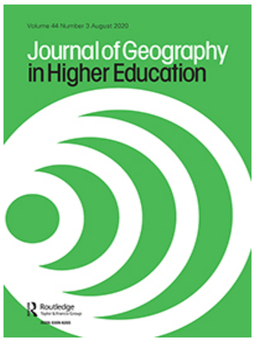

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Development and application of the multi-dimensional integrated geography curricula from the perspective of regional remote sensing

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ABSTRACT

Geography can improve citizens' quality of life by improving their understanding of the population, resources, environment and development of geographical areas. The emergence of remote sensing technology provides a convenient method for understanding the regional geographical landscape. It is important to develop a regional geography curriculum for college students that includes modern remote sensing technology to cultivate their geographic literacy and popularize remote sensing technology. To focus on the development of college students' valuable ability to think critically in spatial terms, this paper introduces methods for observing the spatiotemporal properties (multi-temporal, multi-scale, multi-angle), physical properties (multi-spectral, multi-product), and natural synthetic properties (multi-element, multi-media) of regional geography via multi-dimensional means. Taking the construction of a regional remote sensing geography course as an example, this paper discusses the goals, content structure and teaching management construction. Then, the study discusses plans and anticipations for the development of the course. Geographical observations and the teaching of geography from the multi-dimensional perspective will provide innovative methods and better results in terms of college students' quality of education in higher education curricula.

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Introduction

The geography curriculum has a positive effect on contemporary college students by disseminating relevant knowledge and theory on the regional system of human-land relations, thereby improving geographic literacy and comprehensive quality (Walford & Haggett, 1995). Geography is the study of the Earth and its features, inhabitants and phenomena, and it is a disciplinary system that studies the interactions between the layers of the Earth's surface and their spatial differences and processes (Kalafsky & Rosko, 2017). Understanding the population, resources, environment, development and other issues in a geographical area has become not only a public issue but also one related to the quality of life of citizens (Butler & Hamnett, 2007; Wallace, 1956). Currently, geography-

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related courses are offered in many universities (Bowlick, Goldberg, & Bednarz, 2017; Murphy, 2007) and have the potential to lead students to a successful career (Dyer, Solem, Haigh, & Waddington, 2018; Walkington & King, 2018). The goal of geographic literacy training for college students is to help them observe things from a geographical perspective and obtain the inherent capacity to use geography skills to solve problems. College is an important period for the formation of knowledge, talents and concepts. Therefore, it is especially important for students to engage in geography teaching activities that concern the core of geographic literacy.

Geography is constantly developing and geographical language is gradually evolving and expanding with the advancement of science and technology. The process of understanding the geographical environment requires a geographical language that can facilitate the communication and transfer of geographical information between people. Although fieldwork allows students to get in touch with geography and landscapes (Krakowka, 2012; Leydon & Wincentak, 2017; Maguire et al., 2007), it is also important and necessary to explain theories and knowledge in class. With the rapid development of modern information technology, computers play an important role in teaching geography (Wilson, Boyd, Chen, & Jamal, 2011). Network maps and remote sensing images are no longer mysterious, and tools such as Google Earth (Demirci, Karaburun, & Kılar, 2013; Patterson, 2007) and multi-media (Dong, 2017) have also become important ways for people to obtain the spatial and practical information needed for daily life (Krakowka, 2012). Word expressions, language communications and map expressions are all part of the geographical language. Through the combination of the real geographical environment and the virtual geographical environment described by people, geography conveys the information that people want to express, thus enabling us to better understand the environment in which we live.

The technology and methods of teaching geography have gradually changed and improved in recent years. In the past 30 years, multi-media, mobile digital equipment, geographic information systems and other technologies have been increasingly applied in geography courses (Demirci et al., 2013; Meishar-Tal & Sneh, 2015; Michel, Glasze, & Uphues, 2013; Seong, 1996). The development of modern science and technology, especially the development and application of remote sensing technology, provides a new method for teaching geography (Boyd, 2009; Cheung, Pang, Lin, & Lee, 2011; Estes, Jensen, & Simonett, 1980). Teaching geography requires depicting situations through images, and remote sensing images have the characteristics of real images; thus, they can reflect real records of geographical phenomena and are more expressive than ordinary maps. Remote sensing images can truly represent geographical phenomena, processes and trends, enabling us to recognize and understand the geographical space in which we live. The use of remote sensing technology in geographical observation and teaching has completely changed the previous way of teaching through words and maps.

The multi-dimensional observation method of remote sensing images provides a new method for observing geographical landscapes and their characteristics, making our understanding of geographical regions closer to reality and more systematic. Based on the regional system theory of human-land relationships, regional observations can be carried out in multiple dimensions, such as multi-temporal, multi-scale, multi-angle, multi-spectral, multi-product, multi-element and multi-media, using the Google Earth tool. This method is also called the "multi-dimensional observation method of remote

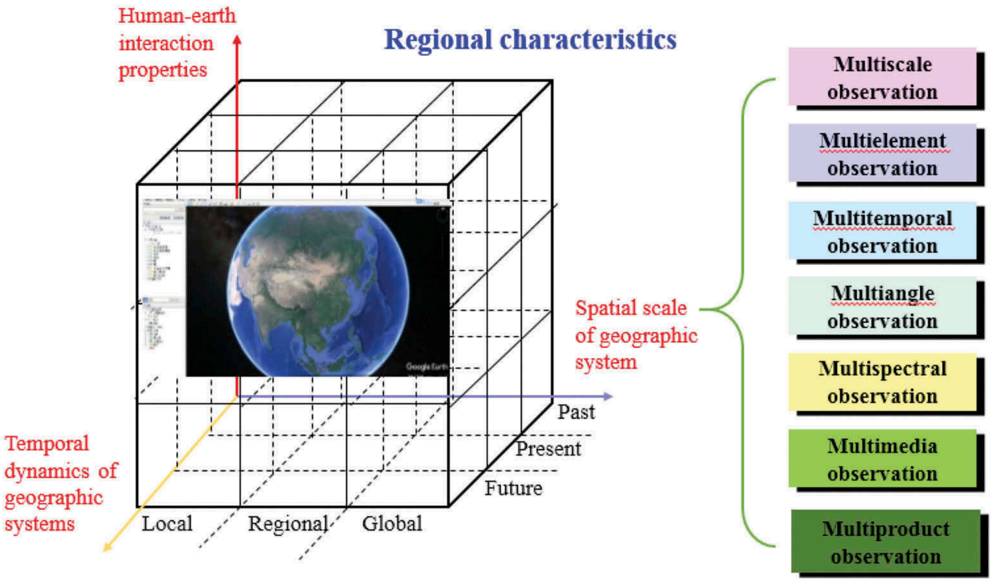

Figure 1. Regional multi-dimensional observation system for remote sensing images.

sensing images" (Figure 1) (Wang, Sheng, & Yu, 2014). It enables students to observe remote sensing images scientifically to recognize regional geographical features.

