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IN-DEPTH TEACHING AS ORIENTED-RESEARCH ABOUT SEASONS AND THE SUN/EARTH MODEL: EFFECTS ON CONTENT KNOWLEDGE ATTAINED BY PRE-SERVICE PRIMARY TEACHERS

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Abstract. *Pre-service primary teachers mostly have negative attitudes towards science teaching and learning, and their science background is usually low. This usually results in them feeling unable or unconfident to teach science at school. A previous step to improve their willingness to teach science to children is that they feel they can learn in-depth any science core idea. To do that, a course conducted as oriented-research about a core science problem was developed and used to evaluate the influence of their previous science background and initial attitudes towards science teaching and learning on content knowledge attainment. The chosen science idea was about diurnal astronomy (Sun movements and the Sun/Earth model). Content knowledge attainment was assessed using learning indicators, which represent what pre-service teachers should "know" and "know how" on this science core idea. Overall, pre-service teachers achieved high learning levels on this topic, and no significant differences in content knowledge attained by students according to both initial attitudes and science background were found. This suggests that this teaching methodology could be useful for pre-service teachers to achieve a thorough knowledge on science core ideas, which is considered to be an important step to improve their willingness to teach science at the primary school.*

Keywords: *astronomy education, science content knowledge, teacher education.*

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Introduction

In the Spanish primary education system, teachers are generalist teachers and so, they have to teach all curriculum areas when they are in-service. However, pre-service teachers, mainly as the result of their previous academic history, usually have negative attitudes towards science teaching and learning at the beginning of their instruction period at the university, as well as a low content knowledge on science topics. In that sense, their education period at the university should be regarded as an opportunity for them to gain content knowledge on some science topics and to develop more positive attitudes towards science, as both are required to instruct their pupils in the future. Therefore, assessing whether their initial situation has an effect in attaining the necessary content knowledge on a core idea of science to be used functionally is an important research question.

Currently, there is a general interest in instructing future primary teachers in a way that enables them to be able to teach science in accordance with scientific practices (e.g. Lawson, 2004; National Research Council, 2012). This has been widely recognized and encouraged by organizations such as the National Science Foundation (NSF), the National Research Council (NRC), the American Association for the Advancement of Science (AAAS), the European Commission and the Inter Academies Panel. In doing so, they should be taught not only the necessary methodology to do that, but also some of the necessary science content knowledge to reach that aim, as these are not separated aspects of the learning-teaching process (e.g. Plummer & Ozcelik, 2015). Therefore, though this is what should be expected during the pre-service teacher education at the university, this seems not to be an easy task to be accomplished given that there are several reasons that may preclude reaching that aim, such as:

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1. Most of pre-service primary teachers entering the university have not studied science subjects at the secondary high school; for example, 80% of pre-service teachers in the Faculty of Education of the University of Alicante (Spain) had a main pre-university education on humanities.
2. Pre-service primary teachers who had prior scientific education have been taught through a direct transmission of the scientific knowledge in its final state (i.e., without tackling the problems that lead to that scientific knowledge or concept), which is quite far away from the methodology currently encouraged.
3. Most of pre-service primary teachers, independently of their previous academic background at the high school (science or humanities), show alternative frameworks about core science ideas, with most of these prevailing during the years (e.g. Shtulman & Valcarcel, 2012).
4. Most of these pre-service primary teachers have negative attitudes towards science teaching and learning when enrolling the university (see Aalderen-Smeets, Walma van der Molen, & Asma, 2012 for a review), which are mostly the result of their "academic history" in science subjects (Jarret, 1999; Mulholland & Wallace, 1996; Palmer, 2001; Tosun, 2000; Young & Kellogg, 1993). Moreover, these negative attitudes are one of the most important reasons for future primary teachers feeling unable to understand science and even transmit the interest in science to children (Osborne, Simon, & Collins, 2003; Tosun, 2000; Van Driel, Veijaard, & Verloop, 2001; Weinburgh, 2007).

Under this scenario, it seems difficult that, in the future, pre-service primary teachers could generate appropriate classroom situations and transmit the necessary emotion to involve their students in the (re)construction of scientific knowledge. Hence, it is not surprising that most in-service primary teachers teach science by following textbooks step by step, removing from their lessons activities that are in accordance with scientific practices (as they feel unable to understand and give sense to most of these) and evaluating their students with exams that promote repetitive learning (i.e., to give the expected answers to closed questions). In fact, most of pre-service primary teachers at the University of Alicante report that, during their practicum at primary schools, this behavior (the "traditional" science teaching) is the commonest one amongst in-service primary teachers.

Therefore, changing this kind of well-established science teaching methodology amongst primary teachers is not an easy task. Future teachers are being instructed as "generalist teachers", and time devoted to science instruction during their education at the university is quite limited. Within this general framework, in some Faculties of Education, most professors choose to instruct pre-service primary teachers with a miscellaneous and general view of science education that includes both a superficial (broad) view of important concepts or ideas of science and some practical (hands-on) activities, which are helpful to show students "how things are", thus laying on an empiricist view of science learning; moreover, in most cases, these activities are expected to be reproduced as such in the future with children. In some other cases, professors completely refuse the idea of teaching scientific concepts or ideas to pre-service teachers, and only show them sequences of activities for primary science education, so they can understand and analyze these sequences for them being able to repeat those activities in their lessons when being in-service. However, those views seem not to be satisfactory for pre-service teachers to attain some content knowledge to be used as a basis to teach science according to scientific practices. When instructed about too much topics, it is very improbable that teacher students attain the necessary content knowledge level simultaneously with (and by) scientific practices and, when instructed about sequences of activities for primary children, students consider that the instructional methodology is only restricted to the children level but when "serious" learning of science is necessary the only way to do it is "traditional" teaching. Another point of view is possible, which is different to those mentioned above: attitudinal change and confidence to teach science using an inquiry-based science education (IBSE) methodology require that pre-service primary teachers have had opportunities during their formation for a "true learning" of any of the core or "big ideas" of science in a coherent manner with that expected they follow in the future to teach their pupils (National Research Council, 2012). This period of instruction must be followed by another one about science teaching sequences for children.

It is of paramount importance that pre-service teachers overcome their initial low self-efficacy beliefs to learn and teach science (Brígido, Borrachero, Bermejo, & Mellado, 2013; Cakiroglu, Capa-Aydin, & Woolfolh Hoy, 2012), which can be accomplished after showing them that they can learn in-depth any scientific core idea, and this might be expected to be achieved, regardless of their initial science background and their attitudes to science teaching and learning. According to this, the instruction process of pre-service primary teachers should not be regarded only as a process of acquiring new content knowledge, but also as a simultaneous process of evolution and change of their attitudes and thinking about science teaching and learning. The constructivist approach of teaching based in the (re)construction of knowledge by children and teachers when confronting questions and problems of scientific interest, demands teachers that can guide, know what is essential and nonessential, ask adequate questions, guess and challenge the ideas of their pupils and scaffold them, passionately, through a previously planned sequence of activities to move them forward (Gil-Pérez & Carrascosa, 1994). To do so, future primary teachers need to experience in person they are able to master some of the core or "big ideas" of science (i.e., understand it, being able to justify their thoughts based in evidence and scientific reasoning, and use it to explain and predict new situations in order to make sense to natural phenomena occurring around them; National Research Council, 1996). They can reach this aim whether they are instructed about core ideas in a coherent manner with scientific practices, i. e. by oriented-research within a problematized structure (Becerra, Gras, & Martínez-Torregrosa, 2012; Gaigher, Lederman, & Lederman, 2014). Here, "oriented-research" refers to the methodology described by Gil-Pérez & Carrascosa (1994); generally speaking, this is a problem-solving approach where teacher is the "expert researcher" that guides and orientates the students (who represent a group of novel researchers) in their work to solve a fundamental problem of interest. When doing this, they can achieve both scientific content knowledge and skills related to scientific practices. Hence, under this scenario, one of the commitments on science teaching to pre-service primary teachers during their training period at the university should be to teach science as oriented-research about core ideas, favoring an in-depth teaching of a single (or very few) science fundamental idea rather than a superficial breadth teaching of several ones.

Nonetheless, this position is not risk-free. As it has been previously stated, there are reasons that may preclude that pre-service teachers attain high levels of knowledge when taught in-depth on a core science idea according to scientific practices. Are these pre-service teachers that have not a scientific background attaining the expected learning outcomes about a science core idea? Are there significant differences in content knowledge attained between students with a previous education on science or humanities? Is this teaching methodology useful for students with initial negative attitudes to attain high content knowledge levels? Summarizing: do this in-depth teaching support the common belief that most pre-service teachers have not the "capacity" to learn difficult topics like science ones? These are the research questions addressed in the present study.

Fortunately, these are questions that can be tested. To do so, a course (four hours per week during fifteen weeks) divided in two parts was designed and carried out. First part (ca. 20 hours) is addressed for students to express their initial attitudes about science teaching and learning, for them to become aware of the possible causes of their attitudes (amongst others, conventional teaching), and to realize about their willingness and confidence for teaching science at the primary school. This part of the course is also devoted to elaborate and justify a plausible model for teaching science in accordance with the scientific practices (as far as possible and desirable at scholar level, and characterized as a problem-solving and tentative activity). The second part of the course (ca. 40 hours) is devoted to teach them one of the core ideas of science (Harlen, 2010) following the proposed model (i.e., teaching as oriented-research about core problems and questions of science). These core ideas (see below the chosen idea) are included in the primary curriculums worldwide and represent the scientific ideas that adult and scientifically literate people should have grasped at the end of their compulsory education (see also Gaigher, Lederman, & Lederman, 2014). As stated before, it is expected that teaching them in-depth this topic would represent an improvement in students' content knowledge, which could lead to an improvement of their skills to teach science in the future as guided inquiry.

