Research Article

Improvement of teaching geological maps and cross-sections in the second-year science classes of upper general secondary education schools (high school, SEC and PSC) in the city of Tahoua, Niger

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Abstract: This work aims to contribute to the improvement of the teaching of geological maps and cross-sections in the second-year science classes (1st C and 1st D) of upper general secondary education schools in Niger, particularly in the city of Tahoua. Twenty-four Life and Earth Sciences teachers who are used to holding second-year science classes in fifteen public and private establishments (High school, SEC, PSC) are subjected to a questionnaire. The results of this study showed that the teaching of geological maps and cross-sections is faced with several difficulties. Indeed, 75% of teachers have insufficient initial and/or continuing training on geological maps and cross-sections. 87.50% of teachers highlight the lack and/or insufficiency of teaching resources necessary to deal with this theme, hence a massive use of the internet to prepare lessons. Further-more, this study showed that teachers have shortcomings in mastering the content to be taught because only 50% know how to correctly read a geological map, 12/24 teachers do not master the construction of a geological cross-sections and a significant number of teachers (37.50%) surveyed are unaware of the usefulness of geological maps and cross-sections. As a result, 50% of teachers are not able to apply the didactic approach (ASEI/PDSI) recommended for science teaching in Niger. To address these shortcomings, recommendations were made: the selection of teacher profiles adapted to these classes, continuous training, the development of appropriate textbooks, and the use of Information and Communication Technologies for Education (ICTE).

Keywords: geological map and cross-section, second-year science classes, high school; teaching approach

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1. Introduction

In Niger, geology plays an important role in the teaching of Life and Earth Sciences (LES) in secondary schools (middle and high school). In high school, geology is mainly taught (75%) in second-year science classes (1st C and 1st D), where geological maps and cross-sections are taught. In geology, geological mapping is a central field (Foucault & Raoult, 1975; Sorel & Vergély, 2006) since geological maps are summary documents (Foucault & Raoult, 1975) that draw on some of the most important specialties in geology (Sorel & Vergély, 2006) (petrography, structural geology, sedimentology, stratigraphy, paleontology, geochronology, topography, geomorphology, hydrology, etc.). However, most high school science teachers find it difficult to teach the concept of geological maps (Rassou et al., 2017) and one of the methods used to interpret them (Archambault et al., 1967), namely geological cross-sections.

These two concepts (geological map and cross-section) were introduced as a chapter in Niger's official curriculum during the last revision of the curriculum in 2015 (Alou, 2025).

The difficulties associated with teaching geology in general, and geological maps and cross-sections in particular, are reflected in the refusal and/or opposition of some teachers to teach science classes in the second-year of high school. As a result, some second-year classes find themselves without LES teachers for a long period of the school year. In addition, there is a high rate of absenteeism among certain teachers, or very often they favor teaching biology at the expense of geology.

This study therefore aims to improve the teaching of geological map and cross-section concepts in second-year science classes (1st C and 1st D) in upper general secondary schools in Niger, and in the city of Tahoua in particular. Specifically, it seeks to identify the obstacles and strengths associated with teaching this chapter and to propose remedial or mitigating measures.

To achieve these objectives, a questionnaire was sent to LES teachers in public and private upper general secondary schools (High school, Secondary Education Complex (SEC) and Private Secondary Complex (PSC)) in the city of Tahoua in Niger. The main research questions were discussed: (1) What are the teacher's qualifications and experience? (2) What teaching resources are used? (3) What is the level of mastery of the content and teaching methods? (4) What suggestions do teachers have for improving the teaching of geological maps and cross-sections?

2. Conceptual review

2.1. Overview of the teaching of geological maps and cross-sections in secondary education

Few studies have been conducted on the teaching of geological maps and cross-sections in secondary education. According to Savaton (1998), the teaching of geological maps in secondary education is limited to a few technical aspects, or even to a simple geographical role. Detailed geological maps are too complex to be studied in secondary school (Gohau, 1995; 2001; Savaton, 1995; 1998). The knowledge required to use them effectively exceeds the objectives set for these classes (Archambault et al., 1967). On the other hand, it could be a useful tool for more general learning about the spatial representation of objects, the interpretative construction of scientific knowledge, or the conditions of observation (Balzarini, 2013; Boughanmi, 2009). The use of artificial documents in these conditions and for these purposes seems relevant. It allows for a more accurate understanding of the real document at a later stage (Sanchez & Prieur, 2006; Sanchez, 2008).

The spatial representation of objects is a necessary condition for the construction of operational geological knowledge (Ault, 1994; Orion & Ault, 2013; Raab & Frodeman, 2002). The study of the cartographic coding of geological space is a key step. The conditions for constructing scientific knowledge are overlooked in teaching. Work on the conditions for the intellectual construction of geological maps is part of an epistemological approach to knowledge (Gaston, 2002; Gohau, 1995; Sanchez & Prieur, 2006).

