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Anna Carolina Barcelos, Silvio Carlos Rodrigues, Jean Roger Bombonatto Danelon

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ARTICLE

GEOSPATIAL TECHNOLOGIES AND DIGITAL RESOURCES APPLIED TO GEOMORPHOLOGY EDUCATION

Barcelos, A.C. [a*] - Rodrigues, S.C. [b] - Danelon, J.R.B. [c]

(a) PHD in Geography
ORCID: https://orcid.org/0000-0001-5461-4508. **LATTES:** http://lattes.cnpq.br/9360376324743490.
(b) PHD in Geography
ORCID: https://orcid.org/0000-0002-5376-1773. **LATTES:** http://lattes.cnpq.br/0563872406702918.
(c) PHD in Geography
ORCID: https://orcid.org/0000-0003-0570-2151. **LATTES:** http://lattes.cnpq.br/7644286879722091.

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(*) CORRESPONDING AUTHOR
Address: UFU. Campus Santa Mônica, Bloco 1H, Sala 16, Av. João Naves de Ávila, nº 2121, Santa Mônica, Zip Code: 38408-144, Uberlândia (MG), Brazil. Phone: (+55 34) 3239-4169.
E-mail: barceloscarolina@hotmail.com

Abstract

The advancement of digital technologies and geospatial technologies has brought about significant transformations in education, particularly in the teaching of Geography and Physical Geography, enabling the development of new methodologies aimed at enhancing the teaching and learning process. In this context, geomorphology education has increasingly incorporated technological tools that support the understanding of landforms and geomorphological processes, contributing to more interactive and accessible teaching practices. This study aims to conduct a review on the use of technologies in geomorphology education, highlighting the main contributions of geospatial technologies and digital resources in this field. The theoretical and methodological framework was based on the analysis of academic publications addressing the use of computational tools, educational software, and Geographic Information System (GIS) interfaces in teaching. The review examines changes in contemporary educational settings, particularly in the post-pandemic context, when the use of educational technologies intensified. The literature reviewed indicates that these tools foster more dynamic teaching practices, broaden access to information, and encourage diverse learning approaches. Furthermore, methodological approaches involving fieldwork, interactive activities in parks, and the use of geospatial technology-related software are highlighted as complementary resources to traditional teaching methods. Therefore, the use of technologies in geomorphology education represents an important strategy for strengthening the process of geographic knowledge construction in higher education.

Keywords: Geomorphology Education; Geospatial Technologies; Digital Resources; Educational Technologies.

Resumo / Resumen

TECNOLOGIAS GEOESPACIAIS E RECURSOS DIGITAIS APLICADOS AO ENSINO DE GEOMORFOLOGIA

O avanço das tecnologias digitais e das geotecnologias promoveu transformações significativas no contexto educacional, sobretudo no ensino de Geografia e Geografia Física, possibilitando novas metodologias voltadas à dinamização do processo de ensino-aprendizagem. Nesse contexto, o ensino de Geomorfologia passou a incorporar ferramentas tecnológicas que auxiliam na compreensão das formas de relevo e dos processos geomorfológicos, contribuindo para práticas pedagógicas mais interativas e acessíveis. O presente trabalho tem como objetivo realizar uma revisão acerca do uso de tecnologias aplicadas ao ensino de Geomorfologia, destacando as principais contribuições das geotecnologias e dos recursos digitais para este fim. O referencial teórico-metodológico baseou-se na análise de produções acadêmicas relacionadas ao uso de ferramentas computacionais, softwares educacionais e interfaces de Sistemas de Informações Geográficas (SIG) aplicadas ao ensino. A revisão contempla discussões acerca das transformações ocorridas no ambiente educacional contemporâneo, especialmente no contexto pós-pandemia, período em que o uso de tecnologias no ensino se intensificou. Observa-se, na literatura analisada, que a utilização dessas ferramentas favorece práticas pedagógicas mais dinâmicas, ampliando o acesso às informações e estimulando diferentes formas de aprendizagem. Além disso, destacam-se propostas metodológicas que envolvem aulas de campo, atividades interativas em parques e o uso de softwares vinculados às geotecnologias como recursos complementares ao ensino tradicional. Dessa forma, conclui-se que o uso de tecnologias no ensino de Geomorfologia representa uma importante estratégia para o fortalecimento do processo de construção do conhecimento geográfico no ensino superior.

Palavras-chave: Ensino de Geomorfologia, Geotecnologias, Recursos Digitais, Tecnologias Educacionais.

