Drawings as a Tool for Understanding Geology in the Environment

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ABSTRACT

This study analyses graphic representations of landscapes, produced by 46 Spanish 10th-grade secondary students and 92 teacher-training students in the last year of their course at the Faculty of Education, and the descriptive power of these drawings in connection with questions posed on the systems being represented. The constituent parts of a suitable description of a landscape as a natural system should include geological, as well as biological, elements. The absence of geological elements makes it difficult for students to build an environmental model. Few of the students who produced drawings represented rocks or geological aspects of the landscape. In general, the students represent the environment as an accumulation of elements, which may or may not be shown as ordered. In only a few cases do the drawings provide a description of the landscape that can be used subsequently, for example, to answer questions about environmental management. Causal relationships are hardly shown in either the drawings or the descriptions. This study uses a tool to analyze students' drawings that can be used to promote the learning of models by producing drawings. © *2014 National Association of Geoscience Teachers*. [DOI: 10.5408/13-001.1]

Key words: drawings, fieldwork, secondary education, teacher trainee

INTRODUCTION

Illustrations have always been part of the history of natural sciences, because at one time, they were the only means of representing reality. There are many exquisite and realistic drawings of plants, animals, fossils, geological cross-sections, etc. Every illustration expresses not only a manner of doing or representing but also a manner of believing and thinking.

Illustrations are an effective tool for communicating information from teacher to students (drawings on the whiteboard, slides, transparencies, videos, cartoons, and especially textbooks), and from students to teacher. Research into the workings of different types of symbolization (Martí, 2003), such as figurative expression or drawing, brings us closer to cognitive and socioaffective representations that individuals produce when trying to understand or express a phenomenon (Goldsmith, 1984; Kress and van Leeuwen, 1990; Kearsey and Turner, 1999; Mathewson, 1999, 2005; Tversky, 1999, 2002). Landscape illustrations by past naturalists, such as Charles Darwin and Alexander von Humboldt, show the causal relationships characterizing the environment, and they are most precisely represented in diagrams and drawings by geologists such as James Hutton and Charles Lyell, which clearly show the environmental model of all these authors, i.e., their understanding of the phenomenon.

Drawing is a powerful communication tool that complements oral and written communication, but it also needs to be taught and learned. Several studies have focused on the role of language and questions in science learning (e.g., Graesser, Person, and Huber, 1992; Sutton, 2003). In contrast, there are fewer studies on the role of drawings in learning science, geology in particular. We now need studies on the role of drawings in science learning.

This study analyses graphic representations of landscapes, produced by teacher-training students and secondary school students, and the descriptive power of these drawings in connection with questions posed on the systems being represented. The teacher trainees studied geosciences during their compulsory education stage. The secondary school students were studying geosciences. We wanted to know whether both groups are capable of representing geological features. By comparing these two student samples (from secondary school and from university), we aim to discover whether the difficulty in using drawings to communicate ideas on natural systems lies in a lack of geological knowledge or not having learned how to use drawings as a communication tool. The constituent parts of a suitable description of a landscape as a natural system should include geological, as well as biological, elements. The absence of geological elements makes it difficult for students to use an environmental model. The drawings produced by students of a specific landscape will be an approximation of the model they have of that landscape. The model should include the causal relationships established by the student, since the explanation of these relations tells us what the student understands about how this particular environment works.

We have specified our research questions as follows and on the basis of the preceding information: Which geological features do secondary students of geosciences represent in their drawings of landscapes? Which geological features do teacher trainees represent in their drawings of landscapes? Do teacher trainees use geological features to answer questions about the functioning of an ecosystem?

IMAGES AS TOOLS OF LEARNING

Drawings, and in general all kinds of graphic representations, are an important part of the science syllabus. Textbooks and other materials include graphs, sketches,

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drawings, and photographs, each with different objectives and forming part of the educational content (Dimopoulos et al., 2003; Van Eijck and Roth 2008; Carvalho et al., 2011; Jarman et al., 2011). Knowledge of the visual language that allows us to read a graph, sketch, diagram, and so on permits us to communicate and makes it possible for us to acquire new information. Yet students not only have to glean information from images but also have to create their own images to communicate knowledge.

In the science classroom, learners mainly focus on interpreting others' visualizations. When drawing occurs, learners are rarely encouraged systematically to create their own visual forms to develop and show understanding (Ainsworth et al., 2011). Pintó and Ametller (2002) investigate the role of images in science learning and students' difficulties in understanding the information in them. Some research shows that students have problems understanding two-dimensional images to illustrate spatial models and difficulty understanding sectional drawings (Constable et al., 1988; Macnab and Johnstone, 1990; Bandiera and di Macco, 2000); for example, students can answer questions about the Sun–Earth–Moon system, but they have difficulty representing the answers through drawings (Martínez-Peña and Gil-Quílez, 2001, 2003). Other authors have found similar problems in student drawings of samples of observations through the microscope (Díaz de Bustamante and Jiménez Aleixandre, 1998). There are also authors, such as Mottet (1996), who questioned whether illustrations were a source of learning. Bachelard (1948) and Piaget and Inhelder (1956) had already pointed out that knowledge is not produced as a result of perception. Given that perceiving an image is not the same as perceiving reality, since it must be constructed through the image (Tversky, 1999), the concept of "seeing," in the purely optical sense of the word, needs to be contrasted with that of "looking," which includes personal, cognitive, and cultural elements. In other words, images should not be mere illustrations of "knowledge" expressed through written language but "joint managers" of this knowledge in a process of symbiosis between both (Catalá, 2005). For this to happen, didactic and cognitive conditions are necessary to allow the transformation of the image into knowledge and subsequently that of knowledge into image (Mottet, 1996). Students need to be helped to develop the abilities required to read images (Goldsmith, 1984; Kress and van Leeuwen, 1990; Reid, 1990a, 1990b; Jarman et al., 2011). This involves developing skills in students to enable them to read landscape images (photographs), as well as to draw representations of the landscape. Multiple factors influence learning, and in many cases, the complexity of images is not matched by the students' interpretive skills (Roth et al., 1999; Bowen and Roth, 2005). For this reason, many authors argue that textbooks should adopt an appropriate iconographic language to communicate relevant information, and for illustrations to be effective in the teaching–learning process, they should be referred to in the accompanying text (Kearsey and Turner, 1999; Mathewson, 1999; Escovedo et al., 2000).