This study on the teaching of geological maps and cross-sections in secondary education leads to proposals for other uses that go beyond the disciplinary content, seeking to contribute to the more general development of scientific thinking (Gaston, 2002; Ault, 1994; Trend, 2000; Gohau, 2001; Sanchez, 2008; Boughanmi, 2009). Savaton (1995) and Orange-Ravachol (2003) show us a significant gap between what a map is for a geologist and what it represents for a student. These investigations raise the issue of how maps are taught, according to what objectives and using what resources.

Some research highlight common obstacles, such as the simultaneous presentation of time and space, of an object in its material and temporal dimensions, or the representation of a practice approached solely through theoretical school learning (Hanaà & Fadi, 2011). It highlights a conflictual situation that goes far beyond the simple production of maps and the relationship between observation and deduction. Through geological maps, geology is presented as a sum of observations detached from reasoning and without established relationships (Gohau, 2001).

In Niger, the teaching of geological maps and cross-sections was not the subject of any preliminary study before its introduction into the official curriculum in 2015. These concepts are taught in the 1st C and 1st D grades of general secondary schools. They are introduced in the form of a chapter (table 1).

Table 1. Content; goals and comment of Chapter: The geological map – The geological cross-section.

Content	Goals	Comment
CHAPTER: The geological map - The geological cross-section - Components of the geological map - Geological cross-section	- Identify the different com-ponents of a geological map - Define a geological cross-section - Recall the usefulness of a geological cross-section - Identify the different geo-logical features on a geological map - Explain the method for creating a tabular geological cross-section - Create a tabular geological cross-section	- To read a geological map, the teacher will introduce students to the geological map (ground layers, toponymy, orientation, layer thickness, dip, dating information, tectonic information, faults, etc.). - The geological cross-section provides information about the subsoil before major work begins. - Various structures can be found on a geological map, including tabular, faulted, monoclinal, synclinal, folded structures, etc. - A geological cross-section is a representation, based on a vertical section, of the terrain hidden deep underground, with only the part that is visible at the surface known. The geological cross-section is therefore based on assumptions and interpretations logically deduced from the information on the map. - A geological cross-section is generally taken perpendicular to the di-rection of the geological structures.

2.2. General information on geological maps and cross-sections

A geological map is a representation on a topographic background of the landforms that are visible at the surface (figure 1) or that are hidden by a thin layer of recent surface formations that are not taken into account (Peycru et al., 2015). The production of geological maps is one of the essential tasks of a geologist. It enables them to reconstruct the geometry of geological formations and the spatio-temporal evolution of their properties. This enables them to locate areas that are suitable for either the construction of engineering structures (dams, roads, railways, bridges, tunnels, etc.) or the accumulation, in economically exploitable quantities, of substances that are essential for human development (water, hydrocarbons, coal, metal ores, geothermal energy, etc.). (Foucault & Raoult, 1975; Sorel & Vergély, 2006). This is why knowing how to read a geological map is important in geology. However, reading a geological map necessarily involves understanding its fundamental elements (figure 1), which are the legend, the grid (coordinates), the orientation (geographic north), the scale, and the geological features (geological formations and structures represented by symbols, colors, or symbols) (Aubouin et al., 1970).

The different geological layers are represented by internationally agreed colors and separated from each other by fine boundaries (Figure 1). These colors indicate their geological age, when known. Bright colors are reserved for magmatic rocks (Foucault & Raoult, 1975). A conventional notation can be used. It consists of a main body and symbols. The main body is a letter that refers to the nomenclature of stratigraphic divisions: C for Cretaceous, J for Jurassic, followed by an Arabic or Roman numeral (C1, C2, C3... or CI, CII, CIII...). Surface formations are represented by: E, Fz, a, GI, OE, Loess; sedimentary rocks: Miocene (M), Oligocene (Ol), Eocene (E), Cretaceous (C), Triassic (T), etc. Magmatic and metamorphic rocks are represented as follows: andesites α, basalts β, granites γ, gneisses μ; faults or abnormal contacts are represented by bold solid lines when they can be observed at the outcrop; if the faults are hidden or presumed, they are represented by bold dashed lines. The legend is printed in the margin of the map. The different layers, represented by their color and corresponding notation, are arranged in a small rectangle in the order of normal superposition (from bottom to top, from the oldest layer to the most recent layer).