TECNOLOGÍAS GEOESPACIALES Y RECURSOS DIGITALES APLICADOS A LA EDUCACIÓN EN GEOMORFOLOGÍA

El avance de las tecnologías digitales y de las geotecnologías ha promovido transformaciones significativas en el contexto educativo, especialmente en la enseñanza de la Geografía y la Geografía Física, posibilitando nuevas metodologías orientadas a dinamizar el proceso de enseñanza-aprendizaje. En este contexto, la enseñanza de la Geomorfología ha comenzado a incorporar herramientas tecnológicas que contribuyen a la comprensión de las formas del relieve y de los procesos geomorfológicos, favoreciendo prácticas pedagógicas más interactivas y accesibles. El presente trabajo tiene como objetivo realizar una revisión sobre el uso de tecnologías aplicadas a la enseñanza de la Geomorfología, destacando las principales contribuciones de las geotecnologías y de los recursos digitales para este fin. El marco teórico-metodológico se basó en el análisis de producciones académicas relacionadas con el uso de herramientas informáticas, software educativo e interfaces de Sistemas de Información Geográfica (SIG) aplicadas a la enseñanza. La revisión contempla discusiones sobre las transformaciones ocurridas en el entorno educativo contemporáneo, especialmente en el contexto pospandémico, período en el que se intensificó el uso de tecnologías en la enseñanza. En la literatura analizada, se observa que la utilización de estas herramientas favorece prácticas pedagógicas más dinámicas, ampliando el acceso a la información y estimulando diferentes formas de aprendizaje. Asimismo, se destacan propuestas metodológicas que incluyen salidas de campo, actividades interactivas en parques y el uso de software vinculado a las geotecnologías como recursos complementarios a la enseñanza tradicional. De este modo, se concluye que el uso de tecnologías en la enseñanza de la Geomorfología representa una estrategia importante para fortalecer el proceso de construcción del conocimiento geográfico en la educación superior.

Palabras-clave: Enseñanza de la Geomorfología, Geotecnologías, Recursos Digitales, Tecnologías Educativas.

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INTRODUCTION

The advancement of technology has brought about significant changes in people's daily lives, and these transformations have also affected educational environments, particularly classrooms. In this context, geospatial technologies have introduced new tools that play a fundamental role in improving Geography education in general and, more specifically, in meeting some of the demands of Physical Geography education, particularly with regard to the updating of teaching methods.

In this context, geospatial technologies encompass a set of techniques used to acquire data from a specific geographic location, with the aim of processing and analyzing these data in accordance with a previously formulated hypothesis (PEREZ FILHO et al., 2020).

Developing an understanding of the fundamental aspects of relief in the classroom is essential for comprehending the behavior and interrelationships of various environmental elements, such as vegetation, climate, geology, and soils, in relation to the configuration of the Earth's surface. Although this is not a simple task, the teaching of Geomorphology can make a significant contribution to fostering environmentally conscious citizens (CASETTI, 2001; BERTOLIN, 2010; BERTOLINI; LYRA, 2020).

New approaches to teaching Geomorphology have been developed over the years, seeking to complement and, in some cases, move beyond traditional teaching approaches. These practices include initiatives such as interactive classes in parks, the use of computational tools, educational software, and resources associated with Geographic Information Systems (GIS) interfaces, thereby expanding the possibilities for visualizing, analyzing, and understanding geomorphological processes (WENTZ et al., 1999; DAVIS, 2002; ARRUDA; GUIMARÃES, 2019; ARAUJO; AQUINO, 2023; OLIVEIRA et al., 2023).

The teaching of Geomorphology plays a fundamental role in the education of professionals in Geosciences and Geography, as it enables the understanding of landforms, their evolutionary dynamics, and the interactions established among the different components of the landscape. In this context, the incorporation of educational technologies and geospatial technologies has expanded the possibilities for representing, analyzing, and interpreting geomorphological processes, favoring more interactive approaches that are aligned with the contemporary demands of higher education.

Given the increasing use of these tools in educational settings, it is important to gather and analyze the contributions presented in the scientific literature regarding their application to the teaching of Geomorphology. Thus, this study aims to conduct a literature review on the use of educational technologies and geospatial technologies applied to the teaching of Geomorphology, highlighting the main tools employed, their pedagogical potential, and their contributions to the teaching and learning process.