In our everyday lives, we relate not only to physical objects (a table, a plant, a person) but also to representative or semiotic objects (writings, photographs, diagrams, road signs). These signs are physical objects that refer us to another reality, so they are considered as external representations of this reality (writing is a representation of language, and images represent objects, people, or scenes). Illustrations understood as external systems of representation are semiotic objects of great importance, essential for representing and transmitting particular types of information related to many human activities: book illustrations, publicity images, and maps, not to mention audiovisual images (television programming, videogames). In this way, symbolization systems can be used as exploratory instruments of internal representations (Tversky, 2002; Martí, 2003; Jarman et al., 2011).

DRAWING AS A REPRESENTATION OF AN ENVIRONMENTAL MODEL

Pickett et al. (1994) state that there are various modes of understanding. One of them is *via science*. The outcome is arriving at a conclusion, and some features of this type of understanding are replicability, use of evidence, linkages of observation and explanation, and creativity. Another is *via art*. The outcome is expression, and some of its features are a singular experience, personal interpretation, and creativity (Alerby, 2000). We want the emphasis to come *via science*, without forgetting personal creativity.

Landscape components are characterized by being clearly evident and easily observable and thus constitute one of the defining characteristics of landscapes: their perceptibility, not only visual but also multisensory. Landscapes offer wide-ranging opportunities as a didactic background to human activity. The observation and interpretation of landscapes opens doors to knowledge of the world around us. By concentrating on their educational value, landscapes can be seen as a text, an open book waiting to be read. However, before we analyze this landscape text, we must learn how to read. Visual reading is the first and essential step toward interpretation. Although all senses are involved in the perception of a landscape, most is perceived through the eyes.

A scientific description of landscape requires the isolation of its qualities by procedures capable of being described and reproduced; i.e., their main characteristics must be detected. A natural landscape can be described objectively by characterizing its constituent elements, for example, types of landforms and the vegetation found. Such a description is of high educational value (Cervera and Pardo, 1987). However, understanding why the landscape is as it is requires an analysis of other aspects. We can construct the landscape scene with the constituent elements, but later we have to build the staging, which constitutes the environment using the interconnections among these elements, i.e., construct a model of an ecosystem.

To understand how an ecosystem functions, knowledge of its geological features is essential, so the model of that particular ecosystem needs to be constructed. These geological features establish some key characteristics of the landscape. Geology is mainly an observational science. One could say that for geologists, research is making inferences from the footprints of nature's activity (experimentation) throughout the history of Earth (Orion and Kali, 2005). It is a strongly interpretative and historical science, because it tries to reconstruct events that have occurred in the past based on records that are the rocks, structures, landscapes, and processes observed in nature in the present (Frodeman, 1995). Spatial thinking is important to many scientific

TABLE I: Groups of students and activities done with them.

	What the Students Know	How the Students Organize the Knowledge	How the Students Apply Knowledge
Activities	Photographs of landscape	Excursions to different areas	A problem concerning the dynamics and evolution of two lakes: one natural and the other manmade
Objectives	Describe landscape elements	Build a known environmental model	Apply an environmental model
Students	4th-year secondary students (n = 46), **Group A**	Trainee teachers (66 core subject and 26 optional subject), **Groups B and C**	Trainee teachers (26 optional subject), **Group C**

disciplines, but when studying aspects of geosciences, learners must have excellent visualization skills. These spatial abilities can be improved through practice, including coursework, working with three-dimensional or interactive computer models and field experiences (King, 2008; Almquist et al., 2011). That is why the observation of landscapes, either directly in the field or indirectly in photographs, is essential for a proper understanding of the geology and environmental relationships. When noting landscape data, drawings are an extremely important option, and they complement written data. All data concerning the landscape have verbal and visual characteristics but are interdependent for understanding and action in the world today (Compiani, 2011).

A fundamental part of teaching and learning the sciences is not only learning scientific models but also encouraging students to construct their own models. This means establishing a type of teaching that helps students to develop an understanding that is coherent, flexible, systematic, and above all, critical. The construction and use of models by students is a useful metacognitive tool for teaching, as has been amply demonstrated (Boulter, 2000), both in terms of thinking out explanations and making predictions. However, in our teaching experience, we have found that students have difficulties taking down data about the landscape by producing diagrams or drawings. Research indicates that drawings can reflect students' knowledge about the subjects in a drawing. Generally, drawings by elementary students include more details and realistic representations for subjects they know more about. Often, students omit drawing subjects they do not know much about (Cronin-Jones, 2005).

METHODOLOGY

The study was carried out with 46 Spanish 10th-grade secondary students (Group A, 15–16 years old) attending a city school and two groups, one with 66 (Group B) and the other with 26 (Group C), of Spanish teacher-training students in the last year of their course at the Faculty of Education (Table I). We worked with secondary school students because they are in the final stages of compulsory education and they are studying geology. We wanted to know whether these students recognize geological features of the countryside. We worked with teacher-training students because, besides being our own students, they will be responsible for the initial (primary) education of children in natural sciences. These teacher trainees do not study geology, although they studied it during their compulsory education stage. We wanted to know whether they are capable of representing geological features in drawings of landscapes in a specific ecosystem, because geology forms part of this system and drawing is a communication tool—and therefore a teaching tool—that will be useful for them in their future profession.

The tasks required of each group varied in their level of complexity. The secondary school students were asked to identify and draw geological features from photographs. The university groups were asked to represent the essential features of a landscape they had visited, which would include geological ones. Finally, Group C was also asked to interpret the dynamics of the landscape where geology plays a significant role, which is a more complex task. In addition to producing drawings of the photographs and landscapes visited, all three groups had to answer a set of questions for which the use of geological concepts was required to describe or interpret the landscapes (Appendix A). The manner in which this was done enabled the drawing and the text to provide insight into the model the students had of the landscape. The activities performed by each group are explained below:

- Group A—Secondary students who were studying the subject "Biology and Geology" were provided with a series of photographs of landscapes. This activity was opted for since, for organizational reasons at the school, the students do not go on field trips. We wanted to know whether their current level of geological knowledge would enable them to represent features in their copies of the photographs. The photographs were familiar to them, given that they are landform types (glaciers, river meanders, cliffs) and emblematic landscapes in their region (Table I). As the teacher was a geologist, the students mainly studied geoscience subjects in depth, and ecology was only studied superficially. The students were asked (Appendix A) about the main types of landforms shown in the photographs, the landscape process, and whether climate had been the main factor in the formation of the relief or other factors (such as the nature and structure of the rock or the action of the sea) had been determinants. Finally, they had to produce drawings, specifically a diagram of the geological shape or shapes that are essential to understand the landscape in the photograph, i.e., those geological features that make the relief what it is.
- Group B—Field trips to an old meander (oxbow), through which no river water flows, located close to a steppe area, were organized with these students in which geology, without being given overriding importance from an aesthetic point of view, never-

TABLE II: Selection of master images of science, which could be shown in landscape drawings, following Mathewson (2005).