Multi-temporal: Satellite remote sensing has the ability to repeat observations within a certain period. The integrated use of multi-source satellite data can study and track historical geographic and geomorphic phenomena and observe the dynamic change process of geographical features, and these trends and changes can be summarized as the multi-temporal features observed by remote sensing.

Multi-scale: High-resolution images can be used to make more detailed observations of a small range of geographic features, while low-resolution images can be used to comprehensively monitor a large portion of the whole study area [16], thus enabling multi-scale joint geographic remote sensing observation.

Multi-angle: By changing the satellite observing angles, the multi-angle characteristics of the target objects can be interpreted. Multi-angle observations can be sued to acquire three-dimensional structure information on the observation object, and this technique has the ability to view surface objects, such as farmland, forest, grassland, water, and construction land comprehensively in order to more fully understand the observation objects.

Multi-spectral: Sensors can obtain radiation within or spread across regions of the electromagnetic spectrum. Ground objects exhibit differences in reflection, radiation or absorption characteristics at different wavelengths. Therefore, different geographic features can be highlighted by combining ground object features at different wavelengths.

Multi-product: A certain object can have different attributes. For example, for vegetation, analyses can be performed to determine the vegetation coverage, albedo, emissivity, surface temperature and other characteristics. Through the analysis of different features of an object based on different remote sensing products, the purpose of interpreting the target object is achieved.

Multi-element: Remote sensing images can simultaneously display various natural geographical elements such as land, clouds, snow, water and vegetation in a certain area, as well as human geographical elements such as cities, industry and agriculture, thereby capturing the complexity of specific geographical environments. More unknown information can be directly or indirectly interpreted according to the information characteristics reflected by ground objects or phenomena themselves or their internal relations with ground objects' attributes, and this process is conducive to in-depth data mining, element information acquisition and a more comprehensive understanding of the overall situation of a certain area.

Multi-media: Maps, photos, videos, audio, text and other multi-media materials related to the target objects can be combined to help people deeply understand and recognize the target objects. The method integrates basic geographic information, the historical human landscape, natural geography and other materials via text, audio explanation and video to analyze all aspects of the target and human landscape.

This paper mainly studies the application of remote sensing technology in regional geographical landscape observation, focusing on an acquisition tool for regional geographical remote sensing images – Google Earth and related geographical analysis methods. On the basis of our existing research (Wang et al., 2014), we further generalize and expand the existing observation methods according to their temporal and spatial attributes, physical attributes and natural attributes. In addition, this paper also clarifies the important role of the recognition and general education of remote sensing, elaborating on the details of remote sensing image observation methods and illustrating remote sensing image atlas analyses with examples. The purpose of this paper is to apply remote sensing observation and recognition methods to the teaching of and research on geography, which are of great significance for the recognition of the geographical landscape.

Spatiotemporal property observations

Multi-temporal observation

Multi-temporal usually refers to the characteristics of a set of remote sensing images in a time series. Broadly speaking, a set of images, maps, or geographical data from the same region acquired at different times can be considered "multi-temporal" data (Munyati, 2000). Remote sensing technology, especially satellite remote sensing, has the ability to achieve repeated coverage of the Earth in a fixed period and can provide multi-temporal remote sensing images with various temporal resolutions to meet the requirements of dynamic analysis. The requirements of multi-temporal remote sensing image data depend on the rate of change in the analysis object and the length of the process. The comparison and comprehensive analysis of multi-temporal remote sensing data are important and effective ways to study and track the evolution of natural history and to monitor the dynamics of the environment and resources.

The phases of geographical phenomena are a very important feature. As time progresses, the cause of development and change is an important part of the study of geographical phenomena. Modern remote sensing technology can obtain multi-temporal remote sensing images, and the multi-temporal nature of these images can provide the most intuitive and clear evidence for the developmental process of targets. These images enable students to gain a clear understanding of geographical aspects that are difficult to show on maps or that change very quickly. Ultimately, the analysis and discussion of the causes of change can be facilitated, helping students form a dynamic perspective of development while thinking about the dimension of time. Multi-temporal remote sensing observations can directly train students to think about spatiotemporal development. By observing the same geographical aspects for a long time, students can understand the changes and development of these geographical aspects more clearly. The multi-temporal observation method shows changes in objects intuitively, allowing the students to observe a changing world. It is helpful for students to think about spatiotemporal changes and develop the ability of logical deduction. The multi-temporal observation method can be applied to the teaching of urban development, natural environmental protection, sea level rise, glacier melting, river migration and other processes.

Figure 2(a,b) show the gradual melting of glaciers in the Yangtze River basin during the past 30 years. The area of glaciers in the region decreases from 1986 to 2016. This process occurred mainly because the main peak of the Tanggula Mountains, Dan Winter Snowy Mountain, experienced a significant wintertime warming trend from 1986 to 2016. The temperature increase in this area is the main reason for the decrease in glacier area (Qibing, Shichang, & Guoshuai, 2016). Figure 2(c,d) show the urban land

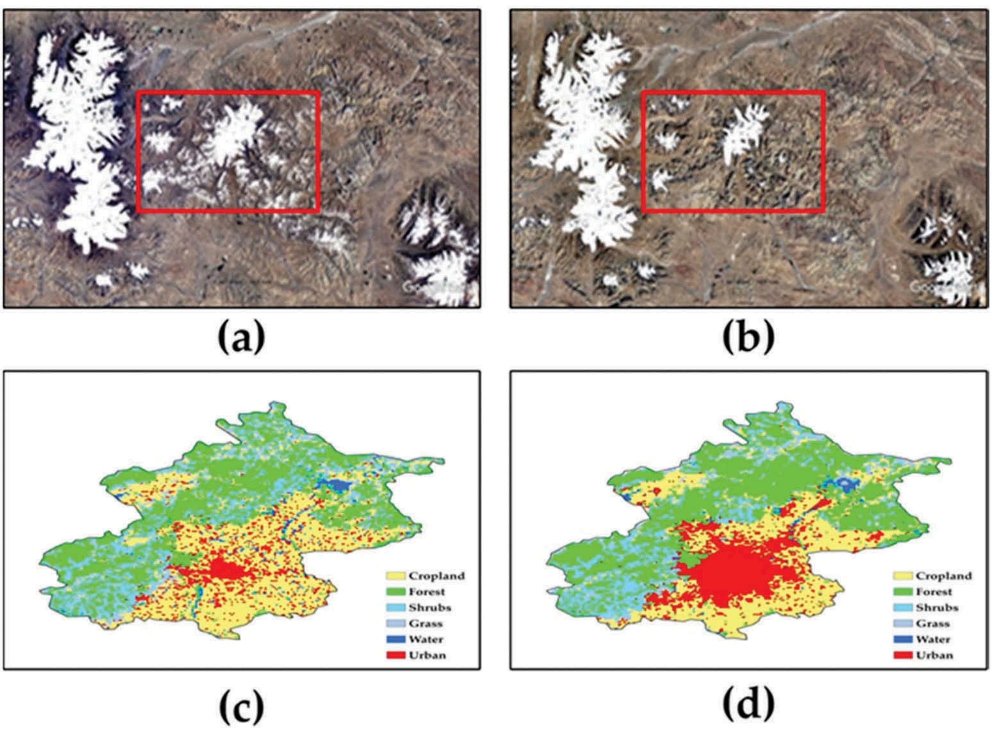

Figure 2. Remote sensing images from different time periods. (a) Image of glaciers on mountains, including Dan winter snowy mountain, in 1986; (b) Image of glaciers on mountains, including Dan winter snowy mountain, in 2016; (c) Beijing 1980 land cover classification; (d) Beijing 2010 land cover classification.

