils learning. The school work involved a total number of 128 pupils: three classes of second grade students, four classes of fifth grade students and one class of pre-school students. PPTs freely organized their activities with the classrooms and were then required to describe and summarize their experience in a written report following the items of Rubric B. The following research questions were investigated: RQ1. How did PPTs profit from the proposed formative intervention (contents, example of experimented school activities, available simple apparatus) in their educational paths? RQ2. Which role did the detailed planning and the perspective of school activity experience play

in the competence gain of PPTs? RQ3. How did PPTs refer on the contribution of the planning and school activity experience in their final report?

4. Intervention module on the theme of TIME

In the first part of the intervention module PPTs were introduced to the concept of time and to the distinction between time as related to irreversible phenomena and to its measurement through periodic phenomena. The theme of Time was then discussed in a presentation of three experiences of learning paths characterized by different starting points: the use of words related to time, to address the concepts of past, present, future, duration, sequentiality and contemporaneity; the conceptions of Time in short readings from some philosophers (Heraclitus, Aristotle, Augustine, Hegel, Heidegger, Prigogine), to address the meaning of Time in terms of its direction; the role of Time in Poetry, Art, History, to address it as a transversal topic. In the three learning paths, the observation of different phenomena and the construction/explanation of various instruments for measuring time (hourglasses, pendulum, calendars, clocks) was proposed. Irreversibility was introduced through examples (evolution during life, falling leaves, broken glasses, spreading of an ink drop) or through the observation and measurements of some irreversible phenomena (movement of fluids/viscosity of running liquids; fusion of an ice cube on different supports; warming of a given mass of water). Periodicity was presented with examples taken from every-day life (day, week, month and year) and construction of wheels of Time or through the observation and measurement of astronomical phenomena (motion of the sun, use of gnomons).
After this introductory part, PPTs explored for about two hours the informal context of the GEI exhibition [23] about various subjects and paths treated in the course and experimented different instruments for time measurement: gnomons, hourglasses, oscillating fluids, pendulum. Almost two hours were finally dedicated to a discussion divided by groups about possible educational paths.

5. Data Collection and Analysis

Rubric A asks for a light planning mainly affected by the performed activities, where the contents catch greater attention. This rubric allows to investigate the formative role of the proposed module that was based on the discussion of disciplinary as well as transversal topics and on the analysis of educational proposals and instruments. Rubric B goes more in depth than rubric A giving the opportunity to explore the role of an operational perspective in the implementation of a detailed project and in the construction of professional competences. In addition, field testing with pupils and its analysis allow to understand the role of situated learning in the context of a real experience for the construction of teaching skills.
Data analysis was performed on Rubric A and on the parts 1 and 3 of Rubric B following an iterative process of Qualitative Analysis [24] by identifying directly from students' answers a set of categories for each specific item of the rubrics and by refining it through successive re-readings of students' reports.

