Jurnal Pendidikan Geografi:
Kajian, Teori, dan Praktik dalam Bidang Pendidikan dan Ilmu Geografi, 29(1), 2024, 78-94
ISSN: 0853-9251 (Print): 2527-628X (Online)
DOI: 10.17977/um017v29i12024p78-94

Opak-Progo watershed's potential for geography experiential learning

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Paper received: 15-10-2023; revised: 28-12-2023; accepted: 19-01-2024

Abstract

The implementation of learning innovation is crucial for 21st-century education, particularly for Generation Z and Alpha students. Additionally, experimental learning (EL) is highly beneficial for learning geography, especially on the topic of geography research. This study evaluates the potential of the Opak and Progo Watersheds as a geography laboratory. This research was conducted with a spatial approach. Data were collected by observation, literature study, interpretation of remote sensing imagery, and documentation. The garnered data were analyzed by matching, scoring, and statistical analysis. A descriptive analysis was performed to support these analyses. The results show that the Opak and Progo watersheds have the potential for learning geography. This potential is inseparable from its heterogeneity of geological, geomorphological, meteorological, and hydrological conditions. The upstream area presents more potential because it has more complex conditions, indicated by the significant difference between the upstream and downstream areas in each watershed, as well as the variation between the four sample locations covering the two watersheds. In sum, this study offers novel insights into the potential of the area for natural laboratories for geography studies, especially the laboratories based on watersheds. This study also provides alternative information regarding watershed areas as a geography learning resource.

Keywords: experiential learning; geography; watershed

1. Introduction

Education plays a crucial role in the advancement of a nation's civilization. In Indonesia, access to education has been positioned as one of the state's goals as mandated in the 1945 Constitution. Therefore, quality education that is accessible to all members of society is essential. Similar to other countries, Indonesia continuously undertakes efforts to enhance the quality of education. However, regardless of these attempts, Indonesia still needs to find and implement various educational innovations to match other countries with more advanced education levels. According to the survey from the Program for International Student Assessment (PISA) in 2022, Indonesia still ranks low, even though it has improved by 5 to 6 ranks compared to the 2018 results (Denty, 2023).

The advancement of education quality can be achieved through various methods, such as by innovating learning models. The learning model is one of the vital aspects in every course, including in geography education, as it is one of the obligatory courses at both high school and university levels. Geography teaches about geospheric phenomena that affect human daily life and their interactions with the environment, along with various places on the earth's surface, including location, distance dimensions, and spatial analyses (As'ari, Rohmat, Ningrum, & Yani, 2022). Accordingly, proper learning is necessary, along with the evaluation of the recent organization of geography learning.

The recent education is popular as the 21st education. According to Carneiro and Draxler (2008), it emerges as a response to criticisms and reflections to establish a closer relationship between education and social harmony. The current high school and undergraduate geography students belong to Generation Z and Alpha. These generations have a distinct learning style characterized by a higher motivation towards group work (Schlee, Eveland, & Harich, 2020). They tend to prefer observation and practice over reading and listening to explanations (Iftode, 2019; Seemiller, Grace, Campagnolo, Alves, & De Borba, 2019). Experiential learning appears as one of the applicable learning models for this generation since it facilitates students to improve their mastery of the material through authentic experiences (Ives-Dewey, 2009; McPhee & Przedpelska, 2018). Additionally, the experiential learning model with fieldwork (field trip) has also been reported as a suitable model for Generation Z and Alpha learning, particularly for the learning of physical geography. This is due to the fact that the subject matter is found in the real world, in the field (Knight & Harrison, 2020; Tadaki, 2020). Fenneman's (1909) classic theory also emphasizes the importance of practical experience in the field of geography learning. In similar nuance, the educational philosophy from the Minangkabau community, 'alam takambang jadi guru,' eaches that learning involves not only teachers but also nature and cultural customs (Handrianto, 2012). Indonesian society values learning directly in the field, as demonstrated by this local wisdom. Learning by doing has been proven to have a positive impact on geography learning outcomes (Markuszewska, Tanskanen, & Subirós, 2018).

The geography courses at the high school or undergraduate levels cover the topic of geography research. In this topic, students have to interact directly with learning resources in the field, enabling them to observe, measure, and analyze various aspects of geography firsthand. According to AECT in 2004, the interaction between learners and learning resources is crucial as it enhances their performance by creating, using, and managing appropriate processes with resources (Januszewski & Molenda, 2013).

To support the implementation of experiential learning through field trips, a preliminary study is essential. The preliminary study identifies and evaluates the potential of areas with specific geographic conditions to be developed as natural laboratories for geography learning, such as the Opak and Progo watersheds. These watersheds, situated on the border of Central Java Province and Yogyakarta Special Region, offer heterogeneous geological, hydrological, geomorphological, and climatic conditions. Therefore, they have the potential to be developed as natural laboratories for geography learning. A study evaluating the potential of the Opak and Progo watersheds is important as a prototype for the development of natural geography laboratories, particularly those based on watersheds.

