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USE OF FIRST-HAND DATA TO CONSTRUCT KNOWLEDGE ABOUT THE SUN-EARTH-MOON SYSTEM

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Abstract. *Inquiry-based educational contexts including observation of the Moon have been found to facilitate students´ understanding of the Sun-Earth-Moon system. However, the role that the collected data play in the knowledge construction process is unclear, as the process that students develop from the collected data has not previously been reported. Use of data is considered one of the three competencies of scientific literacy, and this research focuses on analysing how eighty four pre-service teachers perform it. A five-level scale has been elaborated. Twenty written group reports and 5 oral data discussion have been analysed. Improvement in the students' knowledge, especially in areas that had been reported to be problematic, is observed. Results show that the designed activities and group discussions help students take their data into consideration, establish comparisons and identify patterns. However, difficulties in identifying patterns and especially in explaining their causes arise and are discussed. The role of the teacher in the process of establishing the causes of the identified patterns stands out when oral discussions are analysed. Several interventions of the teacher are found to be the key for the students to be able to use the collected data to construct appropriate scientific knowledge.*

Key words: *knowledge construction, phases of the Moon, pre-service teachers, use of data.*

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Introduction

The importance of incorporating practical scientific activities into science classes so that students develop their scientific competence in understanding the nature of science has already been stated. One of those science practices is the use of data (Osborne, 2014) to reach conclusions, a practice related to scientific argumentation and critical thinking. The competency of scientific argumentation lies within the connection between data and conclusions, in how data are transformed into evidence that supports a conclusion and in how statements are evaluated on the basis of the evidence that supports them. Since one of the characteristics that distinguish scientific knowledge from other types of knowledge is that the former is evidence based, the use of data and argumentation are important constituents of scientific work and, therefore, deserve being taken into consideration in the teaching of science.

When approaching the teaching of the Sun-Earth-Moon system, several proposals designed for students of different ages have attempted to incorporate data collection and utilisation activities (Kavanagh, Agan, & Sneider, 2005). In those proposals students are expected to perform a more scientific kind of work, and rather than obtaining an explanation about the model, or just simulating it through representations, students are expected to construct knowledge through the observation of reality.

Previous studies (e. g. Trundle, Atwood, & Christopher, 2002) in which students were asked to carry out a direct or virtual observation of the Moon show improvement in the student's conceptual knowledge and comprehension of nature of science. The importance of the observation stage is highlighted in these studies, and even longer observational periods are proposed to improve conceptual gains, but no previous work has been found that specifically analyses how students utilise the data obtained during observation for knowledge construction.

Learning about the Sun-Earth-Moon system

Alternative ideas to explain the phases of the Moon and their causes have been presented in different research papers at every educational level. It was found that the main alternative idea used to explain what causes the

Moon's phases is thinking that the Earth casts shadows on the Moon (Trundle et al., 2002) and that the conceptions held by elementary pre-service teachers are largely at the elementary school level (Kavanagh et al., 2005).

Some researchers have focused on analyzing the effect of activities to learn these ideas. The ones mentioned here are those in which pre-service teachers participated and included observation-based activities and subsequent data discussion.

As an example of such an inquiry based perspective, in the studies carried out by Trundle and her colleagues (Bell & Trundle, 2008; Trundle et al., 2002), the students carried out daily observations of the Moon for a period of nine weeks and post observation group discussions. The research focused mainly on the answers students gave to questions during personal interviews before and after instruction. The results reported in the papers show increase in correct answers at the end of the sequence. Other researchers have varied this basic sequence in several ways. For example, the discussion stage in the project of Mulholland and Ginns (2008) was held online and among students of different countries: 72 pre-service teachers from four universities in the United States and Australia made daily observations of the Moon over three and a half months and shared and discussed their observations over the Internet. The 18 pre-service teachers in the study of Plummer, Zahm, and Rice (2010) took a not so guided perspective, they formulated questions and designed and carried out research on several astronomy concepts. On the other hand, Suzuki (2003) and Ogan-Bekiroglu (2007) explicitly refer to the need of fostering student reflection about what they are observing. To achieve this objective, Suzuki (2003) worked with 8 students in Japan over the course of 12 discussion sessions during which they constructed models that reflected what they had observed. Ogan-Bekiroglu (2007) designed several questionnaires to help students reflect on how they were making observations, and he included them at specific moments along the 14 weeks that lasted the sequence.

Most of the studies mentioned above report improvements but a close look at the results leads to the conclusion that problem areas still persist. Very few students understood the topic of the Moon after the investigations in the study of Plummer et al. (2010): only 28% mentioned the rotation of the Earth when referring to the apparent movement of the Moon and none of them was able to explain why the Moon appears to rise and set. At the end of the 14 week-long sequence of Ogan-Bekiroglu (2007), none of the students was able to correctly explain why the moonrise is delayed every day. The same difficulty arose in the results shown by Mulholland and Ginns (2008), that found that none of the questions in the concept domain "Direction of the Moon's orbit around the Earth as viewed from a point above the North Pole" improved significantly and the domain "Phase - location in sky - time of observation relationship" did not show the expected improvement either.