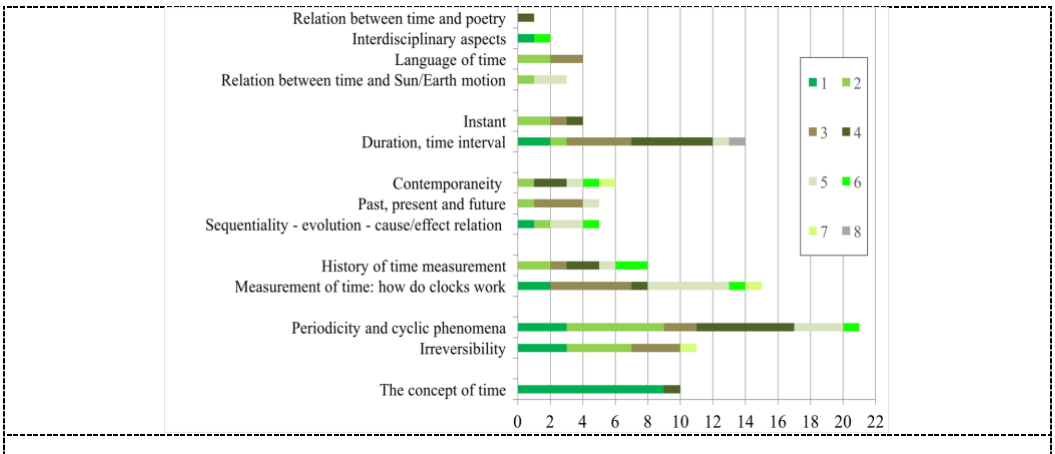

Figure 1. Themes as key-concepts. Colours indicate the position of the concept in the list. The abscissa gives the number of students who indicated the theme.

5.1. Analysis of Rubric A

5.1.1 - Lists of the founding nuclei (key concepts)

The order (as colours) and frequency of the listed key concepts are reported in Figure 1. Periodicity and cyclic phenomena are treated by all the students, followed by measurement of time and duration. Irreversibility is less cited although it is the one that defines the meaning of time (coherently with what we see in section 5.1.3). Almost half of the students (9/21) choose the concept of time as the «attack angle». As a general comment, we find that contexts are missing. Elements related to the comprehension of the concept of time are not structured in their conceptual organization: e.g. almost all PPTs speak about duration but the concept of instant, which gives sense to duration, is not treated. Although abstract concepts should not be chosen as attack angles but should instead be placed at the end, these students make the opposite choice and place abstract concepts at the first place.

5.1.2 - Conceptual knots and difficulties

The order (as colours) and frequency of the listed conceptual knots are reported in Figure 2.

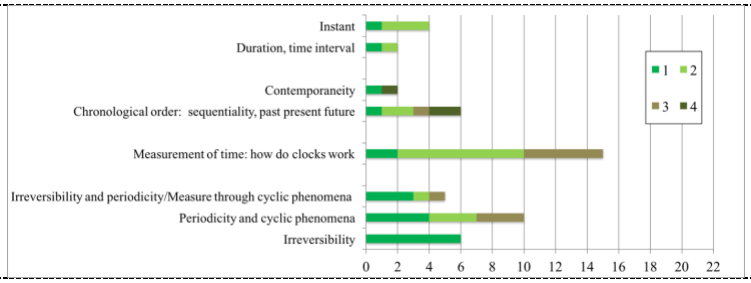

Figure 2. Themes as conceptual knots. Colours indicate the position of the element in the list. The abscissa gives the number of students who indicated the theme.

Operative aspects (how time is measured, how clocks work) and their relations with mathematics prevail. Measurement of time as related to how clocks work is considered the most important knot by 15/21. This knot is confirmed and strengthened by the fact that 10/21 identify as knot periodicity and cyclic phenomena and 6/21 chronological order and sequentiality. A cluster of knots concerns irreversibility and how to reconcile irreversibility and periodicity. Irreversibility is at the first place for the majority of the students: this is a positive indication that they have a clear idea of the need to focus on this conceptual issue. Anyway, periodicity and measurements are the most cited.

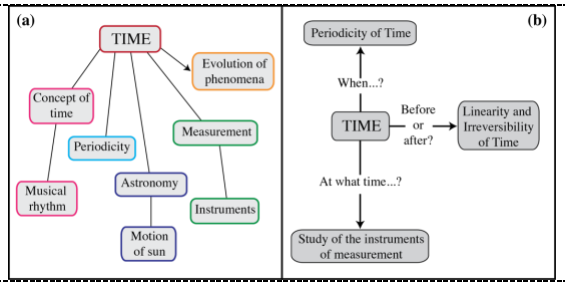

Figure 3. Two typical maps proposed by PPTs: a) Time is placed at the top of the map; b) Time is placed at the centre of the map.