To instruct pre-service teachers on a fundamental problem of science, the topic of Sun and Earth movement was chosen, which is usually treated as "Seasons" and as "Earth movements" in primary school curricula. Within this topic, two sub-problems were set up: a first more empirical sub-problem (about cycles and symmetries in Sun's movement as observed from a given place on Earth: "Are there regularities in the movement of the Sun? Can we organize time and space with them?"), followed by a second more deductive (modeling) sub-problem aimed at explaining empirical data observed when developing the first sub-problem (about a Sun/Earth model that can explain the observed cycles and symmetries in Sun movement: "How do the Sun and the Earth move for the existing cycles and symmetries to occur?"). It has been recently shown that the connection between Earth-based observations of the Sun and the movements of the Earth in space is one of the major challenges that limit student progress in this topic (Plummer & Maynard, 2014), which strengthen the idea of developing these two topics together: first observational data on Sun movement and then finding possible explanations for those data recorded as Earth-based observers.

There are several studies reporting attitudinal improvements towards science teaching and learning after teaching scientific topics as oriented-research (as acknowledged by Viennot, 2010). However, studies showing that a

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thorough content knowledge on a given topic can be attained after instruction using problem-solving approaches are still scarce. Moreover, there is little research on how to improve content knowledge of pre-service teachers (Diamond, Maerten-Rivera, Rohrer, & Lee, 2014; Fleer, 2009; Heller, Daeler, Wong, Shinohara, & Miratrix, 2012). In this work, data on content knowledge attainment level (CKAL) by pre-service primary teachers after instruction as oriented-research on the core idea of science mentioned above is presented. CKAL is measured according to learning indicators (see below for further details on these indicators), which were elaborated by experts in the topic and represent what a person should know and "know how" about a given fundamental science idea if he/she has fully understood it. To that end, this research is arranged as follows: (1) the hypothesis that guides this research is presented and justified, (2) then, classroom environment and the characteristics of the course where instruction as oriented-research is carried out are described, giving some examples, (3) the experimental design followed to test our hypothesis is described, and (4) finally, data on CKAL in pre-service primary teachers are reported, analyzed and discussed.

Hypothesis and Justification

It can be affirmed that pre-service primary teachers instructed in-depth by an oriented-research about core ideas of science (in this case, the movements of Sun and Earth) can achieve high content knowledge on the topic. Operatively, this implies to test that (i.e., the research hypothesis is):

H_1. Most of the students achieve the learning indicators, as defined by experts, on the topic; and these outcomes are, a) independent of their initial attitude towards science teaching and learning, and b) independent of their previous science background (science vs. humanities).

Why is this expected to happen? According to inquiry-based methodologies and the oriented-research approach mentioned above, there are some situations that are present in the classroom during the course. Hence, what is outlined in the abovementioned hypothesis is occurring as these following situations are promoting real learning:

1) Teaching science starting with a fundamental problem or question of interest allows a working environment where there are repeated and systematic opportunities to ask questions, doubt, share, discuss and test ideas (both their own ideas and ideas that other people have). In doing so, students propose their own ideas (predictions, hypotheses, models, explanations…) tentatively and then, they look for evidences and arguments to make advancements to solve the initial problem of interest. To this end, the professors' team had designed a sequence of activities that are proposed to pre-service teachers (which are organized in small groups in the classroom). This sequence has a structure that generates a tentative environment (see Appendix 1) and serves to orientate and guide the students in the process of investigating about the problem of interest. In this environment, pre-service primary teachers and the professor talk about what they have done in each activity, expressing their ideas about the problem that was set at the beginning, as well as their views and thoughts to every question in the sequence. For some activities, the professor provides empirical data (or reliable sources for students to find data) to help in doing the activities properly. Then, they assess, based on evidence and reasoning, if the ideas that have arisen as the result of responding the activities in the sequence made a step forward to advance in the initial problem. When the professor explains some of the aspects or concepts is because it has been created the need of his/her intervention, not just because it should be explained. This open and investigative atmosphere of early stage researchers, guided by an expert (the professor), generates a climate that encourages the emotional involvement of pre-service teachers (Gil-Pérez & Carrascosa, 1994). If students' ideas change, it is not because teaching has been planned to go against their initial ideas but because students take possession of explicit and scientific criteria to accept any idea, which can (or not) be different to "spontaneous knowledge".

2) When teaching science as oriented-research, the plan to solve the initial problem of interest represents the index of the issue (see Appendix 1): the sequence of sections, steps and activities is not arbitrary (for students) but it follows a logic structure (i.e., if this is the problem, what plan could we follow to make any advance towards its resolution?). Both students and professor should draw this plan (for students to be oriented during the research and for they to feel responsible of the plan). However,

whether students cannot propose the entire plan and it must be completed by the professor, the plan proposal must be introduced as a tentative strategy and discussed with pre-service teachers for making it comprehensible and shared by them (the complete sequences of activities are available at: http://rua.ua.es/dspace/handle/10045/71774; see the beginning of each sub-problem as examples of a plan proposal). This means that, from the beginning, it exists both a goal and a guiding thread, favoring recapitulations throughout the course (What was our problem? What have we done to make advancements on it? How much have we advanced and what still remains to be done?). Therefore, pre-service teachers progressively take possession of the problem and they feel they have played their part in the plan (Wong, Wong, & Chau, 2001). It has been shown that this structure promotes guidance and involvement of high school students in science topics (e.g. Verdú & Martínez-Torregosa, 2005). In this context of problem resolution, both students and professors introduce concepts and models in a tentative way, as inventions or well-founded hypotheses which are needed to make advancements to solve the initial problem. Therefore, activities, practical work and problem solving are integrated in a coherent manner, together with introduction of concepts and their relationship, inside the research structure (Gil-Pérez et al., 1999).

For example, the concept of "cardinal points" is introduced when students are asked whether there are changes in the sunrise and/or sunset position and whether these changes occur regularly. Then, pre-service primary teachers need taking a reference point in the horizon circumference to indicate the position of the Sun when it is on the horizon and, at the same time, this point must be universal (they cannot use local references like mountains, buildings, trees, etc. if they need to communicate data to other people). Although students recall the compass and some of them explain why it allows to obtain a reference point on the horizon to measure the Sun's position from this point, the professor points out that before the compass was invented, there were accurate measurements of sunrise and sunset positions: the shortest shadow of a vertical stick (gnomon) occurs every day on the same straight line on the ground (i.e., the Meridian line). This allows organizing the horizon from the point where this line (in the sense opposite to Sun) "intersects" with the horizon. In places where Sun moves from left to right (looking at noon), the intersection point on the horizon is called "north" (the reference point, 0º) and 360º of the horizon circumference are measured clockwise starting from the north. The position of Sun on the horizon can be given by measuring the angle between the straight line that links observer eyes with the north and the straight line that link observer eyes with the center of the Sun globe (when it rises or sets). This angle is called sunrise/sunset azimuth. More detailed examples about how other concepts or models are introduced, after students have worked on the corresponding activities of the sequences, can be also observed in the sequence of activities, such as the introduction of the concept of latitude, or the step between how the Sun and Earth are in a solstice day compared to how they are in an equinox day (being the latter the simplest situation).

3) The assessment system in oriented-research teaching is designed as a tool to enhance learning and improve teaching. It is an instrument to be aware of achievements, obstacles to overcome and to make sure of the strength of the achievements (in every student). This assessment system was elaborated by the team of professors/experts, at the same time that the sequence of activities was designed, following a protocol to make problematized teaching/learning sequences (e.g. Osuna, Martínez-Torregrosa, Carrascosa, & Verdú, 2007; Verdú & Martínez-Torregrosa, 2005), and improved several years before this research began. After a historical and epistemological study about the topic to be taught and educational research about it, professors have to identify a "guiding target", important steps or more specific goals which must be achieved to try to reach this target and obstacles to overcome (as scientific misconceptions) in each of these steps (see Appendix 2). Thus, there is a teaching plan (a plan to progress in the initial problem) and a learning itinerary (and their related obstacles) to help students to attain the expected knowledge (the important things identified within the core science idea). And, in this scenario, assessment is carried out at three different temporal scales, each of which occurs in a different "classroom climate" (Hickey et al., 2006; Ruiz-Primo, Shavelson, Hamilton, & Klein, 2002). The assessment at the immediate scale is done during discussion of activities that have been done by the small groups of students; it takes place in an open and informal atmosphere, and both students and the professor assess the work made and point out possible mistakes or difficulties that they have found

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during the task. The assessment at the close scale is done once every two weeks (at least) and it is carried out in writing, making this a more formal assessment, but it is only aimed at making students aware of the strength of their progress in the plan being followed; it takes 20 minutes and it is carried out during the lesson, or it can be an assessment done through a virtual platform about the topic that has been discussed in classroom (after finishing the test, every student get his/her mark automatically), or through a self-assessment questionnaire to identify which aspects they have not been able to master yet. Finally, the assessment at the proximal scale is carried out in a strictly formal environment (exam), in writing, at the end of each issue (in our case, two exams are done, each one after ca. 18-20 hours of instruction; see below for more details on the exams). The grading is based on learning indicators (see also below for further details on these learning indicators) and each student gets his/her exam back with comments from the professor and with a mark that shows her/his level of acquisition of these learning indicators. Students that have not attained the minimum knowledge according to these indicators (or those who want to improve their marks) do a final exam two weeks after the end of the course, which represents the assessment at the distal scale (results from this scale have not been taken into account in this research). Particular attention is given to the coherence of the assessment at the different temporal scales (guiding to the more relevant aspects, avoiding the success of repetitive learning, and highlighting the importance of reasons of what is being done -including methodological aspects-). Assessment serves as a tool to guide and encourage a successful teaching and learning and not only to give a mark to students (i.e., it must remain at the service of the teaching/learning process).