One of the aspects that researchers propose changing is the period of observation. The observation period in previous studies ranged from four weeks (Cole, Wilhelm, & Yang, 2015; Sherrod & Wilhelm, 2009) to 16 weeks (Mulholland & Ginns, 2008). Bell and Trundle (2008) admit that it might not be realistic to have students collecting data for nine weeks and point to the need to determine the minimum number of observations. On the other hand, surprised by the lack of improvement in some of the topics, Mulholland and Ginns (2008) suggest that 16 weeks of observation may not be enough, but they do realize that providing guidance on observation times would be helpful. In most of the proposals, students are instructed to draw only the shape of the Moon, recording the day and time and the observer-Moon-Sun angle (Trundle et al., 2002), direction (Sherrod & Wilhelm, 2009) or height above the horizon (Suzuki, 2003). In this sense, none of the studies instructed the students to observe the Moon at the same time every day, which facilitates noticing the real movement of the Moon, or at two different moments the same day, which facilitates noticing the apparent movement of the Moon. Conscious of the importance of making these observations, during the fourth week of observation Ogan-Bekiroglu (2007) introduced a questionnaire geared towards helping students to decide to observe the Moon at the same time each day.

Overall, it can be said that there are some inquiry based proposals about the topic that have shown improvements in conceptual understanding, but some problematic areas persist. The aforementioned studies point to observation as a key factor, and even a longer period of observation time has been proposed in order to improve knowledge. However, the results shown in those studies have been mainly obtained after the whole activity was completed and none reports specifically on how or to what extent the observation has contributed to the acquisition of knowledge or how the students utilize the data obtained in the observation to construct knowledge. This study focuses on the performance of this scientific practice by students.

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The use of evidence in the science classroom

Osborne and Dillon (2008) analyzed science education in Europe and highlighted the need to implement an inquiry-based methodology focused on processes in which students will have opportunities to collaborate, discuss and build arguments. Driver, Newton, and Osborne (2000) had already referred to the lack of opportunities for students to participate in scientific discussions in science classes. Among other aspects, they defended the need to reflect about the function of practical activities and the need to redesign them so that they would become a source of data that would lead to formulation of claims and conclusions. The data obtained must be analyzed, interpreted and utilized as evidence, which constitutes a scientific practice (Osborne, 2014), and the validity of the claims must be based on a critical evaluation of the evidence, which lies in the core of scientific argumentation. Therefore, there is a growing interest to include activities in which students have to interpret data, utilize it as evidence, construct arguments based on evidence in science classes (Erduran & Jiménez-Aleixandre, 2008), owing both to the role they play in the development of scientific knowledge (p. e. Uskola, Maguregi, & Jiménez-Aleixandre, 2010) and the inherent value of developing the argumentation skill (Kuhn, 2010). The importance of the utilisation of data and evidence is also reflected in the definition of scientific competence made by the Programme for International Student Assessment PISA (OECD, 2013).

Research on how students develop the competence of data utilisation and argumentation is increasing and varied regarding methods and criteria to define the level acquired. Numerous research studies analyse the quality of argumentation based on its structure using Toulmin's (1958) model. According to this, an argument is considered to be of better quality when it is constituted by a larger quantity of elements or when some particular elements, such as refutations (Erduran, Simon, & Osborne, 2004), are present. However, one of the limitations of this type of analysis is that it does not take into consideration the scientific content involved in the arguments.

After encountering several difficulties in using Toulmin's model for argument analysing the arguments produced by their students, Kelly and Takao (2002) proposed a model to evaluate the written arguments of students that took into consideration the specific knowledge on the discipline and the structure of argumentation. Students were given data related to plate tectonics and were expected to build arguments using these data and geological concepts. Six epistemic levels were defined, ranging from explicit reference to data to more general, abstract expressions; they considered that a good argument needed to consist of elements from the different epistemic levels. Their results showed that the sentences written by students were at a different epistemic level according to the task, that is, in the stage corresponding to data collection, levels related to explicit reference to data predominated, while in the interpretation stage, there were more sentences in the abstract levels.

Sandoval and Millwood (2005) also evaluated the quality of evidence utilisation considering the scientific content of the explanations written by students for two problems relating to natural selection. They identified the four conceptual factors that a complete explanation about evaluation should have, and for each factor they analysed conceptual quality, data sufficiency and rhetoric reference. Mere data accounts were predominant in both problems, which could lead to the conclusion that students believe that data speak for themselves, but authors considered that the students demonstrated to have a capacity for discerning between conclusions and data during oral discussions.

Perceiving patterns in data is one of the first operations scientists must do with them, previous to construct arguments consisting of evidence based conclusions. But even this first operation presents difficulties. Jiménez-Aleixandre and Puig (2010) reported difficulties among secondary education students in perceiving patterns among the different examples of the same phenomenon (gene-environment interaction). Moreover, the difficulties in identifying patterns in data are not exclusive to students. Jiménez-Aleixandre (2014) gives examples of the difficulties encountered by scientists in some cases of Genetics. Solbes and Palomar (2011) make a historical review of how knowledge of Astronomy has been constructed, and the remarkable difficulties faced by scientists throughout history in identifying patterns and their causes.

