Ciência & Educação, Bauru, v. 28, e22007, 2022
https://doi.org/10.1590/1516-731320220007

ARTIGO ORIGINAL

Two decades of learning with the Geo-School Project: a journey to introduce Geoscience into schools

Duas décadas de aprendizado no Projeto Geo-Escola: uma jornada para inserir Geociências nas escolas

Celso Dal Ré Carneiro[1]

Ronaldo Barbosa[1]

Danilo Furlan Amendola[1]

Isabella Nogueira Bittar de Castilho Barbosa[1]

[1]Universidade Estadual de Campinas (Unicamp), Instituto de Geociências, Campinas, SP, Brasil.
Autor correspondente: cedrec@ige.unicamp.br

Abstract: Since 2000, the Geo-School project has implemented successive modules, which have produced, applied and evaluated experimental teaching material, after careful selection of geological topics about some regions of the state of São Paulo (SP) in Brazil. For more than 20 years, technology has changed, and so has our access to it. In this sense, school-university cooperation allows school teachers to explore the cognitive benefits of the Earth Sciences, either by exercising geological reasoning and conceptualization, or to contextualize and improve learning. Looking to promote insights on multidisciplinary activities, the project identified significant methodological issues and the fact that the state government did not achieve gains in terms of innovation, despite heavy investments in equipment and software. This paper analyses successes and failures, errors and benefits of the project. The ongoing modules yield new approaches, thus enhancing the main contribution from the initiative: to explore Geosciences based on local reality to spark students' and their community's interest in it.

Keywords: Geoscience teaching; Basic education; Didactics; Educational policy.

Resumo: Desde 2000 o projeto Geo-Escola reúne módulos regionais interdisciplinares que produzem, aplicam e avaliam material didático digital, buscando promover insights de inovação nos docentes. Em 20 anos, apesar da mudança radical da tecnologia e do acesso a ela, consolidou-se um modelo de cooperação escola-universidade que envolve cuidadosa seleção de tópicos, temas e recursos didáticos. Identificaram-se questões metodológicas significativas e ao menos um impasse: o ensino escolar não obteve ganhos em inovação, apesar do pesado investimento em equipamentos e softwares. Este artigo analisa sucessos e insucessos, erros e acertos do projeto, cujo material experimental explora o potencial cognitivo das Ciências da Terra, inspirando docentes de educação básica a explorar o raciocínio geológico e os conceitos das Geociências para melhorar o desempenho e contextualizar o aprendizado. Os módulos em andamento exploram abordagens novas, revelando o principal benefício da iniciativa: explorar Geociências a partir da realidade local e, assim, despertar o interesse dos estudantes e da comunidade.

Palavras-chave: Ensino de Geociências; Educação básica; Didática; Base nacional comum curricular.

Recebido em: 29/12/2020
Aprovado em: 28/09/2021

Introduction

> Universities are not the best places to teach Geology. Those are elementary schools. They show how our civilization started and works. Where it projects itself. How much our life experience costs, what we consume and what is really essential, and we need to live (SIQUEIRA, 2018, p. 34, our translation).

The Brazilian Basic Education System (BBES) slowly opens up to the cognitive benefits of teaching Earth Sciences to educate future citizens. Not only it lacks a specific discipline to approach this content, studies reveal the huge potential of Geoscience for improving school performance by means of logic reasoning, and contextualized teaching. Knowledge on Geoscience and Geology – all very fragmented, and far away from the student's reality – is scattered among many disciplines (CARNEIRO; TOLEDO; ALMEIDA, 2004). The precarious approach to these subjects prevents the construction of a comprehensive view of the environment, that is, of a "[...] planet Earth and its surface, occupied by society" (TOLEDO, 2005, p. 33, our translation), besides making it impossible to "[...] understand the Earth as a complex and dynamic system" (TOLEDO, 2005, p. 31, our translation).

Culturally, the idea of Geological Time is one of the most relevant in the history of human thought (CERVATO; FRODEMAN, 2012a, 2012b). The availability of instructional materials is scarce and focus on environmental dynamics (SILVA *et al.*, 2019); moreover, they do not help teachers tackle the vastness of Geologic Time and make connections with human experience with time (BONITO *et al.*, 2011).

Currently, BBES is unable to unveil the implications of geoscientific knowledge for a full understanding of life because the educational system has moved away from the basic concepts that are typical of Geoscience teaching. Topics on the planet have lost consistency, turning into a complex, uninteresting, and generic list of isolated notions. This framework also undermines the development of the "[…] sensitivity needed to face the challenges imposed by environmental degradation" (TOLEDO, 2005, p. 33, our translation). Ecological imbalances have the strongest effects for the specific case of Brazil, where social inequalities are evident. It is "[…] a country with marked social disparities, little investment in research, health, education, science and culture", submitted to an accelerated deindustrialization process (CATARINO; REIS, 2021, p. 3, our translation).

Moreover, the traditional teaching method has become obsolete, especially for facing continually evolving technologies, which try to capture the attention of students with constant problematization and stimuli "[…] to think, to discover, to question, to exchange information with the group of colleagues" (DOTTO; ZIEMAN, 2015, p. 5, our translation). The school should favor participatory methodologies, which require actions such as seeking, comparing, researching, producing, and communicating (MORAN, 2013).

If a teacher cannot find ways to approach real and active global cycles, they will not be able to make any sense with students about the long and intricate chain of causes and consequences of natural events (OLIVEIRA *et al.*, 2015), which determined the constitution, origin, and evolution of the Earth for 4.56 Ga. As long as "[…] learning, information and knowledge built in a significant way is necessary" (LÖBLER; LÖBLER; NISHI, 2012, p. 2, our translation) for a person to be considered a citizen, to become a citizen will not be able to form a robust critical spirit to evaluate risks and benefits of human activities, being necessary an "[…] effective and wide introduction of the Geosciences, not in pieces, as nowadays, but as a whole" (TOLEDO, 2005, p. 43, our translation), besides that the scientific literature aligns with the idea that the environment around students can be used to keep them on track, minimizing school truancy and improving engagement and conceptual retention in the classroom (SEMKEN *et al*., 2009). The author explicitly argues:

> How can a citizen be critical, perform, judge, act in society (which occupy the environment and uses its materials and phenomena), being deprived of knowledge about the functioning and organization of the planet, its environments and materials genesis and evolution, about the physical, chemical and biochemical human interactions in nature? [...] **The answer is: he cannot**. (TOLEDO, 2005, p. 33, our translation, our emphasis).

Knowledge about Earth's dynamics is key to education of young people, so that future citizens can understand the basic processes that control the present-day environments (CARNEIRO; BARBOSA, 2005).

We use the terms *Geoscience* and *Earth Science* interchangeably, as they bring together disciplines or specialties that study geological processes and the history of their development. Geology, Earth System Science, Geophysics, Meteorology, Geodesy and Physical Geography: each one focuses on certain measurable processes or properties. Geology, as a dominant branch of Geoscience, seeks to understand the materials, processes, and products throughout the complex evolutionary history of the planet. Earth System Science comprises research on the relationships between the rocky spheres (geosphere) and other planetary spheres (atmosphere, biosphere, hydrosphere, noosphere, or Technosphere) (PIRANHA; CARNEIRO, 2009; POTAPOVA, 1968, 2007). The above-sketched picture of the BBES allows us to identify three key ideas:

- The first key idea refers to the *importance of learning Geoscience* in the BBES;
- The second key idea is the *lack* of systematic and consistent teaching of Geosciences in BBES;
- The third key idea is the *need* to offer teachers and students a wide variety of teaching resources that encourage them to question, ask, and search for detailed aspects of their local environment.

Such challenges are the source of inspiration and the focus of the line of research called Geo-School Project, whose relevance we intend to assess in this article through our findings.

What is the Geo-School Project?