THE USE OF DIGITAL TECHNOLOGIES IN HIGHER EDUCATION

According to Rojas, Ritto, and Barbosa (2008), technology is not making teachers and schools obsolete; rather, they are redefining their roles. Many educational practices have traditionally been, and still are, strongly teacher-centered and focused on the transmission of content. In new contexts, however, greater emphasis may be placed on the learning process and on the development of skills and competencies, including students' cognition, emotions, and interpersonal skills, with learners being regarded as active agents in the learning process. In these learning environments, planned activities may promote self-directed learning and collaborative learning.

Society has experienced significant advances in digital technologies in recent years. Among these, Information and Communication Technologies (ICTs) can be highlighted. This development is associated with the emergence of cyberculture, which has become part of contemporary social practices and is characterized by an increasing reliance on virtual communication (REIS, 2007; LEVY, 2010).

According to Mendes (2008), Information and Communication Technologies (ICTs) can be defined as a set of technological tools that, when integrated, enable automation and/or communication among processes related to education, scientific research, business, and other activities. These

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technologies are used to organize, share, and distribute information. With regard to developing countries, ICTs have a significant impact on all aspects of national life, including politics, the economy, and social and cultural development, as they rapidly affect the way people conduct business, access information and services, communicate with one another, and even engage in leisure activities (KELLES-VIITANEN, 2003; BALI, 2018).

With the advent of globalization and, subsequently, the consolidation of Internet use, which became widespread worldwide particularly from the 1990s onward, an important starting point was established for the creation of new forms of pedagogical support and access to information. The continuous expansion of Information and Communication Technologies (ICTs) has brought advantages to both teachers and students, serving as an important educational resource that promotes multifunctionality in classes with a geographic and cartographic focus (SALGADO et al., 2010; PASSERO et al., 2016; FURTADO, 2022).

McCarney (2004) analyzes the impact of various approaches to ICT workforce development on outcomes related to teachers and knowledge. The skills acquired by teachers as a result of improvements in quality point to the need for greater emphasis on ICT pedagogy.

There are several ways to incorporate technology into teaching, and there is growing interest in the use of digital technologies to support and enhance Geography education, as can be observed in the development of virtual fieldwork techniques. Virtual field trips (VFTs) have a long history in Geography education, as software and web applications have been used to develop knowledge and skills both inside and outside the classroom (STAINFIELD et al., 2000; CLIFFE, 2017).

New technologies have brought advances to the field of education, particularly in higher education, through the adoption of teaching methodologies that allow classes to be delivered in different formats and enable information to be acquired or accessed for effective learning.

University students' performance depends on their focus on learning. This focus can be considered one of the main factors contributing to successful learning. Therefore, technologies can be highly useful tools in the teaching and learning process, particularly when accompanied by appropriate curriculum adjustments and well-planned projects (MARCHIORI et al., 2011; GESSER, 2012).

According to Riedner and Pischetola (2016), the use of digital technologies has increased across different educational settings, giving rise to the need for methodological development. Learning environments broaden and facilitate access to information, as well as asynchronous and synchronous exchanges between teachers and students, allowing knowledge to be shared even when these participants are not in the same geographical location.

According to Kenski (2013), traditional practices still dominate higher education classrooms, especially those based on teachers' verbal presentations. According to the author, at that time, digital culture was still far removed from undergraduate classes and courses, whether offered in person or through distance education. This situation revealed a contradiction between the use of digital technologies in research activities and their application in teaching practices, since teachers and researchers used these resources in their investigations but did not always incorporate them into the teaching process. In this way, the author draws attention to the gap between the teacher's role as a researcher and as an educator, an aspect that may compromise the quality of teaching and, consequently, learning (KENSKI, 2013).

This issue is also discussed by Debald (2020), who highlights the difficulties faced by teachers in moving away from traditional pedagogical practices, which are often consolidated throughout their initial education and professional careers. In this sense, the adoption of innovative approaches requires changes in teaching practices and in the organization of educational activities, particularly regarding students' participation in the learning process. These transformations, however, do not occur immediately, as teachers need time to adapt to new pedagogical perspectives and to develop practices that foster greater student agency.

In light of the above, technologies facilitate the dissemination and sharing of data and knowledge, allowing anyone connected to the network to access millions of pieces of information with just one click. Technological innovation and the web have changed the way new knowledge is disseminated. Regarding the processes to be developed, hybrid models and active approaches are recommended because, in addition to serving as motivating factors, they also facilitate interaction among participants,

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whether in person or online, making them more autonomous and effective in the process of developing and strengthening their skills (BACICH; MORAN, 2018; ANDRADE CARNEIRO et al., 2020).