5.1.3 - Rationale of the proposals and conceptual maps

PPTs were asked to list and map the physical concepts they plan to treat. Time is always a pre-existing general concept or entity (19/20), placed at the top (15/20, Figure 3a) or at the centre (5/20, Figure 3b) of the map. Only in one case irreversibility is introduced before the concept of Time. Inside the first group, 9/15 show a conceptual structure where time is organically related to elements which constitute

the meaning of time, while 6/15 are organized into proposals of activities. In most cases, maps are collections of disconnected, or only partially linked, items. Irreversibility (10/20) is never cited as a property of phenomena, it is always a property of time: in one case, it is defined as 'irreversible time'. Similarly, periodicity (18/20) is a property of phenomena only in 5/18, it is more often a property of time (13/18): in one case periodicity is defined as 'reversible time'. Irreversibility, periodicity, duration, sequentiality are mostly separated, independent, not interconnected: they all are properties, manifestations of time. Measurement itself is independent and related only to periodicity (only in 4/18).

5.1.4 - Questions and associated activities in the proposed path

In most cases, questions were in fact considered as "guide-questions"/arguments and not as inquiry questions. Only in the case of the concept of time the question "what is time" is made to the pupils never to ask for a definition but always to collect their spontaneous ideas. Specific contexts (sun motion, language, poetry) are indicated only by 7 students: relation between rythm and time (1/7), language of time (2/7), relation between time and Sun/Earth motion (4/7). The order and frequency of the arguments proposed in the educational path are reported in Figure 4.

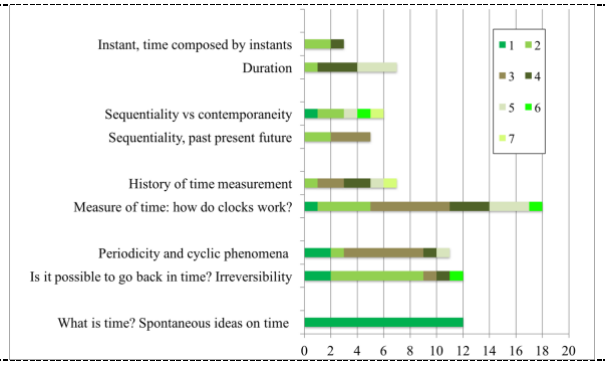

Figure 4. Themes as questions/arguments. Colours indicate the position of the element in the list. The abscissa gives the number of students who indicated the theme.

The concept of time is placed at the first position as an independent subject by the majority of the students (coherently with what we have seen in the previous section). 'What is time' and 'if it is possible to go back in time' are at the same level of interest: there is no contextualization. Periodicity (mainly a key concept) and irreversibility (mainly a conceptual knot) are placed at the first three places by half of the students after the general concept of time, indicating a significant orientation towards conceptual aspects and towards the distinction between the idea of time and the measurement of time. Almost all of PPTs place the measurement of time and the way clocks work at some point of the learning path. History of time measurement was indicated by 7/21: narrative aspects are important also when conceptualization could prevail.

From these data, it emerges that PPTs have acquired the idea of an approach related to every day experience, but they haven't acquired an inquiry based learning strategy: they tend to put general concepts at the beginning instead of starting from contexts and reaching the global concepts at the end. This is known to be a non-effective approach: learning should be contextualized and concepts should acquire a meaning from their correlation inside different contexts. The question 'what is time' is of a metacognitive type and should be posed at the end of the learning path.

The synoptic graphs reported in Figure 5a and 5b allow to see how the frequency with which each element is chosen as an argument of the educational path is related to the frequency with which the same element is identified as a key concept and as a conceptual knot. Duration is seen as a key concept as well as a chosen argument, not as a conceptual knot. For the other themes, there is a coherence in their relevance as key concepts, conceptual knots and proposed arguments, except for the case of periodicity, which is replaced by time measurement in the proposed arguments: this could be an indication that measurement of time and periodicity are considered as associated. This is also confirmed considering that periodicity and time measurement have the highest relevance as conceptual knots. Irreversibility

has the same weight as argument, concept and knot. The measurement of time is proposed by the most part of the students although it is considered less important than periodicity and irreversibility. The concept of time in not critical although important.