development in Beijing, and the red region represents the city. The urban area of Beijing has increased significantly from 1,711 km^2 in 1980 to 3,152 km^2 in 2010.

The advantages of multi-temporal remote sensing are mainly reflected in the "multiple" portion of the phase. Through the refinement of the remote sensing image in the time dimension, multi-temporal remote sensing can capture continuous changes in the reflection, emission and other biophysical characteristics of the same place at the same time by acquiring multiple scenes over a period of time (Shen, Huang, Zhang, Wu, & Zeng, 2016; Xiao, Boles, Liu, Zhuang, & Liu, 2002). By arranging these cell values in chronological order and characterizing time series curves, students can use these curves to determine the growth of crops throughout a year (Quarmby, Milnes, Hindle, & Silleos, 1993; Usman, Liedl, Shahid, & Abbas, 2015). Through the changing characteristics of the multi-temporal curve, we can obtain a variety of information over time. At the same time, it should be noted that in the process of extracting multi-temporal information, it is necessary to ensure that the pixel scales of the same location are the same.

Multi-scale observation

Multi-scale refers to the use of high-spatial resolution images to conduct detailed observations of geographical features in a small area and low-resolution images to conduct comprehensive monitoring of a large area (Di, Jiang, Yan, Liu, & Zheng, 2017) in order to realize multi-scale joint remote sensing observations of geography.

The geospatial system is a complex system composed of subsystems at different scales. Scale is the basis for recognizing geographical objects, geographical space and various geographical phenomena. In spatial cognition, people's cognitive scope of the real world is limited. Therefore, changes in scale will affect the degree of detail in which information is observed, expressed, analysed and transmitted. The multi-scale observation of geographical regions is a more natural method of spatial cognition and analysis and conforms to people's reasoning habits. This technique reflects the depth and breadth of people's understanding of spatial things and phenomena and is the basis of cognitive geography and its structural characteristics.

In remote sensing images, scale is also directly related to resolution. The smaller the scale is, the higher the resolution and the finer and more microscopically expressed the spatial target is. In contrast, the larger the scale is, the lower the resolution and the more general and macroscopic the expression of the spatial target is. The multi-scale transformation of remote sensing images is achieved through the tool in Google Earth that allows zooming in and out. The information obtained by remote sensing data at different scales is not the same, which explains the advantages of different remote sensing data. It is necessary to select an appropriate scale to observe the research target and then obtain a dataset that fits the target of the object for analysis (Boelman et al., 2016). The combined use of high-resolution small-scale images to perform fine-scale monitoring of a small range of ground objects and low-resolution large-scale images to comprehensively monitor a large portion of the whole area (Di et al., 2017) can achieve multi-scale joint geographical observation.

The multi-scale observation process of a remote sensing image based on the Google Earth scaling tool (Figure 3) can be divided into top-down and bottom-up approaches. The former is the process of using the zoom-in tool to observe remote sensing areas from

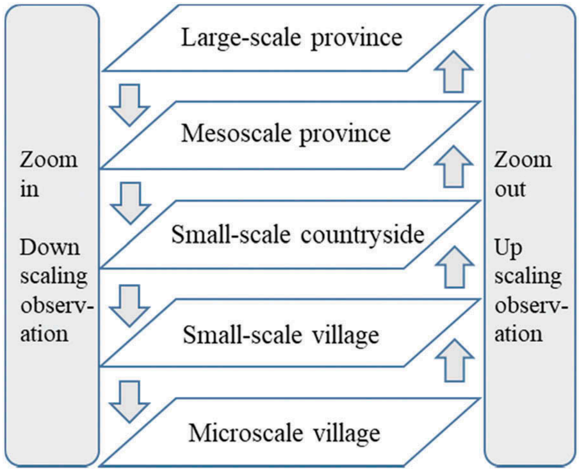

Figure 3. The process of multi-scale observation of remote sensing images.

a large scale to a small scale, the surface landscape structure from macroscopic to microscopic, and the observer's regional cognition from far to near, which is deepened step by step. The latter is the process of using the zoom-out tool to observe remote sensing areas from a small scale to a large scale, the surface landscape structure from microscopic to macroscopic, and the observer's regional cognition from near to far. Regional landscape details taught by teachers will develop into students' active discovery, and they can use the basic knowledge of image interpretation to explore and discover problems only if they master the multi-scale observation of Google Earth.

As a tool, Google Earth can assist students in conducting multi-scale observations and can be applied in different regions. For example, Figure 4 is a case of multi-scale observation of remote sensing images in Beijing, China. This figure shows that the large-scale imagery of Beijing's surrounding geographical environment is macroscopically visible; as the scale decreases, the image resolution gradually increases, and the details of the area become more obvious. In Figure 4(a), the ground landscape details of the area in the red box cannot be seen. After increasing the resolution (5 km), Figure 4(d) shows the rectangular structure of the buildings, and Figure 4(e) shows the water area. After further increasing the resolution (700 m), students can directly see the layout of the internal buildings of the Palace Museum (Figure 4(f)) and the dam of the Ming tombs (Figure 4(g)), thus helping students obtain more details of the surface. The urban areas on the plains are visible at different scales (the old town within the Beijing Second Ring Road – the Forbidden City) by using the scaling tool to observe different scales of remote sensing images. Additionally, the edge of the mountains (Shisanling Reservoir dam) is visible, and the spatial structure of various scales in different regions can be recognized.