In front of each rectangle, the following information is briefly summarized: age, lithological nature, and thickness, when known (Sorel & Vergély, 2006). The geological map is often accompanied by an explanatory note. This note is an essential complement to the geological map, providing everyone with the information they need, within the limits of current knowledge. Reading a geological map is usually followed by an interpretative document, which may be either a geological cross-section (Figure 1), a structural diagram, or a stratigraphic, tectonic, and magmatic commentary (Peycru et al., 2015).

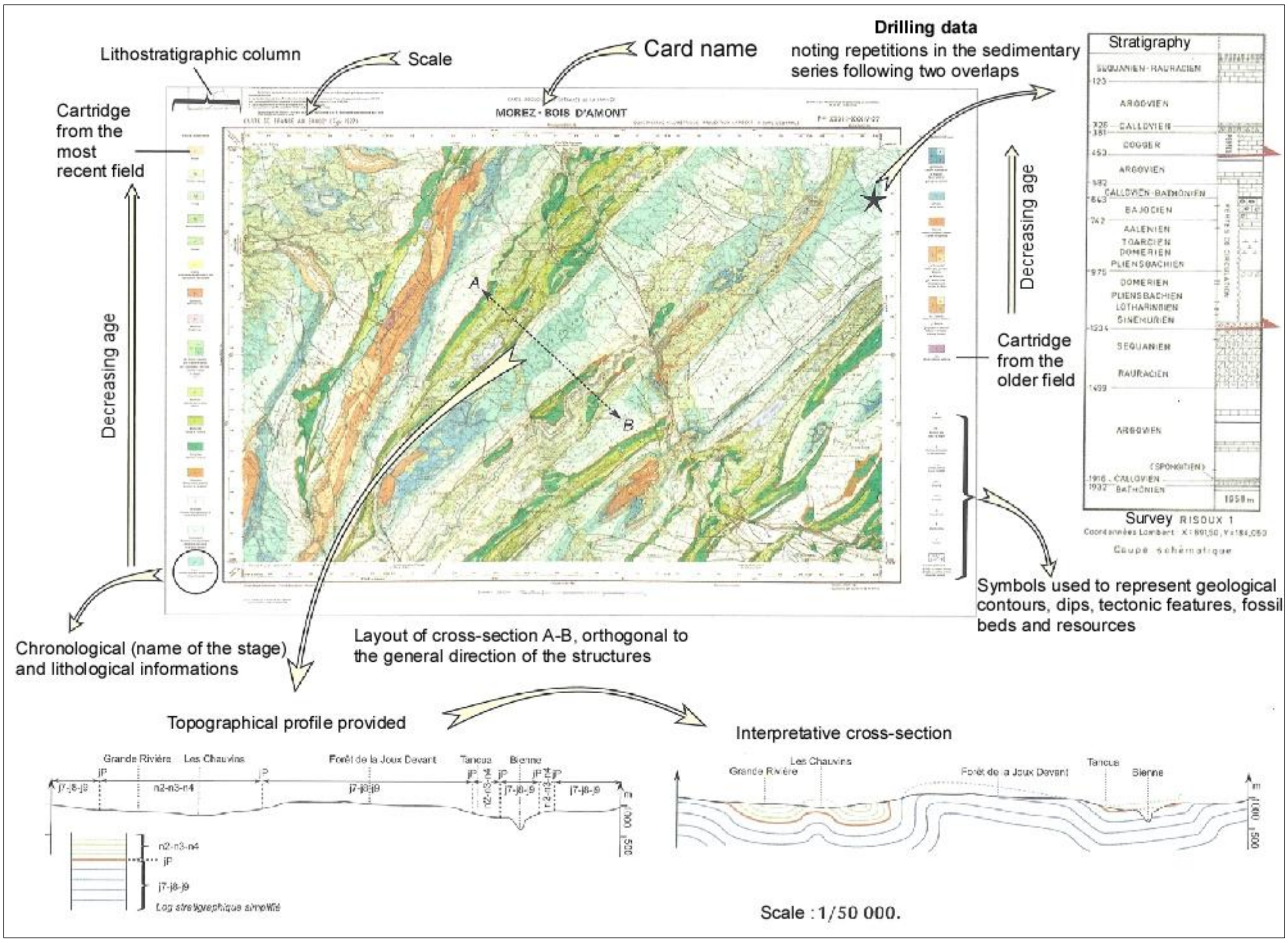

Figure 1. Reading and interpretation (interpretive section) of a geological map.
Source: Peycru et al., 2015.