A number of studies that focus on designing geography learning sources in Indonesia have been carried out. Ashari and Widodo (2019) and Ashari, Purwantara, Arif, and Widodo (2021) have analyzed the potential of the Galunggung Volcano area as a geography education field laboratory. Meanwhile, Fadjarajani and As' ari (2021) report the development of the local landscape as a geography education field laboratory. However, the available studies have only evaluated the potential for the development of the areas without the detailed learning design, especially experiential learning. This study aims to fill the gap in the development of field learning resources that are designed based on experiential learning. Besides, there also has been no study that establishes watershed-based field learning resources. Therefore, this study will contribute to the development of learning resources for experiential learning based on watershed areas.

In addition, similar studies on the geography learning model through direct observation in the field have been conducted in many countries. The results indicate a positive impact on geography learning outcomes, transferable skills, increased learning independence, and encouragement of lifelong learning (Jiusto & DiBiasio, 2006; McPhee & Przedpelska, 2018). Therefore, this study assesses the potential of the Opak and Progo watersheds as natural laboratories for geography learning. In specific, this study proposes three specific objectives: (1) to analyze the geographical characteristics of the Opak and Progo watersheds, (2) to evaluate the potential of the Opak and Progo watersheds as experiential learning geography natural laboratories, and (3) to construct recommendation for further development following the evaluation results. In the end, this study aims to offer alternative information related to these conditions, providing new insights into the implementation of EL in watershed-based regional units.

2. Method

2.1. Data Collection and Analysis

This descriptive study adopted a spatial geography approach. The research applied various geography themes, particularly location, place, and region, to approach and analyze the problem. Primary and secondary data were used, with primary data collected through field observations of landforms, rock types, and river water quality. Systematic sampling was used to determine sample locations during field observations. The Opak and Progo watershed areas were divided into a 10 x 10-kilometer grid system. The Opak watershed had 11 sample locations, with 5 representing upstream areas and 6 representing downstream areas. Meanwhile, the sample from the Progo watershed was gathered from 24 sample locations, with upstream and downstream areas represented by each 12 samples.

The primary data was supplemented by secondary data obtained through literature studies, remote sensing image interpretation, and documentation. The secondary data includes landform, lithology, river order, and river water quality. The water quality data in the previous two years was obtained from the Serayu-Opak River Basin Center (BBWS) and the Yogyakarta Environmental Agency. The landform data was obtained from the DEM SRTM and Indonesian Rupabumi Map, while the lithology and river order data were garnered from the Geological Map and Indonesian Rupabumi Map, respectively. Meanwhile, for the variables, this study examined different aspects of the watershed, such as landform, lithology, river order, and river water quality. During field observations for measurement and sampling, various instruments were utilized, as presented in Table 1.

The collected data were analyzed using scoring, matching, and statistical analyses, such as independent sample t-tests and ANOVA, along with descriptive analysis considering various geographical themes. This descriptive analysis addressed the first objective, which pertains to the physical geographic characteristics of the Opak and Progo watersheds, as well as to formulate recommendations for future development based on the evaluation results. Meanwhile, the suitability of the Opak-Progo watershed as a natural laboratory for geography experiential learning (EL) was assessed using a combination of scoring, matching, and statistical analysis.

Table 1. Instrument for Field Observation

No	Data	Instrument
1	Landform	GPS, observation sheet, digital camera, Abney level, yallon, roll meter, geological compass
2	Type of rock	GPS, geological hammer, geological compass
3	Water quality	1.5-liter sample bottle, multiparameter meter, water pH meter, TDS meter, GPS, digital camera

The initial stage of the analysis involves scoring. Studies have emphasized the importance of prioritizing locations with diverse conditions for geography fieldwork (Lambert & Reiss, 2016; Meksangsouy, Nipithwittaya, & Losiri, 2020; Sugiharyanto, 2007). Accordingly, this study developed a scoring instrument that covers various geographic variables for the watershed, as shown in Table 2, with a higher score indicating more significant potential. A matching analysis was performed to test the suitability between the watershed's potential and the geography learning standards. The analysis compared the physical geography condition data with the geography learning content standards mandated in Regulation of the Minister of Education, Culture, Research and Technology Indonesia Number 7 of 2022, which concerns content standards in early childhood, primary, and secondary education. The last step was performing statistical analysis to assess the variability of potential between upstream and downstream areas in both watersheds. Independent sample t-test analysis was conducted to determine the difference between upstream and downstream areas in each watershed, while ANOVA was used to test the variation among all locations included in this study.

