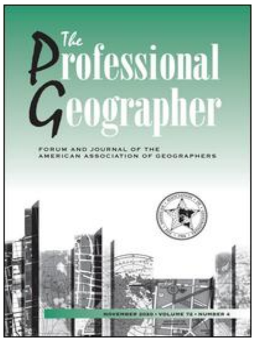

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The Social Dimensions of the Iron Quadrangle Region: An Educational Experience in Geodesign

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Mining brings about positive and negative changes for the residents of regions that are heavily dependent on such economic activity. In Brazil, the so-called Iron Quadrangle fits within a complex regional arrangement that results in various conflicts of interest between different stakeholders, which complicates decision-making processes regarding mining activities. In this article, we introduce geodesign as a methodological approach that could efficiently contribute to mediating these challenges and conflicts. We present an educational experience in geodesign conducted within the framework of a minicourse offered in 2019 to undergraduate students at a Brazilian university. The experience illustrates how students were able to use the framework of geodesign to propose projects and policies to be included in a sustainable development master plan for the Iron Quadrangle region. Specifically, to examine the social dimensions at play in an iron mining region, students applied Steinitz's geodesign framework, premised on six main questions and six corresponding models. This case study contributes to the emerging literature on geodesign pedagogy by demonstrating the benefits of this process and proposing recommendations that are applicable not only in academia but also in real-world situations that would truly benefit from such an approach.
Key Words: Brazil, conflicts of interest, decision-making processes, geodesign, mining applications.

In the early twenty-first century, Brazil experienced a mining boom that made the country a significant contributor to global iron ore exports. The industry is still growing, with mineral extraction expected to increase threefold to fourfold in the next ten years (Coelho, Cordeiro, and Massola 2020). Mining brings about both positive and negative changes for residents of regions that are heavily dependent on the mining economy (on land use change, see Vojteková and Vojtek 2019). The state of Minas Gerais (MG), one of the world's largest iron ore–producing regions, credits the extractive industry for an average of 6 percent of its value-added gross domestic product between 2010 and 2017. MG's so-called Iron Quadrangle boasts 65 percent of the Brazilian iron steel production. Yet, mineral exploitation has very serious consequences for the environment, as is evident in the 2019 collapse of the Córrego do Feijão dam in Brumadinho (MG), where almost 300 people died. The collapse produced damage to the region's ecosystem caused by the spillage of waste from the mining operations that the dam helped to contain. This complex regional arrangement results in various conflicts of interest between different stakeholders and, consequently, entails challenging decision-making processes regarding mining activities. Examples of decisions that are made in this complex context include expansions of mining areas, the provision of affordable housing for workers, the preservation of natural forest, the protection of waterways, and the maintenance of dams used in mining.

Key factors in the decision-making processes related to mining projects include the relationship between mining industries and host communities (Dougherty and Olsen 2014), water management (Freitas and Magrini 2013), reporting (Leong et al. 2014), and conflicts between mining livelihoods and nonmining livelihoods (Arellano-Yanguas 2012). In response to these challenges, geodesign can successfully contribute to decision making involving mining (Porrà et al. 2014; Thanatemaneerat 2015; Janssen and Dias 2017; Jingyi and Menghan 2018). Steinitz (2012) defined geodesign as "an ongoing process of changing geography by design" (91), based on the interaction between design professions, the people of the place, information technologists, and geographic sciences. Interdisciplinary collaboration is a

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core concept of the geodesign, which is extensively supported by geographic information systems (GIS).

The mining industry affects the environmental, economic, and societal dimensions of extractive regions. The social dimension of these effects has been explored through a variety of themes such as poverty or income and employment, health and well-being, and infrastructure and housing. This study focuses on the social dimension of the Iron Quadrangle region and the complex decision-making processes that address this dimension. To examine social dimensions in the region, we present a geodesign experience conducted during the fall of 2019 in Brazil at the Federal University of Minas Gerais (UFMG). Seventeen undergraduate students in architecture and urbanism applied Steinitz's geodesign framework to the Iron Quadrangle region, exploring possible ways in which stakeholders in the region could negotiate and collaborate in decision-making processes.

We believe this educational experience mimics real-world situations. It allows students to represent—and, in so doing, better understand—stakeholders from societal sectors (in this case study, culture, entrepreneurship, housing, tourism) and to simulate discussions that could very well occur outside the classroom. Moreover, students participate in a decision-making process where they learn, understand, assess, and propose, while thinking critically about regionally relevant themes (in this case study, sustainable development). This case study is similar to the work presented by Pettit et al. (2019) because it focuses "on developing novel ideas from cases enabling a deeper understanding of the Geodesign process and the narratives it generates" (141).

Geodesign

Geodesign—design "with" the landscape and "for" the landscape—is based on a methodological framework that can be applied to support decision-making processes in planning (Steinitz 2012), taking into account the natural and cultural features of the study area. This methodological and integrated approach to decision making facilitates stakeholders to discuss and evaluate the possible impacts of design choices. Steinitz's (2012) proposed framework for implementing geodesign has at its core six main questions, and his method is developed through six corresponding models. In comparing geodesign with similar design processes, Foster (2016) found that geodesign is unique in that its framework is centered on a series of layered questions. As depicted in Figure 1, these six methodological steps follow a logical sequence. For the case study presented here, we distributed these as follows: the first three questions and models in a preworkshop and the last three in a workshop.

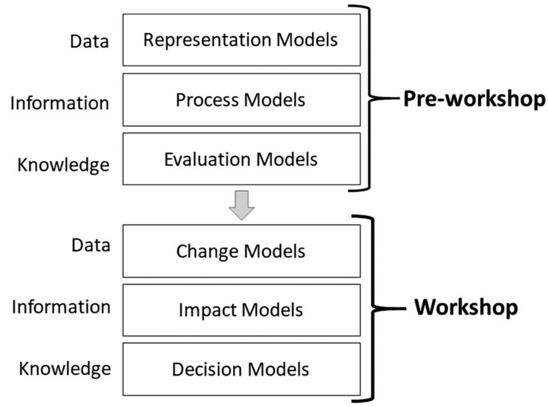

Figure 1 *Six models from Steinitz's geodesign framework.*

In Steinitz's (2012) description of geodesign, representation models allow participants to visualize and organize the spatial data of an area. Process models depict "the area's major physical, ecological and human geographical processes" and how they are connected (Steinitz 2012, 37). Through evaluation models, those working in geodesign attempt to visualize public and stakeholder perceptions and experiences of the study area, including potential concerns about the area, as well as differences in opinion regarding the area's current conditions. Change models examine the potential alterations that the study area might undergo in the future, why these changes might occur, and the community perceptions of those potential changes. Impact models identify the potential impacts of those changes, including the potential costs and benefits (and who will be affected), how the impacts relate to decision making, and the expected permanence and severity of these impacts. Finally, decision models reveal the "decision-making priorities and requirements" (Steinitz 2012, 40) of the stakeholders involved; how priorities, objectives, and values might differ among stakeholders; critical information and evaluations that decision makers need to take into account; potential constraints of the project; and strategies for communication and visualizations with stakeholders.

Educational experiences that use the geodesign framework as a pedagogical tool are starting to be offered in higher education institutions. Thanatemaneerat (2015) developed and tested with students a geodesign framework for water quality that focuses on the role of stakeholders, including the mining industry, in water quality management. Pettit et al. (2019) presented three geodesign studios from universities in Australia. Three cities that were experiencing population growth and were interested in linking land use and transportation planning were used as case studies; each study was analyzed based on data and technology, process, and output. Muller and Flohr (2016) conducted a study of geodesign courses at the University of Colorado, using a very comprehensive rubric that they developed, to evaluate student work and teaching practices. Despite encountering some obstacles, these studies' findings showed that, for many students, geodesign practices in the classroom can enhance analytical skills. Campagna, Steinitz, et al. (2016) described a geodesign workshop conducted at the University of Cagliari, Italy, in which students worked together with scholars and local stakeholders to understand "central design issues, opportunities and options" for the Cagliari Metropolitan City (59). Moreover, the first geodesign workshop held in a Brazilian educational setting was described by Campagna, Moura, et al. (2016), with the focus on "the design of sustainable future alternatives" for an urban district located in Belo Horizonte. Both studies by Campagna and colleagues were essentially descriptive, including several in-depth details about how the framework should be applied in an educational environment.

A global initiative led by Steinitz named International Geodesign Collaboration (IGC) is currently underway and aims to better understand the usefulness of geodesign for addressing challenges in a broad variety of settings of differing scale, with greater or lesser availability of human and data resources (Orlando, Steinitz, and Fisher 2020). Even though the scope of the IGC extends beyond higher education, universities play a central role, because they assist in the implementation of the geodesign workflow. The 2019 IGC, the initiative's first worldwide event, featured a total of fifty-five submitted completed projects by schools located in forty countries.