Methodology of Research

General Background

The methodology used in this research is a design-based research, aimed at showing that the methodology used to instruct pre-service primary teachers provides good results in content knowledge achievement repeatedly. To do that, a course on diurnal astronomy taught as oriented-research was developed to instruct future primary teachers during their education at the university, and it was implemented on six different groups of pre-service teachers at the Faculty of Education of the University of Alicante (Spain).

Content knowledge attainment levels were defined according to the acquisition of learning indicators by pre-service teachers in exams, and the percentage of students in every content knowledge attainment level was calculated. To investigate on the hypothesis previously defined, differences in percentage of students in every content knowledge level in relation to previous education and initial attitudes towards science teaching and learning were explored.

Professors Involved

Taking into account that it was not possible to get other equivalent control groups (i.e., taught with other methodologies but pursuing the same aims), this research is mostly based in showing the consistency in results obtained by repeating the same course in different years and with different professors. That is to say, obtaining good results in content knowledge achieved by pre-service teachers in different years and with different professors should be considered as an indicator of success. Therefore, the same sequence of activities mentioned above was repeated six times (i.e., with six different groups of pre-service teachers), with three different professors and during three consecutive years (two groups per year). All the three professors (namely A, B and C) prepared, revised and used the same sequence of activities, as well as the same assessment system described above. Professor A is an Associate Professor, Professor B is a Full Professor and Professor C is an Assistant Professor. In the first and second year of the research, professors that participated were A and B, whereas in the third year of the research, professors involved were A and C. Professor A taught for the first time at the university during the first year of the research, but he had previous experience teaching as oriented-research this core idea at the high school. In his first year at the university, this professor enrolled when the course had already begun and hence, he only taught the second part of the course (i.e., the part devoted to teaching the scientific content; group A1, see Table 1). Professor C taught the course for her very first time for this research, but she had attended and analyzed the classes of Professor B during the two previous years (i.e., when this research began). Professor B had taught the same course with the same sequence of activities during several years prior to the beginning of this research. It was decided to introduce a new professor in the study (professor C) to test whether a professor teaching the topic for the first time could get from pre-service teachers the same content knowledge attainment than that achieved by more experienced professors; if so, this might be an indication of the strength of the teaching methodology. For all the three professors, mean intervention time during the classes (i.e., time invested to speak) was barely 50% of the total time of the classes, and the rest of the time was devoted for students to respond and discuss the proposed activities.

Sample

Given that in the Faculty of Education at the University of Alicante was not possible to create groups of pre-service teachers taken at random, to undertake this research, groups that had the same timetable and where people enrolled in them in the same dates were chosen, which is equivalent to having the same mean qualifications in the prior (first) course at the university (i.e., having the same grade point average –GPA-). Therefore, the six groups considered in this research were academically homogeneous, and these were randomly endorsed to a given professor every year (number of students in each group is presented in Table 1).

Table 1. Composition, previous scientific background and initial attitudes towards science teaching and learning (as percentage) of six groups of pre-service primary teachers.

Group	Teacher*	Academic year	Number of students	Science (%)	Humanities (%)	Initial attitudes towards science teaching and learning		
						Negative (%)	Neutral (%)	Positive (%)
A1	A	2012-13	52	13	87	45	34	21
B1	B	2012-13	51	24	76	53	20	27
A2	A	2013-14	56	16	84	55	19	26
B2	B	2013-14	54	15	85	57	17	26
A3	A	2014-15	45	22	78	65	11	24
C3	C	2014-15	44	23	77	66	15	19
GLOBAL			302	19	81	57	19	24

** Teacher A: Associate Professor; Teacher B: Full Professor; Teacher C: Assistant Professor (see text for further details).*

Instruments and Procedures

Assessing the Initial Attitudes of Pre-service Primary Teachers to Science Teaching and Learning

In the first session of the course, a questionnaire was used to obtain data on the students' background education (i.e., to assign to every pre-service teacher a prior education: science or humanities). Other two questions in that questionnaire were used to assign the initial attitudes of pre-service primary teachers towards science teaching and learning, which were classified as positive, neutral or negative. These two questions were:

1. If you were an in-service primary teacher and you could choose the contents you are teaching, what subject would this be about? Please score the following subjects from 0 to 10 (0 = if I can, I would never choose contents of this subject; 10 = if I can, I would much like to choose contents of this subject):

   History: Geography: Language: Mathematics:
   Biology: Geology: Physics: Chemistry: Others:

2. Please, indicate two subjects to which you have quite negative attitudes, and two to which you have quite positive attitudes.

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In the first one, they had to score to what extent they were confident and feel able to teach contents of several subjects when they become in-service primary teachers; from all these, the score given to Physics was used to assess their initial attitudes given that, amongst all these, the topic that was being taught to them was mostly related to Physics (nonetheless, they did not know which science topic was going to be taught during the course at the time of completing this initial questionnaire). Previous research reveals that primary teachers usually have a negative attitude towards teaching and learning Physics and Chemistry, whereas their attitudes to Biology are usually positive (e.g. Osborne & Collins, 2001). The second question used to assess their attitudes to science was to ask them to indicate two subjects for which they feel to have overall positive attitudes and two for which they had overall negative attitudes.

With responses to these two questions from each student, it was considered that they had negative attitudes to science if they scored Physics with 4 or lower, or if they specifically mentioned having overall negative attitudes to at least one science discipline (Physics, Chemistry or Biology). If Physics was scored with 5 or 6, and they did not mention having negative attitudes to any science subject, their attitude to science was considered neutral. Finally, if they scored Physics with 7 or higher, or said to have positive attitudes to at least one science subject, it was considered to have positive attitude to science teaching and learning. Responses to these two questions were highly consistent; this is to say, if they mentioned overall positive attitudes to science, Physics was scored with 7 or higher; and the same applied to negative attitudes, scoring Physics with 4 or lower.

Assessing Learning Level of Pre-service Primary Teachers

It is important to mention here that a pre-test (with the same questions used in the exams) was not used to evaluate the initial content knowledge that pre-service teachers had on the topic being taught, but the pre-test used had the same learning indicators as the exams had (see below). This pre-test was a questionnaire with a set of 15 questions about diurnal astronomy written in plain words (e.g. in which period of the year can we record the longest and shortest daytime duration?; Could you use Sun path to accurately determine cardinal points?) that students had to fill out before starting the course. Hence, these questions were much easier than those being asked to them in the exams as, for sure, students were not able to answer the exam questions before instruction. Almost all responses given to these questions by all the students involved in the research were wrong or not properly justified and, any of the students answered correctly all those questions (authors unpublished data). Therefore, it can be assumed that all pre-service teachers had a restricted content knowledge on the topic (at least on the fundamental questions being taught to them). To avoid making this paper excessively long, these results are not included here, as they only represent a repetition of results presented here. However, it was necessary making here an indication of the initial content knowledge level of these pre-service teachers, to highlight the thorough content knowledge they achieve after instruction.

To measure content knowledge attainment level (CKAL) on the topic by pre-service teachers after instruction, a set of learning indicators were developed at the same time that the sequence of activities was designed. These learning indicators were developed by experts on the subject and were modified (adapted and improved) in the previous years before this research began (the considered learning indicators are listed in the Appendix 3); these indicators represent what a student that has fully understood the topics being taught should have learnt ("know" and "know how") after instruction. And, to assess to what extent students attain these learning indicators, two exams were used (prepared by the professors involved in the course together with an external consulter, who is expert in the topic being taught) to be done at the end of each sub-problem (i.e., at the proximal temporal scale), which were scored using a grading sheet based on the learning indicators. An example of the exams is shown in Figure 1, and the criteria and procedures used to analyze and score the students' responses (grading sheet) are presented in Tables 2 and 3.

Table 2. Criteria used to grade CKAL about first sub-problem (Are there regularities in the movement of the Sun?) according to items on the exam (see Figure 1a).

(a) Does he/she know Sun cycles and symmetries, so he/she can use these for temporal and spatial orientation?
(a.1) Can he/she obtain and use observational data on Sun movement for temporal and spatial location in Alicante? (NO: 0; YES: 1 (some errors but not fundamental ones), 2 (without or very minor errors)) "Yes" to this question implies that, when students are given any value of daylight duration, Sun culmination or sunrise/sunset azimuth in Alicante, and its tendency of change, they can identify to which date (± 1 week) this value belongs to and calculate the rest values of the variables used to describe Sun movement (i.e., if they are given sunrise azimuth in a day in a period when it is moving towards the north, they are able to calculate sunset azimuth, culmination and daylight duration, as well as the date when that measure was recorded). That is to say, they should know daily and monthly variations in these variables during the whole year in Alicante (graphically and integrating them in a rational scheme).
(a.2) Does he/she know Sun cycles and symmetries anywhere? (NO: 0; YES: 1 (some errors but not fundamental ones), 2 (without or very minor errors)) "Yes" to this question implies that, when students are given values of the abovementioned variables describing Sun movement in a solstice day in an unknown place on Earth, they can calculate the rest of the values of these variables of the other solstice and equinox days. Contrary to criterion (a.1), pre-service teachers should not know daily (or monthly) variations of these variables everywhere in the world, but they should know and understand the symmetries in Sun movement existing between solstice and equinox days.

Table 3. Criteria used to grade CKAL about second sub-problem (How do Sun and Earth move for the existing cycles and symmetries to occur?) according to items on the exam (see Figure 1b).