Table 2. Scoring of Potential based on Geography Variable

No	Variable	Score		
		3	2	1
1	Geomorphological			
	Landform	>3 land form unit	2-3 landform unit	1 landform unit
	Geomorphic processes	>3 process	2-3 process	1 process
2	Geological			
	Geological structure	Combination of various types	2 types of structure	Not vary
	Lithology	>3 types	2-3 types	1 types
3	Meteorological (largest range)			
	Air temperature	Difference >5^0C	Difference 3-5^0C	Difference <3^0C
	Relative air humidity	Difference >50%	Difference 10-50%	Difference <10%
4	Hydrological (Water quality criteria using the largest range)			
	River order	variations >3 river order	variations 3 river order	No variation
	River water variation	Difference >4^0C	Difference 2-4^0C	Difference <2^0C
	DO of the river water	Difference >2 ppm	Difference 1 – 2 ppm	Difference <1 ppm
	pH of the river water	Difference >2	Difference 1-2	No variation

No	Variable	Score		
		3	2	1
	EC of the river water	Difference >50 µS/cm	Difference 10-50 µS/cm	Difference
	TDS in the river	Difference >50 µS/cm	Difference 10-50 µS/cm	Difference <10 µS/cm
	TSS in the river	Difference >10 ppm	Difference 5-10 ppm	Difference <5 ppm
	BOD in the river	Difference >2 ppm	Difference 1 – 2 ppm	Difference <1 ppm
	COD in the river	Difference >10 ppm	Difference 5-10 ppm	Difference <5 ppm

2.2. Research Location

The research was conducted in the Opak and Progo watersheds, located on the border between Central Java Province and the Special Region of Yogyakarta, Indonesia. The Decree of the Minister of Public Works of the Republic of Indonesia Number 590 of 2010, concerning the Water Resources Management Pattern of the Progo-Opak-Serang River Basin shows that the Opak watershed area is mainly located in the Special Region of Yogyakarta (88.88%), with a small portion in Central Java Province (10.12%). Conversely, the Progo watershed area is mostly situated in Central Java Province (70.54%), with a small part in Yogyakarta (10.12%). The Opak watershed covers an area of 737.68 km^2, while the Progo watershed comprises 2,421 km^2. The main river in the Opak watershed is 65 km long, while the length of the Progro watershed is 138 km, as illustrated in Figure 1.

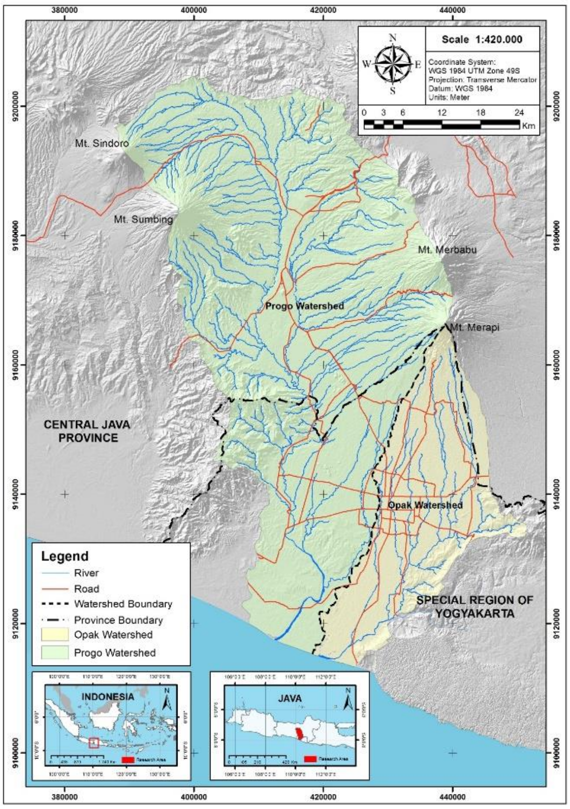

Figure 1. Opak-Progo Watershed Area

Both watersheds have a tropical monsoon climate with two seasons of dry and rainy. Although the rainfall in both watersheds is similar, the larger catchment area of the Progo watershed results in a more significant stream discharge compared to the Opak watershed. At the downstream of the Progo watershed, the central river discharge reaches 58.50 m^3/second, while at the downstream of the Opak watershed, it is 12.35 m^3/second. Further, both watersheds are dominated by volcanic products, with stratovolcano landforms overtop most of the area. Aside from the stratovolcanoes, there are also structural-denudational mountains composed of lithologies resulting from older volcanism, illustrating the dominance of volcanism in geological aspects. The plain areas formed by fluvial-volcanic processes are also filled with volcanic products.

3. Results and Discussion

3.1. Characteristic of Opak Progo Watershed

The Opak and Progo watersheds present complex physical conditions, including geomorphological, geological, hydrological, and climatic aspects. This geographical complexity offers the potential as a natural laboratory for experiential learning, particularly for geography lectures and research. The physical characteristics of the Opak and Progo watersheds are described in the following section, covering geomorphology, geology, hydrology, and climate.