The Geo-School Project started twenty years ago when a group of researchers identified weaknesses and conceptual problems in textbooks and other materials used by students and teachers in BBES. With a few pedagogical examples of use of knowledge about the place where students and teachers live, it was decided to carry out a project to encourage the inclusion of Geoscience into basic education schools and to investigate alternatives for the use of computers in education. The initial project inquiries were:

a. What contribution can Geology and Geoscience bring to basic education?
b. How can computers support teaching of Geoscience?
c. What are the advantages of integrating aspects of local geological conditions into other subject areas of the curriculum?
d. Is it time to change the current situation, in which any approaches to local knowledge are rare?

e. What are the educational benefits of virtual learning environments to audiences of different age groups?
f. Provided that teachers have direct access to resources, information and databases, does encouraging them to produce their own instructional content lead to educational innovation?

   The question (f) introduces another relevant question:

g. Do teachers have autonomy to carry out educational reforms?

The Geo-School research initiative makes use of the educational opportunities presented by information technology in order to improve the teaching of Geosciences by exploring two key factors: (a) in general, local geologists are specialists capable of extracting basic concepts from the great mass of available information; (b) using the computer allows the exploration of visual language in teaching, an intrinsic and necessary skill for the development of geological reasoning.

Place, sense of place, place meanings

Earth Sciences, as well as ecological and environmental sciences, "[…] are taught in and by means of places" (SEMKEN *et al*., 2009, p. 137). *Place* is a "[…] locality or space that has become imbued with meaning by human experience in it" (TUAN, 1977 apud SEMKEN *et al*., 2009, p. 136). *Sense of place* has been defined as a combination "[…] of *place meanings* and *place attachments* that a person or a group develop for a place" (SEMKEN *et al*., 2009, p. 136). The notion of belonging is a similar concept for valuing a place; it was developed by the Geotopos project (PIACENTE; GIUSTI, 2000), revealing the importance of valuing local knowledge and specific feelings, together with people, to establish creative connections between the individual or a group and the environment where they live.

A summary of the project goals

Technology has changed radically in the past two decades, so has the access to it. In the beginning of the project, a serious problem of restricted access to computers was detected in the public schools involved, but this problem has been overcome nowadays. Four regional modules were completed (BARBOSA, 2013; BARBOSA; CARNEIRO, 2020), in which the questions presented above were addressed and partially answered. So far, four project modules have been completed and tested with teachers in the regions of Jundiaí-Atibaia, São José do Rio Preto, Cajamar, and Monte Mor, all in the state of São Paulo, in Brazil. Two are in progress, in the regions of Botucatu and Ribeirão Preto (CARNEIRO *et al.*, 2019).

One study involved ten municipalities in the region between Jundiaí and Atibaia (SP), disseminating a broad knowledge base about local geological-geotechnical dynamics and environmental problems, such as floods, landslides, vulnerability, and water scarcity. The modules that focused on the regions of São José do Rio Preto, Cajamar and Monte Mor were more restricted in terms of interaction with teachers from these municipalities, with little or no participation from neighboring cities. Each module has developed, applied and tested experimental didactic materials composed of geological data, images and maps, which were generated from fieldwork, bibliographic and laboratory studies (BARBOSA, 2013; CARNEIRO; BARBOSA, 2005;

CARNEIRO *et al*., 2007; PIRANHA, 2006; PIRANHA; CARNEIRO, 2006, 2009). Interdisciplinary themes like environment, terrestrial dynamics, nature cycles, available resources (energy, water, soils, and mineral goods) were the main focus, in addition to more comprehensive concepts, such as water and rock cycles.

The research was carried out uninterruptedly in the cited regions of São Paulo, despite not having specific funding. Five master's dissertations, two doctoral theses, and more than 40 publications were produced, in addition to a digital educational collection of geological resources, images, and maps of the studied regions, which can be accessed by teachers and students at the website https://geo-escola.pro.br/.

Paper objectives

This article summarizes educational aspects of the project and describes the features of each research unit for discussing successes, failures, solutions and mistakes. Data collection surveys along the execution of each project module ensured that teachers were interested on geoscientific themes.

The Geosciences are a field of knowledge with an authentic potential to integrate many branches of sciences. In this sense, several studies have confirmed the hypothesis formulated by Piranha and Carneiro (2006) that some typical attributes of Geology and Geoscience can help with the essential objectives of the educational process:

- Geoscience provides a dynamic approach to today’s Earth Systems;
- Geology helps understand environmental evolution and the evolution of life on Earth;
- Geology contributes to sustainability by accentuating the consequences of anthropic interaction with natural dynamics;
- Geoscience permits the exploration of a holistic view of the planet;
- Geoscience facilitates 'nature literacy' by integrating knowledge for a globally informed citizenry;
- Geoscience provides enlightened and responsible public participation in the management of natural resources.

Brazilian's *common core* curriculum and the teaching structure of BBES

Since the middle of the 20th century, Geoscience has virtually disappeared from high school, when the discipline of Natural History was restructured and replaced by Biology. Geological knowledge was also present in elementary school; however, over successive reformulations, curriculum policies favored Geography and Sciences. Geoscience lost even more space when Geography and History were brought together as 'Social Studies' in the teaching of first and second degrees for the first two years of elementary school (BACCI; BOGGIANI, 2015).

The curricular standards known in Brazil as the *Base Nacional Comum Curricular* (National Common Curricular Base, hereinafter referred as NCCB) (BRAZIL, 2018) impose a new perspective that stimulates interdisciplinary approaches and expands the role played by the broad field of Natural Sciences. Nevertheless, a critical analysis of the NCCB points out the degradation of specific conceptual knowledge on this field, as long as the policies issued by the Ministry of Education (MEC) treat it in a minimalist way, promoting a noticeable dilution of disciplinary specificity from every subject area.

As the specificity of each discipline weakens, the contents of Geoscience that could be addressed interdisciplinarily, such as in science and geography lose depth and importance.

The impact of this crisis on education could be less intense if teacher-training courses in these areas were solid, but the workload of Geology and/or Paleontology courses in the curriculum of teacher education is insufficient (BRESSANE; TOLEDO; CARNEIRO, 2019). Usually, Brazilian Teacher Education programs focus on the early years of elementary school, while graduate degrees in Biology prepare teachers to work with Natural Science during the final years of elementary school.

Thus, in this context of dismantling of basic education, a distorted understanding of interdisciplinarity fuels the shrinkage of subjects such as Natural Sciences. As a mechanism to bring young people into the labor market – using the so-called training itineraries – BBES fails to deliver education.

From a less holistic point of view, an ideological deception can be identified with ease. On the other hand, the Geo-School Project presupposes an interdisciplinary treatment that radically differs from the modular interdisciplinarity of the NCCB for a deeper development of Geology and Geoscience that is unseen in the present core curriculum. In addition, this project values the role of non-formal means of geo-education, such as digital platforms, museums, and geoparks, which help disseminate geoscientific content.

The teaching of Geoscience is currently "*invisible* in school curricula" (ERNESTO *et al*. 2018, p. 333, our translation, our emphasis). Furthermore, the education system rarely addresses aspects of the local reality, for two basic reasons: (a) the immense Brazilian territory and (b) the limited access to knowledge about the local environment in teacher training programs. The NCCB excludes contents referring to the individualities of the most diverse domains, such as the social and spatial particularities of each school. This prevents the educational system from considering the plurality of contexts in the most diverse regions of the country. Catarino and Reis (2021) consider that the NCCB carries aspects foreseen in the LDB, which defines, at Article 26, that the Base must be "[...] complemented, in each education system and each school establishment, by a diversified, required part by regional and local characteristics of society, culture, economy and students" (BRASIL, 1996, p. 1, our translation). This broad scientific education branch is the main emphasis of the Geo-School Project.