Science teaching is nowadays adopting a science practicing approach, students are expected to construct knowledge through scientific practices such us use of data. Besides its inherent educational value (Kuhn, 2010), lessons based on argumentation and use of data can be used to develop students' knowledge a way to develop scientific understanding. However, as von Aufschnaiter, Erduran, Osborne, and Simon (2008) concluded, although these lessons have a positive impact on students thinking as they help to elicit students' previous ideas at relatively high levels of abstraction, it can be the case that students do not construct scientific knowledge, depending on, for example, how familiar the content is for them. Given that Sun-Earth-Moon (SEM) system should be a familiar content to pre-service teachers, that reported conceptual gains about this content have been attributed to observing the Moon, and that none has analyzed the issue explicitly, these are the research questions that guided this research:

RQ1. To what extent do students improve their conceptual knowledge construction about the SEM system through the unit?

RQ2. How does the use of data collected to contribute to conceptual knowledge construction about the SEM system?

It is expected that the conceptual gain is similar to the ones reported in other researches that have used inquiry-based teaching units. As for the use of data, the aim is to identify the difficulties they face in the process of constructing knowledge based on their first-hand data, and in the case they are able to overcome them, how do they do it.

Methodology of Research

General Background of Research

The methodology used to answer the first research question is based on quantitative instruments and methods. The sources of data are the answers given by students to closed-format questionnaire before and after performing the teaching sequence.

Exploring how the process of use of data and knowledge construction requires a detailed examination of the actions and discursive moves that students perform to construct their understanding of SEM system. That is the reason to adopt a case study interpretative research design (Erickson, 1989). Participant students observed the Moon through a simulation program individually for a month and then discussed their results in groups during two classroom sessions. The discussions held during the first one were audiotaped and transcribed and constitute the main data of this research. The reports written by the groups were also used as data. The teaching sequence was performed along two months from January to March 2012.

Participants and Setting

The participants were first year elementary pre-service teachers at a public university in Spain. All the students from two classes (84, aged 18-19 years (69% girls)) taught by the same teacher took part. They were divided randomly into 20 groups (3-5 participants).

The students began the teaching sequence by observing the Moon individually during a four week period in January-February 2012. Stellarium simulation software was chosen because of the good results obtained after virtual observation in the study by Bell and Trundle (2008), and because of the difficulties involved in carrying out a real observation in winter. With Stellarium software they could select the date and time and observe the sky from different locations on Earth. The students were instructed to carry out their observations twice a day, at the same time every day and to choose a day to monitor the Moon every hour. Students were also asked not only to draw the Moon, but to make a diagram of the whole landscape observed. After the observation stage, the students discussed their results during two 2 hour sessions. In their groups, students first shared data without any instruction, and then were given a worksheet designed *ad hoc* that contained activities and open format questions that would guide them through the construction process. The activities studied in this work followed this sequence: a) share the individual data and conclusions (activity A1); b) find patterns in the data by answering questions (activities A2-A4, A6-A8), p. e. "Over the course of one day, what movement do we see the Moon making?" (activity A4); c) construct the theoretical model of the SEM system by answering questions (activities A5, A9, A10), p. e. "Why do we see that movement of the Moon every hour?, what causes it?" (activity A5). There were other activities that were not analyzed here, that fostered the use of 2D and 3D models, and to apply the theoretical model to other related phenomena, for example, to transfer it to the context of Earth´s phases (Uçar, 2014).

Data Sources and Analysis Procedures

Knowledge on the SEM system

Data were obtained from individual closed questionnaires answered prior to (n(pre)=84) and after (n(post)=76) participation in the sequence. Closed format questions were taken from the LPCI questionnaire (Lunar Phases Concept Inventory) designed by Lindell and Olsen (2002), who grouped the questions into eight concept domains. The questions have been validated (Lindell & Olsen, 2002) and utilized in investigations by other researchers such as Cole et al. (2015), Mulholland and Ginns (2008) and Sherrod and Wilhelm (2009). The eight domains are: DOM1 Period of the Moon's orbit around the Earth; DOM2 Direction of the Moon's orbit around the Earth as viewed from a point above the North Pole; DOM3 Period of the Moon's cycle of phases; DOM4 "Apparent" movement of the Moon; DOM5 Phase and SEM positions; DOM6 Phase - location in sky - time of observation relationship; DOM7 Cause of Lunar Phases; DOM8 Effect on lunar phase with change in location on Earth.

The percentages of correct answers to each question were calculated. Each question was considered as a dichotomous variable (correct/incorrect) for the size effect calculation. To calculate the effect size using the SPSS statistical package, it was first determined if a null hypothesis could be ruled out (no effect) using the Wilcoxon nonparametric test for scale variables in the case of the open format questionnaire and the McNemar test for dichotomous variables in the closed format. Afterwards, the effect size was calculated using Cohen's *d*, which for the pretest-posttest trials was calculated as the difference of the means divided by the standard deviation of the post-test (Morales, 2011).