The Opak and Progo watersheds contain a variety of landforms, including volcanic, structural, denudational, fluvial, marine, and eolian. The volcanic landform dominates the upper reaches, as characterized by composite volcanic morphology in the form of a cone with concave slopes consisting of several morphological units bounded by slope notches. Verstappen (2013) explains that strato-volcanic morphology typically comprises three distinct parts: an upper section composed of lava material, a middle section composed of pyroclastic material, and a lower section composed of lava flows.

The Opak and Progo watersheds are home to several strato volcanoes, including Merapi, Merbabu, Sumbing, and Sindoro Volcanoes. Merapi Volcano is located in the upper reaches of the Opak watershed and slightly upstream of the Progo watershed and one of the most active volcanoes in the world during the Holocene Period (Ashari, Purwantara, et al., 2021; Lavigne, Thouret, Voight, Suwa, & Sumaryono, 2000; Sudradjat, Syafri, & Paripurno, 2010). Additionally, Merapi has been active for approximately 10,000 years and continues to erupt regularly, with an average interval of 1-7 years (Andreastuti, Newhall, & Dwiyanto, 2006; Newhall et al., 2000). To date, Merapi has experienced more than 80 eruptions, some of which have been large eruptions with a scale of 4 VEI (Gertisser, Charbonnier, Keller, & Quidelleur, 2012).

In comparison to Merapi, the three other strato volcanoes, Merbabu, Sumbing, and Sindoro, are relatively less active. These three volcanoes occupy the upper part of the Progo watershed. According to the Basic Volcano Data from the Center for Volcanology and Geological Disaster Mitigation, Merbabu Volcano is classified as type B. It has been inactive for a long time, causing denudation on its slopes. A similar condition has also been observed in the Sumbing Volcano, which has a perfect cone morphology, with significant valley deepening in its slope due to strong denudation by exogenous processes. In contrast, Sindoro Volcano has a more recent eruption history than Merbabu or Sumbing, but it has a much lower activity level than Merapi.

The volcanic activity in the Opak and Progo watersheds has significantly impacted the development of landforms. Despite their past activity, the Merbabu and Sumbing volcanoes carry a crucial role in the evolution of the landforms around the Borobudur area, transforming lakes from the Pleistocene Period into present-day plains (Gomez et al., 2010; Murwanto, Gunnell, Suharsono, Sutikno, & Lavigne, 2004; Murwanto & Purwoarminta, 2015). Interestingly, this landform development determines the development of human settlements, highlighting the significance of human-environment interaction in geography (Ashari, 2022). The upper Progo Valley's landforms were shaped by the volcanic activity of Sindoro, which also left traces of its eruption exposed in the Liyangan area (Tanudirjo, Yuwono, & Adi, 2019). Meanwhile, for Merapi, its vulcanic activities affect the formation of landforms across a broad region, including Borobudur and Yogyakarta, as well as the fluviovolcanic plains that emerged to fill the Bantul graben (Bronto, Ratdomopurbo, Asmoro, & Adityarani, 2014; Mulyaningsih et al., 2006; Newhall et al., 2000; Sutikno, LW, Kurniawan, & Purwanto, 2007).

Aside from the volcanic landform, there are denudational mountain landforms in the Progo watershed. Bemmelen (1949) and Pannekoek (1949) identified these mountains as having a dome structure morphology, with volcanic rock cores remaining from the activities of three old volcanoes. However, due to strong erosion by exogenous processes, the existing structure is not easily identifiable, thereby, it is categorized as a denudational landform. Meanwhile, different condition is observed in the Opak watershed. The mountainous Baturagung Block in this area clearly displays a fault structure, categorizing it as a structural landform. Meanwhile, the downstream areas of both watersheds contain landforms resulting from marine, fluvial, and eolian processes. The Opak watershed exhibits various landforms. Further, the Estuarine areas are occupied by marine landforms, the main river valleys contain fluvial landforms, and the lower reaches of the Opak watershed exhibit eolian landforms.

Geologically, volcanism becomes the dominant geological process in the Opak and Progo watersheds. Volcanic materials from the stratovolcanic activities of Merapi, Merbabu, Sumbing, and Sindoro, as well as from other older volcanic activities with limited distribution, are widespread in the upstream area. Even denudational and structural mountains are mostly composed of rocks from ancient volcanism.