Software supporting decision making, such as Geodesign System, Phoenix, Geoplanner, Community Viz, and CityEngine, can be applied to geodesign projects (Sutil 2019). As Jankowski (2009) advocated, though, having a facilitator use collaborative decision support software on behalf of team members can be more effective (in terms of consensus and satisfaction) than having the group members use the software individually. To better facilitate such collaboration, Gu and Deal (2020) tested a framework that integrates geodesign, land use evolution, and impact assessment model Planning Support System in a regional design studio "to introduce conceptions of regionally scaled sustainability and resilience" (121). Concerning Steinitz's (2012) approach, his framework was expanded and disseminated through the Web-based platform GeodesignHub, which favors the development of a collaborative workshop (Ballal 2015; Ballal and Steinitz 2015). The case study presented here used this platform during the workshop conducted.

Study Design

The course URB035, Topics about Sustainability, is a one-credit (fifteen-hour) elective course that focuses on instructors' specific research interests. During the fall 2019 minicourse, we chose to focus the course on geodesign. Students were given an assignment: to develop, through a geodesign process, projects and policies to be included in the sustainable development master plan for the Iron Quadrangle region (henceforth, master plan), with a focus on social dimensions. This region was chosen because of its importance to sustainable development: It is located in the Atlantic Forest biome, which is described as "one of the world's most threatened yet bio-diverse ecosystems" (M. C. Ribeiro et al. 2009), and it is experiencing poor land use management, with very high loss of native vegetation, indicating limitations to "achieving long-term sustainable development goals" (Sonter et al. 2014, 70).

To benefit students' learning, we opted to make this master plan hypothetical. We also wanted to provide an example of a geodesign process that could be applied in other educational contexts. URB035 had the following learning outcomes: (1) understand how the geodesign framework functions in practice; (2) understand the issues involved in decision-making processes based on participatory planning; (3) develop scenarios focusing on social dimensions; (4) evaluate new ways of representing regional information when facing conflicts of interest; and (5) learn about the region where UFMG is located. Students were not expected to be familiar with mining-related decision-making processes, nor to know how to use geospatial technologies, nor to have real-world experience of the Iron Quadrangle region. Figure 2 shows teams working during the fourth day of URB035.

In what follows, we describe the process followed for the minicourse and pose the following research questions: To what extent does geodesign stimulate architecture and urbanism students to develop strategies for decision-making processes with a focus on social dimensions? How does the teaching of geodesign contribute to knowledge? What recommendations will help others replicate this experience in educational or community settings? After completing URB035, students received an online survey with questions about their learning experience to help answer the research questions just posed. There was a 65 percent response rate, and the findings are described later.

Literature Review

Social Dimensions of Mining

The mining industry affects the environment, economy, and society of extractive regions. The social dimension has been explored through studies examining a variety of themes such as poverty or income and employment, health and well-being, and

Figure 2 *URB035 students' discussion during the fourth day.*

infrastructure and housing. The UFMG geodesign team referenced these themes as they defined the variables included in the representation models of the Iron Quadrangle region case study.

Poverty or Income and Employment. Mining corporations consistently promise economic benefits to the communities they enter. Although these economic benefits do sometimes materialize (Monteiro, Da Silva, and Moita Neto 2019), the economic reality of mining communities seldom aligns with these promises from the mining industry. Instead, extraction projects can exacerbate poverty rates, unemployment rates, and income disparities. To illustrate, according to Gordon and Webber (2008), Canadian mining companies and their supporters make "idealistic claims" about the benefits of the mining industry when presenting their ventures to the Latin American communities they are entering. In reality, though, mining development often heightens poverty and "leads to displacement, [the] undermining of traditional economies and [the] destruction of local ecosystems" (Gordon and Webber 2008, 68). Furthermore, Monteiro et al. (2019) referred to the United Nations Sustainable Development Goals (United Nations 2020) to argue that the mining industry could actually provide productive employment for all and greatly reduce poverty, as outlined by Goals 1 and 8, but this would require improved salaries, equal distribution practices, and the promotion of inclusion and access for all.

Health and Well-Being. The preservation of cultural values and health is critical to the livelihoods of residents in mining communities. Environmental degradation not only damages ecosystems; it also harms the way of life in many communities, as well as residents' health and well-being. Urkidi and Walter (2011) discussed a case study in Chile where the "indigenous community saw the mining project as a risk for their collective property rights and for their cultural survival" (688). Moreover, air and water pollution from the mining industry cause acute and chronic health problems (Gordon and Webber 2008; Rondon 2009; Helwege 2015). Gordon and Webber (2008) reported that health care workers are among those opposing mining corporations in Chile. Additionally, residents of host communities should have access to education, but sometimes this might be a challenge for them because the mining industry, in particular, often inhibits those opportunities. To illustrate, Goldenberg et al. (2010) researched the social impacts of mining for young people living in a mining community in Canada and found that the economic benefits of working in the mining industry had negative effects on young people's education, because they often chose to prioritize early employment over continued education.

Infrastructure and Housing. In a study of the potential conflicts arising from a mining project in Peru, Delgado and Romero (2016) found that stakeholders from urban areas were not concerned about the effects of mining on water quality and availability. Yet based on their experience with the extraction industry, rural communities foresaw damages to water quality as a result of expanded mining activity. Hajkowicz, Heyenga, and Moffat (2011) acknowledged that mining activity has the potential to harm local water sources and sewage systems. Access to housing is also important for the inhabitants of regions with a strong mining industry. Through objective measures of well-being, Li et al. (2018) found that coal mining activity in Shanxi, China, might lead to improved housing conditions. The results from subjective measures (satisfaction with housing), however, did not align; this indicates that the objective measures might have been too narrow in scope to fully assess well-being as it relates to housing conditions.

Geodesign and Mining

Decisions related to mining involve a variety of stakeholders, landscape factors, and potential social, economic, and environmental impacts. Geodesign—with its focus on interdisciplinary, participatory processes—can prove an effective tool in mining-related planning. In a study conducted in Mozambique, Janssen and Dias (2017) examined how geodesign methodologies contributed to stakeholder participation and negotiation and found that these were successful in encouraging conversation and reaching consensus between mining stakeholders. Porrà et al. (2014) applied geodesign to analyze a district in Sardinia, Italy, which has a history of mining, to determine spatial planning steps that are nondestructive and that take into account both the area's historical and modern landscapes. Jingyi and Menghan (2018) explored a conceptual design in Mongolia through the lens of what they referred to as "ecological design"/"landscape design," a process that shares fundamental ideas with geodesign.

Huang and Zhou (2016) argued that "the places that need Geodesign the most are in many low-tech developing countries where large-scale developments and significant landscape changes are occurring" (81). Huang and Zhou discussed the potential of using geodesign in the Global South, where mining activity is prevalent but where local communities have difficulty obtaining access to geographic information to which mining companies are privy. They argue that geodesign—with its integration of design and geospatial information, as well as its emphasis on sharing that information—could prove beneficial in developing countries where industries such as mining are significantly altering the landscape.

The Preworkshop

Before discussing the workshop (see Figure 1), we provide some basic information about the preworkshop and the context in which we prepared the spatial data. By developing the first three geodesign models (representation, process, and evaluation), faculty and research assistants were able to produce data, information, and knowledge about the study area so that workshop participants could learn about and understand its main characteristics, potentialities, and vulnerabilities. Figure 3 depicts the Iron Quadrangle region, which includes twenty-eight municipalities, with a total area of 11,670 km^2. The region is characterized by inequalities, with municipal gross domestic products ranging from R$10,334 (US$1,812, Mário Campos) to R$289,925 (US$50,864, São Gonçalo do Rio Abaixo) in 2015. Belo Horizonte, the state's capital and the most populous urban area in MG, is located in the Iron Quadrangle.

We defined the themes for the evaluation models by considering the main topic of the workshop: the social dimension of an area characterized by many conflicts of interest related to mining. Based on the preceding literature review and our knowledge of Brazil's pressing social problems, we chose the evaluation models displayed in the first column of Table 1. From our perspective, we considered the models on housing, education, health, and basic sanitation to be the most relevant for this social workshop. In what follows, we describe our process for creating these models in preparation for an educational experience. It is important to highlight that there are other ways of completing these models than those described here. For instance, if the framework is being applied outside academia, the "real" people of the place can define the spatial data to be included in the geodesign process.