Performance in use of data

The debates held by students and the written responses in the first 10 group activities have been the sources of data. The data from transcriptions of five randomly chosen groups have been used in this study: groups A (Amaia, Ana, Ander), B (Bakarne, Bea, Begoña, Blanca), C (Carlos, Charo, Clara, Clemente), D (Daniela, David, Deñe, Dimas) and R (Rafaela, Renata, Rocio, Rosa). The real names of students have been replaced by fictitious ones, respecting their sex.

Taking into account the task students were to develop, that is, building knowledge about the SEM system based on observation data, five levels have been defined to reflect the epistemic operations they perform with the data (Table 1). The different levels range from the most specific, in this case referring to the observation data, to the most complex and abstract operations that deal with reaching a conclusion of the pattern's underlying cause. In the case of the SEM system, the construction of the model involves various concepts, each related with a different pattern of data. On the one hand, the observation of the Moon on two occasions on the same day allows identifying its apparent movement, which is caused by the Earth's rotation. On the other hand, observation at the same time on two consecutive days allows observing its real eastbound movement around the Earth and the change in phase. These patterns have been called apparent movement (AM), real movement (RM) and the change of phase of the Moon (PH). Since the activities studied in this research (A1-A10) were dealing with movement patterns, the focus was on the analysis of such patterns. Thus, explicit reference to data is placed in level 1. The data they can refer to are the time they made the observation (1T), the relative position the Moon had in the sky (1P). In level 2 we find occasions in which students compare data, an operation that precedes pattern identification in data. In this level we find comparisons between position on different days (RM2) and at different times on the same day (AM2). In level 3 we find statements in which the data patterns are identified. In the example in Table 1, we can see how Daniela compares data about where the Moon is at different times on the same day, then she establishes a conclusion, in this case the identification of the pattern of apparent movement (AM3). In level 4, we include the occasions when, once the data pattern identified, students are able to apply it to make predictions in data or to evaluate data. In level 5, students demonstrate they are capable of constructing the SEM theoretical model, as they can explain the cause for the data patterns. That is, they can relate the pattern of apparent movement with the Earth's rotation, the pattern of real movement with the Moon's translation, and the pattern of change of the Moon's shape with the Moon's translation and the view from the Earth of the half of the Moon illuminated by the Sun.

The sequence of inference from data to the establishment of a cause for a pattern would include levels 1, 2, 3 and 5. Level 4 has been established in relation to the data obtained. In a similar way as suggested by Kelly and Takao (2002), the first two levels can be considered to be within the field of Observations, and the two subsequent levels can be considered to be within the field of Interpretations.

The research team members have agreed upon the levels; moreover, the first author and an expert researcher have performed the categorisation of one of the groups separately, reaching a consensus over 80% and reaching an agreement on the parts where they had differed.

Table 1. Levels for reference categorisation of the data utilised.

Level	Operation	Types	Examples
5	Concluding cause	AM5, RM5, PH5	376 RENATA: The movement it makes every night is because of the rotation (*AM5*). And from one day to the other it moves very little (*RM3*). This is the translation (*RM5*).
4	Applying pattern	AM4, RM4, PH4	612 DEÑE: (…) What's strange is that she can see it at 8:40 and you can't at 9. (*AM4*)
3	Identifying pattern	AM3, RM3, PH3	224 DANIELA: And then, if you look another day, I have at 9, at 10, at 11, at 12... As the hours pass, it moves towards there (*AM3*) and as the days pass, it goes towards the opposite direction (*RM3*)
2	Comparing data	AM2, RM2, PH2	387 AMAIA: I have that on 30th at two, it is in SE and at ten it is in SW. (*AM2*)
1	Mentioning data	1; 1P; 1T; 1T,P	57 RENATA Me in the morning, next to the Sun and it is a New Moon. (*1T,P*)

This research lies in the interpretative research frame that aims at understanding the phenomena studied through the meanings given by actors to their actions (Erickson, 1989). For this reason, the oral and written expressions with a meaning that deal with data have been utilised as units for the categorisation. Therefore, various expressions or references from different levels could be found in the same speaking turn, as happens with the statements by Daniel and Deñe in Table 1. Oral discussions have been transcribed for their analysis, and after reading them, episodes have been established, considering that a change in episode happens when the theme of discussion or the activity being performed changes. Thus, all oral and written expressions with a meaning that were dealing with data have been categorised into levels.

Results of Research

Knowledge on the SEM System

In table 2 the average percentage of correct answers obtained for each concept domain can be seen, before and after participation in the sequence of activities. The last column shows the average size of the statistical effect when it has been possible to calculate it for all the questions involved. When it has been not possible, all the results are shown.

Table 2. Mean percentage of correct pre and post responses for concept domains in SEM system.

