Indonesian Society for Science Educators

Journal of Science Learning

journal homepage: ejournal.upi.edu/index.php/jslearning

Effects of Soil Textures, Soil Settlements, and Soil Water-Holding Capacity on Landslides: An Experimental Study for Science Teachers

Donna Hembra Gabor[1]*

[1]Division of Physical Sciences and Mathematics, University of the Philippines Visayas, Philippines

*Corresponding author: dhgabor@up.edu.ph

ABSTRACT Experimentation is a contributing factor to the interest and meaningful learning of Science. In Geology and Earth Science, the effects of soil textures, settlements, and water-holding capacity are parameters for landslides in Barotac Viejo and other flooded areas. Landslides are triggered during heavy rainstorms, causing severe property damage and casualties. This experimental study aims to determine how these parameters are factors for landslides and give accurate information to Science teachers. The study uses two methods to provide ease and continuity of measurements and settings using the Fourier Transform Infrared(FTIR) spectroscopy in analyzing the soil textures. The Imhoff cone instrument is for the settling and water-holding capacity of the soil. FTIR Soil analysis reveals that contents of clay and organic matter directly affect soil water-holding ability due to the larger surface area. A landslide-prone zone has a lesser settling time except for the sand that settles fastest due to larger masses. This study is crucial for science teachers teaching geology and earth sciences besides forecasting and preventing geohydrological processes and developing better landslide warning strategies to mitigate risks and reduce socioeconomic damage.

Keywords Landslide, FTIR soil analysis, spectroscopy, Imhoff cone, Teacher's Learning

1. INTRODUCTION

Teaching geology and earth science courses are difficult for secondary teachers who are not in an experimental study. Information from this research is only for teaching resources and materials in earth science and geology that can help teachers and students.

Landslides are one of the world's geohazards that threaten both exposed areas in urban and rural areas and cause severe consequences on human lives and economic losses. Due to climate change, there is an increase in the frequency and intensity of heavy rainfall along with a shift of locations and recurrence of heavy rain that increases landslide risk in landslide-prone areas. Expansion of urban areas due to population growth, redevelopments of mountains, and shortening of the coastal area caused by roads and railways constructions and deforestation increase exposure to the landslide hazard (Pajalic et al., 2021). There are so many factors that cause landslides to happen. One factor is soil quality which includes its physical and chemical properties. Second, is the soil water holding capacity and settling ability. Lastly, the angle of elevation can be evaluated statistically and interpreted.

A landslide refers to a soil mass's slow or rapid downward movement due to gravity. It is triggered when the shear stresses developed inside the soil exceed those which can resist. Landslides are caused by the liquefaction of small grain silt sand layers or due to a general failure in combination with increased loads due to an earthquake, increased pore pressure, and reduction in the available shear strength of the soil. In particular, Panay island is prone to typhoons, storm surges, and flash floods which constantly suffer from the effects of the outbreak of such destructive phenomena. For this reason, it is necessary to monitor the sources of landslides, and the mechanisms they present, to proceed with the analysis of stability and the calculation of safety factors (Dariagan, Atando & Asis, 2021).

On the other hand, the soil is a heterogeneous system, an upper layer of earth in which plants grow, a black or dark brown material typically consisting of a mixture of organic remains, clay, and rock particles. Soil mechanisms and processes are complex and back-breaking for you to be understood and require analytical techniques. Some traditional methods describe the relationship between soil properties such as physical, chemical, and its main soil

Received: 14 January 2023
Revised: 25 May 2023
Published: 5 July 2023

components. Simple and accurate soil testing procedures in the field and laboratory are necessary for advanced research in landslide monitoring. (Mohamed, Saleh, Belal & Gad, 2018). The Fourier transform infrared (FTIR) spectroscopy is a unique tool for mineral and organic components of soil samples. The FT Infrared spectroscopy offers a sensitive characterization of minerals and soil organic matter (SOM) and mechanistic and kinetic aspects of mineral–SOM interactions that underlie biogeochemical processes (Margenot, Calderón, Goyne, Mukome & Parikh, 2017). FTIR spectroscopy has been used in advanced research in soil composition properties for characterizing soil mineral components, including mineral identification, structural assessment, soil quality, and in situ monitoring of pedogenic processes (e.g., mineral formation) for landslide monitoring (Margenot, Calderón, Goyne, Mukome & Parikh, 2017).

Also, the Imhoff cone tests for soil-settling and water-holding ability estimate erosion ranging from loam to loamy sand in texture as a predictor of soil erosion and sediment concentration affecting land fields and human livelihood (Sojka, Carter & Brown, 1992).

The soil water-holding ability depends on precipitation patterns and holding capability. Changes in weather or region precipitation patterns and the amount of water a soil can hold cause a landslide. The holding capacity of water within the pores of soils depends on capillary action and the size of the pores between soil particles. Sandy soils have large particles and large pores that do not have a sizeable ability to hold water making sandy soils drain excessively. Clay soil has small particles and pores that can hold water that tend to have a high water-holding capacity (Margenot, Calderón, Goyne, Mukome & Parikh, 2017).