Setting: Whether the drawing has a title (In field trips where only one area is visited, the absence of a title may be insignificant and the title of the text corresponds to that of the diagram. However, when several locations are visited, this is an important consideration. In any case, the title of a landscape diagram is its introduction and its context; therefore, it should be considered relevant.)
Signs: Whether the drawing is mute or includes labels, i.e., references to what is represented (rocks, layers, reeds, poplars, etc.)
Boundaries, silhouettes, surfaces, shapes, contacts: Whether landscape silhouettes are drawn (ponds, mountains, etc.) or there is simply a patch of color, for example
Colors: Whether the most characteristic colors of the landscape are included
Containers **Vegetation:** Whether different plants, crops, wetlands, etc., are shown **Animals:** Whether their presence or evidence of their presence is shown **Rocks:** Whether they are shown or referred to
Strata, structures, folds: Whether there is any indication of the arrangement of sedimentary rocks, folds, faults, vegetation structures, etc.
Polarity, shade: Whether there is any indication of geographical location (orientation using the cardinal points, nearby localities, buildings, roads, shade, etc.)
Points or features: Whether the drawing shows any object or place easily identifiable or representative of the area (e.g., a big tree, a spring, a peak)
Flow: Direction of currents of wind, water, etc.
Time: Reference to the passing of time by means of labels, symbols, or explanations (e.g., seasons, trees without leaves, silting of the lagoon, differing water levels depending on the season)
Chaos: Indications in the drawing or in appended explanations of the complexity of the landscape represented (dynamic system behavior, or erratic, complex, irregular behavior of a nonlinear system with interdependent variables developing, evolving, or cycling under the influence of feedback, Mathewson, 2005)
Magnitudes: Indication of some type of graphic or numerical scale
Cycles: Whether there are references to cycles of seasons or water by means of labels or explanations
Organization: Identification of regular occurrences and causal relationships

theless played a crucial role in the organization of the environment. The students were given working guidelines in the field in which they were asked to produce drawings and reply to a series of questions (Appendix A). The questions referred to the differences between the steppe and the riparian forest and the reasons behind these differences. The students took notes and produced drawings in situ. Later, in the laboratory, they compiled a final report of the field trip in groups of three to four (Table I). They were told to include a drawing of the landscape showing the most significant features of the different areas and to explain the relationships among them in the report.

- Group C—Students went on a field trip to two nearby lakes with different origins and characteristics (Table I), and they had to draw those lakes and answer several questions (Appendix A). The drawings were supposed to explain the main characteristics of the visited area. The questions concerned the origin of the lakes; possible explanations for the existence of organisms in one lake but not in the other, and vice versa; and an explanation of the dynamics and evolution of the lakes (Appendix A).

Before the trip, we explained to the students the biological and geological features of the area we were going to visit. For this explanation, we used photographs, illustrations, and maps. During the trip, the teachers, a biologist and a geologist, commented on the landscape and the elements that formed it, i.e., rocks, vegetation, animals, signs of them, relief, etc. Environmental issues were worked on with the university students within the subjects "Knowledge of the Natural Environment" (Group B) and "Diversity of Living Beings" (Group C). The latter is an optional subject in the teacher-training curriculum. The purpose of these issues is to enable students to understand that these specific environments, with all their characteristics, are complex systems and that geological features form part of this system. The students only have the possibility of working on environmental issues in these courses. Both the secondary school students and the teacher trainees at university study drawing courses.

As seen in Table I, each of the groups was asked questions whose level increased in complexity. The university students (Groups B and C), future teachers, had previously done some work on producing and assessing scientific drawings and their role in the teaching–learning process. They used drawings they had produced themselves based on observations made by microscope and stereoscope of cells, leaves, and small organisms, as well as drawings of the Sun, Earth, and Moon model (Díaz de Bustamante and Jiménez Aleixandre, 1998; Martínez-Peña and Gil-Quílez, 2001). The aspects valued in these drawings were adding a title, drawing representative features, labeling, keeping proportions, avoiding anecdotal drawings (such as air bubbles in microscopic preparations), etc. To analyze the drawing, we used a template based on suggestions by Mathewson (2005), who proposed a list of master images of science, i.e., structures and scientific phenomena, excluding concepts that have no visual form (such as the concept of energy). The master images include limits (cellular membrane), circuits (electronic, circulatory), cycles (seasons), order (geological eras), and symmetry. For this study, we selected the categories that had to be present in drawings of a natural environment drawn by students, because they represent the various components of an ecosystem (Table II). These categories allow for an objective and systematic analysis of drawings, lending credibility to the results we obtained.

As previously mentioned, these drawings were accompanied by texts produced by the students to answer the questions set: Group B about similarities and differences between the steppe and the old meander and Group C with questions and final report, explaining the origin of these

TABLE III: Categories used to analyze the texts written by the students (Van Dijk, 1983; Aznar et al., 1991; Izquierdo and Rivera, 1997).

Subject or title: The information is condensed. As with the drawings, the title is the introduction to the text.
Expansion of subject or title
Elements: The constituent parts of the landscape or environment are described (vegetation, rocks, animals, constructions, etc.).
Properties: The qualities of the landscape and its elements are given.
Causal relationships: Connections are made between two, three, or four elements and properties (including organization, cycles, time, and chaos).

lakes. The categories chosen for their analysis (Table III) were based on those used by Van Dijk (1983), Aznar et al. (1991), and Izquierdo and Rivera (1997). In the "Expansion of subject or title" category, information was collected on the enumeration of environmental elements and their characteristics or properties. Another aim was for students to describe causal relationships among different environmental elements in their texts so that the level of complexity of their models could be evaluated. The more relationships a student established, the greater the possibility of reliable applications of the model to diverse environmental situations.

Lastly, the tools used were assessed at the research group meetings by two lecturers from the university Science Education Department and one secondary school teacher.