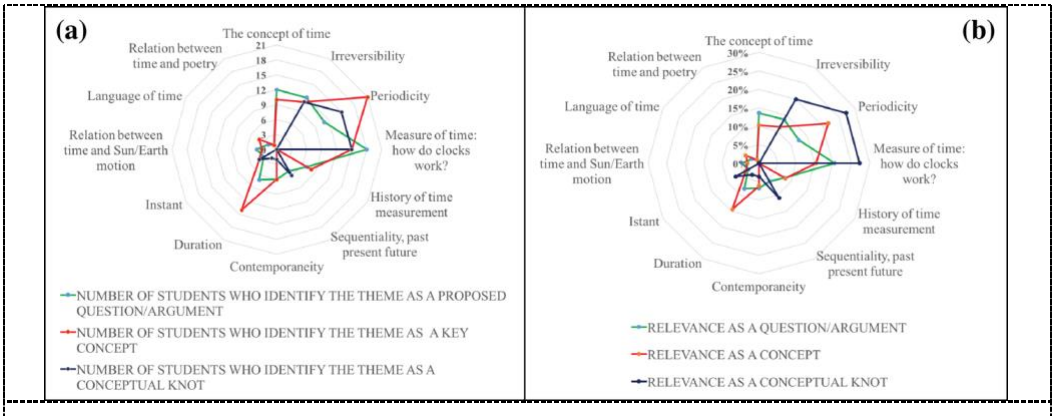

Figure 5. a) number of PPTs who chose a theme and b) relevance of each theme as argument of the educational path (green line), key concept (red line) or conceptual knot (blu line). For each category (argument, concept, knot) the relevance was calculated by dividing the number of students who chose a certain theme in the category by the total number of students who chose the same theme in any of the three categories. The difficulty in conciliating periodicity and irreversibility was considered in both the two themes.

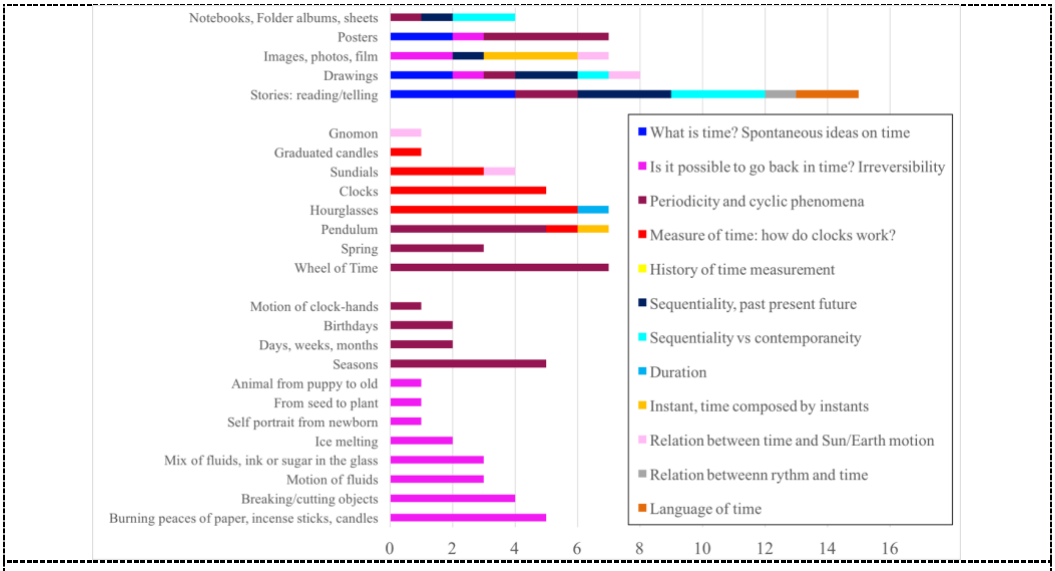

Figure 6. Proposed activities. Colours correspond to questions/arguments for which an activity was proposed. Abscissa gives the number of students who chose that activity.