The quaternary volcanic activity from the four stratovolcanoes in the Opak and Progo watersheds has formed aquifers with high groundwater potential. Further, the volcanic activity from Merapi has even resulted in a highly potential aquifer with immense groundwater discharge (Sutikno et al., 2007). Its coverage area is not limited to the cone of Merapi but also extends to the south, forming the Yogyakarta groundwater basin (Santosa, 2016). The groundwater potential in this area is closely tied to the high rainfall in the volcanic cone region, which serves as a source of groundwater input. Additionally, the high infiltration rate in the area allows a significant amount of water to be absorbed into the aquifer (Purwantara, Ashari, & Ibrahim, 2020). Meanwhile, numerous springs are found in the vicinity of the volcanic cone, with varying distribution patterns (Ashari, 2014; Ashari & Widodo, 2019; Ervin et al., 2022; Ratih, Awanda, Saputra, & Ashari, 2018; Wardoyo & Khotimah, 2021). Besides, the Opak and Progo watersheds contain numerous tributaries, many of which have perennial flow rates. Despite reduced flow discharge during the dry season, some rivers still flow at their peak (Ashari, Purwantara, et al., 2021; Sutikno et al., 2007).

3.2. Potential of Opak-Progo Watershed as Natural Laboratory for Geography Experiential Learning

A scoring and matching analysis was conducted to evaluate the potential of the Opak and Progo watersheds as natural laboratories. The analysis was carried out in four locations: Opak Upstream, Opak Downstream, Progo Upstream, and Progo Downstream. The sample locations were determined using the systematic sampling method, which employs a grid system measuring 10 x 10 kilometers. In the Upper Opak area, there were five sample locations: six in the Lower Opak, 13 in the Upper Progo, and 11 in the Lower Progo, as illustrated in Figure 2. Scoring was carried out based on 15 criteria, as listed in Table 2. The maximum score achievable is 45, while the minimum is 15. The scoring results are divided into three categories, including low, medium, and high potential.