(b) Does he/she understand the Sun/Earth model, so he can use it to make predictions on how the Sun path could be seen at any part of the world during the year?
(b.1) Can he/she locate a place on Earth using observational data on Sun movement at that place (and vice versa)? (NO: 0; YES: 1 (some errors but not fundamental ones), 2 (without or very minor errors)) "Yes" to this question implies that students can calculate the value of Sun culmination and hour of the day when it is seen (the difference with Greenwich) in an equinox day at any place when they are given the coordinates of that site (latitude and longitude). And, vice versa, they can also locate a place on Earth when they are given Sun culmination and time (the difference with Greenwich) when it is seen at that place in a solstice or equinox day (i.e., they can calculate latitude and longitude of any place using observational data on Sun culmination in any of the solstice or equinox days at that site).
(b.2) Can he/she relate the movement of Sun in the local horizon with the position of Earth in its orbit around the Sun? (NO: 0; YES: 1 (some errors but not fundamental ones), 2 (without or very minor errors)) "Yes" to that question implies that, when students are given the latitude of any place and the value of Sun culmination at that site in a moment of the year when days are becoming longer or shorter, they can correctly identify the season and make a draw of where the Earth is in its orbit around the Sun (in relation to where the Earth is in solstice and equinox days).

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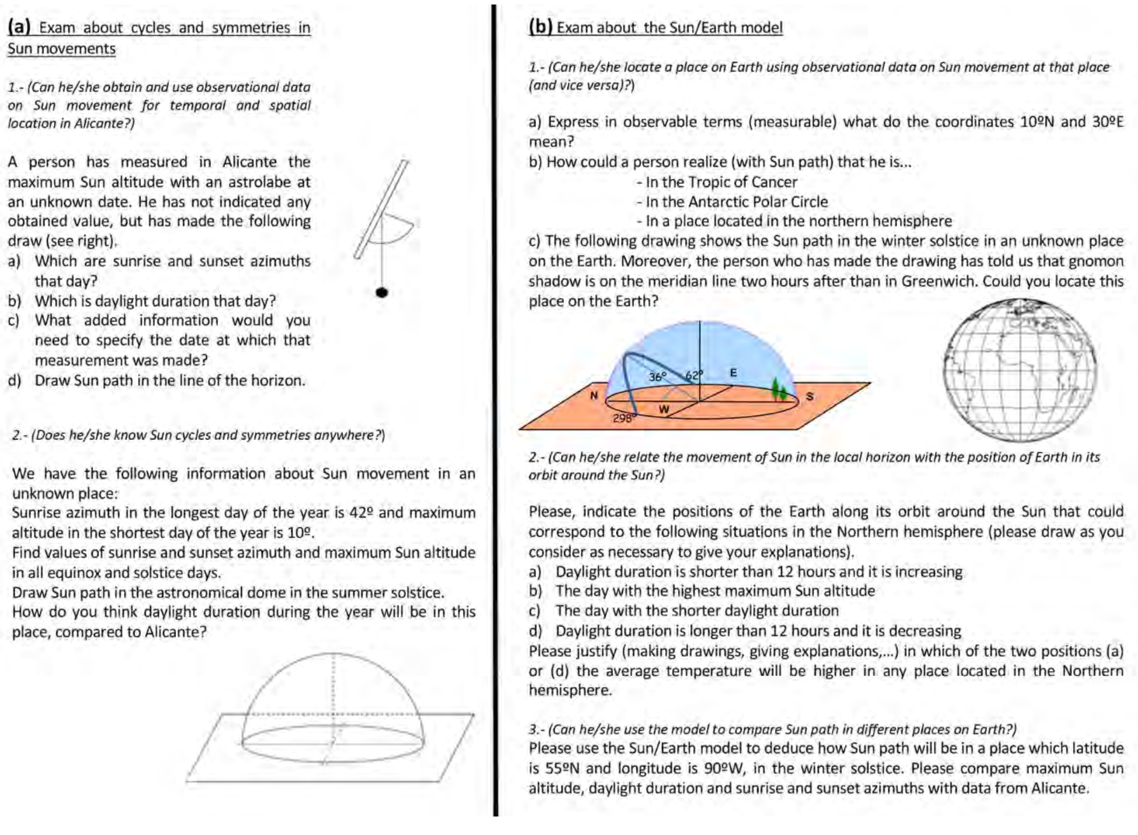
(b.3) Can he/she use the model to compare Sun path in different places on Earth? (NO: 0; YES: 1 (some errors but not fundamental ones), 2 (without or very minor errors))

Students are asked here to compare values of variables describing Sun path in a solstice day (summer or winter) between Alicante and other place on Earth (which could be in Northern or Southern Hemisphere). Hence, "Yes" to this question means that, when students are given the coordinates of any place in the world (they must know the coordinates of Alicante), they can make a draw of a lateral view of Earth in the indicated solstice day to represent the Sun culmination value occurring at both sites in that day; they can also draw a zenithal view of Earth (i.e., as seen from "above" the North Pole, quite far away) to qualitative compare sunrise and sunset azimuths (closer or further from south/north) at both sites, as well as to deduce whether daylight duration is longer in Alicante or the other place in that solstice day.



(a) Exam about cycles and symmetries in Sun movements

1.- (Can he/she obtain and use observational data on Sun movement for temporal and spatial location in Alicante?)

A person has measured in Alicante the maximum Sun altitude with an astrolabe at an unknown date. He has not indicated any obtained value, but has made the following draw (see right).

a) Which are sunrise and sunset azimuths that day?
b) Which is daylight duration that day?
c) What added information would you need to specify the date at which that measurement was made?
d) Draw Sun path in the line of the horizon.

2.- (Does he/she know Sun cycles and symmetries anywhere?)

We have the following information about Sun movement in an unknown place:
Sunrise azimuth in the longest day of the year is 42º and maximum altitude in the shortest day of the year is 10º.
Find values of sunrise and sunset azimuth and maximum Sun altitude in all equinox and solstice days.
Draw Sun path in the astronomical dome in the summer solstice.
How do you think daylight duration during the year will be in this place, compared to Alicante?

(b) Exam about the Sun/Earth model

1.- (Can he/she locate a place on Earth using observational data on Sun movement at that place (and vice versa)?)

a) Express in observable terms (measurable) what do the coordinates 10ºN and 30ºE mean?
b) How could a person realize (with Sun path) that he is...
- In the Tropic of Cancer
- In the Antarctic Polar Circle
- In a place located in the northern hemisphere

c) The following drawing shows the Sun path in the winter solstice in an unknown place on the Earth. Moreover, the person who has made the drawing has told us that gnomon shadow is on the meridian line two hours after than in Greenwich. Could you locate this place on the Earth?

2.- (Can he/she relate the movement of Sun in the local horizon with the position of Earth in its orbit around the Sun?)

Please, indicate the positions of the Earth along its orbit around the Sun that could correspond to the following situations in the Northern hemisphere (please draw as you consider as necessary to give your explanations).

a) Daylight duration is shorter than 12 hours and it is increasing
b) The day with the highest maximum Sun altitude
c) The day with the shorter daylight duration
d) Daylight duration is longer than 12 hours and it is decreasing

Please justify (making drawings, giving explanations,...) in which of the two positions (a) or (d) the average temperature will be higher in any place located in the Northern hemisphere.

3.- (Can he/she use the model to compare Sun path in different places on Earth?)
Please use the Sun/Earth model to deduce how Sun path will be in a place which latitude is 55ºN and longitude is 90ºW, in the winter solstice. Please compare maximum Sun altitude, daylight duration and sunrise and sunset azimuths with data from Alicante.

Figure 1: An example of the exams used to assess content knowledge attainment by pre-service primary teachers in both sub-problems.

(a) cycles and symmetries in Sun movement and (b) Sun/Earth model. For each exam, criteria used to assess the attainment level are written in italics above each question (see Tables 2 and 3 for further details).

A three-level scale (0, 1 and 2) was used to score the level of attainment of every criterion (see Tables 2 and 3). Two independent referees reviewed the students' answers to these questions. None of these referees were a professor involved in this research (i.e., qualifications of exams given by professors were not used). To do this, the two independent referees first decided how to qualify the responses given by students in the exams and then reviewed and gave qualifications by separate to questions in five exams chosen at random; then, they brought together their qualifications to every question and discussed any discrepancies observed. After doing this, they reviewed 10 more exams by separate and brought together again the qualifications given, until the agreement

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rate was equal or higher than 90% (Hogan & Maglienti, 2001), which was successfully accomplished after the first attempt. With this agreement in qualifications achieved, the remaining exams were split in two equal parts and only one referee corrected each half for scoring. After all questions were scored, an overall qualification to both exams should be given (i.e., every student had to have an overall mark for both sub-problems). To this end, it was necessary to account for the qualifications given to each question in the exams and number of questions on them. Hence, for each exam, the qualifications given to every question on them were taken into account to make a reclassification into a four-level scale as follows: (0) student has not reached the expected content knowledge, as they present fundamental errors in concepts or their reasoning; (1) student has reached the expected content knowledge but they show some errors, although not fundamental; (2) student has reached the expected content knowledge, showing only some minor errors in reasoning; and (3) student has fully reached the expected content knowledge and responses are nearly perfect or perfect. The possible combinations of marks given to each question on the exams and the global mark given to exams of every student are summarized in Table 4. Hence, every student was given a single mark for both exams, which were used for further analyses.

Table 4. Combinations of individual marks to questions on the exams that lead to marks on both exams used to measure content knowledge attainment level of pre-service primary teachers on the topic. The order of marks to questions is not important for the final four-level mark to exams.