Completing this wide arc of schooling, many higher education curricular guidelines require knowledge on Geoscience in different courses like engineering, geography, biology, architecture, etc. (CARNEIRO; BARBOSA; PIRANHA, 2005; TOLEDO, 2005). Geology is an essential component in undergraduate courses in several professional categories:

> Undergraduate courses in many branches of Engineering, in addition to Agronomy, Biology, Chemistry and Physics, require strong rigor in the acquisition and application of geological knowledge for good training of graduates. Going further, it can be said that the learning of Geology/Geosciences is a way of building or improving the character of the individual, to the exact extent that it leads us to conceive the uniqueness of each evolutionary stage on Earth and to acquire a sharp critical view our reality, the circumstances under which we live and the need of valuing terrestrial geobiodiversity. Geoethics is an essential component in the formation of several professional categories (CARNEIRO *et al*., 2019, p. 26, our translation).

Over the last 20 years, the focus on a local reality – the place where the students and teachers live – may be an important contribution of the Geo-School Project for teacher education. The two barriers mentioned above establish key research challenges, as researchers must consider the multiple aspects of the geological heritage of the immense Brazilian territory. The deficiencies of knowledge about this local reality in some teacher training or in-service programs is a major issue in Brazil.

Still considering the teaching of Geoscience, Carneiro *et al*. (2020) agreed to the importance of fieldwork to prepare undergraduate students about geoscience reasoning, and to facilitate the learning process in many other school subjects, which is important when considering teaching training in general, not only related to Biology and Geography, for example. In this scenario, a way to help teachers in training build conceptual bridges is discussed by Sanzo, Myran and Clayton (2011) as an outcome of the cooperation between and schools, which must apply a holistic lens to make interdisciplinary combinations of courses – *i.e.*, Geology.

Materials and methods adopted by the modules

Geoscientific education focuses on Earth's history and evolution in detail; covers biological evolution, so that teachers and students can understand the urgency of facing the current environmental challenge, which is an essentially trans- and interdisciplinary subject. There is nothing in the past like the reality that we experience now. It is necessary to correct directions and show the role of geoscientific knowledge in the foundation and formulation of public policies.

The characteristics of each module of the project were adjusted to the local specificities of development and application. It is essential to capture the will of teachers in approaching the contribution of Geoscience to basic education (BARBOSA, 2013). It was necessary to mix approaches, which involved participatory research and case studies, together with detailed observation of context, groups of individuals, documents, or specific events. In the execution of the modules, methods of qualitative collection were used, such as interviews, observations and visits with students, accompanied by the responsible teachers.

The method adopted in the first modules of the project (Jundiaí-Atibaia and São José do Rio Preto) comprises five stages: (a) evaluation of sources of scientific information available in the region covered by the module; (b) sending a questionnaire to the educational institutions of the municipalities concerned; (c) selection, by the consulted professors, of some themes that they consider to be priorities; (d) production of initial didactic material on CD-ROM and postal distribution; (e) evaluation of the material provided and systematization of data on the alternatives for didactic changes implemented by the participating teachers.

In the last modules of the project, the initial strategy was abandoned in direct consultation with teachers, and substituted with the creation of a web portal on the Internet. The Geo-School Portal is intended to be an open platform for hosting educational contributions and proposals, provided they meet a series of operational and content criteria. It was also concluded that it no longer makes sense to work exclusively with computers, given the current technology available, such as tablets and smartphones (AMENDOLA; CARNEIRO; BARBOSA, 2021).

Science teaching for children and adolescents

Information and communication became almost inseparable, as not only they radically affect the universe of work, leisure and education, but also, they continuously change people's lives, as seen everywhere. The Information and Communication Technologies (ICT), or simply Digital Technologies (DT), have raised curiosity for scientific topics. If this trend is effective for adults, it is not so simple to convey that the same DT inputs produce equivalent results among children and teenagers.

The act of learning is "[…] complex and requires a high degree of interaction"; it cannot be confused "[…] with the act of reading or passively watching, since human perception through the senses is very limited" (FAGUNDES, 2007, our translation). The same argument influences science learning in basic education, but there is a new barrier, regarding the "[…] excessive abstraction with which the contents are presented to students" (BARBOSA, 2013, p. 3, our translation).

Theoretical body: geoscientific education

When planning innovative actions in schools, be it with a new resource, model or project, it is necessary to consider the purpose of the educational process. It is common for the effort to innovation in any field to be linked solely with the means (or to the 'how'), when in fact it cannot detach itself from the basic purposes that make up the 'why' of the whole effort (BLANCHET, 2007; POSTMAN, 2002). When discussing the purposes of education, different conceptions of society, different modes of objectification, and analysis of specific contexts of application should be considered. It is worth mentioning a few examples: the school should encourage imagination, as well as a sense of truth and responsibility (OLIVEIRA, 2001; OPPENHEIMER, 2003); education should aim to overcome the relations of inequality, domination, exploitation and exclusion from society; Amaral (1998) considers that the school exists either to reproduce the society around it or to transform it, including intervening in favor of greater justice and social equity.

When assuming the fundamental mission of preparing the student to face new situations, the school becomes more than a locus of knowledge transfer, but an environment of constant renewal (KASSAR, 2016). The internet has made school content increasingly accessible and independent of the classroom, at any level of education, creating a new context, in which institutions must commit to what is vital for human development, far beyond the mere transmission of information. It is necessary to emphasize the act of 'educating' instead of 'informing' students, especially because education is a continuous process that accompanies the individual's life, no longer restricted to the schooling phase (DEMO, 2007). In the spirit of 'educating' citizens, the role of the school can be redirected, to cultivate 'thinking' and 'acting', instead of teaching specific skills that students will soon forget.

A possible purpose of applied (active) education relates to the perspective that the contents are resources that can be mobilized in practice, according to the need. This understanding gives a new and special meaning to 'competences': developing competencies depends not only on acquiring resources in the form of knowledge, techniques and methods, but, above all, on the person developing the ability to 'mobilize' such resources in the face of some need, or new or unforeseen situations

(PERRENOUD, 2008; ROCHE, 2004; SILVA, 2008a). Shipley *et al*. (2013) established a clear distinction between skill and competence, justifying this position as follows:

> [...] the word 'ability' connotes a fixed quality that can be present from birth and is immune to change. To assume that spatial skills are fixed is to rule out the possibility of success in a spatially demanding field for anyone with low spatial skills (SHIPLEY *et al*., 2013, p. 82).

In order to improve the capacity to mobilize knowledge, it is necessary to optimize the contextualization and, in parallel, to honor students' creativity, autonomy and subjectivity. The school focused on the development of competencies does not limit its functions to the pure and simple transmission of ready-made knowledge. Perrenoud (1999, p. 17, our translation) points out that: "[...] if the resources to be mobilized are lacking, there is no competence, if the resources are present, but in practice they are not mobilized in a timely and conscious manner, then, in practice, it is as if they did not exist".

Furthermore, the competency-based approach frees schools from the excess of content that causes a certain saturation to the whole educational system. Slimming down the national curricula could free up time and allow students to reflect on how to mobilize knowledge (PERRENOUD, 1999).

Textbooks and diffusion of Geoscience

Fracalanza, Amaral and Gouveia (1986) point out that textbooks are often the most common resource used in basic education classes, which weakens Earth Sciences because topics related to them are superficially addressed. Unmotivated and unprepared teachers overuse textbooks in the classroom, creating barriers between student, teachers and knowledge (MORAN, 2013). As an example, regarding Geological Time, many Geography textbooks do not articulate the temporal succession of phenomena with the causes and consequences of past events that occurred on the planet (SOUZA; FURRIER, 2020), despite the relevance of these processes to understand the origin of mountain ranges, relief features, rivers and drainage systems, sedimentary basins, and modern landscapes. If textbooks do not link Earth Sciences to school life, they generate profound discouragement, since teachers do not update their knowledge and students cannot satisfy their curiosity.