The geological cross-section, which is the subject of this study, is a representation of the section of the different terrains along a vertical plane (Sorel & Vergély, 2006). It requires a certain amount of interpretation (since we are representing terrains hidden deep underground, knowing only the part that is exposed at the surface). We can then draw the most likely appearance of the strata as logically deduced from the information on the map (figure 1). On the geological cross-section, the different strata are distinguished by conventional symbols. The symbols must reflect the lithological characteristics of the formations represented. They are drawn in relation to the boundaries of the layers and not to the horizontal. The geometry of a plane (geological layer) is determined by two parameters: the dip, which is the dihedral angle of a layer (or fault) with a horizontal plane, and the strike, which is the angular value of a layer with magnetic north (Sorel & Vergély, 2006; Peycru et al., 2015). The secondary school curriculum in Niger only provides for the creation of a geological cross-section of tabular terrain. A tabular or horizontal structure is one in which the geological layers have zero dip (horizontal layers). A dip of less than 5° is tolerated (subhorizontal layers). These layers therefore have no direction or dip. They are therefore structures that have undergone little or no tectonic movement (Sorel & Vergély, 2006; Peycru et al., 2015).

2.3. Different teaching/learning approaches recommended in secondary education in Niger

Several authors have developed concepts on pedagogical approaches to teaching and learning science in general and life and earth sciences in particular (Gaston, 2002; Sauvageot-Skibine, 1995; Galiana, 1999; Trend, 2000; Sanchez et al., 2004; Pernin & Godinet, 2006). All these approaches converge on a common denominator: the teacher possesses specific knowledge and it is he or she who initiates the process of its acquisition by learners. Thus, three approaches can be distinguished (Vlasenko et al., 2019). Approach 1 corresponds to the traditional teaching method, which could be called lecture-style teaching or "teacher-centered teaching." In this approach, the teacher is the holder of knowledge, which they transmit (by imparting it) to learners. This transmission is one-way, i.e., from the teacher to the learners. This method is inspired by the ideas of PLATO. For proponents of this approach, roles are fixed, there is no room for student intuition, and the teacher is an infallible master. In order to learn, the student (with an empty head) must be attentive and docile, hence their passivity in the process of acquiring knowledge.

Approach 2 corresponds to "extreme learner-centered teaching/learning." In this approach, the teacher motivates their learners at the outset, but their role is minimal in classroom activities: it is the learners themselves who are entirely responsible for acquiring the required knowledge. Thus, they may or may not follow the right path to achieve this. In this approach, the teacher intervenes less, and the student can decide whether or not to do what is asked of them. For followers of this educational approach, knowledge, although essential, is not an end in itself. Teaching therefore aims to equip individuals with the tools for self-development, without neglecting or forgetting external influences. Children must therefore educate themselves and be educated with respect for others (adults and children). Teachers are no longer there to impart academic knowledge based on authoritarian directives and programs, but to encourage learners to produce knowledge based on their current interests and concerns.

Approach 3 corresponds to learner-centered teaching/learning (ASEI/PDSI approach). In this approach, teaching is a facilitator that helps learners to gradually understand, and thus leads them to ultimately attain the required knowledge themselves. Rather than the required knowledge itself, the emphasis is more on a process in which learners are involved in learning activities. In doing so, learners will be able to build cognitive skills that are applicable in obtaining other necessary skills and knowledge. This approach is based on the theories of PIAGET and BACHELARD, for whom the teacher's teaching should not be dissociated from the students' learning; the teacher does not only teach but is a guide for the student in their learning process. According to them, a good teacher is one who is open and to whom students can easily ask questions.

3. Materials and Methods

To carry out this work, a survey was conducted in upper general secondary schools with second-year (1st C and/or D) classes in the city of Tahoua (Tahoua Region, Niger). It covered fifteen public and private schools (high schools, SEC, and PSC) (table 2) under the Tahoua I Secondary Education Inspectorate and the Tahoua I Franco-Arab Education Inspectorate, out of the 20 such schools in the city of Tahoua. It should be noted that in Niger, only public schools offer high schools, which the city of Tahoua having only one such school (high school Agabba); the other schools are SEC (public) or PSC (private).

Table 2. Number of teachers surveyed according to selected schools.

No.	Schools	Teachers questioned
1	High school AGABBA	04
2	SEC 1	03
3	SEC 2	02
4	SEC 3	03
5	SEC 2 / FA	02
6	SEC /FA/ CHEICK HAMDAN	01
7	PSC LA VICTORY	01
8	PSC KOULMANI	01
9	PSC LA RACINE	01
10	PSC AMAMA	01
11	PSC GANDOU	01
12	PSC JEAN PAUL	01
13	PSC SOLIDARITE	01
14	PSC IBADOURAHAMANE	01
15	PSC DANTATA	01
	Total	24

These schools were selected on the basis of their geographical distribution and the number of students in second-year science classes (1st C and D). The study targeted a sample of 24 LES teachers (table 2) in general education high schools (high school, SEC, and PSC) who regularly teach 1st C and/or D classes, to whom a questionnaire was sent. The questions asked were designed to gather information on the teachers' qualifications and experience, the teaching resources used, their mastery of the content and teaching/learning methods implemented, and the needs expressed by teachers for improving the teaching of geological maps and cross-sections.