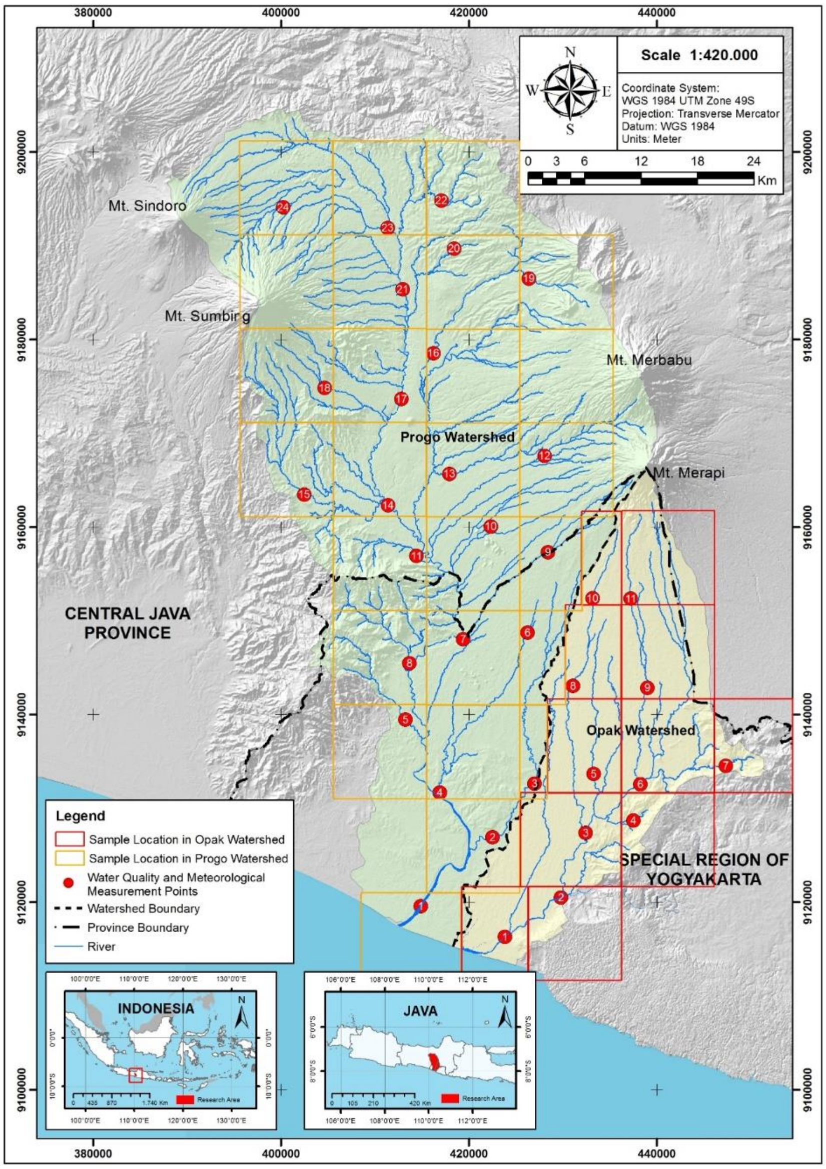

Figure 2. Location of observation samples in Opak and Progo watersheds

The garnered scores indicate varies potential from the Opak and Progo watersheds, ranging between low, medium, and high. The low potential is generally indicated by only one type of landform and little variation in lithology, meteorological conditions, and water quality. Medium potential is generally found in rather varrying landforms and lithology, meteorological conditions, as well as water quality. Meanwhile, the highly potential area is typically characterized by a wide variety of landforms, geomorphic processes, and varied meteorological conditions, as well as complex lithologies and varying water quality across parameters. Among five sample sites, four were categorized as having low potential with scores ranging from 21-24, while only one site, Opak 1, was categorized as having medium potential with a score of 27. In the Upper Opak area, four sites scored in the medium category (26-27), and only two scored in the low category (24-25), which is slightly different from the Lower Opak. In general, there are no areas in the Opak watershed that fall into the high category. Therefore, the upstream area has more potential than the downstream area due to the presence of more sites with medium potential.

In contrast, the Progo watershed presents different results. In the Lower Progo, we observed four sites classified as high (score 31-32), four as medium (score 26-29), and three as low (score 24-25). In contrast, the Upper Progo area had five sites classified as low (score 22-25), six as medium (score 26-28), and only two as high (score 31). In general, the Progo watershed offers more significant potential than the Opak watershed. The region encompasses locations with high potential for development, particularly in the downstream area. This area presents complex geography, positioning it as a suitable natural laboratory for the EL model in geography learning.

The scoring analysis results indicate that the Upper Progo area has the most varied conditions, as suggested by the highly variation ranges of scores in comparison to other areas. In contrast, the Upper Opak area has the most homogeneous conditions, as indicated by the smallest range of scores. This extensive range of scores implies a significant variation between sample sites, indicating the complex geographical conditions potentially becoming EL natural laboratory. Table 3 presents the results of the scoring analysis, while Figure 3 shows the score range in all four areas.

Table 3. Results of Scoring Analysis on the Potential Development in Four Areas

Area	N	Mean	Median	SD	Max	Min
Opak Upstream	6	25,67	26	2,93	27	24
Opak Downstream	5	23,8	24	2,17	27	21
Progo Upstream	13	26,38	26	2,87	31	22
Progo Downstream	11	28	28	2,93	32	24

The statistical analysis revealed an alluring finding. The ANOVA analysis results indicated no differences in the assessment results across all four areas. Additionally, there were no significant differences in the scoring results between the upstream and downstream areas of the two watersheds. This suggests that the entire area has the potential to be developed as an experiential learning nature laboratory. However, it is essential to prioritize areas with high scores, while the absence of significant differences suggests that all areas have equally attractive potential and characteristics for EL-based learning.

Figure 3. Distribution of Assessment Scores in Four Areas

3.3. Recommendations for the Development of Experiential Learning Nature Laboratory

As described previously, all of the research locations offer the potential to be developed as EL geography natural laboratories. However, specific locations with the highest score should be prioritized for development. The six locations that received high scores in the scoring analysis are located in the Progo watershed area, specifically locations 1, 2, 4, 7, 11, and 15.

In formulating recommendations for development, a matching analysis between the conditions in the six locations in the Progo watershed and the standard geography learning needs at the high school level was carried out. As mandated in the Regulation of the Minister of Education, Culture, Research and Technology of Indonesia Number 7 of 2022 concerning Content Standards in Early Childhood Education, Basic Education, and Secondary Education, the content standards for geography subjects in high school cover geospheric phenomena. In specific, the geography learning material focuses on the impact and use of geospheric phenomena in daily life.

To develop an EL natural laboratory, it is necessary to have objects faciltating observation and measurement of the lithosphere, hydrosphere, and atmosphere. The lithosphere aspect should include rock types, geological structures, and landforms. The hydrosphere aspect should consist of river flow and water quality. Meanwhile, the atmospheric element should cover air temperature and air pressure, which can vary between locations. Later on, in each of these locations, students are instructed to make empirical observations and measurements. During the learning, field activities are designed to provide hands-on experience and enhance understanding of the concepts learned, in accordance with the experiential learning principle. The resulting data were further analyzed and evaluated.

The matching results of the physical conditions at locations 1, 2, 4, 7, 11, and 15 show that all of these points enable observation and measurement of physical aspects. However, in locations 11 and 15, measurement of river flow discharge is impractical due to fluctuations between dry and rainy seasons. Although with several limitations, the development of natural laboratories on these points remains feasible. Additionally, Table 4 shows recommendations for development at each location.