Multi-angle observation

Multi-angle observation refers to the analysis method of observing the target from different angles (Figure 5), aiming at understanding the target more comprehensively. Multi-angle observation contains a large amount of three-dimensional structural

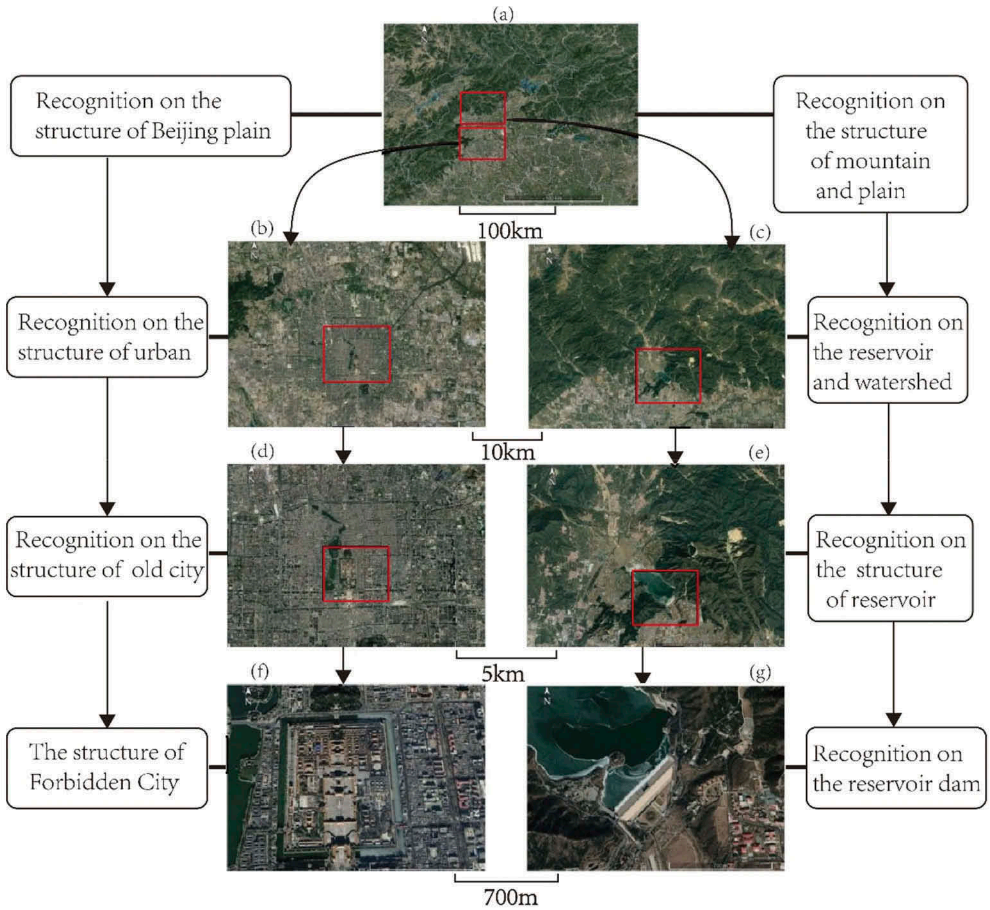

Figure 4. Multi-scale observation and recognition of remote sensing images of Beijing. (a) The palace Museum and the ming tombs reservoir at a 1:10 km scale. (b) The palace Museum at a 1:10 km scale. (c) The ming tombs reservoir at a 1:10 km scale. (d) The palace Museum at a 1:5 km scale. (e) The ming tombs reservoir at a 1:5 km scale. (f) The Palace Museum at a 1:700 m scale. (g) The ming tombs reservoir at a 1:700 km scale.

information of ground objects, e.g., vegetation canopy architecture (Chen, Liu, Leblanc, Lacaze, & Roujean, 2003; Widlowski et al., 2004), digital elevation model (DEM), digital surface model (DSM) or terrain texture (El-Sammany, El-Magd, & Hermas, 2011). For instance, the actual territory of the island was explicitly revealed by stereoscopic pairs given by multi-angle observation (Figure 5), which is unavailable in a single-angle image. Many current instruments have the capacity of multi-angle observation from space, such as Multi-angle Imaging SpectroRadiometer (MISR) aboard the Terra satellite launched by NASA, the High Resolution Visible (HRV) instrument aboard the SPOT commercial satellite maintained by Spot Image, and ZY-3, which is the first civilian high-resolution stereoscopic satellite of China.

Google Earth software provides a general ability to assess territory three-dimensionally and to view remote sensing images from multiple angles when observing an object. For example, 3D viewing technology in Google Earth software allows a 360° omnidirectional

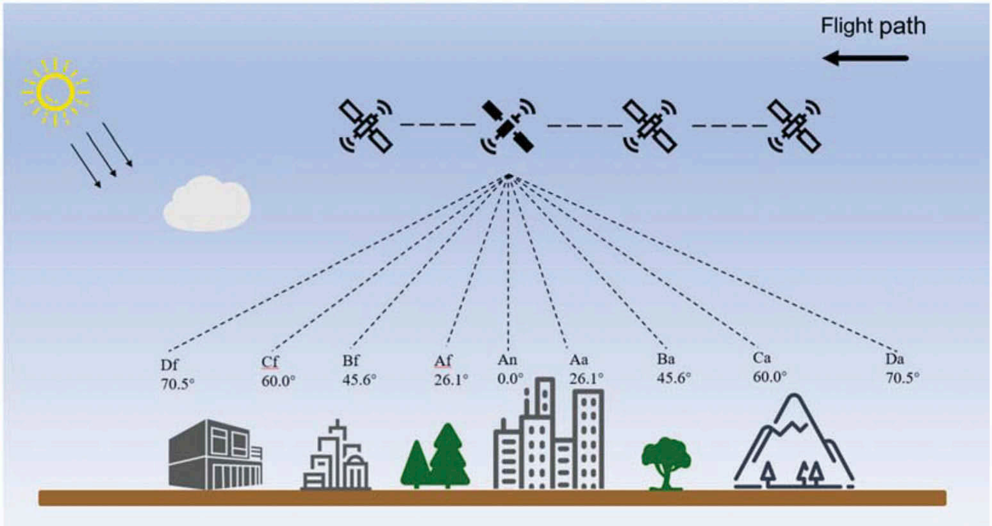

Figure 5. Illustration of multi-angle imaging process by MISR)

observation of an island, a mountain, or even a single building. This type of image simulation technology for spatial environments has more advantages than text descriptions and map expressions. First, it turns an ordinary two-dimensional planar map into a three-dimensional one, making the surface information more realistic and vivid. Second, the three-dimensional image technology successfully presents the observation of an object from all angles so that the blind zone of the observation no longer exists. Figure 6 shows a set of images of Tiananmen Square in Beijing, China, from different perspectives. We can easily see the full scene of the three-dimensional angle of Tiananmen Square with some fade areas that are not normally observed.

This process greatly helps students form a complete understanding of an object and stimulates an interest in learning. Third, it promotes a more vivid and simple understanding of things. Three-dimensional multi-angle observation makes it easy for students to establish geographical impressions that cannot be accessed frequently in normal life, such as three-dimensional mountain peaks and the difference between shady slopes and sunny slopes. For middle school teaching, multi-angle observation can more vividly express the real landscape and allow students to observe things in a three-dimensional way with all-around and multi-angle views. This teaching method can be used in topic teaching, such as key urban areas, landmark buildings, the difference between shady and sunny slopes and river valleys.