EXAM ON CYCLES AND SYMMETRIES IN SUN MOVEMENT	
Four-level scale score	Possible combinations of scores to individual questions
0	0 0
	1 0
1	1 1
2	2 1
3	2 2

EXAM ON SUN/EARTH MODEL	
Four-level scale score	Possible combinations of scores to individual questions
0	0 0 0
	0 0 1
	0 0 2
1	0 1 1
	2 1 0
	1 1 1
2	2 2 0
	2 1 1
3	2 2 1
	2 2 2

Data Analysis

To assess the possible effect of both the previous education and the initial attitudes towards science teaching and learning on CKAL, chi-squared tests in contingency tables were used to compare the percentage of students on every content knowledge levels for both sub-problems in relation to these variables. The same analyses were done for every group by separate, as well as for the total of students considered in the study.

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Results of Research

Number of students involved in the research, as well as the previous formation of students and initial attitudes towards science teaching and learning are presented in Table 1. Overall, 81% of the pre-service teachers did not take any science subject during their high school education, and there were no significant differences between the six groups according to their previous education (χ^2_5= 3.37; p = .644). Similarly, there were no significant differences in percentage of students with the same attitudes between groups (χ^2_{10} = 12.89; p = .230) and, overall, more than 50% of pre-service teachers had negative attitudes towards science teaching and learning.

The percentage of students in every content knowledge attainment level (CKAL) in both exams is presented in Table 5. Overall, nearly 70% of pre-service teachers can spatially and temporally orientate by obtaining and using data on Sun path (see in Table 2 the criteria used to assess students' outcomes for the first sub-problem and exams in Figure 1a), only using a piece of paper, a pencil and a calculator for simple calculations. Regarding the results for the second sub-problem (Sun/Earth model), 76% of students have functionally learnt to use the Sun/Earth model. That is to say, they can, using only a piece of paper, a pencil and drawing instruments, locate an observer on the Earth using data on Sun path at that site; also, they can deduce how Sun path would be in an unknown site in solstice and equinox days, only knowing the coordinates of that site (see in Table 3 the criteria used to assess students' outcomes for the second sub-problem and exams in Figure 1b).

Moreover, there was a steady improvement in results attained by students during the study period, reaching a 90% of students attaining the expected content knowledge on the topic in the last year of the study. A possible explanation for this is that the professors' team analyzed the difficulties that students had during the first two years of the study (for example, the use of instruments to get some data, such as the protractor, mistakes in calculations, and difficulties to represent an observer on the Earth with a gnomon, horizontal plane and cardinal points) and introduced specific additional activities to overcome these most-common difficulties during the last year of the study. Finally, it is also remarkable the low percentage of students that abandoned the course (those that did the first exam but not the second, less than 5% on average).

Table 5. Levels of attainment achieved by the six groups of primary teacher students on cycles and symmetries of Sun's movement and on the Sun-Earth model, after teaching structured as oriented-research.

Knowledge attainment level	Year 2012-13		Year 2013-14		Year 2014-15		Global
Does he/she know Sun cycles and symmetries, so he can use these for temporal and spatial orientation?	Group A1 (n=52) %	Group B1 (n=51) %	Group A2 (n=56) %	Group B2 (n=54) %	Group A3 (n=45) %	Group C3 (n=44) %	(n=302) %
0. No	60	39	34	35	9	16	33
• Yes (total)	40	61	66	65	91	84	67
1. although with some errors	20	17	23	17	16	20	19
2. with some minor errors	10	22	31	26	33	25	25
3. with no errors	10	22	12	22	42	39	23
Does he/she understand the Sun/Earth model, so he can use it to make predictions on how the Sun path could be seen at any part of the world during the year?	Group A1 (n=48) %	Group B1 (n=46) %	Group A2 (n=54) %	Group B2 (n=51) %	Group A3 (n=44) %	Group C3 (n=44) %	(n=287) %
0. No	35	43	13	27	9	14	24
• Yes (total)	65	57	87	73	91	86	76
1. although with some errors	27	33	42	37	36	20	33
2. with some minor errors	23	9	19	22	23	23	20
3. with no errors	15	15	26	14	32	43	23

Note: Results are expressed in percentage of students achieving different levels according to learning indicators.

Influence of Prior Scientific Background

One of the most important concerns that were considered at the beginning of the research was that doing an in-depth teaching of scientific contents could generate significant differences in learning outcomes of students according to their previous academic background (science vs. humanities). If pre-service teachers with humanities background (which are most of the students) obtain bad results in exams, this may result in a decrease in their confidence and willingness to learn and teach science. Results on CKAL obtained for the six groups according to their previous education are shown in Table 6. Percentages of pre-service teachers that achieve the minimum expected content knowledge for the two sub-problems (i.e., those in level one or higher according to the correction criteria) are also illustrated in Figure 2. However, that concerning situation has not occurred: when considering the six groups together, there was no significant differences in percentage of students achieving every knowledge level according to their background education for both the cycles ($\chi^2_3 = 3.31$; $p = .347$) and the model ($\chi^2_3 = 7.17$; $p = .067$) exams. When comparing data within each one of the groups by separate for the cycles' exam, only significant marginal differences were found in the group B2 ($\chi^2_3 = 7.85$; $p = .049$, with $p > .06$ for the rest of the groups; see Table 6 and Figure 2a). Interestingly, in this group, the significant differences arose as a consequence of a higher percentage of students with a humanities background attaining the expected content knowledge, compared to those that had a scientific education. The same analysis revealed no significant differences in any of the six groups for the exam on the Sun/Earth model ($p > .290$ in all the cases, see Table 6 and Figure 2b).

Influence of Initial Attitudes Towards Science Learning and Teaching

Table 7 shows results on CKAL of pre-service teachers according to their initial attitude towards science teaching and learning. Overall, when considering data from all groups together, there were no significant differences in content knowledge attained according to initial attitudes neither for the exam on cycles ($\chi^2_6 = 8.42$; $p = .209$) nor for the exam on the Sun/Earth model ($\chi^2_6 = 9.22$; $p = .162$). The same was true within each of the six groups in both exams ($p > .241$ in all cases), except for the group B2, in the model exam, where significant differences were found in content knowledge attained in relation to their initial attitudes ($\chi^2_6 = 14.52$; $p = .024$; see Table 7b); in this group the percentage of students with positive initial attitude attaining the learning indicators was higher (85%) than for the other categories (70% for students with negative initial attitude). Nevertheless, percentage of students achieving the upper levels (i.e., attainment levels two or three) was higher in those that had negative or neutral attitudes compared to those with positive attitudes. Figure 3 shows the percentage of students attaining the expected content knowledge on the topic (i.e., in level one or higher) for the two sub-problems.

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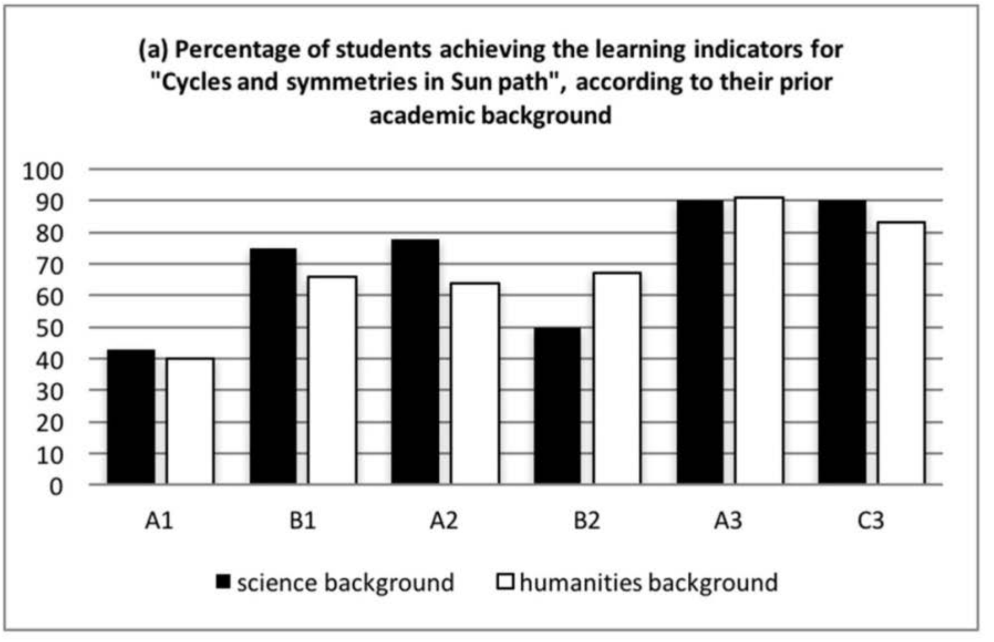