Concept domain (questions)	PRE	POST	d (PRE-POST)
DOM1 (2, 8)	81	93	1.19 / -
DOM2 (3, 20)	47.6	89.1	1.37 / -
DOM3 (5, 12, 17, 19)	77.4	80.1	1.38 / - /- /-
DOM4 (10, 14)	51.2	62.8	- / 0.42
DOM5 (6, 9, 11, 16)	13.7	63.5	1.16
DOM6 (1, 15)	22.1	30.8	- / 0.87
DOM7 (4, 18)	1.2	60.3	1.22 / -
DOM8 (7, 13)	24	83.6	1.66

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As can be seen in table 2, in the departure situation, the domains that have to do with the orbit period (DOM1) and with the period of the moon phase cycle (DOM3) yielded more than 70% correct answers. However, in the other domains, the results were not as good: roughly 50% in DOM2 and DOM4 and below the average of 24% in DOM5, DOM6, DOM7 and DOM8. The results after participation in the sequence of activities show improvement in all domains. In the cases where it was possible to discard the null hypothesis, the effect size value is shown (d) and as can be seen, is superior to 0.5 and 0.8; these values correspond to a moderate and big effect respectively.

Performance in Use of Data

Written reports

The results for the initial activities (A1-A10) of the 20 groups are shown in Table 3. The percentage of groups that have written statements in the different levels for each of the patterns of movement is indicated. The percentage for the selection of the 5 groups whose oral discussion have been analysed is shown in parentheses.

Table 3. Performance in use of data in written reports (N=20).

Level	Apparent Movement (AM)		Real Movement (RM)	
	A1	A2-A10	A1	A2-A10
5		55% (40)		50% (60)
4				
3	50% (80)	95% (100)	50% (60)	95% (100)
2	20% (20)	80% (100)	20% (20)	50% (40)
1				

The results from Table 3 show that in activity A1 half of the groups were able to identify the pattern (level 3) of apparent movement and the pattern of real movement. 40% of the groups can identify both, and 35% none of the two.

In the rest of activities analysed (A2-A10), almost all the groups were able to identify patterns (level 3) and half of them got to identify issues related to the causes (level 5). The increase of comparisons between observational data (level 2) also stands out.

Oral statements

In Table 4 we find data about the time devoted to the task, the number of turns and the number of operations with data performed by all five groups. Since levels 1 and 2 correspond to the field of Observations and the rest to that of Interpretations, it has been analysed what percentage of references to data utilisation have been made at levels 1 and 2 in activity A1 and what percentage in activities A2 to A10, the interpretative ones.

Table 4. Time devoted to the task and operations with data during the discussions in groups A, B, C, D and R.

	A	B	C	D	R
Total time	104´	117´	56´	141´	100´
Time in A1	52´	58´	19´	84´	61´
Total speaking turns	740	472	214	963	568

	A	B	C	D	R
Total operations with data	243	87	57	394	152
% Operations in levels 1-2 in A1	79.3%	37.8%	76.5%	67.4%	75%
% Operations in levels 1-2 in A2 to A10	49.2%	2.4%	39.1%	23.4%	10.7%

Remarkable differences among groups can be observed as for all the aspects represented in table 4. It can also be said that there is no direct correspondence between these aspects, as A, B and R have devoted a similar amount of time to the task but B have performed fewer operations with the data. In the bottom rows in table 4 it can be observed that, comparing activity A1 to the subsequent activities, there is a decrease in explicit references to data and in the comparisons between them (operations in levels 1-2, Observations field); indeed, in groups A, C, D and R these operations go from representing more than two thirds of references of data utilisation to representing less than half. Group B stands out in that references in Observations field are scarce.

Table 5 shows all the levels identified in the written report (W) and in the oral interventions (O) for each of the 5 groups analysed and each of the patterns of movement.

Table 5. Levels of performance in the utilisation of data identified.

Group		AM		RM	
		A1	A2-A10	A1	A2-A10
A	W		2 3 5		3
	O	1 2 3 4	1 2 3 5	1 2 3	1 2 3 4 5
B	W	3	2 3		3
	O	1 2 3 5	2 3 5	1 2 3	3
C	W	3	2 3	3	3 5
	O	1 2 3	1 2 3 4	1 3	1 2 3
D	W	3	2 3 5	2 3	2 3 5
	O	1 2 3 4 5	1 2 3 4 5	1 2 3 4	1 2 3 4 5
R	W	2 3	2 3 5	3	2 3 5
	O	1 2 3	2 3 5	1 2 3 4	2 3 4 5

Note. W= written report; O= oral discussion

It is noticeable that in the oral interventions more different levels appear than in written reports. Data related to oral interventions in table 5 indicate that all five groups have level 3 interventions, that is, of pattern identification in the data, of both types of movement, in activity A1. B and D have interventions in which they identify the cause for the pattern of apparent movement (level 5) in A1; however, most groups perform at this level later in the unit.

Process of Utilization of Data

Group A

Group A students start by mentioning lots of data in levels 1 and 2, as can be seen in Table 4. They find it hard to generalize, seem to get lost in a bundle of data, and say that they cannot see patterns or any regularity in data. This is the group that makes the most mistakes in identifying patterns (level 3), in 48% of the occasions when they attempt to, while the percentage of mistakes in other groups is smaller (B and D 7%, C 19%, and R 18%). As observed in Table 5, in activity A1, they are capable of correctly identifying aspects for both patterns of movement. However, they have difficulties concerning the pattern of apparent movement, they don´t relate it with that of the Sun, which makes it hard for them to identify its cause. Their first attempt to find the cause for the apparent movement is to

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attribute it to a real movement of the Moon, then the teacher challenges them:

> 631 AMAIA: Because it is always doing the same rotation.
> TEACHER: Who is rotating?
> 632 AMAIA: The Moon
> TEACHER: Is it related to the Moon's rotation?
> 633 AMAIA: Or even also with that of the Earth.