Another embodiment of multi-angle observation is the combination of Google Earth and 3D virtual reality (VR) techniques. The use of a joystick or VR head set makes it easy to apply global geological simulation in 3D view in geo-educational curricula (Lim, 2008), creating a way to help students understand Earth science and land processes that is more light-hearted than traditional teaching, which tends to be theoretical and conceptual. Some classes divide the students into groups to design a virtual tour among famous geo-sites in Google Earth using placemarks. Advanced lessons with the development of Google Earth's ability to simulate interactive 3D virtual flights over natural areas (Martínez-Graña,

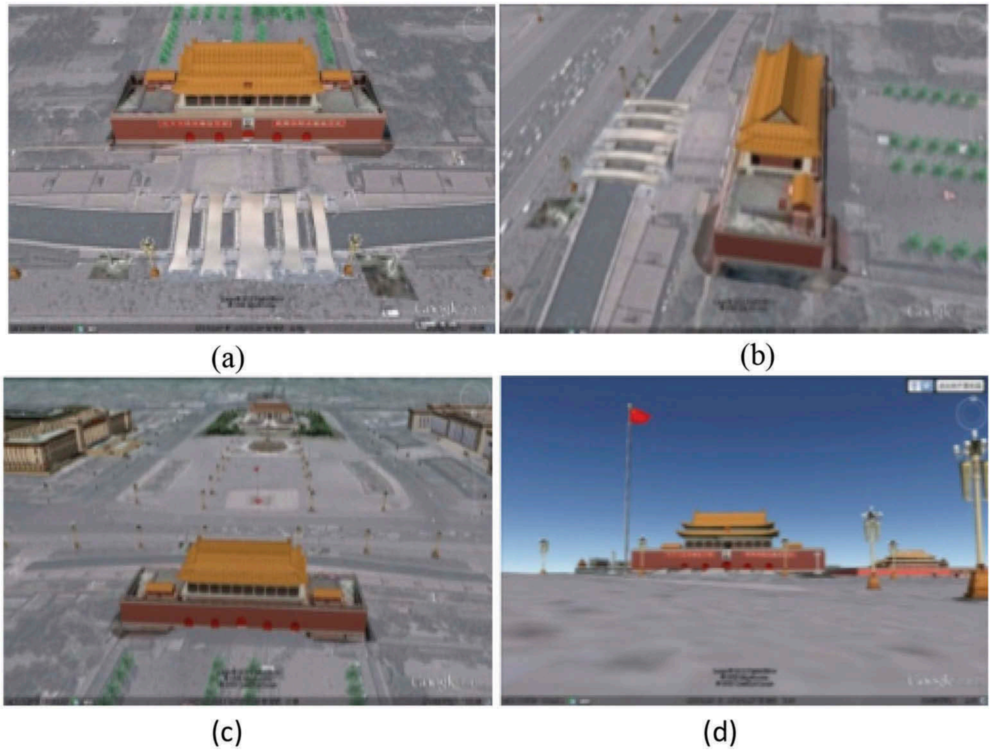

Figure 6. Three-dimensional multi-angle observation of Tiananmen Square in Beijing, China (images from Google Earth; direction of observation: (a) from south to north, viewed from the air; (b) from east to west, viewed from the air; (c) from north to south, viewed from the air; (d) from south to north, viewed from ground level).

González-Delgado, Pallarés, Goy, & Llovera, 2014) can contribute to the development of critical thinking and spatial reasoning.

By combining remote sensing imagery and the abilities of Google Earth, the multi-angle method provides us with a potential new learning approach while helping students better understand geographical processes.

Physical property observations

Multi-spectral observation

Multi-spectral observation refers to the observation of features from bands of different lengths. Remote sensing bands cover a wide range, and different bands can reflect information on different characteristics. Combining the spectral characteristics of various objects, different decision indices can be obtained and can be used to highlight different geographical features (Berni, Zarco-Tejada, Suárez, & Fereres, 2009). Multi-spectral remote sensing uses a sensor to capture the radiation of multiple wavelengths of a ground object to obtain spectral information of multiple intervals. That is, the ground objects are observed from electromagnetic waves of different wavelengths. Hyperspectral remote sensing divides the entire wavelength into tens or even hundreds of subintervals by further subdividing the wavelength interval of multi-spectral remote sensing. Hyperspectral remote sensing can distinguish the subtle reflectance differences between different objects in the interval to carry out more detailed feature recognition. Common applications of hyperspectral remote sensing include mineral identification and urban feature recognition.

The ability of the human eye to distinguish spectra is limited, and the multi-spectral features of remote sensing images allow students to intuitively see things and phenomena that they normally would not be able to see. Multi-spectral observation can highlight geographical aspects that are not obvious under visible light, which is more conducive to students' observation and summarizing geographical laws. Taking the band characteristics of Landsat TM images as an example, different bands have different sensitivities to various characteristics of surface features, which greatly increase the information capacity of remote sensing images. The thematic maps generated by an appropriate combination of bands can greatly enhance the teaching effect (Chuanrong, Beien, & Zixin, 1992). For example, standard false color synthesis using the infrared, red, and green bands can be used to distinguish between natural and artificial turf. Natural turf appears red in this synthesis, while artificial turf appears gray or other non-red colors. A cement roof exhibits a grayish blue color in this synthesis, whereas a red tile roof appears pale yellow.

People can recognize ground objects based on differences in reflectivity of electromagnetic waves. The typical electromagnetic reflectivity of the ground is shown in Figure 7(a). Taking the imaging wavelength data of the SPOT satellite (Chevrel, Courtois, & Weill, 1981) as an example, in the blue band, the reflectivity of bare soil is high. In the red-green