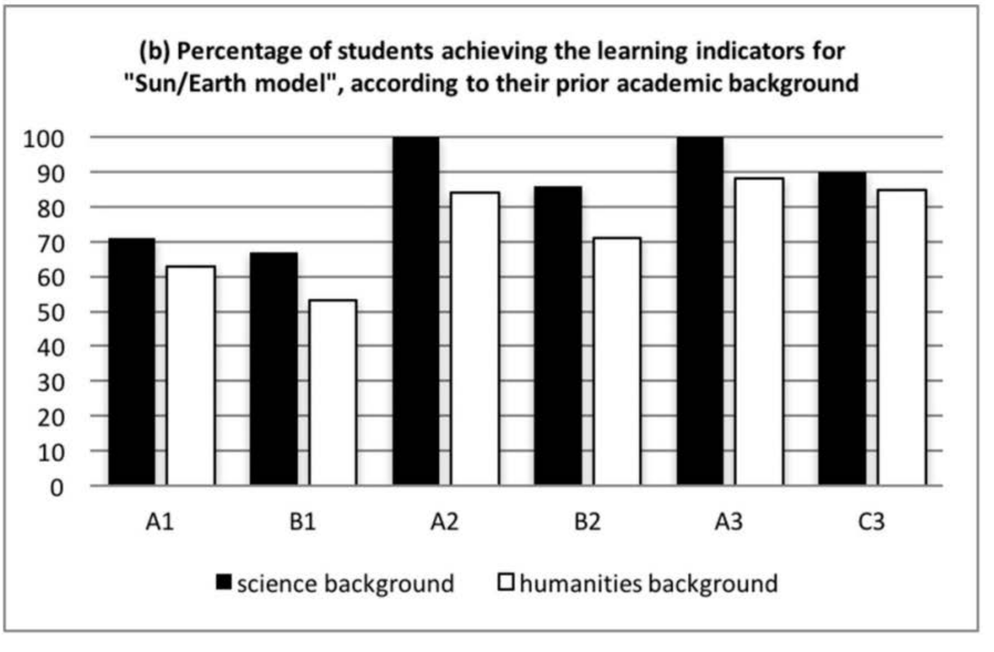
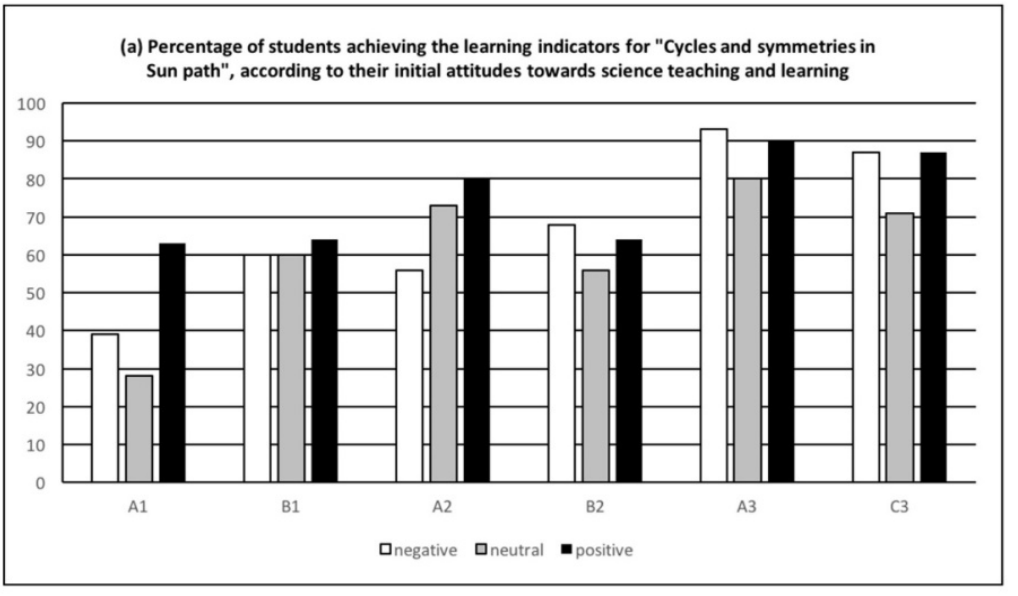


Figure 2: Percentage of students achieving the learning indicators for the two sub-problems according to their prior academic background.



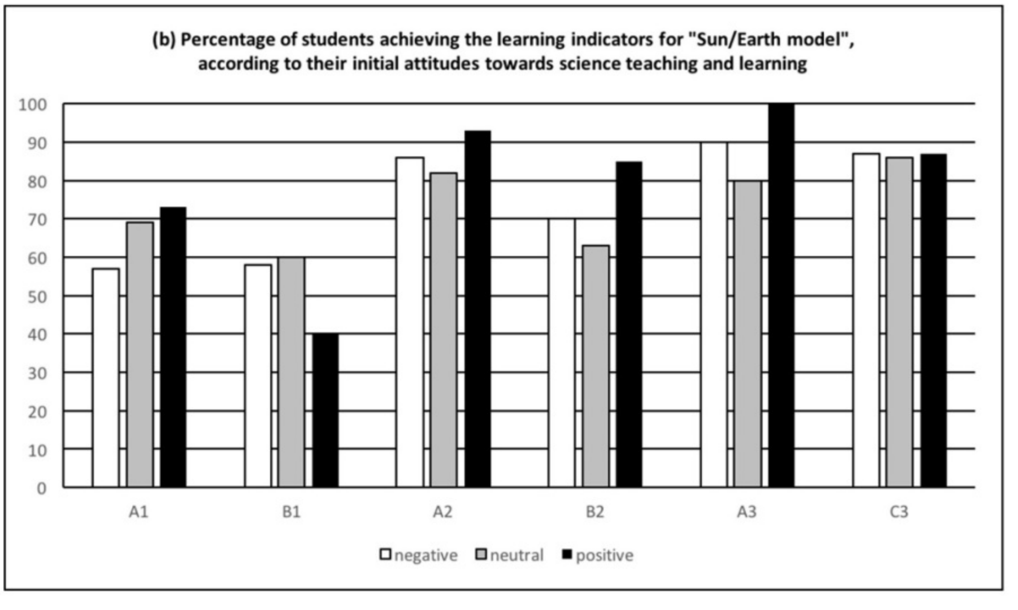


Figure 3: **Percentage of students achieving the learning indicators for the two sub-problems according to their initial attitudes towards science teaching and learning.**

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Table 6. Content knowledge achieved by pre-service primary teachers in the two sub-problems according to their background education (science or humanities). Results are presented as the percentage of students achieving every knowledge level, for each of the six groups considered in the research.

(6a) Cycles and symmetries in Sun movement

Know. Level	A1		B1		A2		B2		A3		C3	
	Sci (n=7)	Human (n=45)	Sci (n=12)	Human (n=39)	Sci (n=9)	Human (n=47)	Sci (n=8)	Human (n=46)	Sci (n=10)	Human (n=35)	Sci (n=10)	Human (n=34)
0	57	60	25	44	22	36	50	33	10	9	10	17
1	14	20	25	15	0	28	0	20	20	14	20	21
2	0	13	42	15	67	23	0	30	20	37	40	21
3	29	7	8	26	11	13	50	17	50	40	30	41

(6b) Sun/Earth model

Know. Level	A1		B1		A2		B2		A3		C3	
	Sci (n=7)	Human (n=41)	Sci (n=12)	Human (n=34)	Sci (n=9)	Human (n=45)	Sci (n=7)	Human (n=44)	Sci (n=10)	Human (n=34)	Sci (n=10)	Human (n=34)
0	29	37	33	47	0	16	14	29	0	12	10	15
1	13	29	33	32	33	44	58	34	20	41	30	17
2	29	22	9	9	22	18	14	23	30	21	10	27
3	29	12	25	12	45	22	14	14	50	26	50	41

Knowledge level: (0) student has not reached the learning indicators as they present fundamental errors in concepts or their reasoning; (1) student has reached the learning indicators but show some errors, although not fundamental; (2) student has reached the learning indicators, showing only some minor errors in reasoning; and (3) student has fully reached the learning indicators and responses are nearly perfect or perfect.

Table 7. Content knowledge achieved by pre-service primary teachers in the two sub-problems according to their initial attitudes towards science teaching and learning (negative, neutral or positive). Results are presented as the percentage of students achieving every knowledge level, for each of the six groups considered in the research.

(7a) Cycles and symmetries in Sun movement

Initial attitude	A1			B1			A2			B2			A3			C3		
	Negative	Neutral	Positive	Negative	Neutral	Positive	Negative	Neutral	Positive	Negative	Neutral	Positive	Negative	Neutral	Positive	Negative	Neutral	Positive
	(n=23)	(n=18)	(n=11)	(n=27)	(n=10)	(n=14)	(n=30)	(n=11)	(n=15)	(n=31)	(n=9)	(n=14)	(n=30)	(n=5)	(n=10)	(n=30)	(n=7)	(n=8)
0	61	72	37	40	40	36	44	27	20	32	44	36	7	20	10	13	29	13
1	17	22	18	19	20	14	23	19	27	19	0	21	13	20	20	27	0	13
2	13	6	18	19	30	21	23	27	46	26	44	14	43	20	10	23	42	13
3	9	0	27	22	10	29	10	27	7	23	12	29	37	40	60	37	29	61

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(7b) Sun/Earth model

Initial attitude	A1			B1			A2			B2			A3			C3		
	Negative	Neutral	Positive	Negative	Neutral	Positive	Negative	Neutral	Positive	Negative	Neutral	Positive	Negative	Neutral	Positive	Negative	Neutral	Positive
	(n=21)	(n=16)	(n=11)	(n=24)	(n=10)	(n=12)	(n=28)	(n=11)	(n=15)	(n=30)	(n=8)	(n=13)	(n=30)	(n=5)	(n=9)	(n=30)	(n=7)	(n=8)
0	43	31	27	42	40	50	14	18	7	30	37	15	10	20	0	13	14	13
1	29	25	27	42	30	17	39	46	46	20	37	77	40	20	33	20	29	13
2	19	31	19	12	10	0	22	9	20	33	13	0	23	40	11	30	0	13
3	9	13	27	4	20	33	25	27	27	17	13	8	27	20	56	37	57	61

Knowledge level: (0) student has not reached the learning indicators as they present fundamental errors in concepts or their reasoning; (1) student has reached the learning indicators but show some errors, although not fundamental; (2) student has reached the learning indicators, showing only some minor errors in reasoning; and (3) student has fully reached the learning indicators and responses are nearly perfect or perfect.