RESULT

The students' drawings of the landscape varied, ranging from "schematic," representing hardly any silhouettes (Figs. 1 and 2), to "artistic" drawings (Fig. 3), which can be viewed as personal interpretations, to "anthropic" (Fig. 4), highlighting human constructions (houses, churches, roads, farms, etc.). The type of understanding these drawings show is encompassed in the art mode instead of the science mode (Pickett et al., 1994); i.e., it is a personal expression rather than a conclusion resulting from linkages of observation and an explanation of an environment.

Group A

Table IV shows the results of the analysis of the drawings. Those with dashes are categories not requested of these students (setting, points, animals, time, chaos, magnitudes, cycles, and organization), since, as mentioned above, the areas these students had worked with in the classroom belonged basically to geosciences. Most of the students copied the photographs, but a few highlighted the most significant features of the geological landscape [Figs. 1(a), 1(c), 1(d), and 1(f)]. The teacher of this group did not require students to produce drawings; i.e., he did not use drawings as a learning tool to teach geology. This circumstance is usual in science teaching (Ainsworth et al., 2011), and it may have influenced the results.

The majority of the students (82%) represented the landscape using silhouettes, or boundaries (Table IV), i.e., all elements making up the "scene," whether or not they were relevant from a geological point of view [Figs. 1(b) and 1(e)]. Only 33% of students highlighted the significant landscape structures (strata, structures, or folding) in the photograph by integrating them into the configuration of the landscape (Table IV). In these cases, the students provided an interpretation of the role of the geological features in the construction of a model of the environment [Fig. 1(c)]. It is striking that although the activity was carried out as part of their geosciences studies, a minimal number of students (12%) made reference to rocks [Fig. 1(a)], despite their importance as a determining factor in the landscape configuration. As in the case of the students who drew the strata, structures, or folding, these students emphasized the presence of the rocks, which indicates an advance in the construction of the model, i.e., an increase in its complexity, since the type of rock (limestone, sandstone, slate, granite, basalt) generates a characteristic type of relief based on climatic conditions and the current arrangement (stratification, fracturing, folding). For example, horizontally stratified limestone originates a *mesa* relief, which differs greatly from the relief on ridges generating a folded limestone with vertical stratification. Table IV shows that 66% of students included labels (signs) to clarify what they had drawn. They indicated obvious elements such as "cave," "mountain," "meander," or "moraines," which added nothing to the description [Figs. 1(a), 1(d), and 1(f)]. In addition, the number of labels was insufficient to characterize the geological landscape. A high percentage, 28% (Table IV) did not draw anything, even though the activity included an item explicitly asking them to draw (Appendix A). This could be because they do not work with drawings produced by themselves as a learning tool, so they probably do not consider drawings relevant, despite being asked for them specifically.

This group's written notes were guided by a set of questions (Appendix A). Taking into account the categories used for the analysis of texts (Table III), these students were only asked questions regarding elements and properties. The first question solicited the students to indicate the main geographical features they observed in the photograph, which we considered as the category of constituent elements of the landscape. The students named various elements in the photograph, such as "rivers, valley, meander, fluvial deposits" or "stalactites, stalagmites," while some mentioned only one element, such as "cave," "dunes," or "limestone rocks." However, only 28% of the students named all characteristics forming the landscape shown in the photograph (Table V). The following questions enabled the properties of this category to be analyzed: What do you think was the principal agent that modeled this relief? In which climate does this type of terrain occur? Although the students were not exhaustive in their responses to the above questions, the majority (61%) wrote about the qualities of the landscape and its elements: "It starts with a process of chemical weathering called carbonation," "The determining factor is water, which causes erosion of the rock," and "The landscape has been shaped by the action of the wind."

A last question asked them to establish causal relationships between the relief forms and their agents: Do you think climate was the main factor or were there other determining factors? Only 13% of the students established causal relationships, though these were not sufficiently well explained; they lacked elements and properties, and consequently real relationships: "It is because of the action