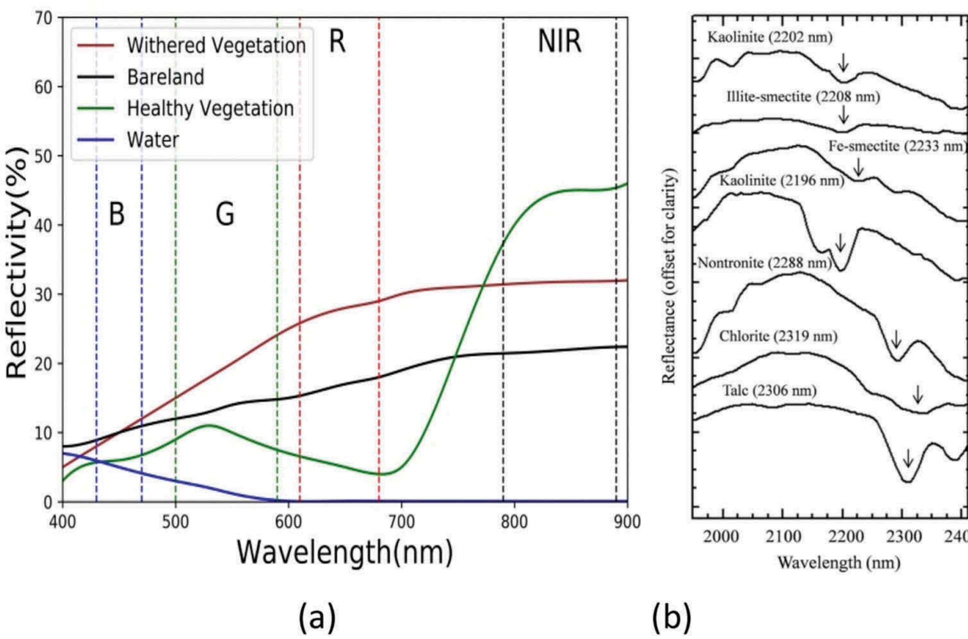

Figure 7. (a) SPOT satellite imaging wavelengths and common ground reflection spectrum curves, B for blue band, G for green band, R for red band, NIR for near-infrared band; (b) reflection spectrum curves for common minerals (Murphy, Taylor, Schneider, & Nieto, 2015).

band, dry vegetation has a high reflectivity. In the infrared range, the reflectance of healthy vegetation is highest. The multi-spectral remote sensing wavelength range is wide. Different spectra can provide information that reflects multiple characteristics. Furthermore, different indices can be obtained by combining different bands of remote sensing images. These indices highlight different geographic features [18]. For example, the normalized vegetation index (NDVI) can be obtained by combination of the red band and infrared band (Pettorelli et al., 2011). Multi-temporal combined images consisting of multiple NDVIs can be used to assess local crop cultivation, harvesting, and growth information. The normalized water body index (NDWI) can be obtained by combining the green band and red band data (Gao, 1996). Using NDWI, water body information can be easily extracted, and the water area can be delineated and extracted. There is also a normalized difference snow index (NDSI) calculated based on the green band and the shortwave red band (Hall & Riggs, 2011). NDSI is similar to NDWI but is more sensitive to ice and snow and can be used to extract information on ice and snow. In addition, mineral identification applications can be performed using spectral features. As shown in Figure 7(b), a trough in the reflectance of kaolinite appears at 2202 nm, and a trough in the reflectance of chlorite appears at 2319 nm. Hence, we can identify these minerals based on these characteristics.

Multi-product observations

Multi-product remote sensing aims to analyze the information from a variety of different remote sensing products of a certain feature to achieve the goal of interpreting the target object. Through the remote sensing exploration of multiple products, the different characteristics of a certain target in different products can be highlighted. For example, by analyzing remote sensing images in multiple products, a series of remote sensing information, such as vegetation growth, surface temperature, albedo, and snow cover, can be obtained in a certain area. The relationship library between a certain type of ground object and different quantitative remote sensing products can be constructed, which can be used for identifying and classifying ground objects. This method can break through the surface information displayed by remote sensing images and extract deep information.

Quantitative processing of the electromagnetic wave signals in a remote sensing image can be used to extract more easily understood geographic physical or biophysiological information (Liang, 2005; Liang, Li, & Wang, 2012). For example, the urban heat island effect refers to the phenomenon of higher atmospheric and surface temperatures in urban areas than in the surrounding rural areas (Bornstein, 1968; Oke, 1973). The surface temperature can be identified and inverted for by using the information of thermal infrared bands collected by remote sensing sensors (C. Wang, Myint, Wang, & Song, 2016; Weng, 2009). Additionally, fractional vegetation cover (FVC) includes the branches, stalks and leaves of plants relative to the total vegetation area (Carlson & Ripley, 1997; Liang et al., 2012), and this parameter can directly reflect the surface vegetation status and is an important quantitative index of vegetation and ecosystem changes (Gutman & Ignatov, 1998; Jiapaer, Chen, & Bao, 2011; Yue et al., 2012). The relationship between reflectivity and FVC can be established by using remote sensing multi-spectral data to obtain the spatial distribution of urban FVC. Figure 8 shows a basic spatial determination of the overall land surface temperature (LST) and vegetation conditions in Beijing. In the figure, the average LST in the center of Beijing is approximately 10°C higher than that in

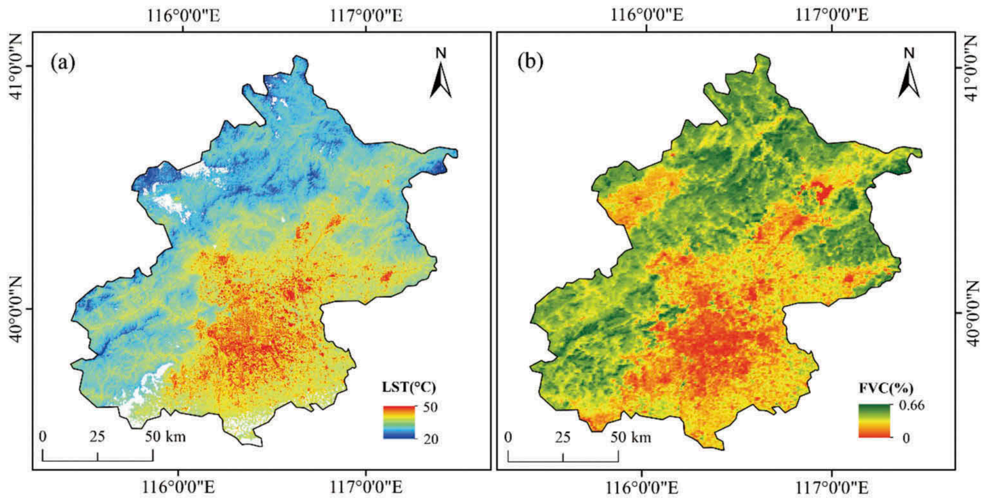

Figure 8. Land surface temperature (LST, left) and vegetation coverage (FVC, right) in Beijing.

the surrounding suburbs, showing an obvious urban heat island effect. Furthermore, the FVC in the downtown areas of Beijing is only approximately 10%, which is relatively low. In contrast, the FVC in the western and northern regions is higher, averaging approximately 50%, which is approximately 40% higher than that in the urban center. Comparison of the spatial distribution of LST (Figure 8(a)) and FVC (Figure 8(b)) in Beijing reveals that the spatial distribution patterns of the two products are similar. The areas with high LSTs are located in the urban center, where the FVC is low, and areas with low LSTs are found in the suburbs around the city, where the FVC is relatively high. Therefore, the low FVC in the urban area is the main cause of the urban heat island.