The representation models can be understood as the "raw" spatial layers that were used to describe the study area and, eventually, to build the process and evaluation models. One of the challenges that Pettit et al. (2019) encountered was access to good quality data. This was not an issue in URB035. The UFMG geodesign team has been working with GIS in MG for more than two decades and is constantly creating and updating their spatial database. The third column of Table 1 shows all twenty-seven variables used in this minicourse; some are discrete, such as "number of households with garbage collection," and others are categorical, such as "rain forest." Most of our data came from the 2010 Brazilian Demographic Census, conducted by the Brazilian Institute of Geography and Statistics. (Other sources include the National Infrastructure of Spatial Data and Geological Maps of MG, and some spatial layers were created based on satellite images, using a variety of remote sensing techniques. Most countries from the Global South do not have access to data between census returns, which is a notable contrast from the annual estimated values in the American Community Survey in the United States. Because of this, census data from 2010 were the most recent data available, so we primarily made use of these data in the minicourse. Concerning the spatial unit of analysis, most layers were represented at the census tract, a few were polygons of unique shape representing the presence of iron ore, and some were raster data represented in cells.

Once we identified and visualized all of the spatial layers through the representation models, we built the process models. The second column of Table 1 shows all of the processed variables: Some raw data from the representation models became

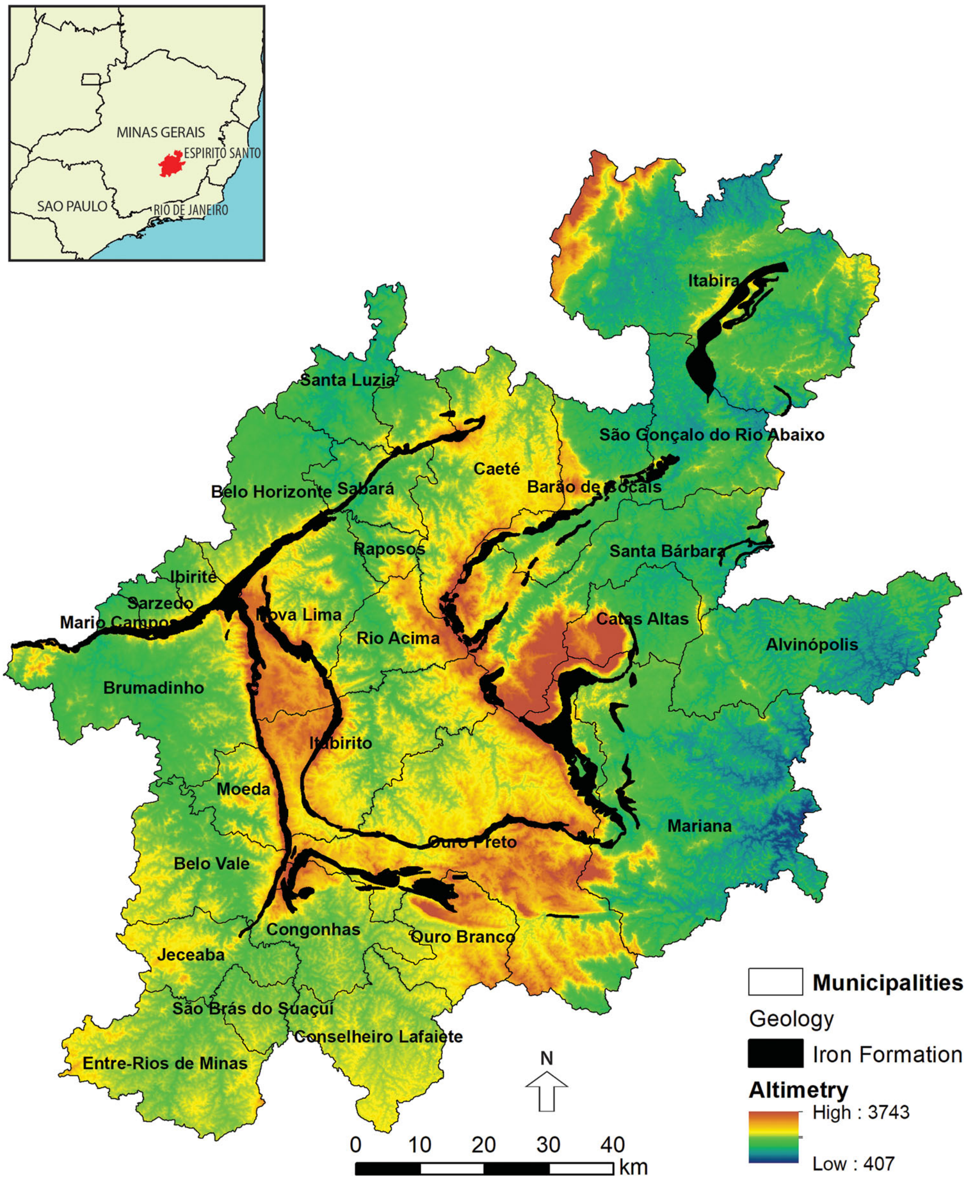

Figure 3 *The Iron Quadrangle region.*

percentages, others were transformed into density data, and others were buffered, among other processes, and the social processes (related to the social dimension variables) are highlighted in bold. To illustrate, for social processes, the values for number of residents who are Black at the census tract level were divided by total population at the census tract level to be processed as percentage population who is Black, and location of schools were buffered to identify the service area of each school and be processed as school service areas. For environmental processes, for example, types of vegetation included various categories in the representation model and were processed as rupestrian vegetation after a selection by attribute in the process model.

Comparable values were necessary to produce the evaluation models, so all layers from the process model were standardized using z scores. Some standardized layers had to be multiplied by -1 to represent social need. The second column of Table 1 displays all of the layers that needed to be standardized, and the ones with (–1) indicate the layers that needed to change signs to represent social need. For instance, the education evaluation model was composed of three process model layers: school service areas, population density, and average monthly income. From a social dimension perspective, for the workshop, locations of population density should be high and school service areas and average monthly income should be low. These high and low

Table 1 *From "raw" variables, to process models, to evaluation models*

Evaluation models	Process models	Representation models
Basic sanitation	**Percentage of households with garbage collection**	Number of households with garbage collection
	Percentage of households with sanitary sewage	Number of households with sanitary sewage
	Average monthly income (nominal)	Average monthly income (nominal)
Culture	Percentage young population	Number of residents by age
	Percentage elderly population	Number of residents by age
	Percentage literate population	Number of residents who are literate
Education	**School service areas**	Location of schools
	Population density	Total population
	Average monthly income (nominal)	Average monthly income (nominal)
Environment	Conservation and protection area	Conservation typology
	Rain forest	Types of vegetation
	Rupestrian vegetation	Types of vegetation
	Conservation and sustainable use areas	Conservation typology
Health	**Health center service areas**	Location of health centers
	Population density	Total population
	Average monthly income (nominal)	Average monthly income (nominal)
Housing	**Percentage Black population**	Number of residents who are Black
	Percentage home ownership	Number of households who own their dwellings
	Percentage women head of household	Number of women who are head of household
	Average monthly income (nominal)	Average monthly income (nominal)
Mining	Mining companies	Mining companies
	Absence of iron ore	Absence of iron ore
	Presence of iron ore	Presence of iron ore
	Existing infrastructure	Existing infrastructure
New housing	Densified areas	Densified areas
	New urban settlements	New urban settlements
	Nonverticalized urban areas	Nonverticalized urban areas
	Vacant land	Vacant land
Transportation	Paved urban roads	Paved urban roads
	New urban settlements	New urban settlements
	Existing urban settlements	Existing urban settlements
	Conservation and protection area	Conservation and protection area

Note: Process models shown in bold represent the social dimension–related evaluation models.

values could be interpreted as areas where many poor people were located with not many schools available. In this example, we had to multiply school service areas and average monthly income by -1. Finally, as pointed out earlier, some layers were in vector format and others were in raster; therefore, we transformed all of the layers to raster.

Once we completed all standardized process models, we used Map Algebra in ArcGIS software to combine the process models and create the evaluation models. Using the sum tool, we overlaid the process models according to the evaluation model to which they belong (Table 1). To illustrate, for the culture evaluation model, three raster process models were overlaid in Map Algebra: percentage young population, percentage elderly population, and percentage literate population. Each cell had a z-score value that was summed, and a final value was the output for the evaluation model. The final nine evaluation models had to be classified in a common scale: existing, feasible, suitable, capable, and not appropriate. These classifications are described as follows: existing—the location has already implemented projects and policies; feasible—the best location to receive ideas for projects and policies; suitable—not the best but a very good location to receive ideas for projects and policies; capable—not very good but an acceptable location to receive ideas for projects and policies; and not appropriate—locations not suitable for projects or policies. Table 2 shows examples of how the scale was defined for three evaluation models.