Selwyn (2016) understands digital technologies in a broad sense, including both electronic devices, such as computers, tablets, and smartphones, and digital platforms, virtual learning environments, online services, and software used for text production. In addition, these technologies enable internet access in different settings, expanding the possibilities for using digital resources beyond the home environment, particularly through mobile devices.

New technologies contribute to different teaching methods, transforming crisis situations into spaces for pedagogical possibilities. Technology is no longer an "adversary" of the teacher, but rather an ally in teaching practice. Technology does not solve all educational problems; however, when associated with social practice and human interaction, it can effectively facilitate the (re)construction of knowledge (RODRIGUES; LEMOS, 2019; HABOWSKI et al., 2019).

It is important to understand that higher education is also affected by all these changes, considering the new reality shaped by digital technologies, whose effects are directly reflected in society and culture. Therefore, teachers need to adapt course content to the innovative nature of pedagogical strategies and resources. This will allow students to acquire knowledge in different ways, leading to a teaching process that is increasingly relevant to those immersed in this new digital culture (QUINTANILHA, 2017; BATES, 2022).

According to Lucena (2016), the understanding that we live in an interconnected reality shows that the introduction of Information and Communication Technologies (ICTs) into the classroom can further enhance knowledge construction, which can occur in a more collaborative and collective manner through networks that enable interaction, communication, and different types of relationships in various virtual environments that depend on access to the web.

The outcome of this intense technological transformation, which has reached its fourth phase within only a few decades, is reflected in the convergence of the biological, physical, and digital worlds, creating major opportunities for improving resource use and efficiency. From this convergence, a range of products can be identified that may bring significant changes to the educational process, such as the Internet, artificial intelligence, 3D printers, and cloud storage, among others. These technologies may provide unprecedented benefits to education, provided that institutions are prepared to keep pace with and participate in this evolution (SCHWAB, 2017; KENSKI et al., 2019).

Digital devices are increasingly used for educational and learning purposes. This became particularly evident between 1997 and 2006, when networked computers were widely used for collaborative learning, and between 2007 and 2016, when so-called online digital learning became widespread. During both periods, the potential of emerging technologies was examined, including computer-mediated communication, the use of mobile devices, and virtual learning environments (MASON; BACSICH, 1998; WANG et al., 2012; MUÑOZ-CRISTÓBAL et al., 2017; BOULTON et al., 2018; ZAWACKI-RICHTER; LATCHEM, 2018; OYARZUN; MARTIN, 2023).

GEOMORPHOLOGY: CONCEPTS AND IMPORTANCE FOR TEACHING ABOUT THE EARTH'S SURFACE

The Earth's surface is composed of a variety of landforms with different sizes, categories, ages, and genetic processes. Although this dynamic is continuous, it is often imperceptible to the human eye. Changes in landforms occur at different rates, with periods of greater instability and others of greater stability. This dynamic can be influenced by both natural factors and human interventions (ROSS, 1992; ALMEIDA; RIBEIRO, 1998; PENHA, 2007; SOUZA, 2008).

In the eighteenth century, Geomorphology emerged from geological studies of the Earth's crust, establishing connections between Geography and Geology through a naturalistic approach. During this period, some researchers supported the theory that relief was shaped mainly by the action of rivers. Initially, the prevailing idea was that river valleys resulted from catastrophic events, suggesting that rivers had begun to erode pre-existing valleys. However, throughout the century, this perspective was gradually abandoned in favor of the understanding that river valleys are shaped mainly by the erosive

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action of the rivers themselves (FONTES, 2010; SOARES et al., 2013). The geographical cycle theory proposed by William Morris Davis (1899) marked a significant advance in geomorphological thought, representing the first more fully developed conceptual framework. This evolutionary model aimed to explain landforms and adopted a methodological paradigm applicable to the forms observed in the field. Davis's work provided an important impetus to the development of Geomorphology by offering a comprehensive conceptual framework for understanding the evolution of landforms over time (CHRISTOFOLETTI, 1980; SALGADO, 2007; ALMEIDA; SILVA, 2015).

As pointed out by Souza (2008), the sequence of natural events, such as tectonic activity, uplift, and erosion, together with the assumption of long periods of tectonic stability, was interpreted in a systematic and predictable manner, over a timescale that was difficult to verify. However, over time, this model was gradually set aside, giving way to a new geomorphological paradigm driven by technical transformations in science.

The classical systematization of relief as an element interconnected with others in the formation of the Earth's surface was established by Penck (1984) and W. Penck (1910). Within the German school, the relationship among relief, climate, and vegetation developed from the analysis of internal and external processes involved in relief formation, with significant contributions from Passarge (1926). Subsequently, Troll's (1950) studies on landscape physiology contributed to the development of the concept of landscape (MENDOZA et al., 1982; SUERTEGARAY, 2018).