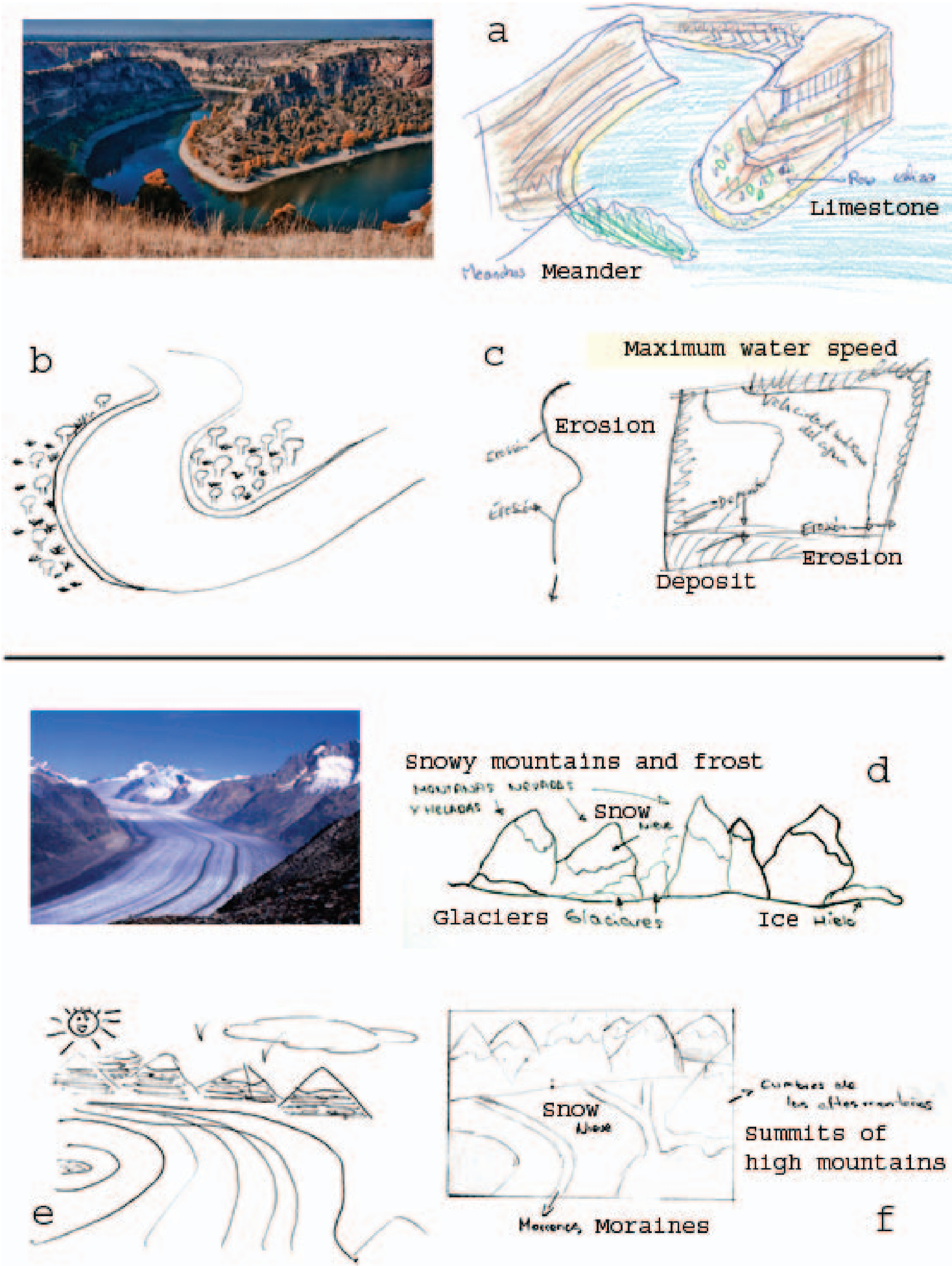

FIGURE 1: Drawings of landscape photographs. Secondary school students, Group A. (a), (c), (d), and (f) Features of the geological landscape. (b) and (e) Only silhouettes. (c) Flows.

of the river in the higher part. This part has a big slope where water flows very quickly so that it has considerable erosive power." "The calcium carbonate precipitate deposited on the walls of the caverns, from water with dissolved calcium bicarbonate that slides down them, forms flow stones."

These results show a lack of descriptive elements of the landscape, i.e., the students find it difficult to describe a landscape, and although a high percentage makes reference to properties, this could be because they are familiar with this type of question, since they are similar to the ones set in examinations. This means that it is difficult to establish satisfactory causal relationships between elements and properties.

To conclude, in general, the texts produced provide more information and are better than the drawings. However, it is the texts, which lack the descriptive elements hinder a proper understanding of geology and environmental relationships (Cervera and Pardo, 1987; Compiani, 2011). In addition, the students who wrote more complete responses made the best drawings, according to the analysis categories in Table II.

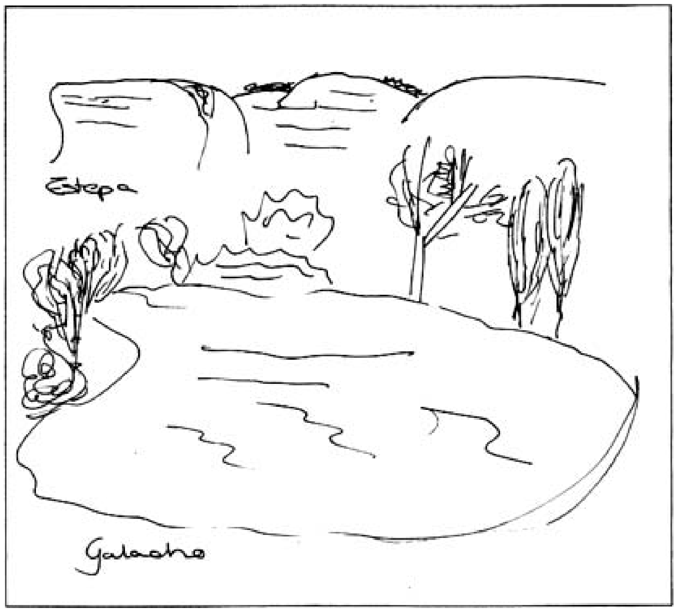

FIGURE 2: Drawing, with only two labels: steppe *(estepa)* and oxbow *(galacho)*. Trainee teachers, Group B, field notebook.

Group B

Sixty-six students participated in the field trip to the steppe and the riparian forest, and 63 questionnaires were collected. As can be seen in Table IV, only 25% of the field notebooks contained a drawing of the landscape. Most students did not produce any drawings, although there was a box in the notebook specifically for a drawing and in the class prior to the trip they were given precise instructions about what was to be done in the field, including producing a drawing. During the field trip, students were again reminded about the drawing, and it was explained that a drawing is a personal construction given that the person producing the drawing provides an interpretation of the landscape, unlike the taking of a photograph (Tversky, 2002; Martí, 2003; Jarman et al., 2011). It could be said that the students considered that a written text enumerating the elements of the landscape was more relevant than a drawing done by them.

There were no titles (setting) to any of the drawings (Table IV). As in the excursion, this was a visit to two areas (the meander and steppe). We considered it relevant that the students referenced the setting (Table II). The drawings are mute; few students included labels or made any reference to animals, rocks, or structure (Table IV). All drawings showed silhouettes (boundaries) of the mountains, the river and vegetation, the most obvious features of the landscape, but none indicated that the mountains have escarpments, which shows the horizontal layers of gypsum, or that the oxbow is on gravel, favoring water infiltration and leading to the formation of gaps (Fig. 2). All these aspects were discussed in the classroom before the field trip and then again in the area. As in Group A, the drawings depicted a scene, i.e., only what could be seen, without any elaboration. Nobody shows the orientation or any other type of reference point, unusual features, scales, colors, or flows.

FIGURE 3: Artistic drawing. Trainee teachers, Group B, final report.

In the field notebooks, the students had to answer questions referring to the differences between the steppe and the riparian forest and the reasons behind these differences. All the students included various lists of constituent elements (Table V), mostly referring to animals and plants: "brambles, fennel, tamarisk," "broom, wormwood, thyme, thistle," "ants, spiders, flies, butterflies," and "gypsum, clay, pebbles." Some referred to certain properties of the environment (40% students): "The high humidity in the abandoned meander (oxbow)," "the sparse vegetation on the steppe," and "the soil is poor in nutrients." However, only 9% established causal relationships between the organisms and the environment ("The vegetation on the steppe has very small leaves so as not to lose water and to avoid evaporation"), yet these few established relationships do not refer to geological characteristics. These results come from the field notebooks, so it is coherent that these data, taken in situ, focus mainly on descriptive aspects, such as landscape elements and some of their properties.