Figure 4 depicts all nine evaluation models, with the culture evaluation model highlighted for detail. The greens coincide with urban areas because one of the process models used to create this model in Map Algebra was population density.

The Workshop

The main goal of the workshop was to develop one final design for the Iron Quadrangle, taking into account the social dimension of a region characterized by conflicts of interest due to extensive mining activity, the presence of natural resources valued for different reasons by the community and by the mining industry, and rapid urban growth. The workshop illustrates a decision-making process based on geovisualization, which, as previously shown, can contribute to students' geospatial skills and effective decision making (Carbonell-Carrera and Hess-Medler 2019). Once all of the evaluation models were uploaded in the GeodesignHub, the five-day minicourse started with seventeen registered undergraduate students (all from architecture and urbanism, noninterdisciplinary). As described in Table 3, the first day was devoted to individual preparation outside the classroom.

Table 2 *Examples of scale for three valuation models*

	Existing	Not appropriate	Capable	Suitable	Feasible
Education evaluation model	Description: Priority areas to offer programs and policies related to education				
	Not applicable because even in areas with services they are not considered totally effective	Empty areas with no residents	Areas with medium percentage of schools, medium density of residents, and medium percentage of poor population	Areas with low percentage of schools, high density of residents, and high percentage of poor population	Areas with very low percentage of schools, very high density of residents, and very high percentage of poor population
Housing evaluation model	Description: Priority areas to promote housing programs and policies				
	Not applicable because even in areas with housing opportunities they are not considered totally effective	Empty areas with no residents	Areas with medium percentage of houses that belong to the owner and are already paid off; medium density of poor people, Black people, and female heads of household	Areas with low percentage of houses that belong to the owner and are already paid off; high density of poor people, Black people, and female heads of household	Areas with very low percentage of houses that belong to the owner and are already paid off; very high density of poor people, Black people, and female heads of household
Health evaluation model	Description: Priority areas to promote health programs and policies				
	Not applicable because even in areas with services they are not considered totally effective	Empty areas with no residents	Areas with medium percentage of health centers, medium density of residents, and medium percentage of poor population	Areas with low percentage of health centers, high density of residents, and high percentage of poor population	Areas with very low percentage of health centers, very high density of residents, and very high percentage of poor population

To mimic the real world, the participants were divided into teams representing four groups of society that have interest in development but hold different values and expectations concerning the social dimension of mining. Culture stakeholders were interested in the existing values of the local population, captured in the way they live and use their land. These stakeholders proposed culture-related ideas and activities for economic development purposes. Entrepreneurship stakeholders were engaged in sustainable economic development, including real estate, commercial and industrial areas, and the expansion of mining activities. Housing stakeholders advocated for affordable housing and therefore looked for optimal locations to implement new housing projects as a development approach. Finally, tourism stakeholders were interested in exploring sustainable tourism-related activities, focusing on nature and historical heritage as alternatives to the mining industry. In sum, these four groups represented the forces that are transforming the Iron Quadrangle region, as well as the intrinsic values of the region. Tourism stakeholders and entrepreneurship stakeholders are the drivers of changes, and housing stakeholders and culture stakeholders are concerned with the outcomes of such changes. This division was intended to enable participants to explore new possible paths for promoting sustainable regional growth.

During the workshop, students were exposed to various characteristics of the Iron Quadrangle region (represented in several spatial layers), giving them the chance to learn about the region, a biome that plays a central role in sustainable development. Before working in teams, students initiated the change model together. They were asked to develop at least two diagrams with project and policy proposals to an assigned evaluation model, using the drawing tool available on the GeodesignHub platform. After that, they could develop diagrams for whatever evaluation models they wanted.[1] This approach was chosen to ensure that every evaluation model would have at least a few diagrams. For example, a student assigned to the health evaluation model proposed a project to build a new health center. This health center was displayed as a polygon in the platform, with the exact area in hectares and cost in U.S. dollars attached to it, as shown in Figure 5. It is important to highlight that students were told to consider the evaluation model scale (from existing to feasible) when locating their polygons in the study area.

Once the students had developed a variety of projects and policies (i.e., diagrams) from which to choose, it was time to develop the decision model; that is, to decide what to include in the master plan. As teams worked to develop the first design, they adhered to the values and expectations of the group of society that they represented and each team was advised to consider all of the evaluation model diagrams in their first design to avoid issues during the negotiations. For instance, students from

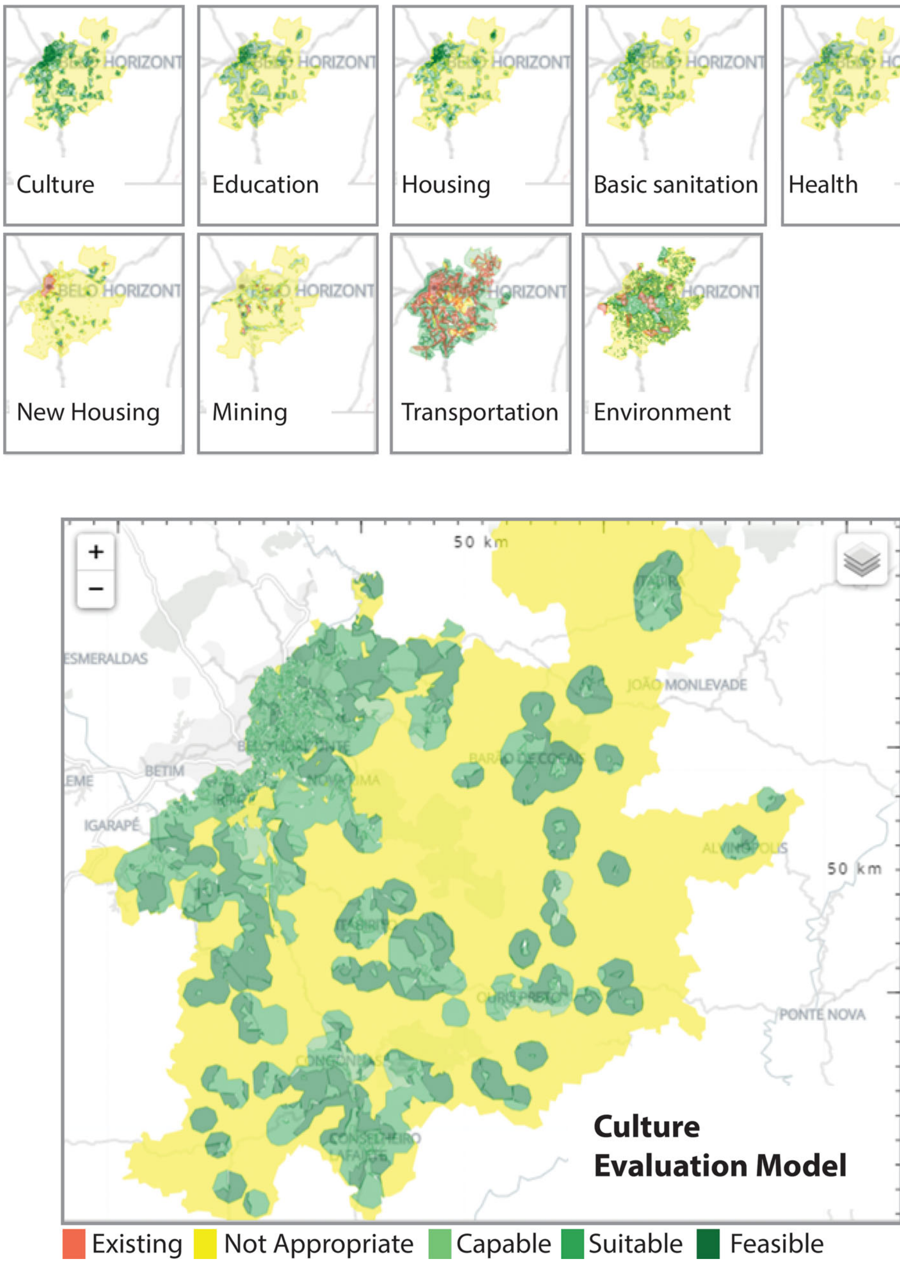

Figure 4 *Nine evaluation models for the workshop (captured from the GeodesignHub).*

entrepreneur stakeholders would naturally tend to avoid environment diagrams to focus on development. Stakeholder groups, however, should also consider diagrams that are not directly related to their values and are located in areas that do not directly affect their own interest. In doing so, the teams can enhance flexibility and minimize conflicts of interest during the negotiation process.