Until the early 1950s, Geomorphology was predominantly focused on the description and classification of landforms, without direct concern for understanding the role of the environment in society–nature interactions. The relative lack of concern regarding society–nature interaction was largely the result of a body of academic work focused on the understanding of morphogenetic and pedogenetic processes. However, this approach lacked an analysis of landscape physiology aimed at providing a more detailed understanding of the relationship between land use/occupation and the genesis of landforms (SOUZA, 2008; VITTE, 2010; COLTRINARI, 2012).

In the second half of the twentieth century, Geomorphology underwent significant transformations. Scientific and technological advances enabled the use of more sophisticated resources, including more accurate topographic maps, advanced instruments, high-resolution aerial photographs, and more refined equipment for both fieldwork and laboratory activities. These innovations expanded the research and analytical capabilities within the field of Geomorphology (MARQUES, 2007; SUERTEGARAY, 2018).

Between the 1940s and the 1970s, drainage basin studies gained prominence in Geomorphology through the contributions of Horton (1933), Strahler (1952), and Gregory and Walling (1973). These studies marked an important phase in the discipline by introducing quantitative approaches, systems theory, flow analysis, and the incorporation of computer-based methods (CASSETI, 1991; FLORENZANO, 2008; ZAIDAN, 2011).

In addition, the French school, represented by Emmanuel de Martonne (1964) and Tricart (1977), also exerted significant influence, playing an important role in the development of Geography and Geomorphology in Brazil. In the Brazilian context, German influence is evident in the studies of Ab'Saber (1969), whose work is considered one of the major contributions to geomorphological theory in the country (AB'SABER, 1974; ABREU, 2006; VITTE, 2010; NETO, 2012).

Therefore, geomorphological studies focus not only on the overall shape of the Earth, but especially on the forms identified on its surface. In this sense, Geomorphology is devoted to the study of the characteristics of terrestrial surface forms, investigating their distribution, origin, interrelationships, and evolution over time (COLTRINARI, 2012; HARVEY, 2022; SCHAETZL; MARSTON, 2025).

GEOMORPHOLOGICAL MAPPING: TRADITIONAL TECHNIQUES AND THEIR APPLICATIONS

Passarge (1914) pioneered the introduction of the initial concept of a detailed geomorphological map, presented in the form of a Morphological Atlas. This atlas comprised eight maps at a scale of 1:50,000. These included a topo-orographic map with vegetation, slope gradients, valley forms, a

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stratigraphic-geological map, physical resistance, chemical resistance, a petrographic map, and a relief development map. The latter represented relief elements, their evolution, the structure of the substrate, and susceptibility to weathering (CHRISTOFOLETTI, 1980; GUSTAVSSON, 2006).

From the 1950s onward, geomorphological cartography was officially adopted as a method for basic research in Geomorphology. This development contributed to the advancement of the discipline, providing it with a solid theoretical framework and practical applications in a variety of contexts. Initially developed in Poland, geomorphological mapping evolved over time. Today, such maps are used in several countries for ecological, economic, and agricultural zoning, while also contributing to theoretical studies of the landscape (GELLERT, 1972; DEMEK, 1982; COLTRINARI, 2012).

The absence of an internationally unified method for geomorphological mapping is attributed to the diversity and complexity of the objects of study in Geomorphology, which creates challenges for their classification. The best-known and most widely used systems for geomorphological mapping include that of the International Geographical Union (IGU), the French system, and the system developed by the International Institute for Aerial Survey and Earth Sciences (ITC) (DEMEK, 1972; TRICART, 1972; VERSTAPPEN; ZUIDAM, 1975).

In the Brazilian context, the theoretical foundations developed by Jurandyr L. S. Ross contributed significantly to the implementation of technical geomorphological studies aimed at socioeconomic and environmental planning. In addition, the RADAMBRASIL Project stands out for having as its main objective the development of comprehensive mapping of the Brazilian territory, highlighting both renewable and non-renewable resources. The project employed imagery obtained from sensors and radar, providing a comprehensive approach to the characterization of Brazil's geographical environment (RADAMBRASIL, 1983; ROSS, 1992).

The taxonomic classification proposed by Ross (1992) considers not only the size of relief forms but also the physiognomic aspects of the different forms, based on their age and genesis, while taking into account their morphogenetic significance and the structural and sculptural expressions of relief.