The 66 students worked in groups to compile their final reports, and 18 were handed in (Table IV). Of these, only 33% contained original drawings (Fig. 3), since the other illustrations were photocopies or copies of other drawings taken from various documentary sources relating to the area (Fig. 4). It is remarkable that the number of drawings was not much higher than those handed in with the field notebooks. In the final report, students were specifically asked to produce a drawing representative of the model of the environment visited, and unlike during the field trip, they had material to consult and time to produce the drawing. The analysis in the template (Table IV) shows that the drawings produced for the report had lost some information. In the field notebook, the students included more labels, drew some animals, or made references to the rocks. The only improvement, in terms of the points given in the template, was an artistic impression with the inclusion of colors (Fig. 3). There was less personal preparation, although working in groups should encourage discussion among students and they had access to bibliographical information about the area. Although the students had a substantial

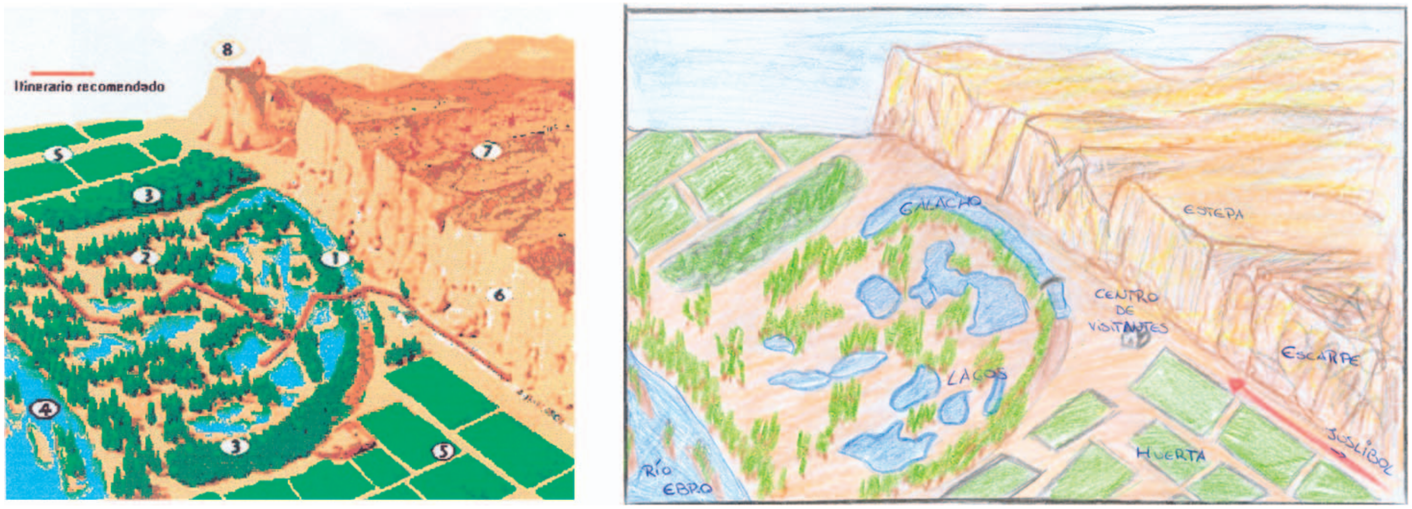

FIGURE 4: Drawing (right) and copy of tourist brochure (left). Trainee teachers, Group B, final report.

amount of information available in the classroom, they tended to copy the external information rather than use it together with what they have acquired in the field to produce their own work (Fig. 4).

As has already been pointed out in connection with the drawings, the final report text provided more opportunities to work on causal relationships, since the students worked in a group, which enables them to share information and discuss any questions they had been set. The reports contained more data than the drawings, but this was bibliographic information incorporated literally into the report without any personal analysis of the causal relationships that characterize the two environments, steppe and riparian forest.

All the reports included the title—although they merely pointed out the name of the area, steppe or meander, and the constituent elements of both zones—and 44% of the final reports made reference to properties (Table V). Describing the properties of the elements forming an environment is the step prior to being able to establish causal relationships, and not doing so makes it difficult to produce an interpretation of the environment, as well as an explanation of the differences between the steppe and the riparian forest: "The steppe zone is formed by sedimentary rocks (gypsum) that tend to be salty, and it is also characterized as being a dry zone" and "In the meander the vegetation is abundant, luxuriant, leafy, and it is characterized by being irrigated given that it is by the river bank.. . . It is a plain, and there are no rocks. The soil consists of sedimentary rocks that have been deposited by the river." Regarding the establishment of causal relationships, the students included more in their final reports than in their field notebooks (Table V). As has been mentioned above, the students had more time, more information, and more

TABLE IV: Results obtained from the analysis of the drawings.[1]

	Group A	Group B: Field Notebook	Group B: Final Report	Group C
No. Documents	46	63	18	26
Not Drawings	28%	75%	67%	35%
Drawings	72%	25%	33%	65%
Setting	—	0%	100%	100%
Signs	66%	50%	16%	53%
Boundaries	82%	100%	100%	100%
Points	—	0%	16%	88%
Colors	30%	0%	83%	2%
Vegetation	12%	100%	83%	94%
Animals	—	37%	33%	6%
Rocks	12%	25%	50%	0%
Strata, Structures, Foldings	33%	0%	0%	0%
Polarity	0%	0%	16%	100%
Flows	9%	0%	0%	0%
Time	—	—	0%	0%
Chaos	—	—	0%	0%
Magnitudes	—		0%	0%
Cycles	—	—	0%	0%
Organization	—	—	0%	0%

[1]The categories marked with a dash were not requested of these students.

TABLE V: Data on students' texts.

	Group A	Group B: Field Notebook	Group B: Final Report	Group C
Title	100%	0%	100%	35%
Elements	28%	100%	100%	54%
Properties	61%	40%	44%	27%
Causal Relationships	13%	9%	17%	11%
No. Documents	46	63	18	26

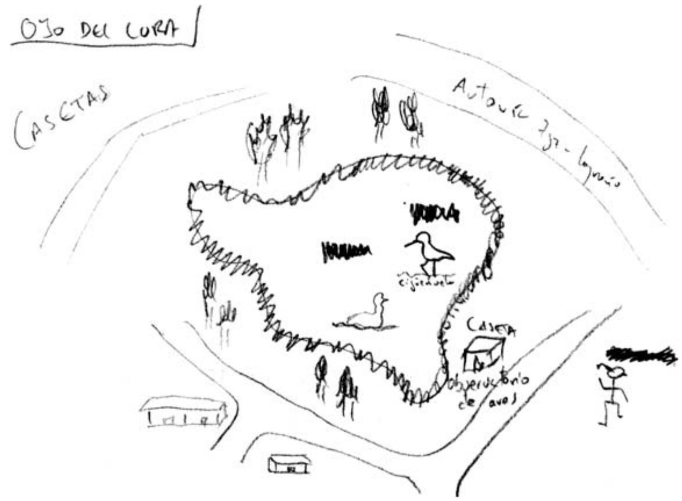

FIGURE 5: Drawing with title: ***Ojo del Cura;*** **silhouettes; animals, vegetation; polarity: nearby locality** ***(Casetas),*** **road** ***(Autovia Zgz-Logroño);*** **or buildings. Trainee teachers, Group C.**

opportunity to discuss among themselves to write the final report.