For the impact model, GeodesignHub has tools to calculate the impacts of designs by summing up the areas and costs of all diagrams included in a design. This allows participants to verify whether they have achieved the targets in hectares expected per evaluation model and to analyze possible costs. The targets for each evaluation model were defined by faculty during the preworkshop, establishing a minimum area of land expected in each diagram.[2] For each evaluation model, the target area was defined as an increase of 30 percent of the existing area; this threshold was arbitrarily defined for the purpose of the minicourse. To alert the teams about the areas of their diagrams, the platform displays the target area in a histogram side by side with the achieved area, allowing teams to easily make

Table 3 *Description of minicourse meetings*

	Meeting 1 (outside classroom)	Meeting 2 (in person)	Meeting 3 (in person)	Meeting 4 (in person)	Meeting 5 (in person)
Goals	• Develop participants' interest about the characteristics of the Iron Quadrangle region • Motivate participants to be proactive when it is time to share their opinions and points of view	• Inform participants about the geodesign process and describe the workshop outline • Answer questions about the characteristics of the Iron Quadrangle region	• Initiate the collective process of drawing proposals for policies and projects for the region using diagrams for each of the ten evaluation models • Propose the design containing selection of policies and projects (i.e., diagrams) according to values and expectations of groups representing different stakeholders from society	• Carry out a detailed analysis of the impacts of the proposed designs for possible adjustments or changes • Regroup teams to prepare for the decision model, through negotiation model and consensus maximization	• Assess the final design
Major tasks	Faculty 1. Send participants a PDF explaining what the Iron Quadrangle region is in terms of its physical and social components (landscapes, geomorphology, environmental values, risks, cultural assets, conservation units, and types of occupation) 2. Send participants a tutorial about how to navigate the WebGis platform	1. Lecture about the geodesign process 2. Present case studies as examples about geodesign 3. Present the dynamics of the workshop 4. Present information about the Iron Quadrangle region and listen to the participants' ideas about it	1. Using the ten evaluation models, ask participants to draw at least two diagrams of policies or project proposals for a given model and as many diagrams as they want for all other models 2. Divide participants into four teams of society, representing the values of stakeholders regarding the social approach (housing, tourism, culture, and entrepreneurship)	1. Conduct a collective analysis to assess the impacts of the four proposed designs 2. Ask participants to vote and then regroup in two teams 3. Encourage adjustments or changes to two proposals and remind participants about collegiality being the guiding principle when teams present and defend their designs 4. Coordinate the final negotiation when participants reach consensus on one design	1. Evaluate the impacts of the final decision: compliance with targets, resulting costs, identification of possible conflicts of interest, and motivations of the decisions 2. Listen to the validity of geodesign: benefit and vulnerability of the process
	Participants 1. Read explanatory material about the Iron Quadrangle region 2. Access WebGis to examine the thematic maps distributed according to different approaches (vegetation, hydrography, geomorphology and risks, territorial and urban condition, housing, cultural heritage, economic geology, nature tourism) 3. Propose initial ideas for policies and projects on the platform, through georeferenced points and following a legend of colors, according to the themes: water resources, remarkable landscape, vegetation cover, ecotourism, sustainable enterprises, sustainable urban expansion, social services (education and health), sanitation, and housing	1. Clarify doubts about the geodesign process 2. Clarify doubts and present on the Iron Quadrangle region	1. Design policy and project diagrams for each evaluation map 2. Elaborate the first design, which is a sum of selection of diagrams (i.e., policies and projects) taking into account the social value of each team of society 3. Defend orally the team design, by each of the four teams	1. Analyze the partial results obtained in the first designs, using the frequency table to understand the popularity of each proposal 2. Vote to express preferences about which design participants would like to be added 3. Elaborate on the second design, based on the composition of the two teams 4. Discuss two new designs, with collegiality, between groups to defend ideas 5. Present the second design resulting from the composition of the two teams 6. Compare the two final proposals 7. Perform final negotiation	1. Discuss and defend final design and motivation for decisions 2. Give feedback on the learning process

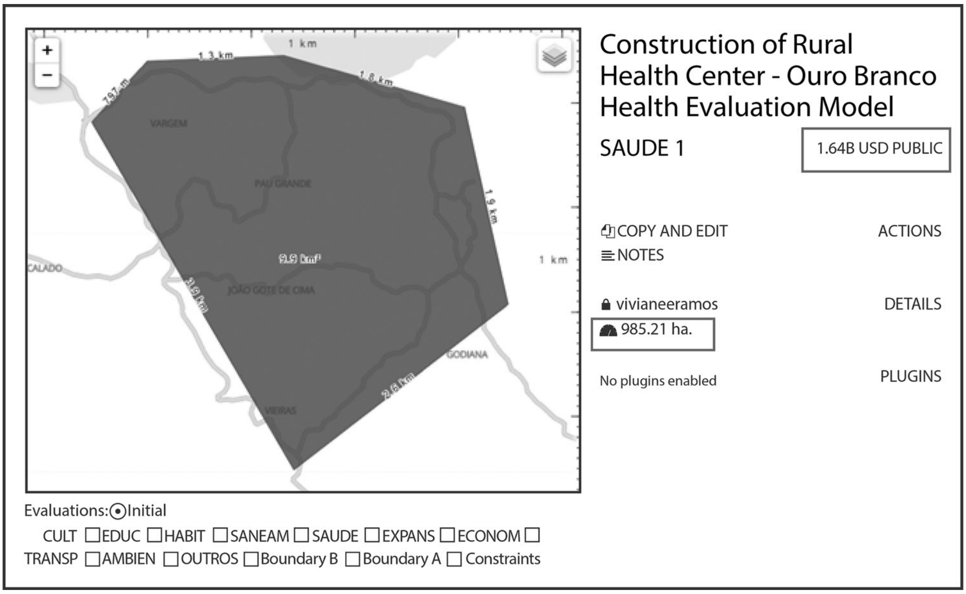

Figure 5 *Example of a project diagram.*

comparisons and understand if their proposed area is too low, too high, or matching the target.[3] Concerning the cost for projects, the faculty estimated an average U.S. dollar value per hectare for the construction of projects for each evaluation map, and they uploaded these values in the GeodesignHub. The platform displays the cost per evaluation model and also the total cost of the design so teams can compare their performances. It is important to highlight that the platform does not compute cost for policy. Moreover, even though the platform could also include a budget for teams to work with, the minicourse did not use this tool.

Additionally, the platform generates an impact map for each design and project based on a scale from most negative impact to most positive impact. In between both extremes of the scale, there is neutral, which means that a project was located in an area of no need, indicating money spent without a purpose. For example, if an education project is located in an area of the education evaluation model that is feasible, then in the impact map it will be indicated as having the most positive impact. Once teams completed their first design, it was time for the first round of decision models, where presentations, discussions, and negotiations took place. The main goal of the workshop, however, was to have one final design, and therefore it was necessary to consolidate the four teams into two teams. To facilitate this consolidation process, each team voted to determine whether they would agree or disagree to work with the other teams or were neutral about this. The outcome of this vote was the merger of entrepreneurship stakeholders and tourism stakeholders into a new team, entre-tour, and housing stakeholders and culture stakeholders into hou-cult. By following the logic of sociogram (Moreno 1934) to merge teams (Rivero et al. 2015; Campagna, Steinitz, et al. 2016), a new task for teams entre-tour and hou-cult was to develop a second design by combining the first design produced by each team of the two merged teams. Using the tools available through the platform, teams were able to compare their proposals, identify agreements and disagreements through the use of a frequency matrix, discuss possible adaptations, and cocreate new diagrams. The matrix becomes a tool to compare the frequency of diagrams between teams' designs, making negotiations and decisions easier when developing a new design.

As the decision model process continued, all seventeen students got together and the two teams presented their second designs. To complete the final design, a final round of discussion and negotiations took place to combine the second designs from both teams (Figure 6). Because the social dimension was the main topic of this minicourse, all of the diagrams from the evaluation models directly related to this dimension were discussed first. Students discussed, negotiated, and made the final decision. The final design put forward a total of twenty-two policies and twenty-three projects for the master plan, but not all evaluation models achieved the target areas.[4] On a scale from most negative impact to most positive impact, some diagrams were at the neutral scale, such as one of the basic sanitation projects that was partially located in an unpopulated area. Some of the diagrams had a negative impact, such as a project for preservation of the environment situated in a conservation area.