For students, multi-product remote sensing can be used to more intuitively understand the development trends and distribution characteristics of a target. There are many common remote sensing products, such as vegetation index products, that can be used to identify the location and density of vegetation. Surface temperature can represent the spatial distribution of LST, which is an important data source for studying the urban heat island effect. The water index can be used to identify the boundaries of lakes and reservoirs, and historical development has been further understood over many years. The application of multi-product remote sensing in geography teaching can help students better understand geographic information and further improve their knowledge of advanced remote sensing products.

Synthetic observation of natural properties

Multi-element observation

The remote sensing image itself is a multi-factor complex. In the same remote sensing image, images of various natural elements, such as roads, land, oceans, clouds, snow, water bodies, and vegetation, as well as images of human factors, such as land use changes, can be observed. The primary task applied to remote sensing images is interpretation, which requires the correct identification, discrimination and interpretation of features that are closely related to each other on remote sensing images. For the interpretation of a region or a remote sensing image, a comprehensive method is needed. Only by clarifying the relationship between various types of interpreted features can we enhance our ability to interpret remote sensing images.

Remote sensing images are a comprehensive simulation of the objective world. In teaching, it is very natural to break through the original knowledge barriers of students and improve their geographical ability and literacy through the specific discrimination, analysis and further integration of objects with various attributes. Multi-element observation is an effective method for training students' geoscience analysis ability and comprehensive analysis ability because the knowledge content of geography is not simple but complex and diverse. Multi-element observation can not only train students' comprehensive analytical thinking but can also enable students to deepen their understanding of remote sensing images. Using the correlation between multiple factors, such as elevation, precipitation, temperature, population, hydrology, geology, and economy, more unknown information can be obtained from existing data. This process can help us dig deeper into the data and obtain more information, thereby providing a more comprehensive understanding of the overall features of a region.

Multi-media observation

Multi-media observation refers to the combination of remote sensing images, maps, photos, videos, audio, text and other multi-media materials related to target objects to help people deeply understand and recognize the target objects in the initial understanding of remote sensing images (Wei, Xiong, & Yan, 2006). This method integrates basic geographical information, historical human landscape, natural geography and other materials. Combining text, audio and video, we can analyze the basic features of the target object and the human landscape from all directions.

The information obtained by remote sensing can be displayed not only in the form of images but also in the form of multi-media. Aerial video, the most common form of multi-media observation, usually comes from helicopters and drones and not only fulfills the need for multi-angle and multi-scale observations but also shows the changing characteristics of dynamic objects. The most common remote sensing video resources come from aerial videos in various documentaries, such as Aerial China. In addition, compared with remote sensing images, real-life photos are also a means of multi-media observation, through which students can better recognize scenes corresponding to remote sensing images. Students can easily understand the characteristics of objects in images and can be prepared to interpret similar features in other images. Multi-media observation is conducive to letting students establish the relationship between actual objects and remote sensing data so that they can more easily understand remote sensing images and better observe and identify the information in those images.

Multi-directional observation mode of remote sensing of regional geography

The basic mode of analysis for regional geographic observation using remote sensing images is divided into four steps: regional location, structure, evolution and landscape recognition.

Regional location is the first step in conducting local regional observations. According to the regional system theory of human-land relationships, remote sensing images can be interpreted from two dimensions: multi-scale and multi-element. Gradually reducing the scale from country→province→city→local, the observed geographical microscopic features are correspondingly refined into population, GDP and river by the macroscopic geographic features of the latitude, longitude, relative position, and climatic and topographic unit of the region. Then, the local features and the connection of different geographical locations are obtained, as shown in Figure 9(a).

The observation and analysis of the structure of a region can be divided into three levels, namely, the overall structure, characteristic features and personal growth memories. The first

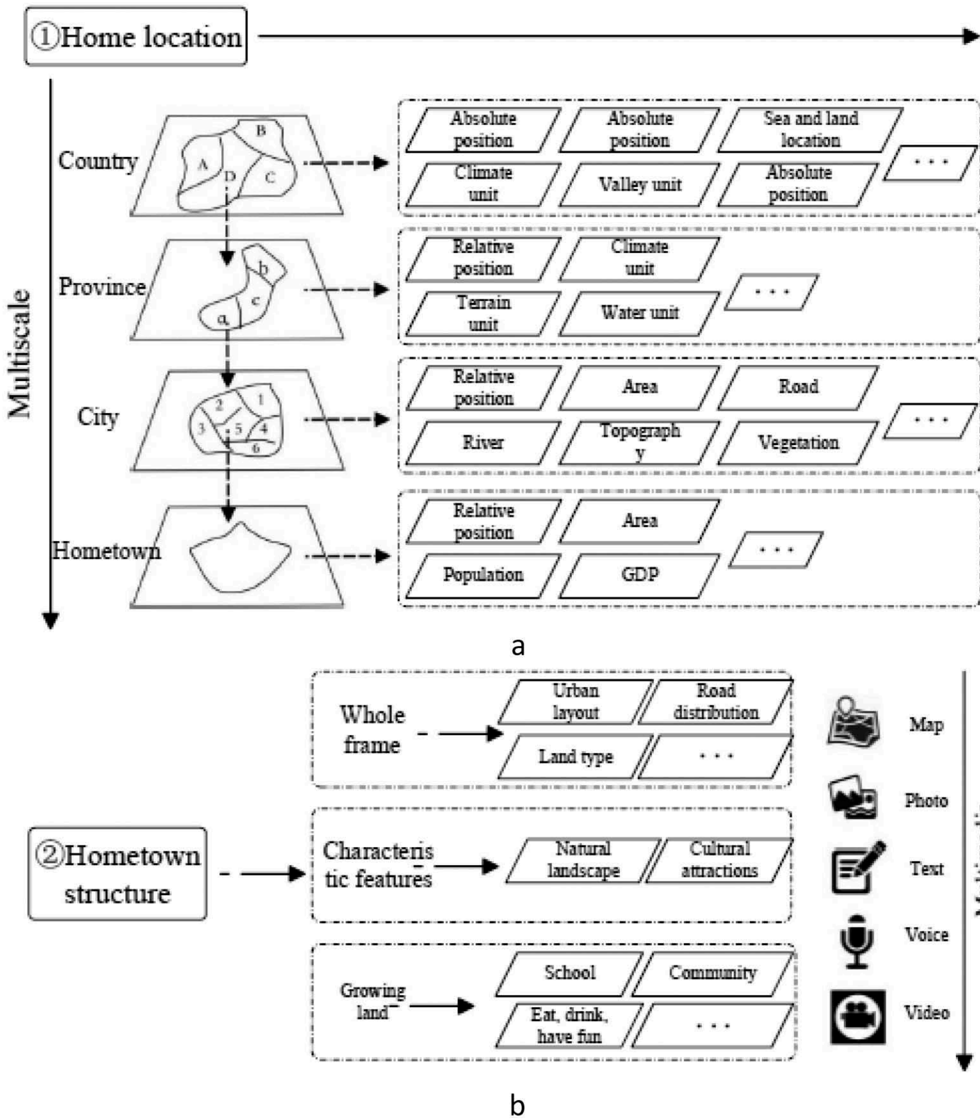

Figure 9. Remote sensing regional geographic observation model (home location and structure).

involves observing the overall structure and interpreting the features of topography, hydrology, urban layout, road distribution and functional division to form an overall impression of the geographical pattern of the local area. Then, one selects the features or phenomena from the overall impression of the region, analyzes the natural scenery, human aspects, folk customs and historical culture in the local area and devises questions to be explored. Finally, combined with personal growth experience, one can observe images evoking childhood memories (such as residences, schools, and parks) to contrast the landscape between reality and memory and explore changes in one's hometown. In the process of hometown structure observation, multimedia, multi-element maps, real-life photos, literature, audio and video can be used to achieve multi-dimensional and intuitive regional interpretation, as shown in Figure 9(b).