Furthermore, the Institute for Technological Research of the State of São Paulo (IPT) proposed an approach to systematize relief classification, which resulted in the preparation of the geomorphological map of São Paulo. This proposal was based on the concept of relief systems, leading to the development of a classification that divides relief into homogeneous sets, which are subsequently subdivided into provinces, zones, and subzones. In parallel, the Brazilian Institute of Geography and Statistics (IBGE) presented an equally significant methodology in its Technical Manual of Geomorphology. This approach involved organizing geomorphological events according to a temporal and spatial classification (IPT, 1981; IBGE, 2009). Geomorphological maps, in contrast to other thematic maps, involve greater complexity in representing the essential elements required for geomorphological analysis. According to Ross (2007), although there is consensus within the geomorphological community regarding the general content to be represented on maps, particularly information on landform types, their genesis, and age, the main difficulty lies in the lack of standardization of cartographic representation. This occurs because of the absence of a standardized model capable of accommodating the diverse interests of different research studies.

As pointed out by Ferreira (2005), discussion of this issue dates back to the 1960s, when it was debated in scientific meetings and commissions by various geographers and geomorphologists. Along the same line of reasoning, Ross (1992) argues that this situation results from the lack of uniformity or standardization in geomorphological cartographic representation. In addition, Cunha et al. (2003) suggest that some of these difficulties may be related to differences in the methods, scales, and working techniques adopted by researchers.

GEOSPATIAL TECHNOLOGIES AND DIGITAL RESOURCES APPLIED TO GEOMORPHOLOGY EDUCATION

In the early 1990s, the use of Geographic Information Systems (GIS) began to develop within the field of Geographic Information Science, with greater emphasis placed on theories concerning how data

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are spatially represented in GIS environments, while other theoretical foundations also became an important part of GIS education. By the mid-2000s, spatial thinking began to receive greater emphasis according to emerging needs, while software, methods, and theories were taught to help decision-makers understand spatial relationships and concepts and use GIS tools more effectively (GOODCHILD, 1992; KERSKI, 2008).

Rocha (2002) defines Geographic Information Systems (GIS) as systems capable of performing a set of operations related to the management of georeferenced digital information. These operations range from data acquisition, storage, and updating to processing, integration, manipulation, modeling, and analysis, enabling the retrieval and representation of spatial information, which may be associated with alphanumeric databases.

Teaching through the use of GIS allows for real-world assignments and assessments rather than true-or-false or multiple-choice assessments. Teaching with GIS enables students to understand problems that exist in the real world rather than problems created specifically for the classroom. Students who use this inquiry-based approach formulate research questions, develop methods, collect and analyze data, and draw conclusions. This approach is based on a learning theory known as constructivism, which holds that knowledge is not transferred from the teacher to the student, but rather constructed by the student based on their own experience and by making connections (DRIVER, 1994; TRINDADE et al., 2014; SILVA, 2021).

The use of GIS offers several advantages in the teaching and learning process when applied to Geography education (SILVA et al., 1996; ALVES, 2011; MEDEIROS et al., 2021), including:

1) Allows students to analyze, correlate, and synthesize information with the efficiency and speed provided by these systems when processing large amounts of data.

2) It provides students and teachers with continuous access to resources and enables them to manipulate files, databases, and multimedia, as well as integrate other types of technology, such as remote sensing.

3) It enables participation in the processes of collecting, storing, analyzing, and presenting information, which serve as learning tools for discovery and personal experience.

It assists in the development of analytical, synthetic, and logical mathematical reasoning, as users explore new possibilities for answers and analyze and synthesize information based on the questions presented.

According to Carrara, Zaindan, and Paula (2018), geospatial technologies encompass geoprocessing, digital or automated mapping, satellite remote sensing, Global Positioning Systems (GPS), aerial photogrammetry, geodesy, conventional surveying, and Geographic Information Systems (GIS), among others. Within the field of geospatial technologies, geoprocessing stands out, particularly in the development of Geographic Information Systems (GIS).

According to the Brazilian National Institute for Space Research (INPE), geoprocessing corresponds to a set of technologies designed for the collection and processing of spatial information for specific purposes. Activities related to this set of technologies are carried out through systems that enable the processing of georeferenced data, from data collection to the generation of products such as maps, reports, and digital files. These systems also provide tools for storing, manipulating, and analyzing geographic information (INPE, 2009).

Geoprocessing, therefore, can be understood as a field of activity and may be defined as a set of techniques, theoretical and computational methods associated with data collection, input, storage, processing, and manipulation, with the purpose of generating new spatial information, georeferenced information, and/or data (BALUZ, 2010; ZAIDAN, 2017).