Silva and Souza (2020, p. 2, our translation) recognize that, over the last decades, resources on geoscience "[…] have been reduced in the school curriculum and are widely attached to the subjects of Sciences and Geography in Elementary School". These authors indicate results of research that verified and quantified the presence of Geoscience topics in this cycle of education, bearing in mind the thematic units proposed by the NCCB (BRASIL, 2018). The documents investigated are Teacher's Manuals of Science, which follow the guidelines of the National Textbook Plan (PNLD) (BRASIL, 2019) in the municipal education system of Natal, in the state of Rio Grande do Norte. The presence of Geoscience topics is very high when it comes to the 'Earth and Universe' thematic unit, where it takes more than ¾ of what is defined by the NCCB (SILVA; SOUZA, 2020), but it drops down considerably in the units named 'Matter and Energy' and 'Life and Evolution'. Among the studied textbooks, almost 40% of the contents on Geoscience are represented by images, including photographs, diagrams and illustrations.

In contrast, the Internet is a source of unlimited connections between what is local and what is global. The convergence of geological reasoning with the school environment helps students develop new skills, through access to links for geoscientific dissemination that present results of academic research in Geology (BARBOSA; CARNEIRO, 2004). However, it is necessary to pay attention to the problem of reliability and accuracy of data and concepts over the web, due to the lack of rigorous filters, such as those that are part of the editorial evaluation of high-level scientific books and journals.

Approaching Geoscience in the Geo-School Project

The educational investigation conducted by the project team is linked with other lines of research, which reveal the great potential for Geoscience to contribute to developing a sense of citizenship, which can be explored in different ways since elementary school. The ideal implementation strategy involves three steps (BARBOSA; CARNEIRO, 2004): (1) Combating audiovisual illiteracy. (2) Providing local information and new resources to teachers and students. (3) Interaction with teachers.

Combating audiovisual illiteracy requires convincing the public that an image seen on any screen does not portray the *truth*. Implicit messages can be manipulated, thanks to "increasingly accessible digital resources" for capturing and editing. Therefore, no image constitutes reality, thus consisting of "a mere record of the real" (BARBOSA; CARNEIRO, 2004, p. 45, our translation). This understanding is key in the scope of the Geo-School Project:

> Just as an individual who is unable to understand a written text is considered 'illiterate', combating visual illiteracy requires the development of the idea that the image is just a record, not the fact or its historical truth. A similar attitude can be applied to videos, television programs and films, whether they are educational or not, whether they are focused on science or not (BARBOSA; CARNEIRO, 2004, p. 45, our translation).

The study of places can bring students closer to the reality of the emerging issues of nature (CARNEIRO *et al*., 2014). Lima (2013) lists factors that support such a view: (a) place is the space that is occupied, where things are produced and built; (b) knowledge on how the place was conceived, from the natural and social points of view, is essential for understanding the reality and taking actions and decisions.

> The fascination aroused by topical themes such as volcanoes, earthquakes, dinosaurs, floods and other natural disasters illuminate the eyes of children and young people. Although it is well known that Geoscience topics attract great interest from people in this age group, in general the coverage and scope that such subjects receive at school are very limited, when they are not entirely absent (CARNEIRO *et al*., 2019, p. 1, our translation).

Participants in the Geo-School project identified the existence of several barriers, in most of the schools surveyed (CARNEIRO; BARBOSA; PIRANHA, 2005), such as precarious material conditions, insufficient geoscientific education of teachers and students' lack of interest, a highly harmful framework for science learning. Dozens of participants revealed the need to invest in their qualifications, after being challenged to address interdisciplinary concepts such as terrestrial dynamics and natural cycles, such as those of water and rocks, because they consider that such knowledge is critical to help students understand the evolutionary mechanisms of the planet and the permanent interaction of terrestrial spheres.

The initiative introduces a new look to establish creative connections and seek ways to validate them, being able to assign new roles for both the teacher and the student: teacher-author and student-author. If the books or the blackboard simply give way to large computer screens connected to the internet, but keeping the same teaching routines, there will be just a change of support, and the traditional school will remain as it has always been. On the other hand, if teaching opens doors to new approaches, there will be a turnaround in the traditional roles of students, who will no longer be recipients of information, and the teacher, who is often a mere transmitter (CARNEIRO *et al*., 2007).

When spreading Geoscience, teachers must bring some critical themes from the municipality and the region to the center of the debate. Thus, promising educational innovation can be unleashed as long as research raise relevant methodological issues and highlight several obstacles. One of them refers to the insufficient education of teachers, a challenge that has been perpetuating remains unsolved, especially when it comes to the lack of knowledge on basic scientific concepts. Another barrier identified is that large investments in software and equipment in schools by successive state governments of São Paulo, have not resulted in good cognitive results or innovation (BARBOSA, 2013), as will be discussed below.

Availability of computers and their use in basic schools

The Geo-School Project strongly relies on computer infrastructure. Several surveys were conducted to evaluate the real context where the research was expected to occur. However, throughout 20 years, technology has changed completely, which means that the information collected by the Geo-School Project about the availability of computer equipment is now useless. For example, an initial evaluation at the Campinas Module between 2005-2007 revealed the existence of computer labs in the majority of public schools, comprising both computers and digital didactic resources on CD-ROM. "Today, with students and teachers having access to their equipment from their homes, many of the barriers of time and space are broken and much of the limitations we saw at the time disappear" (BARBOSA, 2013, p. 119, our translation).

Unfortunately, due to the precariousness of facilities and infrastructure, in many schools, the access for students and teachers was not allowed by the time when Barbosa (2013) conducted such an investigation. This means that one of the Geo-School Project premises was proved false, which is the dependence on computer labs for research on DT innovation: "In the new context in which equipment is becoming more and more popular, access to computers does not depend on computer labs, which lose their relevance" (BARBOSA, 2013, p. 63, our translation).

The National Educational Technology Program (Brazil’s Proinfo) introduced a partnership between the Ministry of Education and state and municipal governments to stimulate Digital Technologies (DT) at schools, but "…] this initiative is not enough to implement an ICT culture at the service of the teaching and learning process" (LÖBLER; LÖBLER; NISHI, 2012, p. 2, our translation). The authors also identify huge distinctions regarding the sequential path of use and implementation of computer labs at schools.

Many authors recognize a need for taking into account the contradictions of cultural and economic access to technologies and networks in schools. This means that the problem of school access to computers and the internet is not yet overcome: "[…] despite the belief that the use of computers brings broad benefits to primary and secondary education, there is no empirical evidence based on studies of an experimental nature that supports this hypothesis" (DWYER *et al*., 2007, p. 1308, our translation).

Thus, before expanding governmental programs related to DT, whether by monitoring and maintenance or by renewing public investment, there is a need to collect more data in schools to qualify the discussion and to indicate aspects of the governmental programs that must be revised.

Outcomes and results

> [...] Geoscience education, while promoting new ways of dealing with current issues, contributes significantly to teaching that meets *social urgency*, *global reach, understanding of reality, and social participation* (PIRANHA; CARNEIRO, 2006, p. 392, our translation, our emphasis).

At the current stage, various types of instructional materials about the studied regions are available online, along with open tools and other geoscientific information (see PROJETO…, 2018). The project's portal has shown good receptivity by students and teachers from various subject areas. The final results of the completed modules are available on the project's website, as well as preliminary material from Ribeirão Preto and Botucatu. Carneiro *et al*. (2019) briefly describe each one of them as well.

Some achievements of the Geo-School modules

Basic education teachers were invited to approach Geology/Geosciences in the classroom in the successive modules of the Geo-School Project. Distinct strategies were defined for developing materials and content (**table 1**). The main achievements at Monte Mor (SP) include a geological map and other mural maps of the municipality, which were donated in the form of printed panels to municipal and state schools in the region.