The sample included all science teachers from the fifteen selected schools. It should be noted that most of these schools have only one second-year science class (1st D). For this study, we chose to use a questionnaire as our data collection tool because it has the advantage of eliciting responses that can be quantified and summarized, particularly thanks to the closed-ended questions. It also has the advantage of being able to be used with a large number of respondents, while respecting their anonymity and allowing them to express their opinions freely. The questionnaire given to teachers is preceded by a collection of personal information used to define the profile of the teacher concerned.

This survey was carried out in two phases. Phase 1: this is the questionnaire test phase. It consisted of introducing the questionnaire to ten targeted teachers in order to verify the relevance and effectiveness of the questionnaire. Phase 2: this was the data collection phase. This phase lasted two months. All the targeted teachers received a questionnaire submitted to the administration of their school. All the teachers approached agreed to respond to our questionnaire. The teachers' responses were entered and processed using Word and Excel.

4. Results and Discussion

All of the LES teachers surveyed, teach one of the second-year science classes (1st C and/or D) and reported having covered the topic of geological maps and cross-sections.

4.1. Teachers' qualifications and experience

The survey provided information on each teacher's status, qualifications (degree, specialization, and knowledge of geological maps and cross-sections), and length of service in teaching life and earth sciences. In Nigerien secondary education, there are three categories of teacher status: tenured, contract, and National Civic Service (NCS).

Tenured teachers are civil servants; contract teachers are teachers on fixed-term contracts; and NCS teachers are recent graduates who voluntarily commit to two years of community service in various fields, including education. The survey results show that 58.33% of the teachers surveyed are tenured, 25% are contract teachers, and 16.66% are national civic service volunteers (table 3). This predominance of tenured teachers is an asset for quality education, given the stability and improved living conditions of these teachers compared to other categories.

Table 3. Distribution of teachers by status.

Status	Tenured	Contract	NCS	Total
Effective	14	6	4	24
Percentage	58.33%	25%	16.66	100%

The academic backgrounds of the teachers surveyed show a predominance of bachelor's degrees and equivalent qualifications (TSS: Senior Health Technician) (13/24), representing 54.16%, and a considerable proportion of holders of Baccalaureate (BAC) +4/5 qualifications (Master, Engineering, DEA, Mastery, CAPES, and MPPES) (10/24), or 41.66% (table 4). It should be noted that in Niger's secondary education system, teachers who can teach high school classes are those with a minimum of a BAC +3 degree.

However, those with a BAC +4/5 degree are the most qualified. They represent 41.66% of the sample in our study, which is significant in Tahoua compared to other localities in Niger. However, this rate remains insufficient to drive improvements in the quality of education. It should be noted that this rate includes degrees (CAPES and MPPES) from the Graduate School of Education, which are highly qualified degrees for teaching life and earth sciences in secondary schools in Niger.

Table 4. Distribution of teachers in function of their diplomas.

Diploma	CAPES/MPPES	Ing/Master/DEA	Mastery	Bachelor	TSS	Not specified	Total
Effective	3	5	2	11	2	1	24
Percentage	12.50%	20.83%	08.33%	45.83%	08.33%	04.16%	100%

Note: CAPES: Certificate of Aptitude for Teaching in Secondary Education. MPPES: Professional Master's Degree in the Secondary Education Professorship. Ing: Engineering. DEA: Advanced Studies Diploma. TSS: Higher Health Technician.

With regard to teacher training, it appears that only 37.5% (9) of teachers have a degree in geology (geology or biology + geology) (Table 5), compared to 62.5% (15) whose degree specialization is different from geology. This low percentage of teachers specializing in geology seriously hinders the teaching of geological maps and cross-sections in Niger's second-year science classes of high schools.

Table 5. Distribution of teachers according to the specialties of their diplomas.

Diploma specialties	Biology	Geology	Biology + Geology	Psychology	Others	Total
Effective	9	5	4	3	3	24
Percentage	37.50%	20.83%	16.66%	12.50%	12.50%	100%

With regard to the topic of "geological maps and cross-sections," 62.5% (15) of the teachers surveyed reported having received training (initial, continuing, or both initial and continuing), while 37.5% (9) had never been trained on this topic (table 6). Among the teachers who had received training (initial and/or continuing) on geological maps and cross-sections, 9 considered the content of the training to be moderately satisfactory and 6 said the content was insufficient. These results reveal that a significant number of teachers (62.5%) teach the chapter on geological maps and cross-sections either without any training in geology or with insufficient training. However, all teachers reported having participated in several continuing education courses during their careers. It is therefore regrettable that the continuing education resources in geology available to teachers are, in a way, insufficient and only concern a minority of them. We can therefore agree with Sanchez (2004) that the greatest difficulty in teaching/learning geological maps and cross-sections is the inadequacy of teachers' initial and continuing training, since it is these shapes teaching practices.