Figure 6 reports the activities that PPTs plan to perform in the proposed educational path related to the subjects (as colours) which they were referred to and divided into three groups: 1) educational tools (reading, writing, story-telling, organizing previous knowledge); 2) construction and use of instruments for time measurement; 3) exploring phenomena. In the first group, reading and story-telling are the most utilized educational tools. In the second group, all the cited instruments are related to conceptual aspects of time as the wheel of time or hourglasses and pendulum, less frequent is the use of clocks and sundials; most simple instruments such as gnomons and graduated candles are totally neglected. As far as the exploration of phenomena is concerned, interestingly PPTs propose phenomena that are or have been

historically used for time measurement only as a way for illustrating the concept of irreversibility. Elements of the calendar (seasons, days and months) are the natural phenomena chosen to illustrate periodicity. Measurement of time is only related to a cyclic phenomenon and to periodicity, which in fact is a conceptual conquest due to modern technologies of time measurement. The most common associations to personal experience (birthday, portrait of children, changes due to their own growth or to animal or plant growth) are rare with respect to stories, technical aspects or seasons.
The relevance of each subject in terms of number of related activities is given in Figure 7, where, for each subject (same colours of Figure 6), the total number of proposed activities was weighted by the number of students who chose at least one activity for this subject. The subjects of the proposed activities are coherent with those indicated as conceptual knots. Periodicity and then irreversibility have the highest weight in the proposed activities, while activities related to measurement weigh only 15% although measurement is the most cited among critical issues and among the proposed arguments. The number of activities related to the ideas of time is comparatively low (8%). Chronological order and sequentiality related to the need of distinguishing it from contemporaneity have the same weight (6-7 %). Other subjects have a much less weight in term of related activities.

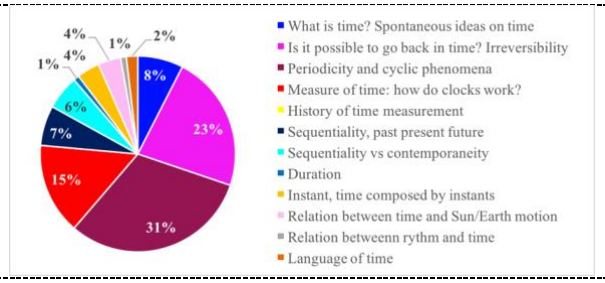

Figure 7. For each subject (colour) the total number of activities of any category is weighted by the number of PPTs who chose at least one activity for the subject.

5.2. Analysis of Rubric B

The eight projects have been analyzed following the main items of Rubric B. Data analysis shows that PPTs adopt the proposed examples creating new learning paths in which irreversibility and time measurement are interrelated and in which the main learning goals are addressed adopting active learning strategies and an inquiry approach.

5.2.1 - Cultural, educative and social motivations for the topic

As regards the motivation for the choice of the theme of time as the subject for their experimentation with pupils, the answers were: (i) "it is related to every-day life" (6/8); (ii) "it is in the national ministerial directives and allows projecting transversal and interdisciplinary paths" (5/8) and (iii) "it allows children to orient themselves in a temporal perspective" (4/8).

5.2.2 - Approach, strategy and methods

The chosen approaches emerge from the detailed proposed learning paths discussed in subsection 5.2.4. The Prediction, Experiment, Comparison (PEC) strategy is chosen by all the PPTs involved. Concerning the methods: 3/8 PPTs prefer to propose experiments; 2/8 to collect children spontaneous ideas on Time; 2/8 choose the spontaneous exploration after stimulus questions and 1/8 chooses stimulus questions about experiments. An approach based on operation and spontaneous ideas on Time prevails. Typical questions proposed by PPTs are: **"**if you say the word "time", what do you think about?", "which instruments for measuring time do you know?", "how can a candle help us in measuring time?", "use an hourglass to measure the time necessary to eat your snack". As a whole, the questions proposed and related to the activities with pupils are 175, categorized and resumed in Figure 8. It can be observed that the same weight is given to the expression of spontaneous ideas, prediction and interpretation;

observation and explanation questions are only a little bit less relevant. Procedural and operative indications are indeed very few, in agreement with an Inquiry Based Learning approach.