They attribute the change in the Moon's position on consecutive days at the same time to a difference between the Moon's translation speed and the Earth's rotation speed. They discuss the different speeds involved, but they spend time thinking that the Moon's translation is faster. Ander gets close to constructing a suitable model almost near the end.

Group B

Group B has very few data references at the Observational levels (1 and 2) compared with other groups, as can be observed in Table 4. From the beginning, they depart from the patterns they have identified individually:

> 36 BLANCA: The thing is that the Moon, depending on the time, moves to the right [*AM3*], but depending on the day, is further to the left [*RM3*].

On one occasion that they relate the Moon and the Sun's apparent movement, the teacher tries to get them to explore this idea more deeply to identify the cause for such movement:

> 283 BLANCA: Now let's see, does the Moon turn in the same sense as the Sun?
> 284 BEA: It does.
> 285 BEGOÑA: The Sun does not turn.
> 286 BLANCA: The Earth does. How do we know that?
> 287 BEGOÑA: Because it rises in the East and goes to the West.
> …
> 290 BLANCA: I just realised the World turns in one direction
> TEACHER: What direction? Simulate it.

With the help of the teacher and using gestures, they get to understand the cause of the apparent movement. Regarding the real movement, they mistake month's data with a day's data to identify the direction of the translation.

Group C

This is the group devoting the least time to the task, as can be seen in Table 4. In spite of that, they utilise data and manage to identify the two movement patterns in activity A1. Unlike other groups, they infer a pattern in relation to the time when the Moon is visible and its phase, they realise that when it is visible at dawn, it is growing, but they never wonder what the cause is. In fact, when attempting to find the causes for patterns, they do not delve deeper and accept all answers as being correct. This is the only group that does not show oral stances that indicate they get the cause of the patterns (level 5). Thus, they first think that the Moon takes somewhat less than 24 hours in its translation (they say they think it's about 22 hours), and later a little more than 24 hours, but they do not test their conclusions with the data:

> 207 CARLOS: It said on the internet that the Moon's translation coincides with the Earth´s rotation and this is why you need another hour to see it in the same place.
> 208 CLARA: Well, then it will need 25 hours, instead of 24 to get to the same place.

Group D

Group D devoted a long time to the task, as can be seen in Table 4, and they are the group with a higher number of operations with data. In fact, at times when they are stuck they suggest resorting to data. They are able to apply a pattern they have identified to make predictions (level 4) and question data, as can be observed in Deñe's intervention (turn 612, in Table 1). They discuss among themselves, using data from observations, and this leads them, for example, to identify the pattern (level 3) of real movement quite at the beginning. At one point during activity A1 they get the cause of the apparent movement (level 5) but they do not delve deeper. But, in spite of having the idea from the very first moments, when they later need to explain the reason for the apparent movement, they initially mistake it with the real movement. With the help of the teacher they construct an appropriate response:

> 817 DEÑE: Because the Moon turns around the Earth in this direction.
> TEACHER: And is this the movement we see in one day? In one day, from East to West.
> 818 DIMAS If the Moon was still we would be moving towards the East.
> TEACHER: Is this why we see it from East to West?
> 819 DIMAS: Because if we move towards the East … If I move towards here and I look, I will see it moving in the opposite direction.

The discussion they have about the delay in the time Moon rises gets to be very productive to understand both patterns of movement:

> 838 DAVID: At the same time. Then, to see it here tomorrow. Tomorrow at 10 it is here [*RM4*], so to see it here, it's before [*AM4 incorrect*], isn't it?
> …
> 852 DANIELA: Let's see, this is the 4th at 10 pm. The following day at 10 it was here [*RM2*]. That's when you need to look, got it? As the hours pass, where does it go? Towards there?
> 853 DAVID: It goes East [*AM3 incorrect*]
> 854 DANIELA: No. As the days go by.[*RM3*]
> …
> 857 DIMAS: As the hours go by, it sets in the West. [*AM3*]
> …
> 881 DANIELA: This is how it goes, isn't it? Kind of, this is yesterday's, then it is here at 10, and here at 11. [*AM2*] Today it is going to be further to the East, at 10 it would be further to the East, [*RM4*] at 11 where it was yesterday at 10pm. [*AM4*]
> …
> 894 DAVID: So, as the hours go by, will it be further to the West?
> …
> 904 DAVID: (…) You should have told me that, it is later for sure. [*AM4, RM4*]

Daniela and Dimas argue that the Moon rises later each day, and David that it rises earlier. David is applying correctly the pattern of apparent movement with the mistaken direction (853), as he himself realises (894 and 904). What's interesting is that during the discussion they apply patterns to make predictions (level 4). Since it is at this level where they differ in their conclusions, they compare data again (level 2), identify patterns again (level 3) and finally apply them (level 4) in order to build a scientifically correct response.