The large volume of instructional materials produced in SJRP resulted from contact with teachers in the municipality that exceeded expectations (PIRANHA, 2006). The Cajamar module revealed that local educational managers have poor success rates after efforts with first graders to promote a positive image of the municipality and its history, which is marked by mining. Even after finishing elementary school, many students not feel connected to the city – *i.e.*, they were unaware of what was behind the famous sinkhole that formed in their city (**figure 1**), named *Buraco de Cajamar*[1] (SANTORO *et al*., 1988). Lima (2013) took advantage of the students' life context, explaining to them the importance of limestone mining for the local economy since the first half of the 20th century. High school students understood that the presence of a limestone cave under the city was unknown, and that human activity – excessive extraction of groundwater – was one of the possible causes of the phenomenon. The resulting discussion fostered a feeling of belonging, formation of identity, and provided a remarkable positive perception of Geoscience: "[...] the Geo-School portal presents a

[1]Cajamar Hole.

beginning of possibilities to develop teaching strategies that address the local scale" (LIMA, 2013, p. 92, our translation).

Table 1 – Main strategies used in the modules of the Geo-School Project to design instructional materials and course contents that help basic education teachers approach Geology / Geoscience in the classroom

Module	Approach strategy	Final products	Concluding steps
Jundiaí-Atibaia[1]	Professors prioritized Geology / Earth Sciences themes	CD-ROM with photographs, presentations, maps, and geological information	2003
Cajamar[2]	The researcher prioritized Geology / Earth Sciences themes	WEB[4]: Maps and information on natural disasters and geological risk	2013
Botucatu	Interviews and consultations with teachers and schools	WEB: Maps, geological data, and concepts about groundwater	In progress
Monte Mor	Interviews and consultations with teachers and schools	WEB: Mural maps and concepts on the regional geological evolution	2013
Ribeirão Preto	Interviews and consultations with teachers and schools	WEB: Maps, geological data, and concepts about groundwater	In progress
S. J. Rio Preto[3]	Professors prioritized Geology / Earth Sciences themes	CD-ROM with photographs, presentations, maps, and data about Geology and groundwater	2010

Notes: [1]Of the 168 schools consulted, 36 are private and 132 are public; [2]Of the eight schools consulted, two are private and six public. [3]The 92 schools consulted includes both private and public schools; [4]The Geo-School web portal has permanent access at URL http://www.geo-escola.pro.br/.
Source: prepared by the authors.

In Monte Mor, the idea of "[…] understanding the place based on Geology, when interpreting its history" is introduced using available records (MALAQUIAS JR., 2013, p. 48, our translation). Teachers need to overcome the barrier of previous knowledge on Geology to work with students on the complex local geological history. Malaquias Jr. (2013) has explored, for example, the erratic blocks of the Volpe site (**figure 2A**), composed of granite with mega crystals; the glacial sequences of Permo-Carboniferous age exhibiting nontectonic deformations, such as anticlines (**figure 2B**) and synclines cut by secondary failures. Outcrops of coal-bearing layers were documented (**figure 3A**) (MUNE; OLIVEIRA, 2007) at a site where coal was mined (**figure 3B**) from 1914 until the end of World War II (PARDI; RANGEL; CORADEL, 1999).

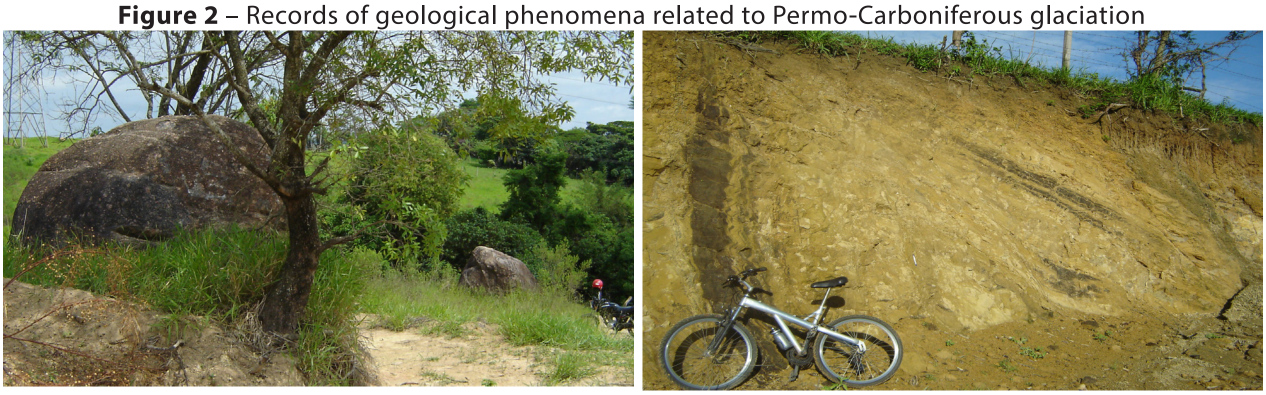
The two modules that are under development explore new approaches, according to the topics to be addressed. Due to the radical changes in technology and teaching resources, teachers can easily access the internet to obtain information and design instructional materials. Thus, the central objective of the Ribeirão Preto module of the Geo-School Project is to raise information about the existence or not of a feeling of belonging among the local population that stems from groundwater reserves and resides in the unique presence of rocks with water from the Guarani Aquifer System (CASTILHO-BARBOSA *et al*., 2020). This topic alone can lead to new inquiries and point out ways to explore important relationships between geological heritage and public supply with teachers, students and community members – fostering discussions on Geology, Geomorphology, and the Environment. The elements already obtained in the initial diagnosis made it possible to organize activities for knowledge dissemination, including the designing of instructional materials about the local reality.

Figure 1 – Students explore the phenomenon known as *Buraco de Cajamar*

(a) In the Cajamar module of the Geo-School Project, the phenomenon known as *Buraco de Cajamar* – a sinkhole formed in the Neoproterozoic limestones of the city – was explored with students; (b) The activity created an *environment for the revaluation of the place* by stressing out the relevance of mining in the region and establishing links with the students' life context.

Source: Santoro *et al*. (1988).

Figure 2 – Records of geological phenomena related to Permo-Carboniferous glaciation



A **B**

The Monte Mor module of the Geo-School Project has focused on records of geological phenomena related to Permo-Carboniferous glaciation, such as erratic blocks (A) and nontectonic folds (B).

Source: Malaquias Jr. (2013).

Figure 3 – Investigation about the presence of coal horizons (A), which were explored during World War II (B)

A **B**

In the Monte Mor module of the Geo-School Project, the presence of coal horizons (A), which were explored during World War II (B), was investigated.

Sources: (A) Malaquias Jr.; (B) Pardi, Rangel e Coradel (1999).

As the Cajamar module, Botucatu also employs the context of students' and teachers' lives to promote immersion in Geoscience and to explore the region's geology and geomorphology. Geological data are being collected to compose a collection of geoscientific information and maps, and geological, geomorphological and geological-geotechnical maps are used in the immersion. As the municipality is in a region dominated by basalt and sandstone *cuestas*, Botucatu allows the interaction of the participants with the central focus of the project, addressing the relationships between citizens' lives and issues – *i.e.*, areas for garbage disposal and the good surface water availability. Geological heritage features and public water supply are topics that reappeared in the module, due to the existence of a series of features and geosites whose relevance has been investigated, along with problems such as erosion and contamination in the recharge areas of the Guarani Aquifer System. Most of the local population and neighboring cities are unaware of the contamination vulnerability of the aquifer. The initiative explores several linked themes of Geosciences from the local reality, trying to foster the interest of students and the community. As new technology advances, participants no longer depend on digital media such as CDs, so that the produced materials are readily and freely available on the web. In addition, in the 21st century, people have access to a plethora of social media, images and digital solutions of all kinds, captured and conveyed in multiple ways (BARBOSA, 2013). Moreover,

> […] equipment enters classrooms in the hands of students and a huge variety of new tools emerges, seemingly inexhaustible sources of information and new opportunities for teaching and learning. *Students choose what they want to access, generate, publish and share*. The debate continues because DT allow for varied achievements and the analysis of completely new learning environments, which may not fit into current standards (CARNEIRO *et al*., 2020, p. 41, our translation, author's emphasis).