Table 4. Recommendations for EL Natural Laboratory Development Opak-Progo Watersheds

No. Location	Name of Areas	Characteristics	Potential for Development	Recommendation for Experiential Learning Activities
1	Downstream area of Progo River, Srandakan Sub-district, Bantul Regency	The downstream area of the Progo River has a large flow discharge, flat topography, and a wide river valley	Lithosphere: Observation of alluvium material Observation of fluvial processes Hydrosphere: River flow discharge measurement River water quality measurement Atmosphere: Air temperature measurement Air pressure measurement Measurement of wind speed and wind direction Air humidity measurement	Make observations of rocks, land morphometry, and geomorphic processes Measuring river flow discharge with the floating method Measuring water quality with multiparameter meter instruments Measuring air temperature, air pressure, air humidity, and wind
2	Downstream area of Progo River, Pandak Sub-district, Bantul Regency	The downstream area of Progo River has tributaries with moderate flow discharge, flat topography	Lithosphere: Observation of alluvium material Observation of fluvial processes Hydrosphere: River flow discharge measurement River water quality measurement Atmosphere: Air temperature measurement Air pressure measurement Air humidity measurement	In general, the activities capable of being carried out in this area are similar to the activities in location 1 due to the relatively similar characteristics of the area. Wind measurements could not be taken due to many vegetation obstructions.
4	Confluence of Krasak River and Progo River, Tempel Subdistrict, Sleman Regency Area	The meeting area of the two rivers has undulating relief, positioned in the area of the Tinalah River with moderate discharge and relatively calm flow.	Lithosphere: Observation of volcanic breccia rock alluvium material Observation of Progo fault Fluvial process observation Hydrosphere: River flow discharge measurement River water quality measurement Atmosphere: Air temperature measurement Air pressure measurement Air humidity measurement Wind measurement	Observe the types of rocks resulting from volcanism in the past Observe erosion and sediment deposition by fluvial processes Measure river flow discharge using the floating method Measure water quality with a multiparameter meter instrument Measure various weather elements

No. Location	Name of Areas	Characteristics	Potential for Development	Recommendation for Experiential Learning Activities
7	Confluence of Krasak River and Progo River, Tempel Subdistrict, Sleman Regency Area	The meeting area of the two rivers has flat relief, positioned around the confluence of the Krasak and Progo Rivers	Lithosphere: Observation of lava material from the eruption of Merapi Volcano Observation of breccia and conglomerate rocks Observation of sediment deposition Fluvial process observation Hydrosphere: River flow discharge measurement River water quality measurement Atmosphere: Air temperature measurement Air pressure measurement Air humidity measurement Wind measurement	Observe the characteristics of lava material from the eruption Observe the process of sediment deposition by the fluvial process Observe the transport of river material as bed load and suspended load Measure river flow discharge with the floating method Measure water quality with a multiparameter meter instrument Measure various weather elements
11	Borobudur Basin Area, Borobudur Sub-district, Magelang District	Borobudur Basin Area, flat topography bordering the slopes of the Menoreh Mountains	Lithosphere: Observation of volcanic breccia rocks from ancient eruptions Observation of river erosion process Observation of black clay lacustrine sediments Observation of ancient rivers and ancient lakes Observation of structural landforms Hydrosphere: River flow discharge measurement River water quality measurement Measurement of water quality of saltwater springs Spring discharge measurement Atmosphere: Air temperature measurement Air pressure measurement Air humidity measurement	This area facilitates relatively complete activities, including: Observation of ancient volcanic eruptions, ancient Borobudur lake, and ancient river valleys Paleogeomorphological studies Measurement of river flow discharge using the manning method Measurement of river water quality Measurement of water quality of saltwater springs Measurement of spring discharge by volumetric method Measurement of various weather elements except wind

No. Location	Name of Areas	Characteristics	Potential for Development	Recommendation for Experiential Learning Activities
15	Sumbing Volcano Foothills, Kaliangkrik Sub-district, Magelang District	East Sumbing Volcano Foothills, hilly relief	Lithosphere: Observation of the volcanism process Morphometric measurement of valley deepening Observation of the erosion process Observation of various types of erupted materials Hydrosphere: Measurement of river flow discharge Measurement of river water quality Atmosphere: Air temperature measurement Air pressure measurement Air humidity measurement	Identify the characteristics of volcanic landforms Observe the process of erosion and valley deepening Identify the past eruption process based on the type of material present: tuff, lava, lahar, pyroclastics Measurement of river flow discharge using the manning method Measurement of river water quality Measurement of various weather elements except wind

David Kolb's experiential learning model defines that the learning process consists of five stages, namely (1) experience/exploration, (2) sharing/reflecting, (3) processing, (4) generalizing, and (5) application (Arent & Thesalonika, 2023). During the experience stage, students are required to measure and observe various physical aspects. In the following stage, students share the results obtained from these measurements and observations to inform other students about the events that occurred at the observation location. In the processing and analysis stage, they are instructed to identify the primary and typical characteristics or findings of the observation location to determine the significance. Meanwhile, during the generalizing stage, students are expected to interpret the findings based on the basic theory of physical geography. In the final stage, students are required to design practical applications of their findings in everyday life.