Discussion

Here, it has been found that most of pre-service teachers achieve an in-depth knowledge on observable data of Sun's movement and the related Sun/Earth model that can explain the empirical data we could record from the Earth, and that content knowledge achievement is independent of their previous academic background and their initial attitudes, when teaching is carried out using this investigative approach.

This is an important fact because it is well known that in many developed countries there is a decrease in numbers of young people taking up studies in science (Harlen, 2010). It is common amongst most pre-service primary teachers at the university to believe that they are not as clever as those people that study science during their high school education. That is the reason for most of them having taken humanity subjects at the secondary level, and also for most of them having overall negative attitudes towards science teaching and learning (as they feel unable to understand and teach science). On the other hand, those pre-service teachers having studied science at the primary and secondary levels, they feel that content knowledge acquired is not enough to respond scientific questions when confronting the real word. Independently of their background education, they remember these contents as to be memorized, without having a "real" understanding of what they mean, including a lot of formulas that they feel to be completely useless. And hence, when they arrive to the university, they feel unable to teach science when being in-service at the primary school, despite them having to do so. As stated earlier in the introduction, the first step to increase willingness of primary teachers to teach science is to show them that they are able to learn in-depth a core idea of science and use this content knowledge to explain natural phenomena. If they have a full understanding of a science topic, they will feel more confident to develop inquiry-based lessons in the future (Plummer & Ozcelik, 2015).

There are several studies that report improvements in content knowledge on diurnal astronomy of pre-service teachers after instruction using different teaching methodologies (e.g. Lelliott & Rollnick, 2010; Plummer, Zahm, & Rice, 2010; Trumper, 2006). The main difference of most of these studies with results presented here is that students of the University of Alicante have reached a very in-depth and meaningful knowledge of the topic. For example, if they are just given a value of Sun maximum height in a solstice day and time difference at which midday occurs respect to Greenwich, in an unknown place of the world, they can deduce and properly justify where that place is on the Earth. And this is a good functional knowledge of the topic, specially taking into account the initial overall feeling amongst students of their inefficacy to understand science topics.

As mentioned above, these results were obtained using the same sequence of activities and the same teaching methodology, from six different groups of pre-service teachers, taught by three different professors and during three consecutive years. Therefore, it can be affirmed that when pre-service primary teachers are taught in-depth on a science core idea (in this case, how should the Sun and the Earth move for us to observe the existing cycles and symmetries in Sun movement?) using a methodology that is in accordance with scientific practices, they attain a good functional learning on the topic ("know" and "know how"). Obtaining very similar results repeatedly

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(with different students and different professors), reinforce the idea that this teaching methodology is appropriate for students to get a detailed and functional knowledge on a core idea of science as a previous step for them to feel confident to teach science in the future. Similar results were obtained by Trumper (2006) when using also a constructivist approach to teach this topic to future elementary and high school teachers.

On the other hand, it has been also found that teaching science to future primary teachers using the proposed methodology (and using the planned problematized sequence of activities) results in a good content knowledge achievement by pre-service teachers even when teaching is carried out by novel professors. Professor C obtained quite good results in her group the very first time she taught the course; nonetheless, it was helpful to attend classes of the "expert" professor (professor B in this research), to have an idea on how to behave in the classroom and how to carry out the sequence of activities to obtain the necessary attitudinal involvement of pre-service teachers in the course for them to attain high levels of learning on the topics. Moreover, there is also a progressive improvement on results obtained by the same professor during consecutive years, as shown in results observed for professor A; despite that the results obtained in the first year may be due to the fact that the professor enrolled the course when it had already begun, there is also an improvement in content knowledge attainment by students from their groups between the second and third year of the research.

The teaching methodology proposed here has been a very useful tool not only to get an in-depth knowledge on that topic but also it could have a positive effect in teachers' confidence to teach core science ideas in the way that is expected (and desired) to teach. Data recorded in this research indicate that it is possible to overcome the initial concerns of students on their ability to teach science. As they feel that they have achieved a very good content knowledge on a science topic, this enables the opportunity for them to develop a metacognitive awareness of their own learning (Heywood & Parker, 2010). It is likely that this very in-depth content knowledge achievement has occurred as they have been guided during their instruction process to overcome the obstacles that were previously identified. This teaching methodology has been also encouraged in the Next Generation Science Standards (National Research Council, 2015; page 11), which suggests removing from lessons the traditional oversimplification of activities for students who are perceived to be less able to do science and engineering. If they feel they have fully understood a "complex" issue, they will be probably more confident to teach science in the future. When pre-service teachers take inquiry-based science courses, they are better prepared to teach using this methodology than when only traditional courses are taken (e.g. Avraamidou & Zembal-Saul, 2010; Luera, Moyer, & Everett, 2005).

Conclusions

In this research, it has been shown that pre-service primary teachers can get a very complete and detailed knowledge on a science topic when taught using an oriented-research approach, and this knowledge level is attained regardless the initial attitudes and previous education they had. This indicates that these initial traits of pre-service teachers do not have a significant effect when these students had to get an in-depth content knowledge on a science topic. Therefore, these initial attitudes and previous education cannot be regarded as an obstacle in pre-service teacher education, which was one of the possible risks that can be faced when trying to teach them a scientific topic in depth. Overcoming these initial concerns amongst pre-service teachers it is quite important in their training period at the University, especially if it is expected them to be able to teach science to their pupils in the future using an inquiry-based approach. Based on previous studies that stress the importance of these types of methodologies in science teaching and learning, the good content knowledge level achieved by these students is the result of conducting the course following an investigative approach. These results are useful for students to overcome their initial concerns they have on their ability to learn (and teach) science topics, realizing that it is possible to get an in-depth knowledge on a science topic despite their initial overall negative attitudes and their previous background on science content knowledge.

Finally, there are, at least, three more issues to assess in this regard. Firstly, the attitudinal changes that may occur in these pre-service teachers after being taught using this demanding oriented-research approach. It may happen that the good learning outcomes obtained could be achieved at the expense of them being pushed to learn, which may be perceived as negative for these students given that they have made a great effort to achieve this in-depth learning; thus, it seems necessary to evaluate how students have emotionally lived this learning process, as well as to check whether their overall attitudes towards science teaching and learning are still negative or, on the contrary, these have been improved after the course (see also Demir et al., 2017). Secondly, it may be of great interest to assess if the good results observed here could be achieved after using the same methodology to teach pre-service teachers a different science core idea than the one taught in the present research. And finally, it also seems necessary to assess whether, after the course, the thought they have to teach science at the primary level has changed from their previous thoughts before the instruction period. To get optimal results, based on our experience, this period of instruction must be followed by another one about science teaching sequences for primary students, as mentioned above.

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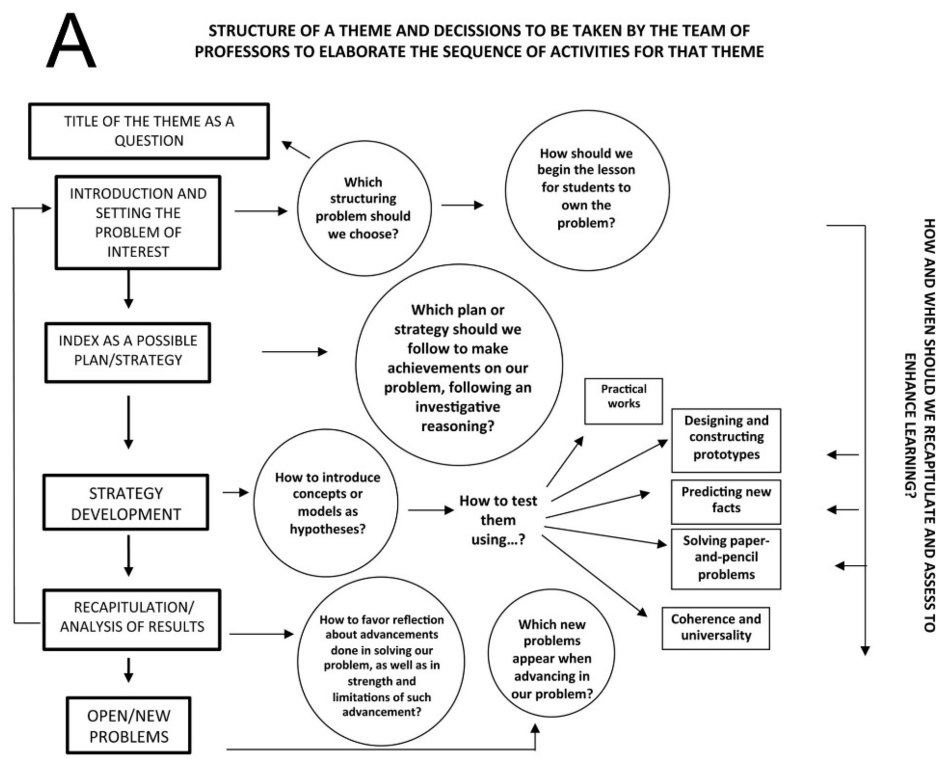
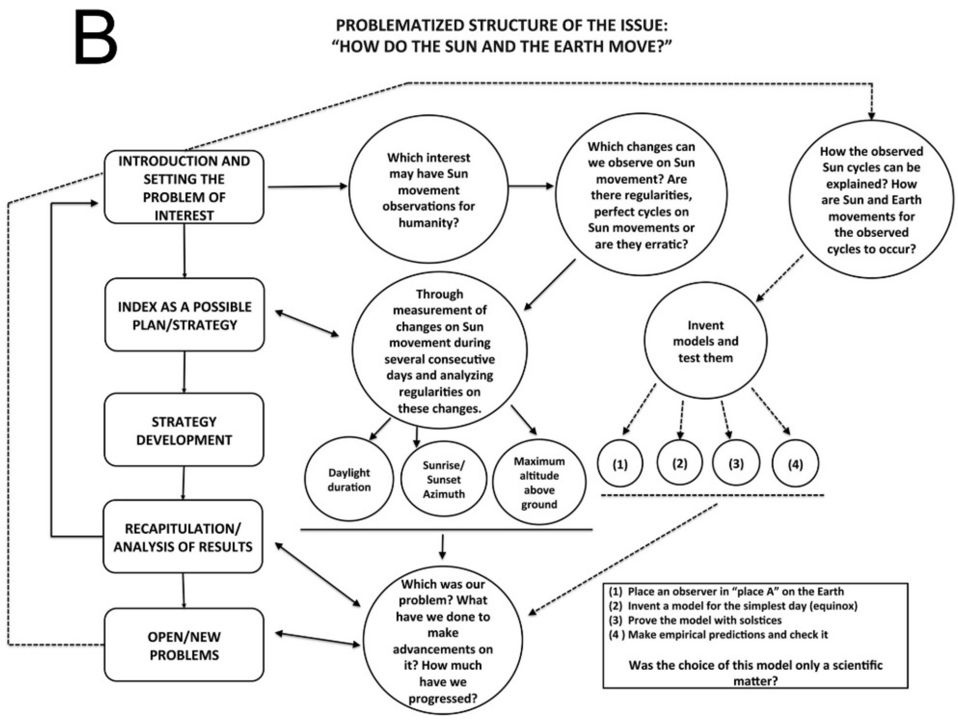
Appendix 1. (A) General structure to elaborate a sequence of activities on a science topic using an oriented-research on core science ideas approach. (B) Problematized structure of the issue taught in the course: "How do the Sun and the Earth move?".