Geolocation technologies are an example of this trend, as they enabled a new ecosystem of maps and diagrams. Combined with the internet, cartographic information real-time events, people and objects are now a thing.

The Geo-School portal

> […] the issue of circulating the scientific knowledge at the university, at school and in the society is the core question to think about ways for the universities in the XXI century and for the world we want to build. Central, but quite opaque (SILVA, 2008b, our translation).

The Geo-School's open-source web platform is free and permanent, and aims to disseminate knowledge on Geology, taking advantage of the ease of access to the internet. Scientific dissemination is a socially necessary activity because scientific illiteracy evokes two dangers: (a) the "alienation of the common man" in the face of an increasingly technical environment, and (2) the "[...] 'rise' of scientific elites with power and private means of mass control" (AUTHIER-REVUZ, 1998, p. 108, our translation). One of the functions of scientific dissemination is to bridge the gaps of communication between scientists and the general public using representation (AUTHIER-REVUZ, 2015).

During normal school work, teachers are rarely encouraged to explore resources offered by smartphones and modern internet access resources, mostly due to the scarcity of mechanisms to measure results. These are factors that restrict the school's ability to open channels of direct communication with the student and between students and the teacher.

The portal can publicize similar geo-educational projects, expanding the range of options for students and teachers. The scientific base, concentrated in Geosciences and virtual learning environments, connects the educational system to the innovative potential of Digital Technologies. The portal encourages teachers to employ strategies to spark students' interest and develop new skills. Everyone is expected to be the conductor of their own education (CARNEIRO *et al*., 2019):

1. *Originality and connection to Geology and/or Earth Sciences*. The portal accepts only original and unpublished educational materials on Geology and/or Earth Sciences, although external institutional repositories may be included even if the idea is to not replicate easily accessible resources.
2. *Open-source software and codes and free use license*. The material must comply with the open-source code standard. The user can download programs and applications for personal use or for use with students or colleagues. Thus, the author(s) must comply to use a free license, which eventually requires user registration and identification.
3. *Reliability and reproducibility*. Facts or topics without a scientific basis are rejected. The author(s) of material for the portal must assess the reliability of the knowledge base and ensure reproducibility.
4. *Focus on regional or local themes*. Geoscientific knowledge on a given region, city, or set of municipalities is encouraged.
5. *Educational strategies based on problem situations*. Strategies similar to Problem-Based Learning techniques or intuitive materials with good theoretical foundation are the most welcome.

Conclusions

> Geosciences and ICT invite educational innovation: they are dispersed in the prescribed curriculum; they do not have very formalized roles; they are means to integrate different knowledge; they allow combining student interests with major contemporary environmental issues (BARBOSA, 2013, p. 167, our translation).

Two forms of illiteracy 'alienate the common man': scientific illiteracy and digital illiteracy. Both must be fought by all of us, as long as they hinder learning and political participation. This is a problem because it endangers the possibilities of individual maturation and collective ability to act and make critical decisions in the contemporary world. Interdisciplinary approaches are necessary to understand the world, such as those prioritized by the Geo-School Project. Divided into subjects or specific disciplines, school education is unable to face the current framework of complexity, conflicts and challenges.

Each Geo-School Project module encourages the use of digital equipment and materials in interdisciplinary projects, always emphasizing the need to involve the school structure in it whenever possible. The project motivates teachers and students to explore local geological knowledge as a teaching component as long as a mere imposition of instructional materials can only lead to ephemeral gains.

Over time, the researchers involved with the project have identified which scientific skills and attitudes must be pointed out and clarified by the initiative and how educational challenges must be addressed by teachers so that they can be able to introduce students to the suggested topics to improve learning. Thus, the concept of *sense of place* is key because the teaching of Ecological, Environmental and Earth Sciences is deeply rooted in local knowledge. Fieldwork or a brief field study of the local environment can establish connections with the students' daily lives and lead them to associate observable local features into a broader environmental dynamic framework.

Targeted educational exchanges catalyze innovation, increase academic achievements and reduce student dropout levels by establishing a continuous movement: as new educational connections and practices emerge, motivation will lead teachers to mobilize students' desire for more knowledge and abilities. The context can cause students to assume an autonomous and non-contemplative attitude to find answers to questions.

Acknowledgment

The authors would like to thank Brazilian Council for Scientific and Technological Development (CNPq) for granting us a level 2 scholarship to Celso Dal Ré Carneiro until February, 2021, and Brazilian Coordination for the Improvement of Higher Education Personnel (CAPES) for the masters and doctoral scholarships granted to Danilo Furlan Amendola and Isabella Nogueira Bittar de Castilho Barbosa. The authors also acknowledge the valuable comments and suggestions provided by two anonymous reviewers of the journal *Ciência & Educação*, which helped in improving the manuscript.

References

AMARAL, I. A. Para quê ensinar ciências no mundo contemporâneo? *In*: ENCONTRO DE FORMAÇÃO CONTINUADA DE PROFESSORES DE CIÊNCIAS. *Atas [. . .]*. Campinas: Faculdade de Educação, Unicamp, 1998. p. 13-52.

AMENDOLA, D. F.; CARNEIRO, C. D. R.; BARBOSA, R. Duas décadas de trajetória [2000-2020] do projeto geo-escola na Unicamp. *In*: BARBOSA, P.; MA, J. B. C.; TOLEDO, C. (ed.). *Geologia e sociedade*: construindo pontes para um planeta sustentável. Brasília: Sociedade Brasileira de Geologia, 2021. v. 1, p. 64.

AUTHIER-REVUZ, J. Dialogismo e divulgação científica. *RUA*, Campinas, v. 5, n. 1, p. 9-16. 2015.

AUTHIER-REVUZ, J. Palavras incertas: as não-coincidências do dizer. Campinas: Editora da Unicamp, 1998.

BACCI, D. C.; BOGGIANI, P. C. O currículo do curso de licenciatura em geociências e educação ambiental, LiGEA, USP: formação de professores com visão sistêmica do planeta Terra. *In*: BACCI, D. C. (org). *Geociências e educação ambiental*. Curitiba: Ponto Vital, 2015. p. 9-25.

BARBOSA, R. *Projeto geo-escola*: geociências para uma escola inovadora. 2013. Tese (Doutorado em Ensino e História de Ciências da Terra) – Instituto de Geociências, Universidade Estadual de Campinas, Campinas, 2013.

BARBOSA, R.; CARNEIRO, C. D. R. Divulgación científica y educacion en las ciências de la tierra. *In*: SIMPOSIO SOBRE ENSEÑANZA DE LA GEOLOGÍA, 13., Alicante, 2004. *Actas [...].* Alicante: AEPECT. 2004.

BARBOSA, R.; CARNEIRO, C. D. R. Régua de inovação: uma ferramenta de apoio à educação em geociências. *Terræ Didatica*, Campinas, v. 16, e020015, p. 1-10, 2020. DOI: https://doi.org/hnnr.

BLANCHET, R. Conhecimento da terra e educação. *In*: MORIN, E. *A religação dos saberes*: o desafio do século XXI. Rio de Janeiro: Bertrand Brasil, 2007. p. 145-151.

BONITO, J.; REBELO, D.; MORGADO, M.; MONTEIRO, G.; MEDINA, J.; MARQUES, L.; MARTINS, L. A complexidade do tempo geológico e a aprendizagem com alunos portugueses (12-13 anos). *Terræ Didatica*, Campinas, v. 7. n. 2, p. 81-92, 2011. DOI: https://doi.org/hnns.

BRASIL. Lei nº 9.394, de 20 de dezembro de 1996. Estabelece as diretrizes e bases da educação nacional. *Diário Oficial da União*, Seção 1, Brasília, p. 27833, 23 dez. 1996. Retrieved 2 Nov. 2021 from: https://cutt.ly/VS5tZPw.