Group R

In activity A1 we find statements on levels 1, 2 and 3 and then in the rest of the activities, mention of data (level 1) statements disappear, leaving only levels 2, 3 and 5. In activity A1 they try to identify which is the cause of the pattern of apparent movement, but as other groups, they mistakenly attribute it to the Moon's translation movement. It is further on that they construct a correct answer, when the teacher asks them to think "why do we see the Moon rising in the East and setting in the West":

364 RENATA: Which direction is the Earth moving toward?
…
368 RENATA: Counter clockwise. Like this. If it rotates like this, it is logical … If I go like this, East first, isn't it?
369 RAFAELA: Yes, if you rotate.
370 RENATA: (…) the Moon appears in the East to me
…
372 RENATA: Of course, for the rotation.
…
376 RENATA: The movement it does every night is because of the rotation [*AM5*]. And from one day to the other it moves a little bit. This is the translation. [*RM5*]

Discussion

The first research question was about the conceptual knowledge constructed by the students. The results obtained in the closed questionnaire (Lindell & Olsen, 2002) show that in most questions, knowledge progress is notable, with big effect sizes (*d* bigger than 0.8) in many cases. Comparing results with those of other researchers with teacher training students participating in similar sequences, results are comparable, if not even better in some aspects. For example, compared with the findings reported by Mulholland and Ginns (2008), and grouping the results into domains, they were found to be similar in DOM1, DOM4 and DOM6, and greater by over 15 points in DOM2, DOM3, DOM5, DOM7 and DOM8. In DOM2, they reported that none of the responses improved significantly in their study, whereas in our case they both yielded a result of nearly 90% with a statistically significant improvement found in one of them.

This research has contributed to increase the number of studies on how students utilise data in knowledge building. Utilisation of data is one of the three components of scientific competence (OECD, 2013) and one of the scientific practices to introduce into the science classroom (Osborne, 2014), yet studies focusing on how students develop data utilisation are deemed scarce. Moreover, the study has been carried out in one subject area, the Moon's phases, in which numerous studies (Kavanagh et al., 2005) have analysed the conceptual knowledge built by students after participating in data collection and their utilisation but no study has been found to analyse the process of data utilisation.

One of the salient results is the difference in performance shown in written reports and in oral discussions. For example, the situation reflected in the written reports by the 20 groups indicates that 35% of groups do not identify any pattern in activity A1. However, when analysing discussions it has been found that one of them, Group A, do show stances in which they identify patterns. Indeed, the five groups whose oral discussions have been analysed show higher levels of performance in the data utilisation in oral discussions than in the written reports. Therefore, it may be the case that groups have developed better data management than reflected in the written report analyses. The better performance in oral discussions than in written reports was also observed by Bravo (2012). We endorse her conclusion about the importance of analysing the discussions of students and not just their written assignments when assessing students' efficiency in a given competence. It is also true that not writing in a level in which students perform at least in some occasions in the oral discussions can be interpreted in other ways that should be studied.

One such possibility is that students haven´t internalized the pattern of data and although they mention it, they don´t write it explicitly. The five groups whose discussions were analysed show evidence of having identified the patterns of the Moon's real and apparent movement without any external help in the activity of data sharing (A1) and two of them show occasions where they identify the cause for the apparent movement pattern (level 5). These results may seem very positive, but as mentioned in the results section, the fact that some interventions show that a pattern is identified doesn't mean that it has been internalised. For example, group B persist in mistaking data from one month with data from one day, even in turn 374 (out of 472); this happens to be the group who made the fewest references in Observations field (levels 1 and 2). But there are groups, such as D, which members discuss over and over again about how the two patterns of movement work, and that helps them internalise these patterns and not get them confused.

One of the operations in which students find the greatest difficulties according to the analysis of the group discussions, is in identifying the cause for the pattern of apparent movement. All groups try to relate it, at least at the beginning, to some real movement of the Moon and not to the Earth's rotation. Related to this, it is noteworthy that none of the students in Plummer et al. (2010) study could explain why the Moon rises and sets, and that none of the 36 student graduates in Physics who participated in Ogan-Bekiroglu's study (2007) could answer why there was a delay in the Moons rising time. In both studies, the obstacle was in being unable to identify the pattern of apparent movement and its causes. In this case, for example, students in group D do, they get to construct knowledge about this pattern cooperatively by applying previously identified patterns, by discussing the patterns and reaching an agreement after comparing data again.