The remote sensing observation and analysis of the evolution of one's hometown is realized by constructing a comprehensive spatial and temporal map of the image, which highlights the combined results of human-ground interactions compared with traditional expressions. The temporal and spatial variations in the region expressed in this method can deeply describe the evolutionary characteristics and drivers of a certain aspect of the hometown, as shown in Figure 10(a).

According to the comprehensive overall recognition formed by regional remote sensing, the area is expressed in a comprehensive and innovative way from remote sensing images to landscape sketches. Compared with traditional geographical sketches, multi-directional observation can not only quickly combine composition and detail but also accurately extract and identify features, as shown in Figure 10(b).

Conclusion

In the process of teaching geography, we use multi-dimensional technology as a new and innovative teaching method. Multi-dimensional technology represents an important way to improve the quality of teaching. These technologies can be used in the teaching or research of human geography, physical geography and economic geography. Therefore, scientific methods should be applied throughout all teaching activities, following the principles of systematics, applicability, dynamism and enlightenment. For college students, using modern technologies such as multi-dimensional remote sensing to observe geographic information in many directions can enable students to use remote sensing images to recognize regional surface features. Through the curricula of regional remote sensing, we use spatiotemporal attributes (multi-temporal, multi-scale, multi-angle), physical attributes (multi-spectral, multi-product), natural comprehensive attributes (multi-element, multi-media) and many other methods to understand and observe remote sensing images, learn the preliminary steps of remote sensing analysis used in geoscience, and provide national geography education. This type of curriculum design, based on improvement of the original ways of teaching geography, will make it easier to strengthen the students' ability to think spatially and to understand the abstract concepts and processes of geoscience analysis.

Flexible and diverse teaching methods are helpful to the study and understanding of regional geography. To enable students to think independently and actively explore more opportunities in a more relaxed environment, we can use classroom discussions, thematic debates and other methods to enhance students' learning enthusiasm. For example, in the process of teaching, students can be arranged to introduce their hometown in

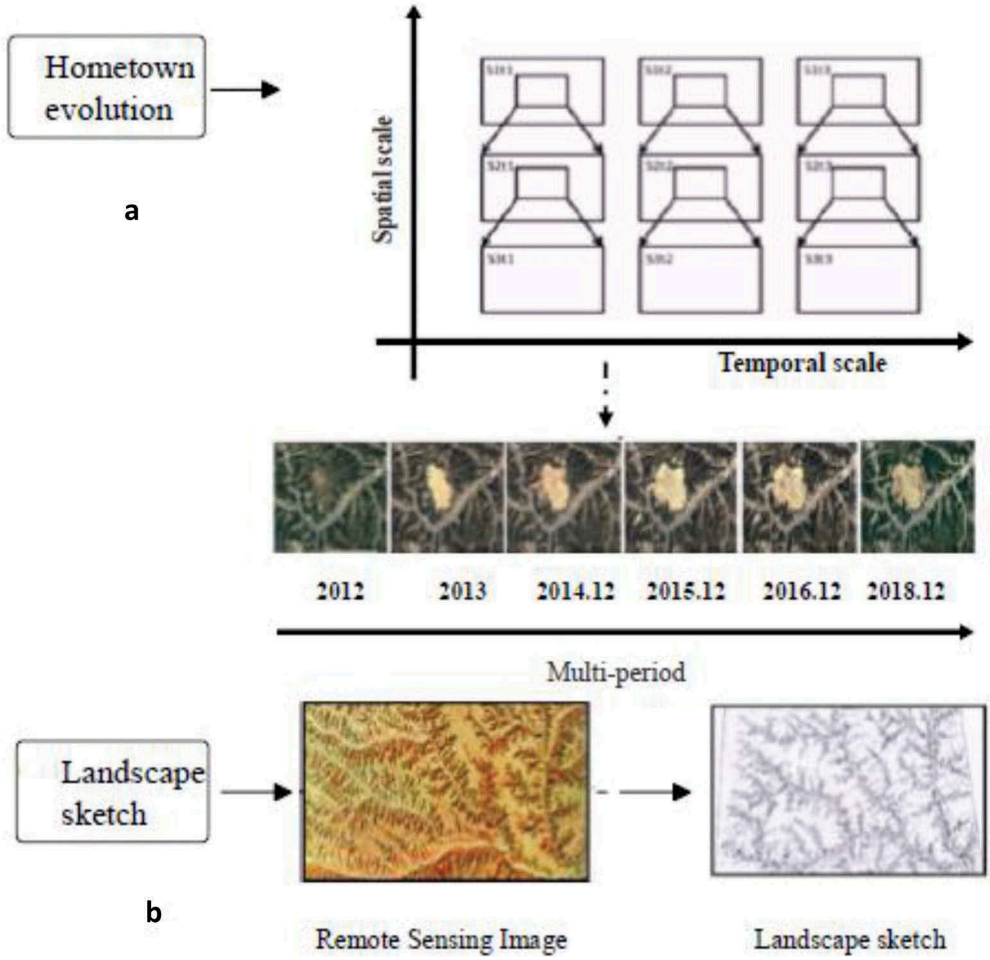

Figure 10. Remote sensing regional geographic observation model (Hometown evolution and landscape sketch).

a multi-dimensional way. Students should go to the library to consult relevant documents, write lecture notes and complete special reports. In the process of literature retrieval and analysis, students naturally enter the curriculum. This process not only exercises the students' ability of information retrieval processing and summarization but also obtains the latest knowledge points and enhances the students' learning enthusiasm.

Generally, the introduction of multi-dimensional remote sensing in geography teaching, including the reform of teaching content and methods, aims to improve the quality of geography teaching and learning. Geography teaching should be integrated and complementary with existing advantageous specialties and characteristic disciplines. Such efforts can not only embody the teaching of modern basic geography theory but also strengthen students' learning of Earth system science knowledge to broaden the students' knowledge.

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