BRASIL. Ministério da Educação. *Base nacional comum curricular*. Brasília: MEC, 2018. Retrieved 21 Oct. 2020 from:https://cutt.ly/3S5uqRp.

BRASIL. Ministério da Educação. *Programas do livro*: dados estatísticos. Brasília: MEC, 2019. Retrieved 2 Nov. 2021 from: https://cutt.ly/GS5oDzc.

BRESSANE, E. A.; TOLEDO, M. C. M.; CARNEIRO, C. D. R. Curso de extensão universitária para professores de ciências da natureza sobre o tema "terra e universo". *Terræ Didatica*, Campinas, v. 15, p. 1-8, e19021. 2019. DOI: https://doi.org/hnnt.

CARNEIRO, C. D. R.; BARBOSA, R. Projeto geo-escola: disseminação de conteúdos de geociências por meio do computador para docentes de ciências e geografia no nível fundamental em Jundiaí-Atibaia, SP. *Geologia USP*: publicação especial, São Paulo, v. 3, p. 71-82, 2005. DOI: https://doi.org/hs34.

CARNEIRO, C. D. R.; BARBOSA R.; PIRANHA J. M. Bases teóricas do projeto geo-escola: uso de computador para ensino de geociências. *Revista Brasileira de Geociências*, São Paulo, v. 37, n. 1, p. 90-100, 2007. DOI: https://ppegeo.igc.usp.br/index.php/rbg/article/view/9290.

CARNEIRO, C. D. R.; BARBOSA R.; PIRANHA J. M. Professores, computadores e ensino de geociências: o projeto geo-escola. *In*: ENCONTRO NACIONAL DE PESQUISA EM EDUCAÇÃO EM CIÊNCIAS, 5., Bauru, 2005. *Caderno de Resumos […]*. Bauru: ENPEC. 2005. p. 239.

CARNEIRO, C. D. R.; TOLEDO, M. C. M.; ALMEIDA, F. F. M. Dez motivos para a inclusão de temas de geologia na educação básica. *Revista Brasileira de Geociências*, São Paulo, v. 34, n. 4, p. 553-560, 2004. DOI: https://ppegeo.igc.usp.br/index.php/rbg/article/view/9787/.

CARNEIRO, C. D. R.; BARBOSA, I. N. B. C.; AMENDOLA, D.; BARBOSA, R.; MALAQUIAS JR., J. R.; PIRANHA, J. M.; LIMA, A. T. F.; SIGNORETTI, V. V.; MIGUEL, G. F.; GRAMINHA, C. A. Plataforma open-web geo-escola: critérios para inclusão de novos materiais didáticos. *Terræ Didatica*, Campinas, v. 15, e019040, p. 1-9, 2019. DOI: https://doi.org/hm7q.

CARNEIRO, C. D. R.; BARBOSA, R.; GONÇALVES, P. W.; MIGUEL, G. F.; ANDRADE, W. S. Trabalhos de campo e inovação educacional em geologia. *In*: REIS, F. A. G. V.; KUHN, C. E. S.; CARNEIRO, C. D. R.; WUNDER, E.; BOGGIANI, P. C.; MACHADO, F. B. (org.). *Ensino e competências profissionais na geologia*. Jaboticabal: Ed. Funep, 2020. p. 31-58.

CARNEIRO, C. D. R.; BARBOSA, R.; MALAQUIAS JR., J. R.; LIMA, A. T. F. Projeto geo-escola em Cajamar e Monte Mor (SP): ambientes para ensino-aprendizagem e revalorização do lugar. *In*: CONGRESSO BRASILEIRO DE GEOLOGIA, 47., Salvador, 2014. *Anais […]*. Salvador: SBGeo. 2014. 1 CD-ROM.

CARNEIRO, C. D. R.; BARBOSA, R.; PIRANHA, J. M.; SIGNORETTI, V. V. Portal web geo-escola: uma ponte entre conceitos de geociências e os professores de ensino fundamental e médio. *In*: SIMPÓSIO DE PESQUISA EM ENSINO E HISTÓRIA DE CIÊNCIAS DA TERRA, 1. e SIMPÓSIO NACIONAL SOBRE ENSINO DE GEOLOGIA NO BRASIL, 3., Campinas, 2007. *Anais […]*. Campinas: Unicamp, 2007. p. 146-151.

CASTILHO-BARBOSA, I. N. B.; CARVALHO, A. M.; MIGUEL, G. F.; CARNEIRO, C. D. R. Conhecer para conservar aquíferos: como torná-los visíveis? *Terræ Didatica*, Campinas, v. 16, e020018, p. 1-12, 2020. DOI: https://doi.org/hm7s.

CATARINO, G. F. C.; REIS, J. C. O. A pesquisa em ensino de ciências e a educação científica em tempos de pandemia: reflexões sobre natureza da ciência e interdisciplinaridade. *Ciência & Educação*, Bauru, 27, e21033, p. 1-16, 2021. DOI: https://doi.org/hm7t.

CERVATO, C.; FRODEMAN, R. A importância do tempo geológico: desdobramentos culturais, educacionais e econômicos. *Terræ Didatica*, Campinas, v. 10, n. 1, p. 67-79, 2012a. DOI: https://doi.org/hm7v.

CERVATO, C.; FRODEMAN, R. The significance of geologic time: cultural, educational, and economic frameworks. *In*: KASTENS, K. A.; MANDUCA, C. A. (ed.). *Earth and mind II*: a synthesis of research on thinking and learning in the geosciences. Washington: Geological Society of America, 2012b. p. 19-27. (GSA special paper, n. 486). DOI: https://doi.org/hm7w.

DEMO, P. *O porvir*: desafios das linguagens do século XXI. Curitiba: Ibpex. 2007.

DOTTO, B. C.; ZIEMANN, D. R. A inserção das geociências no ensino básico através de instrumentos pedagógicos. *In*: CONGRESSO NACIONAL DE EDUCAÇÃO, 2., 2015, Campina Grande, PB. *Anais […]*. Campina Grande, PB: CONEDU, 2015. p. 14-17. Retrieved 12 Dec. 2020 from: https://cutt.ly/OS6vi6a.

DWYER. T.; WAINER, J.; DUTRA, R. S.; COVIC, A.; MAGALHÃES, V. B.; FERREIRA, L. R. R.; PIMENTA, V. A.; CLAUDIO, K. Desvendando mitos: os computadores e o desempenho no sistema escolar. *Educação & Sociedade*, Campinas, v. 28, n. 101, p. 1303-1328, 2007. Retrieved 2 Sep. 2021 from: https://cutt.ly/wS6nJ1J.

ERNESTO, M.; CORDANI, U. G.; CARNEIRO, C. D. R.; DIAS, M. A. S.; MENDONÇA, C. A.; BRAGA, E. S. Perspectivas do ensino de geociências. *Estudos Avançados*, São Paulo, v. 32, n. 94, p. 331-343, 2018. DOI: https://doi.org/hm72.

FAGUNDES, L. Seminário do projeto "um computador por aluno" (UCA). *In*: SEMANA DAS MÍDIAS, 2., 2007. Retrieved 15 Apr. 2012 from: https://cutt.ly/VDWCe8S.

FRACALANZA, H.; AMARAL, I. A.; GOUVEIA, M. S. F. *O ensino de ciências no primeiro grau*. São Paulo: Atual. 1986.

KASSAR, M. C. M. Escola como espaço para a diversidade e o desenvolvimento humano. *Educação & Sociedade*, Campinas, v. 37, n. 137, p. 1223-1240. 2016.

LIMA, A. T. F. *O conhecimento socioambiental local como estratégia de valorização do lugar*: projeto Geo-Escola em Cajamar, SP. 105 f. 2013. Dissertação (Mestrado em Ensino e História de Ciências da Terra) – Instituto de Geociências, Universidade Estadual de Campinas, Campinas, 2013.