The geological references were mainly in connection with the steppe, pointing out the presence of gypsum and pebbles, even relating them to the river terraces. They also commented on the area's aridity, but they made no causal connections among soil, climate, and organisms. They occasionally produced simplistic relationships among these elements: "The area of the grove and the meander has more water, is more protected from the wind, and lies at a lower level. In contrast, the escarpment and particularly the steppe (totally unprotected) remain at the mercy of the strong summer sun and the winter wind so that water evaporates more easily." In this case, they state the obvious, that the steppe is higher than the riverbank and that there are hardly any trees to "protect" it from the wind and sun. When mentioning the differences between the steppe and the meander, they generally concentrated exclusively on the vegetation. The only reason for these differences according to the students is the presence of water. However, they did not explain the location of the water that enables the development of thick vegetation in the meander area but not on the steppe or why the plants in each of the zones, meander and steppe, are so different. They did not talk about the water table or soil features.

In short, the students again refer principally to descriptive elements in their reports. They point out the constituent parts (vegetation, meander) and properties (humidity, thick vegetation, fertile area), but they do not provide sufficiently well-argued causal relationships to explain the differences between the two zones. Furthermore, there is no reference to the geology of both areas. One might say that students cannot build the model of this ecosystem.

Group C

The 35% of the field notebooks not containing a drawing of the lakes (Table IV) is a high percentage, considering the students were explicitly asked to make a drawing (Appendix A). In this group, the students produced drawings with more personal input than those in the other groups. However, as they were taking an optional subject, "Diversity of Living Beings," they should be interested in the organism–environment relationship. All drawings had silhouettes of the lakes, and because two lakes were visited, all included a title noting the name of each zone (Fig. 5). However, none provided any information about the area in the sense outlined in Table II. Slightly more than half (53%) of the students included labels (signs) to show what was being represented, such as huts, a viewpoint, and poplars (Table IV). In other words, students perceive landscape signs and features, as indicated in Table II. The majority drew vegetation (94%) using silhouettes of trees; i.e., they drew schematically some generic features common to all trees (trunk and crown), what Martí (2003) called the canonic character of representation. However, the particular characteristics of these trees were not drawn. Only 8% drew animals and used colors in their notes (Table IV). No reference was made to the rocks (gypsum and clay), even though geological characters played an important role in the origin of these lakes and therefore in the shaping of this environment.

The students had to answer questions concerning the origin of the two lakes and the existence of organisms in one lake but not in the other, and vice versa; finally, they had to write an explanation of the dynamics and evolution of the lakes (Appendix A). Only 35% of the notebooks included a title (Table V), but no students provided information about the area in the sense outlined in Table III. Although 54% referred to all constituent elements of the lakes, only 27% referred to the properties and only 11% mentioned causal relationships enabling them to interpret the environment. At first glance, one might think that the results are worse than those obtained from Groups A and B, but this group was given some activities to discover how they apply knowledge (Table I). These activities involved a higher cognitive demand.

Some students gave an intelligible explanation of the characteristics of the naturally formed lake: "The water is salty because of the concentration of salts in the soil, a fact that gave rise to the lake, the natural origin of the lake resulting from the sinking of a sinkhole that was formed when the gypsum was dissolved by the action of infiltrated rain. The hole then filled with rainwater and irrigation water." Others confined themselves to including labels relating to elements and properties, offering neither explanations nor interpretations: "The origin of the pool is a sinkhole with a lot of gypsum." About the other lake, which is anthropic in origin, the students did not write a clear explanation for the origin of water in the manmade lake: "It was a clay quarry, which sank and where water entered."

The students used their data to refer essentially to descriptive elements in their written notes. The texts have a title, refer to the constituent elements or parts (lake, vegetation) and to properties (saltiness of the water, variable water levels), but they barely touch on interpretive elements of the landscape to answer the set questions, and any causal relationships they mention are insufficiently explained. In their texts, the students referred to sinkholes, gypsum, dissolution and sinking, clay quarries, groundwater, and the influence of irrigation water, but surprisingly, none of these things are reflected in their drawings. We can say that the students of Group B they have not built the model of this ecosystem.

DISCUSSION

The results of the study reveal that a high number of students, both those at university and in secondary education, did no drawings either on the field trip or when preparing their reports, even though this was the task they had been set. With Group A, this result is logical considering that the teacher did not use the students' drawings as a learning tool. The objective was to know whether these students recognized the characteristic geological aspects from a photography. With Groups B and C, we had worked on the importance of drawing as a learning tool using drawings produced by students in other classroom activities: observations made by microscope and stereoscope of cells, leaves, and small organisms, such as stick insects and crickets. Moreover, the instructions on the drawings were given before and during the trip and were written in the field notebook (Appendix A). The lack of drawings may be due to the secondary role played by drawings in school education in sciences (Ainsworth et al., 2011) compared to the importance attached at school to oral and written communication as a learning tool. As mentioned above, several studies have shown the difficulty students have not only understanding various types of drawings on scientific issues but also producing any themselves (Constable et al., 1988; Macnab and Johnstone, 1990; Bandiera and di Macco, 2000; Pintó and Ametller, 2002). This difficulty may result in the students not producing drawings.

Evidence of the lack of importance they attribute to drawings as a learning tool is that some university students from Group B submitted photocopies instead of drawings or a recreation of a drawing found in the bibliography on the area visited. They might not rate producing personal drawings highly for the reasons described by Sanmartí et al. (2002), who point out that students do tasks only in response to teachers' requests without considering whether they could be useful for their learning. In this case, the students believe they are responding to the teacher's request for a drawing of the landscape by submitting a copy of a drawing taken from information leaflets. Drawings are considered key elements in science education (Ainsworth et al., 2011), particularly in primary education. We wanted future teachers to realize not only the potential in drawings when working on geological and environmental subjects but also the difficulties involved in drawings, i.e., the need to teach drawing as a communication tool in science classes.