Table 6. Distribution of teachers in function of kind of training in geological maps and sections.

Training in geological maps and sections	Initial training	Continuing education	Training initial and continuing	Initial training
Effective	4	6	5	9
Percentage	16.66%	25%	20.83%	37.50%

The survey revealed that only 20.83% (5/24) of teachers have less than 5 years' experience. This means that the majority of teachers (19, or 79.16%) have sufficient experience to teach the chapter on geological maps and cross-sections (table 7). Therefore, the majority of teachers are experienced, which suggests a significant improvement in their teaching skills.

Table 7. Seniority of the teachers by slice of age.

Seniority (years)	Less than 5 years old	5 to 10 years	More than 10 years	Total
Effective	5	10	9	24
Percentage	20.83%	41.66%	37.50%	100%

4.2. Teaching Resources Ysed

The survey examined the teaching resources used by teachers in teaching the chapter on "geological maps and cross-sections" as well as their content. The teaching resources used by teachers consist of textbooks (geology books, past exam papers, course and exercise books, etc.), the internet, and practical materials (wall maps, paper maps, and teaching models). In response to questions relating to official recommendations, 100% of the teachers surveyed emphasized compliance with official instructions and programs. Teachers' responses on the use of teaching resources show that very few teachers (1 to 2) limit themselves to using textbooks and/or paper geological maps when preparing lessons (table 8). In fact, they find the content of these textbooks outdated. This confirms the work of Galiana (1999), who finds certain arguments used in high school textbooks to be illegitimate. The overwhelming majority of these teachers make extensive use of the internet (87.50%), most often in conjunction with textbooks and/or paper geological maps. However, all the teachers surveyed stated that they had never had access to a geological cross-section teaching model (table 8); many were not even aware of its existence. The lack of this element in the teaching of geological maps and cross-sections is a significant shortcoming because, as Sauvageot-Skibine (1995) points out, representations are an effective tool for teaching Earth sciences. Most teachers rely primarily on the internet because they find the content of school textbooks on geological maps and cross-sections available to them (at school or on the local market) insufficient. Nevertheless, most teachers say they find it difficult to select appropriate content on the internet given the wealth of data available on search engines. This situation leads some teachers to use other resources (university courses and books, social networks, YouTube, etc.) to supplement their lessons on geological maps and cross-sections. University-level documentation, although it exceeds the elementary level taught in secondary school, gives teachers more confidence by providing them with many arguments, as suggested by Archambault, Lhénaff, and Vanney (1967).

Table 8. Distribution of teachers according to the use of teaching resources.

Educational resources	Effective	Percentage
School textbooks	1	04.16%
Internet	2	08.33%
Geological maps on paper	0	00%
Geological cross-section model	0	00%
Textbooks + Internet	5	20.83%
Textbooks + Geological maps on paper	2	08.33%
Internet + Geological maps on paper	2	08.33%
Textbooks + Internet + Geological maps on paper	12	50%
Nothing	0	00%
Total	24	100%

4.3. Mastery of Content and Teaching Methods

To teach the chapter on geological maps and cross-sections effectively, it is essential that teachers be proficient in reading geological maps and constructing geological cross-sections. Knowledge of the usefulness of these two concepts is also a major asset. In addition, using a teaching approach tailored to teaching/learning geological maps and cross-sections would promote the optimal achievement of learning objectives. With regard to reading geological maps, which is one of the specific objectives of teaching geological maps, 25% (6/24) of the teachers surveyed do not know how to read a geological map. Only 50% of teachers know how to read a geological map correctly (table 9).

Table 9. Distribution of teachers according to their ability to read a geological map.

Reading a geological map	Weak	Average	Alright	Total
Effective	6	6	12	24
Percentage	25%	25%	50%	100%

The creation of a geological cross-section is also one of the main focuses of teaching/learning about geological maps and cross-sections. Mastering its construction is therefore essential for science teachers. This study shows that half of the teachers surveyed (12/24) do not know how to construct a geological cross-section (table 10). This is not surprising, as 37.50% of the teachers surveyed have never been trained in this subject. Among the teachers who have learned how to make a geological cross-section, only 80% have applied this skill in the classroom. The remaining 20% justified not constructing geological cross-sections with their students due to lack of time, the complexity of making the cross-section, and the absence of geological maps in their schools. It is above all the general complexity of geology that creates a barrier to its understanding. This is one of the reasons why En-Nhili and El Alaoui (2024) believe that the teaching of geology has not been successful in Morocco. Hanaà and Fadi (2011) see this as one of the greatest obstacles to the teaching of Earth sciences. Gohau (2001) also believes that these same reasons are at the root of the antipathy towards geology and therefore the difficulties students have in understanding it.