LÖBLER, M. L.; LÖBLER, L. M. B.; NISHI, J. M. Os laboratórios de informática em escolas públicas e sua relação com o desempenho escolar. *Renote*: novas tecnologias na educação, Porto Alegre, v. 10, n. 3, p. 1-11, 2012. DOI: https://doi.org/hm73.

MALAQUIAS JR., J. R. *O ensino de geociências como ponte entre o local e o global*: projeto geo-escola em Monte Mor, SP. 2013. Dissertação (Mestrado em Ensino e História de Ciências da Terra) – Instituto de Geociências, Universidade Estadual de Campinas, Campinas, 2013.

MORAN, J. M. Desafios que as tecnologias digitais nos trazem. *In*: MORAN, J. M. *Novas tecnologias e mediação pedagógica*. 21. ed. São Paulo: Papirus, 2013. p. 30-35.

MUNE, S. E.; OLIVEIRA, M. E. C. B. Revisão da tafoflora interglacial neocarbonífera de Monte Mor, SP (subgrupo itararé), nordeste da bacia do Paraná. *Revista Brasileira de Geociências*, São Paulo, v. 37, n. 3, p. 427-444, 2007.

OLIVEIRA, M. R. N. S. Do mito da tecnologia ao paradigma tecnológico: a mediação tecnológica nas práticas didático-pedagógicas. *Revista Brasileira de Educação*, Rio de Janeiro, n. 18, p. 101-153, 2001. DOI: https://doi.org/d96rrh.

OLIVEIRA, M. J.; BAPTISTA, G. M. M.; VECCHIA, F. V.; CARNEIRO, C. D. R. História geológica e ciência do clima: métodos e origens do estudo dos ciclos climáticos na terra. *Terræ*, Campinas, v. 12, n. 1-2, p. 3-26, 2015.

OPPENHEIMER, T. *The flickering mind*: the false promise of technology in the classroom and how learning can be saved. New York: Random House, 2003.

PARDI, M. L. F.; RANGEL, Z.; CORADEL, A. Levantamento do patrimônio arqueológico da região de Monte Mor-SP. *In*: REUNIÃO CIENTÍFICA DA SOCIEDADE DE ARQUEOLOGIA, 10., 1999, Recife. *Anais [...]*. Recife: Editora da UFPE, 1999.

PERRENOUD, P. Construir competências é virar as costas aos saberes? *Pátio*: revista pedagógica, Porto Alegre, n. 11, p. 15-19, 1999. Retrieved 3 Sep. 2021 from: https://cutt.ly/0S6PtoH.

PERRENOUD, P. *Dez novas competências para ensinar*. Porto Alegre: Artes Médicas Sul, 2008.

PIACENTE, S.; GIUSTI, C. Geotopos: una oportunidad para la difusion y valoracion de la cultura geologica regional. *In*: SIMPOSIO ENSEÑANZA DE LA GEOLOGÍA, 10., 2000. *Actas [. . .]*. Santander: AEPECT, 2000. p. 134-137.

PIRANHA, J. M. *O ensino de geologia como instrumento formador de uma cultura de sustentabilidade*: o projeto geo-escola em São José do Rio Preto, SP. 2006. Tese (Doutorado em Geociências) – Instituto de Geociências, Universidade Estadual de Campinas, Campinas, 2006.

PIRANHA, J. M.; CARNEIRO, C. D. R. Contributos da educação em geociências para o exercício da interdisciplinaridade. *In*: SIMPÓSIO IBÉRICO DE ENSINO DA GEOLOGIA, 1. e SIMPOSIO SOBRE ENSEÑANZA DE LA GEOLOGÍA, 14., 2006, Aveiro. *Livro de Actas [...].* Aveiro: AEPECT, 2006. p. 389-393.

PIRANHA, J. M.; CARNEIRO, C. D. R. O ensino de geologia como instrumento formador de uma cultura de sustentabilidade. *Revista Brasileira de Geociências*, São Paulo, v. 39, n. 1, p. 533-543, 2009. DOI: https://ppegeo.igc.usp.br/index.php/rbg/article/view/7634/.

POSTMAN, N. *O fim da educação*: redefinindo o valor da escola. Rio de Janeiro, Graphia. 2002.

POTAPOVA, M. S. Geologia como uma ciência histórica da natureza. *Terræ Didatica*, Campinas, v. 3, n. 1, p. 86-90, 2008. DOI: https://doi.org/hs4c.

POTAPOVA, M. S. Geology as an historical science of nature. *In*: SHCHERBAKOV, D. I.; BELOUSOV, V. V. *et al. Interaction of sciences in the study of the earth*. Moscow: Progress, 1968. p. 117-126.

PROJETO geo-escola. Campinas: Unicamp, [2018]. Retrieved 25 Mar. 2022 from: https://geo-escola.pro.br/.

ROCHE, J. A dialética qualificação-competência: estado da questão. *In*: TOMASI, A. (org.). *Da qualificaçao à competência*: pensando o século XXI. Campinas: Papirus. 2004.

SANTORO, E.; CARNEIRO, C. D. R.; OLIVEIRA, M. C. B.; HACHIRO J. Estrutura geológica da região de Cajamar-Jordanésia, SP. *Revista Brasileira de Geociências*, São Paulo, v. 18, n. 3, p. 353-361, 1988.

SANZO, K. L.; MYRAN, S.; CLAYTON, J. K. Building bridges between knowledge and practice: a university-school district leadership preparation program partnership. *Journal of Educational Administration*, Bingley, UK, v. 49, n. 3, p. 292-312, 2011. DOI: https://doi.org/cfgqrk.

SEMKEN, S.; FREEMAN, C. B.; BUENO WATTS, N.; NEAKRASE, J. J.; DIAL, R. E.; BAKER, D. R. Factors that influence sense of place as a learning outcome and assessment measure of Place-Based Geoscience Teaching. *Electronic Journal of Science Education*, Fort Worth, US, v. 13, n. 2, p. 136-159, 2009.

SHIPLEY, T. F.; TIKOFF, B.; ORMAND, C.; MANDUCA, C. Structural geology practice and learning, from the perspective of cognitive science. *Journal of Structural Geology*, Dordrecht, v. 54, p. 72-84, 2013. DOI: https://doi.org/f5cbqz.

SILVA, J. S.; MACHADO, F. B.; TEIXEIRA, D. M.; ZAFALON, M. M. A geologia que não se ensina nos livros didáticos de ciências do 6º ano nas escolas municipais de Maceió, AL, Brasil. *Terræ Didatica*, Campinas, v. 15, e019053, p. 1-7, 2019. DOI: https://doi.org/hnnj.

SILVA, M. V. Conhecimento, educação, sociedade. *Revista de Letras*, Brasília, v. 1, n. 1, p. 7-14, 2008b. Retrieved 19 Apr. 2020 from: https://cutt.ly/0DWLvtS.

SILVA, M. V. Currículo e competências: a formação administrada. São Paulo: Cortez, 2008a.

SILVA, C. P. A.; SOUZA, R. F. Conteúdo de geociências em livros didáticos de ciências do ensino fundamental I: identificando a presença e os temas abordados. *Ciência & Educação*, Bauru, v. 26, e20055, p. 1-15, 2020. DOI: https://doi.org/hnnk.

SIQUEIRA, L. M. P. *Geologia humana*. Recife: Ed. Coqueiro, 2018.

SOUZA, A. S.; FURRIER, M. Estudo da escala do tempo geológico em livros didáticos de geografia do ensino médio. *Terræ Didatica*, Campinas, v. 16, e020010, p. 1-15, 2020. DOI: https://doi.org/hnnm.

TOLEDO, M. C. M. Geociências no ensino médio brasileiro: análise dos parâmetros curriculares nacionais. *Geologia USP*: publicação especial, São Paulo, v. 3, p. 31-44, 2005. DOI: https://doi.org/hnnp.