In Brazil, the systematization of Geomorphology began in the 1930s, mainly with the institutionalization of several universities and the creation of the Brazilian Institute of Geography and Statistics (IBGE). These universities played an essential role in the education of geographers with knowledge of Geology and Geomorphology, who subsequently contributed to understanding Brazil's diversity and to the expansion of the country's internal frontiers. By the late 1950s, Professor Aziz Ab'Saber had observed that scientific production in Geomorphology was expanding as a result of these two developments (MACHADO, 2000; VITTE, 2011; LOPES; ABRANCHES JUNIOR, 2023).

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Geomorphology, as a science dedicated to investigating the processes that shape relief, based on climatic, hydrological, lithological, pedological, and tectonic characteristics, constitutes an essential field for analyses across various domains, particularly in environmental and social studies. The relationship between the physical environment and human activities becomes increasingly evident when examined through the study of terrestrial relief, since relief can guide, enable, and condition human activities (FLORENZANO, 2008; SILVA; RODRIGUES, 2009; FURRIER, 2013).

In his study, Souza (2009) described the usual context of Geomorphology education in undergraduate Geography programs, noting that students consider the subject interesting but difficult. This makes it possible to hypothesize that learning difficulties in Geomorphology may arise from epistemological and methodological barriers, as well as from the language used.

According to Correa, Fernandes, and Paini (2010), geospatial technologies are highly relevant to the development of the teaching and learning process and serve as fundamental tools for enhancing classroom activities and encouraging students to engage with the body of knowledge accumulated by society, particularly geographical knowledge and, more specifically, geomorphological knowledge.

Thus, it is important to highlight the use of GIS and geoprocessing in the context of Geomorphology studies, as they contribute significantly to the development of research in this field of knowledge. According to Silva and Rodrigues (2009), the study of relief constitutes a fundamental element of environmental and social research, particularly with regard to territorial planning and management. In this sense, relief analysis makes it possible to understand the relationships between the physical environment and human activities, since its characteristics can guide, favor, and condition the development of these activities.

According to Kerski (2008), one of the most appropriate ways to teach content related to the Earth's surface is through the use of geospatial technologies. Geographic Information Systems (GIS), Global Navigation Satellite Systems (GNSS), and remote sensing (RS) are among the resources encompassed by geospatial technologies. In its early stages, the use of GIS was almost entirely focused on learning how to operate the software, as the teaching and learning process involved a steep learning curve for most individuals who came into contact with this technology.

According to Cruz (2017), geospatial technologies contribute to the understanding and application of categories, concepts, and logical principles of Geomorphology at different scales of analysis. When used with appropriate theoretical and methodological consideration, they contribute significantly to the development of professionals capable of using the languages and technologies of their time, as well as performing effectively in the labor market.

Combined with the use of geospatial technologies, fieldwork activities provide support across different scientific fields and can be adapted to different levels of education, from basic to higher education. At both educational levels, one of their main contributions is the possibility of establishing a direct relationship between students (researchers) and the object of study. They also highlight the importance of closer interaction between teachers and students, making the teaching and learning process more dynamic (VIVEIRO; DINIZ, 2009; NEVES, 2015; OLIVEIRA, 2022; ARAÚJO et al., 2024).

According to Stoddart and Adams (2004), observation and fieldwork play a fundamental role in Geomorphology. The authors distinguish two broad meanings of the term "field." The first refers to places located beyond the geographer's immediate surroundings and to a form of social practice involving travel, observation, and recording, including places that require a specific itinerary to be reached. The second refers to fieldwork itself and to the field as the place where research is conducted, knowledge is produced, and observations are recorded through specific activities.

Therefore, fieldwork is essential for investigating the processes and structures that shape relief, since it is through fieldwork that the aspects involved can be understood, providing students with a more detailed view of the reality in which they are situated. In other words, it enables them to observe the dynamics, transformations, and relationships present in that environment (BARBOZA; RODRIGUES, 2016; FURLAN; TRENTIN, 2024; TRINDADE et al., 2026).

Geomorphology is well positioned to embrace and harness the power of education to transform society and contribute to addressing environmental crises. Geomorphologists have the field as a natural laboratory and the classroom as a space for working with the knowledge acquired in the field. In this

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way, fieldwork serves as a mechanism for linking theory, concepts, and technologies to the real world (FULLER et al., 2006; SCOTT et al., 2006; RYDANT et al., 2010; BRIERLEY; FRYIRS, 2014; THORNBUSH et al., 2014; FRANCE; HAIGH, 2018).