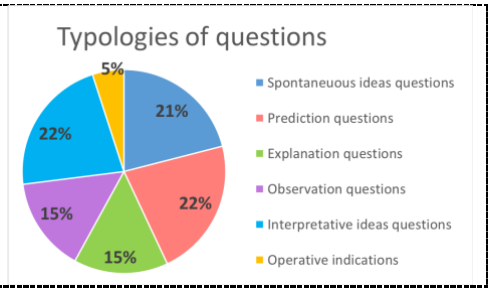

Figure 8. Categorized questions proposed by PPTs in their activities with pupils.

5.2.3 – Rationale, conceptual maps and detailed path with a description of the proposed activities
All PPTs proposed conceptual maps. Of these, 7 maps have time as their nucleus (projects addressed to primary school pupils) and 1 map, the one related to the project addressed to pre-school pupils, has as its nucleus the measure of time. The maps show 2 up to 4 branches which in turn split into other ones.
The learning paths were developed following different perspectives. The order and frequency of the addressed topics are reported in Figure 9. All the PPTs addressed the concept of interval and two PPTs put it at the first place; the concepts of time measurement, periodicity/cyclicity and irreversibility follow. Time as an entity is placed at the first position by two students. As a whole, comparing these findings with those of Rubric A (section 5.1.3 and Figure 5), we can say that students facing the practical task of implementing a formative module with pupils are less focussed on the concept of time/time as an entity and more focussed on operative aspects. As regards the activities, all the PPTs propose the calibration and use of the instruments seen in the learning path. In addition, almost all of them propose to study at least one of the following phenomena: movement of fluids/viscosity of running liquids; fusion of an ice cube on different supports; warming of a given mass of water. Only in the project addressed to pre-school children the study of these phenomena was not considered.

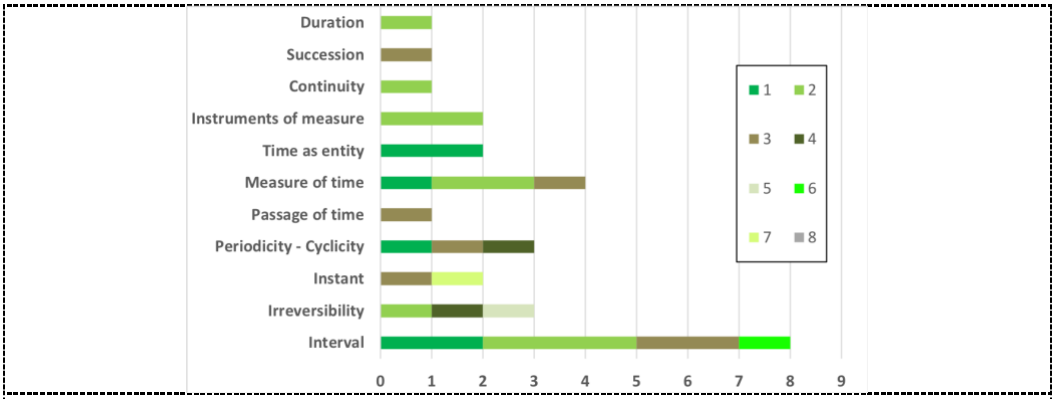

Figure 9. Addressed topics. Colours indicate the position of the element in the list. The abscissa gives the number of students who indicated the topic.