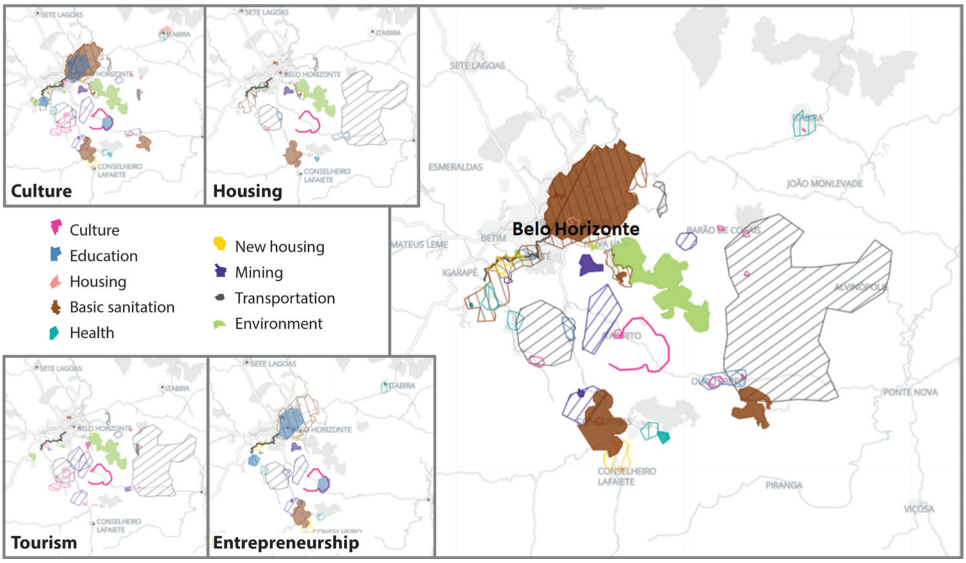

Figure 6 *First design of each team and final design. Note: Solid colors represent projects, and "patterned" polygons represent policies.*

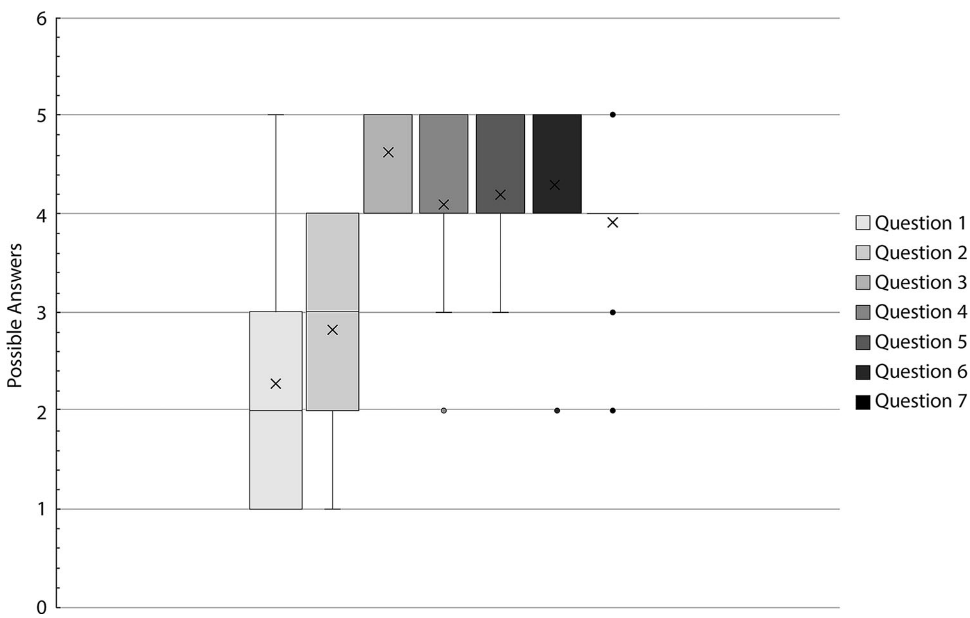

Figure 7 *Boxplot showing the level of agreement's central tendencies of the seven closed-end questions included in the short online survey.*

Discussion

By taking this minicourse, students (1) understood how the geodesign framework works in practice; (2) understood the dynamic of a decision-making process based in participatory planning; (3) understood how the social dimension of mining can be integrated with other projects and policies; (4) evaluated new ways of representing information about a region when facing conflicts of interest; and (5) learned about the Iron Quadrangle region. These benefits were observed during the minicourse's final meeting in an open discussion about the learning process that involved all participants, as well as in a short online survey completed by students after the minicourse. Based on students' self-perceptions, learning outcomes were met.

Table 4 and Figure 7 display the results of the seven questions with a five-point Likert scale (i.e., 5 [*strongly agree*], 4 [*agree*], 3 [*neutral*], 2 [*disagree*], 1

Table 4 *Summary results of short online survey (posttest)*

Questions	Strongly disagree (1)	Disagree (2)	I am not sure (3)	Agree (4)	Strongly agree (5)	Descriptive statistics			
						M	*SD*	Minimum	Maximum
1. Before taking URB035, I already knew about the geodesign framework.	45.50% (5)	18.15% (2)	9.10% (1)	9.10% (1)	18.15% (2)	2.364	1.629	1	5
2. Before taking URB035, in which the focus was on the Iron Quadrangle region, I already knew the main characteristics of the region.	9.10% (1)	27.25% (3)	36.40% (4)	27.25% (3)	—	2.909	1.044	1	4
3. After completion of URB035, I believe that my knowledge about the geodesign framework was expanded.	—	—	—	36.40% (4)	63.60% (7)	4.636	0.505	4	5
4. After completion of URB035, I believe that my knowledge and interest about the Iron Quadrangle region were expanded.	—	9.10% (1)	9.10% (1)	45.45% (5)	36.35% (4)	4.091	0.944	2	5
5. For me, incorporating the social dimensions in my projects and policies for the master plan was an easy task.	—	—	9.10% (1)	63.60% (7)	27.30% (3)	4.182	0.603	3	5
6. I felt that the geodesign framework was easy to understand.	—	9.10% (1)	—	45.45% (5)	45.45% (5)	4.273	0.905	2	5
7. I felt it was easy to participate in the geodesign process.	—	9.10% (1)	9.10% (1)	63.60% (7)	18.20% (2)	3.818	0.874	2	5

[*strongly disagree*]) that were included in the short online survey. Results from Questions 1 and 3 were compared and indicate that the majority of students learned about the framework of geodesign, gaining a higher level of understanding through the course. Results from Questions 2 and 4 were compared and indicate that the majority of students learned about the Iron Quadrangle region characteristics but that they gained less knowledge about the region than about the framework of geodesign. This is somehow similar to what Pettit et al. (2019) described as "a challenge for some students to develop a deep knowledge of the relevant study area" (158). Even in the case study they conducted in which students had a field trip to the study area, the students' knowledge was insufficient for them to propose comprehensive design of projects and policies. The responses to Question 5 suggest that, from the students' perspective, the final design would have more projects and policies from the social dimension evaluation models than it actually did. Two out of four evaluation models related to the social dimensions achieved the target in the final design, indicating that the students were not able to fully incorporate these models, a finding that differs from their perspectives. When students were asked whether "the geodesign process is easy to understand," and "it was easy to be a participant in the geodesign process," results indicate that, for the majority, the geodesign process was easy to understand but participating in a geodesign process was more complex.

The survey also had three open-ended questions and students' responses reveal some critical reflections about the geodesign process. When students were asked about the strengths of the geodesign framework, comments emphasized participatory planning, highlighting that it "makes public engagement and collective action possible." When asked about the weakness of the geodesign framework, students' comments underlined the difficulty for disadvantaged populations of securing access to an Internet connection, such as "access to technology by socio-economic[ally] vulnerable population." Thanatemaneerat (2015) also observed that the socioeconomic status of participants could be connected to the degree of power they have in the process; some residents (e.g., those with less money and power) are likely to have less of a voice. Based on a real-world experience of a geodesign workshop with the indigenous Navajo Nation's Dilkon community, Davis et al. (2020) also highlighted that reliable access to Internet connection was a challenge when working with minority populations as people of the place.

There were also comments on a variety of issues that could also occur in an actual context indicating that these dynamics should be taken into consideration if the framework is applied in a real-world context. Some examples follow: "Participants may not know the study area well," "The use of maps may hide some subjective aspects of conflicts of interest, giving me the impression that the framework 'puts makeup' on the conflicts to promote a calmer discussion, but hides the real motivations behind participation," and "Not enough time to complete assignments." When asked about additional comments concerning the geodesign framework, students' comments included: "It is important that participants understand the scale of projects and policies to avoid confusion during the process" and "Some participants have difficulty understanding the difference between projects and policies, and other participants have a more authoritarian personality and don't know how to discuss to achieve consensus." Even though the minicourse described here is not very similar to the 2019 IGC event, a few observations from our online survey coincide with the IGC poststudy survey, in which 39 percent of the respondents were students. As described by Campagna (2020, 147–48), "Individual teams faced a variety of issues such as the available time frame" to complete the project, and local stakeholders had little knowledge of structured ways of developing and comparing spatiotemporal scenarios.