It is striking that few of the students who produced drawings (both university and secondary school students) represented rocks or geological aspects of the landscape. The secondary students, who were studying geology, recognized simple geological features such as glacial modeling or meanders (Fig. 1)—in other words, elements in the environment. However, they did not include essential geological elements, i.e., those forming the geological relief: central moraine, lateral moraine, zone of erosion and sedimentation in the meander, etc. These elements' features are therefore missing. We understand the photographs as representative of semiotic objects, which convey specific information, which the students have not known how to represent. This means they cannot establish causal connections and produce drawings interpreting the environmental model, i.e., drawings including representations of magnitudes, cycles, organization, etc. (Table III). The difficulty lies not in producing a drawing but in making connections between the landscape and the geological processes that have created it.

The process of reading images is complex and should be taught to students (Mottet, 1996; Tversky, 1999; Catalá, 2005). As Landin (2011) points out, it is not enough for students to learn about nature; they also need to work on having superior observational skills. This would enable them to detect key elements of the landscape and understand how natural systems work. The need to develop these skills, especially in geosciences, has been pointed out by several authors (King, 2008; Almquist et al., 2011).

The teacher-training students listed the geological features only as elements, but they barely emphasized their properties or the ways in which the geological features interacted with other aspects of the environment. They tended to indicate the type of rock with an arrow, but they did not generally show the stratification, the dominant structure in the area (e.g., sedimentary rocks). Although they referred to geological aspects in their written notes (gypsum, clay, sinkhole, dissolution, sinking, etc.), these were not shown in the drawings. Group B's questions were intended to guide their observations (Appendix A) so that they could use them to produce drawings of landscapes with geological features. We believe that these questions provided enough guidance, but they did not suffice. Drawings as systems of external representation show, in this case, that these students do not have a mental representation of the role of rocks in the construction of the environmental models studied, despite their important role: gypsum dissolving to form a sinkhole that later fills with water, plants pertaining to saline soils, lakes formed by clay depressions in the meander, etc.

Geosciences scarcely appear in the school curriculum of compulsory education (primary and secondary education) in Spain and in many other countries (Dodick and Orion, 2003; Eurydice, 2008; Compiani, 2011). This could be one reason the students only perceived the rocks as a ''floor'' for life and buildings and do not refer to the geological features of the landscape, i.e., how the types of rocks and their structure determine the environment.

In general, the university students represent the environment as an accumulation of elements, which may or may not be shown as ordered. Causal relationships are hardly shown in either the drawings or the textual descriptions. In only a few cases do the drawings provide a description of the landscape that can be used subsequently, for example, to answer questions about environmental management. Therefore, they do not have an understanding of the landscape via science in the sense indicated by Pickett et al. (1994), as discussed above.

When producing a drawing directly from a natural environment, the student decides which elements are fundamental to understand how this environment works. The need for observational skills and knowledge is greater than in the case of drawing a photograph. Students must take a holistic view of the landscape to build the model system based on a geoscientific approach (Orion and Kali, 2005; King, 2008).

We believe that the ideal drawing on field trips should illustrate not only the scene but also its hidden aspects. This means that it should include, for example, a section of the land showing the role of rocks in groundwater drainage. This type of drawing would address the question of differences among areas, their dynamics, and evolution. However, as the notebooks and final reports confirm, it appears that the conceptual organization required to establish causal relationships had not yet been developed; therefore, they could not be illustrated in a drawing. Perhaps this is because a high level of abstraction is required to imagine hidden phenomena occurring below ground or in other ages (Ben-Zvi-Assaraf and Orion, 2005).

We can apply to the language of images from Sutton (2003) and Carlsen (2007) to the language of science. This means we need to know more about how students use the language of drawing when they try to communicate something. We should examine the perceptions students have about how they use visual language in the science class, how they think teachers use it, and how they think scientists use it. As teachers, we should ask ourselves whether students have an idea of visual language, drawings, diagrams, etc., as instruments of scientific creativity and whether they have visions of them as tools for their learning.

EDUCATIONAL CONSEQUENCES

It would appear that there is an obvious need to provide students with appropriate tools to enable them to produce landscape drawings, both from photographs and in the field. The complexity of the observation process is especially relevant for knowledge organization in any empirical science teaching, such as geosciences. Producing an orientation-based proposal determines a series of guidelines to be taken into account when creating a landscape drawing. Consequently, each group of students would have to produce a drawing and a description of different landscapes and then present their drawings and read their descriptions to their classmates. Preservice teachers would require classroom work with landscape photographs before the excursion.

Setting, signs, boundaries, containers, strata, and structures (Table II) are closely linked with knowledge of geoscience, so we believe that the master images proposed by Mathewson (2005) or the template used in this study can be used for this purpose. They act as a guide (or orientation) for the students when they draw pictures and evaluate their peers' drawings (peer assessment). Drawings help students learn to observe. Rather than teaching students to draw, the key lies in showing them how to see. One question we considered was whether we would have obtained the same results with the drawings if the students had not had to reply to written questions (Appendix A). This aspect could be addressed in future research.

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APPENDIX A

Group A Questions

- Which are the main geographical features that you observe in the photograph?
- What do you think was the principal agent that modeled this relief?
- In which climate does this type of geological relief occur?
- Do you think climate was the main factor, or were there other determining factors?
- Draw a sketch or diagram of the shape or landforms that are essential in the landscape you can see in the picture, i.e., those that make the geological relief as it is.

Group B Questions

Steppe

- What type of rocks do you find?
- Point out and draw four representative plants of this area.
- Have you seen any animals? Which ones?
- What are the features of this area?

Oxbow and Ponds

- What type of rocks do you find?
- Point out four representative plants of this area.
- Have you seen any animals? Which ones?
- What are the features of this area?
- What are the differences between the steppe and the riparian forest? Why do these differences occur?
- Make a drawing representing the most significant aspects of both landscapes.

Group C Questions

- Do a sketch or diagram of the areas visited, noting all the elements that enable the origin and dynamics of these ponds to be described and subsequently explained, i.e., a description and explanation that will help answer questions such as: What is the origin of the two lakes?
- Why are the animals in one of the ponds different from the animals in the other pond?
- Write an explanation about the dynamics and evolution of the lakes.