Table 10. Distribution of teachers according to their ability to carry out a geological cross-section.

Construction of the geological cross-section	Weak	Average	Alright	Total
Effective	12	6	6	24
Percentage	50%	25%	25%	100%

With regard to knowledge of the usefulness of geological maps and cross-sections, teachers were asked about the following areas of interest: discovery and exploitation of georesources; risk prevention and management; land use planning and the environment; water resource management; establishing geochronology; understanding the geological evolution of a region; knowledge of the relief and subsoil; teaching and training. This study shows that the majority of teachers surveyed (62.50%) have a good understanding of the usefulness of geological maps and cross-sections (table 11). However, it is regrettable that a significant number of teachers (9/24) have little or no knowledge of the importance of geological maps and cross-sections. Yet knowledge of the practical usefulness of lesson objectives is a key element in student understanding. This is why some scholars (Rassou et al., 2017) see this as one of the greatest difficulties in teaching/learning geology in high school.

Table 11. Distribution of teachers according to their knowledge of the usefulness of geological maps and cross-sections.

Knowledge of the interests of geological maps and cross-sections	None (0 interest)	Weak (1 to 2 interests)	Average (3 to 4 interests)	Very good (> 4 interests)	Total
Effective	6	3	9	6	24
Percentage	25%	12.50%	37.50%	25%	100%

To achieve teaching/learning objectives in Niger, three pedagogical approaches are currently used: Approach 1 (lecture-based or teacher-centered teaching), Approach 2 (extreme learner-centered teaching/learning with a minimal role for the teacher) and Approach 3 or ASEI/PDSI Approach (learner-centered teaching/learning). The ASEI/PDSI (Activity-Student-Experiment-Improvisation/Plan-Do-See-Improve) approach is a pedagogical model adopted by Niger and recommended for teaching mathematics and science in Niger. During this study, 50% of science teachers in the second-year of science classes in the city of Tahoua in Niger said they had used the ASEI/PDSI approach (table 12). This teaching method is in line with Savaton's (1998) recommendations following a historical and didactic review of geological map teaching. Oliemat and Alsharayah (2024) specify that a similar approach is recommended for teaching geology in Saudi Arabia. The ASEI/PDSI method allows teaching to be scripted by preparing activities for each lesson objective. Pernin and Godinet (2006) find this approach excellent for all areas of learning and particularly for Earth sciences (Sanchez & Prieur, 2006).

Table 12. Distribution of teachers according to the teaching approach used.

Teaching approach	Approach 1	Approach 2	Approach 3	Total
Effective	3	9	12	24
Percentage	12.50%	37.50%	50%	100%

However, a significant number of teachers (50%) (Table 12) indicate that it is not feasible to apply the recommended teaching/learning method (ASEI/PDSI) given the inadequacy and/or unavailability of teaching resources and the large number of students in classes (more than 75). Teachers are therefore forced to adopt approach 1 (lecture-style teaching) or approach 2 (dividing the concepts of geological maps and cross-sections into research projects and/or presentations).

4.4. Teachers' Suggestions for Improvement of Teaching of Geological Maps and Cross-sections

During this study, the opinions of the teachers surveyed were collected on their proposals for improving the teaching of the theme of geological maps and cross-sections. They expressed the following needs (with their frequency in percentage) : endowment of the schools in manuals school appropriate (75.50%); the training of the teachers on the geological maps and cross-sections (83.33%); educational activities on the theme (62.50%); the organization of field trips (33.33%); the use of Information and Communication Technologies for Education (ICTE) for teaching geological maps and cross-sections (50.00%); the development or provision of educational sheets dealing with geological maps and cross-sections for the implementation of the ASEI/PDSI approach (41.66%). In addition to these, there are those who expressed no need (25.00%). The results of this survey show that the overwhelming majority of teachers propose as a solution for improving the teaching/learning of the geological maps and cross-section's theme, the training of teachers on the said theme, the provision of schools with appropriate textbooks and the regular organization of educational activities (table 13). The emphasis on these needs can be explained by the fact that the majority of teachers surveyed do not have basic training in geology. Furthermore, a significant number of teachers (50%) believe that the use of ICTE can be an effective solution. Indeed, ICTE allows the realization of complex experiments through simulations or modeling. This approach is similar to the work of Sanchez (2008) and Balzarini (2013), who find modeling as an effective tool for teaching Earth and Environmental Sciences. Furthermore, the organization of formative field trips and the provision of teaching sheets adapted to the ASEI/PDSI approach to teachers could effectively strengthen teachers' capacity (table 13).