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Appendix 2. Guiding aim, necessary steps and associated obstacles to advance in the core problem of science proposed to pre-service primary teachers. This structure is related to the teaching methodology used: oriented research about a fundamental problem of science.

<table>
<tr><td colspan="2">GUIDING AIM
The main objective of the lesson is to understand and be able to make a functional use of a Sun/Earth model that is useful to explain the observed regularities in Sun movement and make predictions on how is the Sun path where we live as well as in other places on the Earth.</td></tr>
<tr><td>The PROBLEM that structures the teaching and learning
How should the Earth and the Sun move for us to record the changes in Sun path that we observe where we live or at any other place on the Earth?</td><td>The SUB-PROBLEMS that structure the teaching and learning
- Are there observable regularities or cycles in Sun movement?
- How should the Sun and the Earth move for us to record the observed cycles and regularities in Sun movement throughout the year?</td></tr>
<tr><td colspan="2">PARTIAL GOALS (OR NECESSARY STEPS) AND RELATED OBSTACLES
1. To be aware of the practical interest of having a detailed knowledge of the movement of heavenly bodies; also, to know the influence of the evolution of scientific thinking on the Sun/Earth model.
The possible associated obstacles are:
- A decontextualized and linear view of what science is.
- The image transmitted by media and books, which make “evident” how the Solar System is.

2. To have a detailed knowledge of cycles and symmetries of Sun movement where they live and in other places on Earth (to make approximate predictions on Sun path elsewhere, as well as for spatial and temporal orientation in the place where they live).
The possible associated obstacles are:
- Alternative frameworks (of social and scholar origin) about observable aspects of Sun movement. For example: believe that Sun always rises in the East and sets in the West; believe that in Alicante, in summer, Sun is over our heads (i.e., angular elevation is 90º) at midday; assign “extreme” features to summer and winter and “intermediate” to spring and autumn (influenced by meteorological aspects).
- Repetitive learning of some definitions, with any empirical meaning, such as: cardinal points, latitude, longitude, meridian (north-south direction or meridian line), parallel, Equator…
- Stereotyped ideas on how the Sun moves in other latitudes (confusion between what happens in North/South Poles and in Arctic/Antarctic Polar Circles; assuming that daylight duration is always shorter in northernmost latitudes; Sun is always over our heads in the Equator…).
- Inexperience in using basic techniques and instruments for astronomical observations (drawing the natural horizon, orientate using the compass, using a gnomon and an astrolabe, drawing the Sun path in an astronomical plastic dome…).
- Thermal analogy: associate higher and lower temperatures only with the distance from Earth to Sun. This, makes that they do not take into account the influence of the angle at which sunlight arrives to a specific place on Earth, as well as geographical factors to explain why temperature is higher or lower in a place in a specific date.

3. To invent and take possession of a Sun/Earth model that can explain observable cycles and symmetries of Sun movement (day/night; daylight duration, sunrise/sunset azimuth and Sun maximum angular altitude variation throughout the year). To do this, it is necessary to fulfill two big steps:
- To locate an observer in the spherical Earth with all the instruments needed to track Sun path (gnomon, horizontal ground, compass…), corresponding to a local observer in the place where they live.
- To use the Sun/Earth model, both using paper and pencil and using a prototype, to determine how should the Sun and the Earth move for that observer located on the spherical Earth to see the same Sun path (and related variations) than the local real observer. This is to say, use the Sun/Earth model to explain Sun movement in equinox and solstice days, as well as cycles in its movement, both in the place where they live and other sites on the Earth.
The possible associated obstacles are:
- Spatial view and visual relativity (historical obstacle: Copernicus made big efforts to try to convince people that the same apparent Sun movement would be seen whether the Earth rotates on its axis or whether the Sun moves around the Earth). They should transfer observations done from a sphere in motion (i.e., the Earth) to what we would see from the Earth’s surface, and vice versa.
- Using Sun/Earth models that are deformed or show errors: scale errors; showing an elliptic orbit of Earth around the Sun (it is almost circular); locate the Sun closer to Earth in summer in the Northern Hemisphere; and drawing sunlight arriving to Earth divergently (sunlight arrives to Earth in parallel beams).
- Identification of observations and explanations: they assume as “facts” some aspects of the model that are inventions. For example, they believe that the distance from Earth to Sun or the axis tilt are observable traits; they also relate the Sun altitude above ground with the distance from Sun to Earth, or a longer daylight duration with the Earth being closer to Sun.
- Thermal analogy: they associate higher and lower temperatures only with the distance of Earth to Sun. This is one of the most persistent alternative frameworks amongst students, so it requires a specific treatment for them to be able to explain the several causes for the differences in mean temperature, without explaining it by the distance between Earth and Sun.
- Prior knowledge of some stereotyped definitions such as tilted axis, meridian, parallel, latitude and longitude, must be changed by concepts that have an empirical meaning and that can be measured and, most important, within a process of solving a problem (how could we know where we are in a spherical Earth if we live on its surface?).</td></tr>
</table>

Appendix 3. Learning indicators used to evaluate content knowledge achievement on the topic by pre-service primary teachers.

1. To be aware of the practical interest that an accurate knowledge of the movement of heavenly bodies may have, as well as on the influence that the evolution of the knowledge on the Sun/Earth model has had on the occidental culture.
2. To accurately know (enough as to make approximate predictions) the existing cycles and symmetries in the apparent movement of the Sun (Earth-based observations from a given place on the Earth):
   a. a. Be able to arrange the local horizon to track Sun movements and graphically represent Sun path over the horizon (to do this, they should be able to use a gnomon, a quadrant, a compass, a protractor and an astronomical plastic dome, as well as to get data using these instruments).
   b. b. Identify the “special days” or “natural marks” (i.e., solstices and equinoxes) that could be used to organize and count time, according to their observable characteristics (daylight duration, sunrise/sunset azimuths and maximum Sun altitude).
   c. c. Identify (approximately) the existing daily symmetries (in daylight duration respect to the moment at which Sun altitude is the maximum, and in sunrise/sunset azimuths respect to south). Also, the annual cycles and symmetries respect to the values in an equinox day (i.e., from an equinox day to a solstice day): daylight duration changes respect to 12 hours, sunrise azimuth varies respect to east, sunset azimuth varies respect to west and Sun maximum altitude varies respect to its specific value at the equinox day.
   d. d. Know which cycles and symmetries are common to every place on the Earth and use that knowledge to calculate data describing Sun path in different places on Earth (different to those where we live) if any data on any special day is provided.
   e. e. Relate mean temperature in a given place on Earth (climatological trait) with factors that lead to this mean temperature (geographical and astronomical traits), and also to understand the influence of Sun on this. Particularly, they should have observational data (size of Sun disk) that demonstrate that distance from Earth to Sun has no influence (or a very small influence) in temperature cycles.

6. To be able to place an observer on the spherical Earth corresponding to a local observer. To do this, we need to:
   a. a. Know how to represent the vertical (local up/down) and the plane of the horizon with the cardinal points of an observer on the spherical Earth.
   b. b. Know how to locate an observer on the spherical Earth (i.e., know latitude and longitude), using observational data on Sun path in the “special days” in the place where the observer lives (longitude in relation to Greenwich).

3. To be able to use, using lateral and zenithal views of the Earth, the Sun/Earth model (heliocentric) to:
   a. a. Describe Sun path from the place where we live (daylight duration, sunrise/sunset azimuths and maximum Sun altitude) in the singular days (equinoxes and solstices).
   b. b. Predict and compare (sunrise/sunset azimuths should be qualitatively compared, whereas daylight duration and the Sun maximum altitude should be quantitatively compared) Sun path in the place where we live with Sun path in other place on the Earth (knowing its latitude and longitude) in special days.
   c. c. Explain the differences in mean temperature between winter and summer, overcoming the thermal analogy (i.e., temperature only depends on the distance from Earth to Sun).

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