When combined with fieldwork practices, digital technology enables a wider dissemination of information, and these technological resources are responsible for numerous changes in society, affecting everyday activities and transforming the ways in which knowledge is understood and reproduced. Thus, when used for educational purposes, technology emerges as an important tool for supporting and innovating teaching practices. The incorporation of new technologies into education is a reality with a major impact on the country's educational context, since it may become impractical for a society not to adapt to new processes and technologies (AGUIAR, 2013; FERRÃO, 2013; SELWYN, 2016; BACICH; MORAN, 2018; DEBALD, 2020).

According to Nunes et al. (2020), practical classes can support the teaching of Geomorphology, making learning more enjoyable, stimulating, relaxed, and less abstract, particularly for higher education students.

In Geomorphology education, the use of different forms of language, particularly those associated with technology, is a strategy that can contribute to the better development of classes and to the understanding of the relationships among geomorphological concepts, society, and nature (CRUZ et al., 2017; ARAUJO; AQUINO, 2023; OLIVEIRA et al., 2023).

In the context of Geomorphology, according to Santos et al. (2006), geomorphological cartography is understood as an important means of representing the relief of the Earth's surface and constitutes one of the main research and study techniques in Geomorphology, as well as serving other purposes, such as environmental planning and territorial planning.

Seemann (2013) points out that difficulties still remain in the teaching of Geomorphology content in higher education, with the inefficient use of cartography, or even its absence, standing out as important issues in this context. In addition, mathematics may also contribute to discouraging students' interest in this subject.

In contemporary contexts, geomorphological cartography has benefited significantly from technological advances. Current technologies based on remote sensing and geoprocessing provide Geomorphology with important resources for the development of a wide range of research activities (PELECH, 2019; GIRÃO et al., 2021; RODRIGUES et al., 2023).

The use of geospatial technologies to support the development of instructional materials for Geomorphology education is important for addressing spatial issues at different scales. Teachers often use textbook content in the classroom that may be considerably removed from students' actual realities, while such materials tend to give limited attention to local issues. Access to and use of materials produced through geospatial technologies have therefore become important for providing students with a more meaningful approach and for supporting the Geography teaching process (CONCEIÇÃO et al., 2009; NOSOLINE, 2011; MARTINS, 2017; FURTADO, 2022; BARCELOS; RODRIGUES, 2023; SILVA et al., 2025).

CONCLUSION

Geospatial technologies and digital resources have assumed an increasingly important role in Geomorphology education. The use of these tools has contributed to expanding the possibilities for representing, analyzing, and understanding landforms and geomorphological processes, favoring more dynamic and interactive approaches in the teaching and learning process.

In this context, resources such as Geographic Information Systems (GIS), remote sensing, Global Navigation Satellite Systems (GNSS), digital terrain models, and other computational resources show potential to support teachers and students in the construction of geomorphological knowledge. In addition, when combined with field activities and other teaching resources, they enable a closer connection between the content addressed in the classroom and the reality observed by students.

Therefore, the use of geospatial technologies in Geomorphology education is not limited to the introduction of new technological tools into educational environments, but also involves expanding the

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methodological possibilities available for teaching this field of knowledge. In this sense, their use can contribute both to strengthening academic education and to developing technical competencies related to the increasingly present demands within Geography and the Geosciences.

Given this, the integration of geospatial technologies, digital resources, and teaching methodologies represents an important alternative for improving Geomorphology education, contributing to a more meaningful teaching and learning process that is aligned with the technological transformations observed in contemporary society.

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DATA AVAILABILITY

Not applicable

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Author's Affiliation

Barcelos, A.C. - Federal University of Uberlândia, Uberlândia (MG), Brazil. Rodrigues, S.C. - University of São Paulo, São Paulo (SP), Brazil.
Danelon, J.R.B. - Federal University of Uberlândia, Uberlândia (MG), Brazil.

Authors' Contribution

Barcelos, A.C. - The author contributed to conceptualization, methodology, investigation, formal analysis, original writing, review and editing.
Rodrigues, S.C. - The author contributed to writing, review and editing.
Danelon, J.R.B. - The author contributed to writing, review and editing.

Editors in Charge

Alexandre Queiroz Pereira
Jader de Oliveira Santos

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The authors declare that there is no conflict of interest.

Research Data Availability

All the data supporting the results of this study were published in the article itself.

Use of AI

No Artificial Intelligence tools were used.

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