Following with this difficulty found in the apparent movement pattern, when we analyse in detail the questions in Lindell and Olsen's questionnaire (2002), the cause of this pattern needs to be understood to respond to questions 1, 10 and 15, those with the worst results among the questions in the post-test (13%, 54%, 49%). It is remarkable that usually educators and researchers focus on the cause of the Moon's phases while little importance has been given to the patterns of movement, especially the apparent movement, which is not linked to the phases of the Moon. One of the difficulties in finding the cause for the patterns of movement lies on having to put together the system's visualisation from two perspectives: from an Earth-based standpoint as an observer (intrinsic) and a space-based standpoint outside the SEM system (extrinsic). This difficulty has been pointed at by researchers such as Suzuki (2003) and Padalkar and Ramadas (2011) when identifying the cause for the Moon's phases. Plummer, Bower, and Liben (2016) have studied children´s skill of making connection between the two reference frames when explaining some astronomical phenomena and have pointed to the difficulties found and the need for additional support. Making observations, either virtual or real, is precisely what allows students to place themselves in the position of an intrinsic viewpoint, where they find patterns in data, while building 3D models afterwards, or making simulations with their own bodies, allows them to have an extrinsic view. Connecting both frames is related to the process of finding the cause of the patterns, so we support the conclusion of Plummer et al. (2016) in that student face difficulties in making this connection and they will need scaffolding.

Designing activities that help students focus in and analyse their data can be part of the scaffolding. Activities help students focus on what it is expected from them (Sandoval & Millwood, 2005). This is observed in the different performances between activity A1 and activities A2-A10. It can be observed that in the more guided activities A2-A10, students make more reference to data comparisons and get to identify causes for patterns. This is to be expected, as activities were designed for this end; therefore, students seem at least to have understood their task as Kelly and Takao (2002) concluded. Nevertheless, this indeed proves that specific activities need to be designed so that students pay attention to data, devote time to data analysis, so as to identify patterns and their causes. The designed activities play this role to some extent, but as can be seen in some of the speaking turns in groups A, B and D, when the teacher intervenes, that intervention seems to activate students´ construction process. For group A the teacher challenges the idea they have about the cause for apparent movement and makes them take a different perspective that they try to represent using gestures. In group B, when the group had produced ideas in the right direction, but these had not been articulated, the teacher provides the keys to help them make such an articulation. Clues are given to group D to link the pattern of the Moon's apparent movement that they have identified, with that of the Sun. These interventions unleash episodes in which students revise the identified patterns, make simulations using gestures to model the cause for patterns, and evaluate their hypothetical models basing on their data. This is in line with what Schalk, van der Schee, and Boersma (2013) concluded, when they observed that the teacher made possible for students most generalizations and explanations in the process of appropriation of quality criteria of a research, and that students without the presence of teacher hardly surpassed the level of description. They needed the presence and action of the teacher to pass from description to explanations. In a similar way, the presence and action of the teacher is necessary for students to articulate conclusions.

Conclusions

Observing nature and using the data collected to answer the questions about the observed phenomena are part of the scientific work. As such, they are constituents of the scientific literacy students must develop during their schooling, and they deserve activities being designed to foster them.

Scientific practices such as utilisation of data can also serve as a means to develop conceptual knowledge on scientific phenomena. For example, in the case of the phases of the Moon, observation of the Moon and use of the collected data have been considered important contributors to the learning process and longer periods for observation are proposed so as to improve the gains in conceptual knowledge. Despite the limitations of this research being a case study in which the sample is not representative and the results not generalizable, there are some conclusions that are worth stating. Taking the results of this research into account, it can be said that students are able to construct knowledge about SEM system through the use of data they have collected, but results also lead us to say that in most cases they cannot do it by themselves. There are students that after discussing the data, still do not perform their interpretation as expected. So it seems that the issue is not that much in how long the observation period needs to be but in how to give students the scaffolding they need, first to collect the kind of data that can be interpreted and used as evidence to construct knowledge, and second to make that process of interpretation, pattern finding and use of evidence. The results of this research, although with the declared limitations, also show clues that can be taken to design those scaffoldings.

The scaffoldings for the first part (to collect the kind of data that can be interpreted and used as evidence) should include giving observation guidelines, which in the particular case of the Sun-Earth-Moon system can be the ones used in this research: observe every day at the same time, draw the entire landscape, do the follow-up during one day.

The second part, helping students in their performance of the scientific practice of using data is not that straightforward. Two sources of scaffolds have been identified. One has to do with the questions and the activities. Activities that demand students explicitly to look at the data, to compare data, to look for patterns are necessary so as students are able to make the first steps. Those steps can be named as the first levels of performing the competency of using data, and comprise referring explicitly to data and establishing comparisons between them. But students have difficulties to go further in their use of data, in formulating conclusions based on those data. Then the scaffolding that comes from the teacher becomes key for students to formulate the conclusion, for example, to construct an explanation of what a pattern of movement in the SEM system is indicating. That is, the presence and action of the teacher is necessary for students to pass from the first levels of referring to data or comparing them to higher levels that demand interpretation, to articulate the conclusions based on the data. Therefore, the presence and action of the teacher is necessary for students to develop conceptual knowledge through the use of first-hand data.

The implications for teaching are obvious, the teacher must be present in the groups although students are discussing and working autonomously. In a real setting in a classroom this may be not easy to carry out, for example, the teacher in this research was working with ten groups at a time, so it was difficult for her to notice in which moments had her students the need for her scaffolding. More research is needed to find out what the best teacher's actions are to help students analyse and utilise data to construct scientific knowledge, and how to combine students' autonomous work with the need for teacher´s presence and action in that process.

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