Porrà et al. (2014) also made observations that echo those of Thanatemaneerat (2015) concerning participation and power. They emphasized in their article the importance of ethical considerations in processes such as these, arguing that there are "a lot of dangers as there are in all participatory approaches: it can raise people's expectations, unlearning through the shared information, endangering communications or generating conflicts" (Porrà et al. 2014, 7). These observations should be taken into account when applying geodesign to landscape planning that includes sectors such as mining and, consequently, complex power dynamics within local communities.

Conclusion

Based on this experience in geodesign conducted in this minicourse, we synthesize some recommendations for educators who are interested in using this methodological framework for future courses exploring mining and other planning-related projects. First, we observe that four of the six evaluation models related to the social dimension in this minicourse did not achieve the target areas, and the basic sanitation evaluation model had more diagrams included in the final design. This might be an indication that, in preparation for the minicourse, students should learn more about the focus of the workshop (in this case study, the social dimension) and the groups of society they will represent. Therefore, we recommend that, prior to the first day of class, faculty should post reading material about the values and expectations of such stakeholder groups in relation to the main topic of the workshop, as well as identify local experts on the main topic to attend the class as guest speakers or to share a recorded video with students. Faculty should also promote some active learning activities during the first day of the workshop, before students start working with the framework. For example, faculty could select current news articles or media coverage related to the workshop's main topic and encourage the class to discuss these current events from the perspective of the group of society they would be representing.

Second, it was observed that negotiations for new designs were based on general knowledge, without a systematic and in-depth exchange of information. Similarly, Pettit et al. (2019) noted that "the negotiation in and between Geodesign teams" (157) was a challenge for all students. Thanatemaneerat (2015) also observed that, in his study, few students participated in the discussion, revealing that deeper knowledge of the topic is essential to structuring a session in which participants will assume a role and contribute in a meaningful way. Hence, we recommend assigned readings between classes and that every class should start with a minilecture to increase the quality of negotiations. These readings and minilectures should highlight specific topics of interest that arise during the negotiations—a type of "on the go" approach.

Third, students complained about the lack of time to accomplish all the required tasks. Future workshops should have six days in the classroom instead of four days: First-day learning outcomes should not change; the second day should be dedicated to drawing diagrams only; the third day should allocate time to understand in detail the values of the stakeholders students are representing; the fourth day should emphasize the first design; the fifth day should focus on the second design; and the sixth day should prioritize the final design and assessment of the experience. We believe that extending the duration will improve the learning process, even though Steinitz (2012) argued that geodesign workshops should be short.

Fourth, as previously noted, although GeodesignHub does allow users to factor in the cost of a project, there is no such function for policy initiatives. As a consequence, policies are not included in the calculation of target areas, so the achieved target areas end up misinforming the designs. This is particularly troublesome at the regional scale, where regional policies are much more effective than projects. As the platform continues to evolve, we recommend including a tool to compute costs for policies. If time would allow, students could also evaluate the costs based on their location, using available local resources related to policy design and implementation costs. Fifth, when possible, minicourses such as this one should attract students not only from architecture and urbanism but also from different disciplines to promote interdisciplinary collaboration, which is a core concept of the geodesign framework.

Although mining activity in Latin American countries undoubtedly improves the average regional economy, regional inequalities persist (Loayza and Rigolini 2016; L. C. D. S. Ribeiro et al. 2018). Despite being one of the world's largest producers of a variety of minerals, the majority of Brazil's mining activity is concentrated in limited areas and controlled by a few producers, leading to an "unbalancing effect on the economy" (da Silva Loureiro et al. 2019, 2). As mining continues to grow rapidly in Brazil, various social problems expose deeply rooted conflicts of interest between different stakeholders.

We believe that this case study conducted in the Global South can inspire participation at different levels of decision making and result in more consensus than traditional, nongeographical processes. This experience can be applied more broadly outside of an educational setting by first engaging with groups of stakeholders from societal sectors that have interests in the region. As demonstrated in our approach, geodesign makes it possible for each group's preferences and needs to be considered on an individual basis. Then, the data collection for the representation models can be conducted, taking into account each group's input. All stakeholders should be aware of all groups' preferences and needs before starting the process model. This is an essential strategy to starting a geodesign process and ensuring that it is inclusive and that all voices are heard. As Pettit et al. (2019) alerted, however, negotiating in and between teams could be a challenge for real-world applications, and further research should be conducted.

To illustrate, let us imagine that the residents of the Córrego do Feijão dam, whose houses vanished in the sea of mud, were putting pressure on the mining company responsible for the collapse to provide new housing. A geodesign workshop could be developed, having one university as a partner, with the main goal of coproducing affordable housing projects and policies to be located and implemented in the Córrego do Feijão subwatershed. The residents would be the people of the place, and the mining company and the environmental stakeholders could represent two different groups of society. As described earlier, though, there are obstacles to such application, and extensive planning should be used to increase the effectiveness of geodesign workshops in the real world. Finally, Davis et al. (2020) offered suggestions for future improvements for geodesign workshops that involve minority groups as people of the place in general: Organizers should be mindful of the location so people of the place can have easy access to these workshops. Davis et al. (2020) also recommended that the workshop be widely advertised ahead of time in ways that emphasize its potential benefit for the community and the advantages of attending and that organizers provide transportation and meals for community members to and from the workshop. ■

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Notes

[1] A total of eighty-eight diagrams were developed for the evaluation models: seventeen for culture, eleven for education, eight for housing, ten for basic sanitation, nine for health, eight for hew housing, nine for mining, nine for transportation, and seven for environment. From the total of eighty-eight, forty were policies and forty-eight were projects.

[2] For this minicourse, the following target areas were defined by faculty: 7,000 ha for culture, 7,000 ha for education, 15,000 ha for housing, 15,000 ha for basic sanitation, 7,000 ha for health, 20,000 ha for new housing, 10,000 ha for mining, 10,000 ha for transportation, and 30,000 ha for environment.

[3] GeodesignHub calculates and compares areas only for projects but not for policies. For this case study, the authors calculated the areas for all policies diagrams and included their values for the final design to understand how the final design matched with the target areas.

[4] The final design had the following the number of diagrams per evaluation model: four for culture, six for education, three for housing, nine for basic sanitation, six for health, four for new housing, five for mining, five for transportation, and three for environment. Considering the forty-five diagrams included in the final design, the following evaluation models achieved the target area: health, mining, environment, basic sanitation, and transportation. Education, housing, new housing, and culture did not achieve the target area.

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Literature Cited

Arellano-Yanguas, J. 2012. Mining and conflict in Peru: Sowing the minerals, reaping a hail of stones. In *Social conflict, economic development, and extractive industry: Evidence from South America*, ed. A. Bebbington, 89–111. London and New York: Routledge.

Ballal, H. 2015. Collaborative planning with digital design synthesis. PhD diss., University College London.

Ballal, H., and C. A. Steinitz. 2015. Workshop in digital geodesign synthesis. In *Peer reviewed proceedings of Digital Landscape Architecture at Anhalt University of Applied Sciences*, ed. E. Buhmann, S. Ervin, and M. Pietsch, 400–407. Berlin: Herbert Wichmann Verlag.

Campagna, M. 2020. How geodesign processes shaped outcomes. In *The International Geodesign Collaboration: Changing geography by design*, ed. T. Fisher, B. Orlando, and C. Steinitz, 145–53. Redlands, CA: ESRI Press.

Campagna, M., A. C. M. Moura, J. Borges, and C. Cocco. 2016. Future scenarios for the Pampulha region: A geodesign workshop. *Journal of Digital Landscape Architecture* 1:292–301.

Campagna, M., C. Steinitz, E. A. Di Cesare, C. Cocco, H. Ballal, and T. Canfield. 2016. Collaboration in planning: The geodesign approach. *Rozwój Regionalny i Polityka Regionalna* 35:55–72.

Carbonell-Carrera, C., and S. Hess-Medler. 2019. Interactive visualization software to improve relief interpretation skills: Spatial data infrastructure geoportal versus augmented reality. *The Professional Geographer* 71 (4): 725–37. doi: 10.1080/00330124.2019.1595064.