Table 13. Frequency of teachers' suggestions for improving the teaching of geological maps and cross-sections.

Educational resources	Frequency	Percentage
Provision of appropriate textbooks	18	75.50%
Training on the theme of geological maps and cross-sections	20	83.33%
Educational animation on the theme	15	62.50%
Organization of field trips	8	33.33%
Use of ICTE for teaching the theme	12	50.00%
Development/provision of educational sheets (ASEI/PDSI)	10	41.66%
No proposal	6	25.00%

Therefore, the results of this study highlight a clear consensus among teachers on the need for targeted interventions to improve the teaching of geological maps and cross-sections. Priority measures include teacher training, the provision of appropriate textbooks, and the implementation of practical educational activities. Additionally, the integration of ICTE, formative field trips, and tailored teaching sheets appear to be valuable complementary strategies. Addressing these needs could not only enhance teachers' pedagogical skills but also foster more effective and engaging learning experiences for students in Earth and Environmental Sciences.

5. Conclusions

The study conducted on improving the teaching of geological maps and cross-sections in second-year science classes (1st C and 1st D) in secondary schools in the city of Tahoua in Niger highlighted the main difficulties faced by teachers. The questionnaire survey revealed that teachers lack adequate initial and/or continuing training (62.5%) on the subject of geological maps and cross-sections. A large number of teachers have never been trained in geology in general, and in geological maps and cross-sections in particular, despite proven teaching experience (79.16% of teachers surveyed). Teachers lament the lack of teaching resources to address this topic and the inadequacy of the content in textbooks. This situation forces them to rely heavily on the internet to fill these gaps. Added to this is the fact that some teachers do not have a good grasp of the content to be taught. In fact, only 50% of teachers know how to read a geological map correctly, while half of the teachers surveyed (12/24) do not know how to construct a geological cross-section. Furthermore, a significant number of teachers (37.50%) surveyed are unaware of the usefulness of geological maps and cross-sections. This situation does not favor the application of the teaching/learning approach (ASEI/PDSI) recommended for science education in Niger, as highlighted by half (50%) of the teachers surveyed. The majority of teachers surveyed (over 72%) believe that providing schools with appropriate textbooks, training teachers on geological maps and cross-sections, and using ICTE could effectively remedy the difficulties associated with teaching/learning geological maps and cross-sections.

To improve the quality of teaching practices in the teaching of geological maps and cross-sections in secondary schools, the following recommendations should be taken into account:

Firstly, recruit teachers whose profiles are suited to teaching life and earth sciences.

Secondly, head teachers and deputy head teachers must take into account the profile (initial and continuing training in geology, teaching experience) of science teachers who will be assigned to science classes in the second-year of high school, given that approximately 80% of the geology curriculum in Niger's high schools is concentrated in the second-year of high school.

Thirdly, develop appropriate, relevant, and geology-specific textbooks that cover the topics developed in the Niger curriculum. These textbooks must be accompanied by practical work guides, equipped with well-developed technical data sheets, with learning objectives to be achieved, necessary materials, practical work descriptions, completion times, etc.

Fourthly, provide schools with adequate teaching resources (textbooks, wall and paper maps, geological cross-section models, etc.).

Fifthly, school principals, censors, and heads of teaching units must ensure that practical work sessions are carried out effectively when conditions are favorable.

Sixthly, organize regular continuing education for teachers on geology in general and geological maps and cross-sections in particular.

Seventhly, train teachers and provide them with teaching resources related to ICTE. These resources make it possible to remedy the shortage of documents and enable the simulation or modeling of geological phenomena, and even the performance of complex experiments that cannot be carried out in the classroom.

And eighthly, it is necessary for the State to develop and make available to teacher's digital resources that can be used for teaching life and earth sciences in general, and for teaching geological maps and cross-sections in particular. This requires scientific and educational databases (websites managed by regional education authorities or by the Ministry responsible for secondary education) that are accessible and essential for teachers and students

To conclude, the study underscores the urgent need to strengthen both the training and resources available to teachers of geological maps and cross-sections in Tahoua. By addressing gaps in teacher preparation, providing adequate textbooks and practical materials, and integrating ICTE, the quality and effectiveness of science education can be significantly improved. Implementing these measures will not only enhance teachers' competencies but also foster more meaningful and engaging learning experiences for students.

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