Experiential learning (EL) has been commonly practiced, including in geography learning. EL learning is derived from real-life experiences, thereby, providing opportunities for students to enhance their experience in applying theoretical concepts and analytical tools to address real problems and develop solutions and recommendations. This model supports critical thinking, problem-solving, and inquiry (Ives-Dewey, 2009).

The primary features of this EL model are centered on student learning and process-based activities, where students actively engage in the learning experience. It focuses primarily on understanding problems and potential solutions rather than memorization. EL is a part of experiential education, a process by which learners construct knowledge, skills, and values from direct experience. This learning model takes many forms and names. Experiential learning encompasses problem-based learning, fieldwork activities, and projects commonly used in geography lessons (Ives-Dewey, 2009).

The available studies reported that the EL model has been successfully applied to undergraduate geography learning (Elwood, 2004; Ives-Dewey, 2009; McPhee & Przedpelska, 2018). With the widespread use of out-of-class geography learning at the high school level in

Indonesia, the implementation of this learning model in Indonesian high schools is highly feasible. Additionally, this model has been proven to improve geography mastery in many countries. This model has also been reported to promote students' self-development in transferable skills, including communication, interpersonal relationships, self-management, creativity, decision-making, problem-solving, field observation, and interpretation of evidence. Furthermore, the adoption of this learning model also fosters personal qualities such as confidence, initiative, independence, determination, and imagination (Ives-Dewey, 2009; Mellor, 1991).

Elwood (2004) suggests that experiential learning is highly suitable for geography learning, particularly through field exploration. Geography learning requires practical application, referred to as 'return to the field.' Therefore, for effective implementation of experiential learning, the identification of a representative location for a nature laboratory is necessary. Prior to implementing this model, it is important to assess the feasibility of the Opak and Progo watersheds as natural laboratories for this learning model.

The exploration and evaluation of the watershed area as an EL natural laboratory serves as an effort to provide a suitable learning area for the geospheric phenomena related to physical geography. This area should be designed in accordance with the learning objectives. In the research conducted by Elwood (2004) in the 'Explore Chicago' program, the learning area includes the city center and popular tourist destinations. In contrast, McPhee and Przedpelska (2018) focused on the cultural and population landscape when exploring the Lake William region, with the location being determined based on the learning topic. Further, Mellor (1991) described that the selected location must be representative of fulfilling cognitive, affective, and psychomotor aspects. Based on this, the site selection and activity recommendations were organized as shown in Table 4.

In general, our analysis results suggest that the watershed area is suitable for experiential learning (EL). However, the study conducted in the Opak-Progo watershed reveals that several areas are not equally suitable for EL implementation. In specific, the areas with geological, geomorphological, climatic, and hydrological complexity have the highest potential. These areas offer the complexity that enables the delivery of physical geography materials, including the lithosphere, hydrosphere, and atmosphere. The Progo River's downstream area offers opportunities to study fluvial processes, alluvium deposition, river water discharge, and quality, as well as meteorological characteristics of the lowlands. Additionally, the confluence of two rivers provides a chance to examine differences in water quality, geomorphic processes, and transported materials based on differences in their catchment areas. The Borobudur Basin area offers unique potential for paleogeomorphological studies due to its hydrological and meteorological characteristics typical of basin areas. Similarly, the Sumbing Volcano Foothills Area has the potential for studying the process of volcanism, as well as the discharge and water quality of upstream areas, and the meteorological characteristics of high-elevation areas.

In comparison to other available studies, this study presents novel contributions to the development of natural laboratories for EL implementation. The study from Ashari, Wardoyo, Jamaludin, Kharisma, and Rosa (2021) focused only on one landform, volcanoes, in their study at Galunggung Volcano. The study objects developed in the area also focus on the lithosphere and biosphere. Meanwhile, Ashari (2022) expanded the research by creating zoning based on function, including study, research, and community services. However, they did not provide examples of implementing natural laboratories for learning based on specific learning models. Fadjarajani and As' ari (2021) explored the landscape area and drew a number of recommendations for geography learning focusing on physical and human aspects, including improving spatial thinking skills. However, they did not provide a specific learning model. Therefore, this study fills that gap by presenting the analysis on a more complex landscape. Compared to previous studies, this study offers more comprehensive insights and specific recommendations for implementing EL in each potential location.

4. Conclusion

Experiential learning is crucial in geography education, with field study serving as the most applicable model for this learning. Accordingly, to support the successful implementation of this model, exploration of the potential area for a natural laboratory is necessary. This study conducted in the Opak and Progo watersheds has identified six most potential locations for the development of natural laboratories. These locations are located in the Progo watershed. These areas have been observed possessing characteristics for various geography observation and measurement activities. In addition, this study has successfully identified and evaluated the feasibility of implementing EL in these sites, concluding that several areas present higher potential than others. Further studies are recommended to design the implementation of various forms of EL in these locations, such as projects and problem-based learning. Meanwhile, users should adjust to the objectives and expected learning outcomes in their respective educational institutions.

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