Coelho, P. S., M. P. Cordeiro, and G. M. Massola. 2020. Effects of female political participation on insecurity in a mining area. *International Perspectives in Psychology: Research, Practice, Consultation* 9 (1):18–35. doi: 10.1037/ipp0000121.

da Silva Loureiro, A. C. N., D. Blundi, F. V. Lopes, G. T. P. da Silva, M. F. Jorge, S. M. P. de Carvalho, and V. Orind. 2019. Technology appropriation and technology transfer in the Brazilian mining sector. Economic Research Working Paper No. 53, GE, Geneva, Switzerland.

Davis, J., D. Pijawka, E. A. Wentz, and M. Hale. 2020. Evaluation of community-based land use planning through geodesign: Application to American Indian communities. *Landscape and Urban Planning* 203:103880. doi: 10.1016/j.landurbplan.2020.103880.

Delgado, A., and I. Romero. 2016. Environmental conflict analysis using an integrated grey clustering and entropy-weight method: A case study of a mining project in Peru. *Environmental Modelling & Software* 77:108–21. doi: 10.1016/j.envsoft.2015.12.011.

Dougherty, M. L., and T. D. Olsen. 2014. "They have good devices": Trust, mining, and the microsociology of environmental decision-making. *Journal of Cleaner Production* 84:183–92. doi: 10.1016/j.jclepro.2014.04.052.

Foster, K. 2016. Geodesign parsed: Placing it within the rubric of recognized design theories. *Landscape and Urban Planning* 156:92–100. doi: 10.1016/j.landurbplan.2016.06.017.

Freitas, A. H. A., and A. Magrini. 2013. Multi-criteria decision-making to support sustainable water management in a mining complex in Brazil. *Journal of Cleaner Production* 47:118–28. doi: 10.1016/j.jclepro.2012.10.043.

Goldenberg, S., J. Shoveller, M. Koehoorn, and A. Ostry. 2010. And they call this progress? Consequences for young people of living and working in resource-extraction communities. *Critical Public Health* 20 (2):157–68. doi: 10.1080/09581590902846102.

Gordon, T., and J. R. Webber. 2008. Imperialism and resistance: Canadian mining companies in Latin America. *Third World Quarterly* 29 (1):63–87. doi: 10.1080/01436590701726509.

Gu, Y., and B. Deal. 2020. Geodesign, resilience and planning support systems: The integration of process and technology. In *Handbook of planning support science*, ed. S. Geertman and J. Stillwell, 110–31. Cheltenham, UK: Edward Elgar.

Hajkowicz, S. A., S. Heyenga, and K. Moffat. 2011. The relationship between mining and socio-economic well being in Australia's regions. *Resources Policy* 36 (1):30–38. doi: 10.1016/j.resourpol.2010.08.007.

Helwege, A. 2015. Challenges with resolving mining conflicts in Latin America. *The Extractive Industries and Society* 2 (1):73–84. doi: 10.1016/j.exis.2014.10.003.

Huang, G., and N. Zhou. 2016. Geodesign in developing countries: The example of the master plan for Wulingyuan National Scenic Area, China. *Landscape and Urban Planning* 156:81–91. doi: 10.1016/j.landurbplan.2016.05.014.

Jankowski, P. 2009. Towards participatory geographic information systems for community-based environmental decision making. *Journal of Environmental Management* 90 (6):1966–71. doi: 10.1016/j.jenvman.2007.08.028.

Janssen, R., and E. Dias. 2017. A pictorial approach to geodesign: A case study for the Lower Zambezi Valley. *Landscape and Urban Planning* 164:144–48. doi: 10.1016/j.landurbplan.2017.03.014.

Jingyi, L., and Z. Menghan. 2018. Ecological design in the perspective of complexity–conceptual design of nomadic landscape in Hulunbuir. *Landscape Architecture Frontiers* 6 (5):102–19. doi: 10.15302/J-LAF-20180511.

Leong, S., J. Hazelton, R. Taplin, W. Timms, and D. Laurence. 2014. Mine site-level water reporting in the Macquarie and Lachlan catchments: A study of voluntary and mandatory disclosures and their value for community decision-making. *Journal of Cleaner Production* 84 (1):94–106. doi: 10.1016/j.jclepro.2014.01.021.

Li, Q., N. Stoeckl, D. King, and E. Gyuris. 2018. Using both objective and subjective indicators to investigate the impacts of coal mining on wellbeing of host communities: A case-study in Shanxi Province, China. *Social Indicators Research* 137 (3):895–921. doi: 10.1007/s11205-017-1624-2.

Loayza, N., and J. Rigolini. 2016. The local impact of mining on poverty and inequality: Evidence from the commodity boom in Peru. *World Development* 84 (C): 219–34. doi: 10.1016/j.worlddev.2016.03.005.

Monteiro, N. B. R., E. A. Da Silva, and J. M. Moita Neto. 2019. Sustainable development goals in mining. *Journal of Cleaner Production* 228:509–20. doi: 10.1016/j.jclepro.2019.04.332.

Moreno, J. 1934. *Who shall survive?* New York: Beacon House.

Muller, B., and T. Flohr. 2016. A geodesign approach to environmental design education: Framing the pedagogy, evaluating the results. *Landscape and Urban Planning* 156: 101–17. doi: 10.1016/j.landurbplan.2016.05.010.

Orlando, B., C. Steinitz, and T. Fisher. 2020. Improving our global infrastructure. In *The International Geodesign*

Collaboration: Changing geography by design, ed. T. Fisher, B. Orlando, and C. Steinitz. 3–10. Redlands, CA: ESRI Press.

Pettit, C., S. Hawken, C. Ticzon, and H. Nakanishi. 2019. Geodesign—A tale of three cities. In *Computational urban planning and management for smart cities: CUPUM 2019 lecture notes in geoinformation and cartography*, ed. S. Geertman, Q. Zhan, A. Allan, C. Pettit, 139–61. Cham, Switzerland: Springer.

Porrà, D., G. Ranieri, A. Trogu, and S. Calcina. 2014. Non-destructive methods and GIS technologies for spatial planning strategies in mining areas. *International Journal of Emerging Technology and Advanced Engineering* 4 (12):1–12.

Ribeiro, L. C. D. S., E. P. Domingues, F. S. Perobelli, and G. J. D. Hewings. 2018. Structuring investment and regional inequalities in the Brazilian northeast. *Regional Studies* 52 (5):727–39. doi: 10.1080/00343404.2017.1327709.

Ribeiro, M. C., J. P. Metzger, A. C. Martensen, F. J. Ponzoni, and M. M. Hirota. 2009. The Brazilian Atlantic forest: How much is left, and how is the remaining forest distributed? Implications for conservation. *Biological Conservation* 142 (6):1141–53. doi: 10.1016/j.biocon.2009.02.021.

Rivero, R., A. Smith, H. Ballal, and C. Steinitz. 2015. Promoting collaborative geodesign in a multidisciplinary and multiscale environment: Coastal Georgia 2050, USA. In *Peer reviewed proceedings of Digital Landscape Architecture at Anhalt University of Applied Sciences*, ed. E. Buhmann, S. Ervin, and M. Pietsch, 42–58. Berlin: Herbert Wichmann Verlag.

Rondon, G. 2009. Canadian mining in Latin America: Corporate social responsibility and women's testimonies. *Canadian Woman Studies* 27 (1):89–96.

Sonter, L. J., D. J. Barrett, B. S. Soares-Filho, and C. J. Moran. 2014. Global demand for steel drives extensive land-use change in Brazil's Iron Quadrangle. *Global Environmental Change* 26:63–72. doi: 10.1016/j.gloenvcha.2014.03.014.

Steinitz, C. 2012. *A framework for geodesign: Changing geography by design*. Redlands, CA: ESRI Press.

Sutil, T. 2019. Avaliação ambiental estratégica (AAE) e geodesign como instrumentos de zoneamento Para áreas de proteção ambiental (APA): O caso da APA do rio maior, Santa Catarina—brasil [Strategic environment assessment and geodesign as a zoning tool for environment protection areas (EPA): A case of the Rio Maior EPA in Santa Catarina—Brazil]. PhD diss., Universidade do Extremo Sul Catarinense.

Thanatemaneerat, W. 2015. Geodesign for water quality management. PhD diss., University of Washington, Seattle.

United Nations. 2020. Sustainable development goals. Accessed June 23, 2020. https://sustainabledevelopment.un.org/.

Urkidi, L., and M. Walter. 2011. Dimensions of environmental justice in anti-gold mining movements in Latin America. *Geoforum* 42 (6):683–95. doi: 10.1016/j.geoforum.2011.06.003.

Vojteková, J., and M. Vojtek. 2019. GIS-based landscape stability analysis: A comparison of overlay method and fuzzy model for the case study in Slovakia. *The Professional Geographer* 71 (4):631–44. doi: 10.1080/00330124.2019.1611454.

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