5.2.4 – Monitoring pupils learning outcomes
The instruments utilized by PPTs to monitor pupils learning outcomes are: recording pupil responses and logbooks (6); recording the type of pupil responses at each activity/stimulus (3); tutorial worksheets (3); pre- and post-tests (3); drawings (2). Data are presented using tables and graphs in all the reports. Learning outcomes have been analysed by 6/8 through a qualitative analysis of pupil answers organized into learning categories that were defined with the same phrases used by pupils in their answers. Only in 2 cases analyses were carried out by counting the number of correct, incorrect or partially correct answers. As regards the aspects that PPTs highlight as relevant in their experience with pupils we find: with respect to the children: interest, participation, attention (6/8); active role (8/8); connection with their life (4/8) - with respect to the teacher: the ability in conducting the formative intervention (4/8);

the chosen questions and statements (7/8); taking into account the children way of reasoning (2/8); being flexible (5/8). The aspects of their experience with pupils that PPTs recognize as important for the development of their professional skills were 86 and are categorized and resumed in Figure 10.

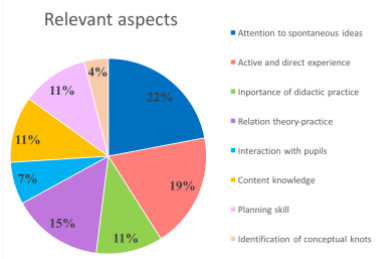

Figure 10. Categorized aspects (on a total of 86) of their experience with pupils that PPTs recognize as important for the development of their professional skills.

6. Conclusions

Transforming knowledge into practice is one of the most difficult and important tasks for future primary school teachers, which involves appropriation and re-elaboration of the knowledge of the didactic proposals analyzed. It requires contextualization choices and the creation of learning environments. This task is very difficult as it relates to transversal topics, which are multidisciplinary conceptual referents. The present study on how PPTs construct and implement an educational path on the theme of Time points out: a) the difficulties encountered by PPT and their needs; b) the topics and the methods resonant with their perspective; c) the strategies adopted and d) how they under-evaluate the coherence of path developing in a real classroom context. Although our results need further study on other classes of PPTs in order to increase their statistical significance and confirm the identified trends, some very interesting conclusions can be drawn.

First, there is a deep difference in the outcomes of the two experiences based on Rubrics A and B. Rubric A highlights that in simply *planning* a learning path PPTs don't face and don't overcome the difference between the concept of time and its measurement. The proposed projects represent an improvement of partial and qualitative suggestions that can be found in textbooks. PPTs show a marked tendency towards classification (general concepts are placed at the beginning of the learning path and are not constructed as the end-points of the educational proposal; learning is not contextualized; reference to the personal experience or to contexts in the proposed activities is relatively rare; Inquiry Based Learning strategies are not acquired) and are not able to distinguish between physical entities and phenomena (periodicity and irreversibility are mostly considered as properties of time rather than of physical phenomena). It also emerges that much attention is paid to methodologies rather than to concepts, thus indicating the need to work on the coherent connections among concepts, which are the basis for organizing a coherent learning path (maps are mostly collections of disconnected, or only partially linked, items).

On the other hand, data analysis on the eight plans of intervention-modules (Rubric B) suggests that in facing the *implementation* of an educational path PPTs adopt the proposed examples creating new learning paths in which the concepts related to the meaning of time are addressed in terms of irreversibility and time measurement. Active learning strategies are adopted and inquiry approach is based on significant concepts. Moreover, it is worth noting that, in monitoring pupils learning, PPTs explicitly declare that they have acquired another PCK competence, considering situated learning a fundamental experience in their professional development.

Notwithstanding these differences, an interesting common trait arises between the two groups working on Rubrics A and B: they don't include (except in really very few cases and only in the group working on Rubric A) the trans- and inter-disciplinary aspects of the theme of Time, even though these were strongly addressed in the introductory formative step. It seems that PPTs are not able to take advantage of this kind of given suggestions, they are poorly sensitive to interdisciplinary aspects. This sensitivity and the capability of making connections not only among concepts inside a given subject but also among different disciplinary contexts is an important competence that still needs to be better addressed in the development of the professional competence of primary school teachers.

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