This research study aims to determine how parameters like soil textures, soil water holding capacity, and settlement ability are factors for landslides and uses the results to give information to geology and earth science teachers. In this study, the researcher used two processes; where first is the development of methods to identify landslide parameters through FTIR spectroscopy and Imhoff cone to test soil textures, soil settlements, and soil water-holding capacity. The second process is to use these results to teach geology and earth science, particularly in landslide monitoring. The first process divides into two methods; the use of FTIR Spectroscopy for soil textures and the second is the Imhoff cone for soil settling and holding capacity. In the first method, the Fourier transforms infrared (FTIR) spectroscopy analyzes soil components to provide accurate and valid identifications of soil components investigated. It aimed to identify soil components to ensure that the soil tested in the laboratory is also a factor for soil erosion leading to landslides. The use of the Imhoff cone for the settling and water-holding capacity of soil to test how much the soil samples can hold water. Using 1000 milliliter (mL) of water to the five soil samples for settling sediment and 250 mL for water-holding volume capacity with the Imhoff cones. These samples with different textures came from places in the flooded area in Iloilo province as soil sediment material.

The researcher's additional aim is to provide correct information to science teachers through this experimental approach and the ability to develop a module for landslide parameters.

1.1 Experimental Approach in Teaching Sciences

Incorporating technology into science courses is becoming a practice in universities, particularly in the experimental approach to science teaching, where technology is part of teaching work in any educational institution. However, it is hard in geosciences to find technology that can carry a role between the experimental method and the traditional classroom setting. FTIR spectroscopy and IMhoff cones are ideally suited to bridge this gap. Here, I fully integrate the FTIR spectroscopy and Imhoff cones as an educational tool for graduate-level K–12 in-service teachers who teaches earth science and geosciences with the developed experimental approach in a classroom setting for the student to understand landslide parameters. The researcher has established classroom course objectives and integrates technology through procedures that entail hands-on activities that engage and motivate students to learn in the geoscience classroom. I assess the impact of this experimental approach on teachers teaching in these courses through the surveys that developed the ability of students to analyze and solve problems and improve innovation for the teachers. The experiment provides a simple and engaging framework for familiarizing teachers with landslide parameters through a developed procedure with FTIR spectroscopy and Imhoff cone. Also, the researcher shows how experiments give accurate information to the teachers in the classroom environment.

According to Soares, de Campos, Thomaz, da Cruz Pereira & Roehrs (2016), the existence a set of factors that hinder the learning of science teaching; not only teachers being responsible but also a lack of interest, a lack of laboratories, overcrowded classrooms, school infrastructure, among many other factors. To lessen this problem in any institution, teachers should learn an experimental approach that motivates and seeks students' interests that relate to their daily life. Science teachers used experimentation to arouse interest among students in various levels of learning. Students attribute the experimental approach as a motivating character that increases learning ability and permits them to involve in the topics addressed during theoretical classes based on the experimental results.

With the occurrence of non-significant learning, the COVID-19 pandemic and other related issues help curriculum planners and supervisors analyze the importance of giving accurate information to teachers through an experimental approach. Therefore, with experimentation dedicated to the fundamental level, students will be provided with a better and more concrete base in science education as an attempt to introduce students to advanced laboratory approaches in learning natural sciences, geology, and earth sciences.

1.2 Transform Infrared (FTIR)Spectroscopic Analysis of Soil Textures

In recent decades, most studies have focused on soil components like organic matter, texture, and mineralogy (Hassani, Bahrami, Noroozi & Oustan, 2014). Nandiyanto, Oktiani & Ragadhita (2019) stated that Fourier transforms infrared (FTIR) is one of the advanced analytical techniques for researchers to characterize samples in liquids, solutions, pastes, powders, films, fibers, and gases. FTIR analysis is also for analyzing the material on the surfaces of the substrate that is rapid, accurate, and relatively sensitive (Jaggi & Vij, 2006). In the FTIR procedural analysis, samples with infrared (IR) radiation affect atomic vibrations of molecules that result in the specific absorption and transmission of energy, making the FTIR determines specific molecular vibrations contained in the sample. The infrared (IR) spectrum has three wavenumber regions: far-IR spectrum (<400 cm-1), mid-IR spectrum (400-4000 cm-1), and near-IR spectrum (4000-13000 cm-1). Mid-IR is the most widely used in the sample analysis, but the far- and near-IR range also provides information about the samples analyzed. In this study, the researcher used the mid-IR wavelength that is into four regions; the single bond region (2500-4000 cm-1), the triple bond region (2000-2500 cm-1), the double bond region (1500-2000 cm-1), and the fingerprint region (600-1500 cm-1).

In imaging spectroscopy, the spectroscopic modes emitted electromagnetic energy from a light source collides with the given phenomenon, light rays were absorbed, reflected, and the other part passed through it. Spectroscopy is a quantitative calibration of reflection, absorption, or passing. One of the advantages of Fourier transforms infrared spectroscopy is that this is a non-destructive technique with no hazard or destruction to the environment (Guerrero, Viscarra & Mouazen, 2010). Fourier transforms Infrared spectroscopy is for farming and environmental studies on soils within two visible and infrared ranges. In addition, infrared spectroscopy may also provide for specifying various soil components. Most studies have shown that soil spectral reflectance is affected by soil properties like humidity, texture, structure, and quantity of organic matter (Soriano-Disla, Janik, Viscarra & Macdonald, 2014). The soil spectral reflectance is within visible and near-infrared (NIR) ranges at wavelengths (350-2500 nm) (Iurian & Cosma, 2014).

Of other important soil properties, which affect the quantity of the given spectral reflection, one can refer to the type and frequency of clay minerals, carbonates, hydroxyl groups in water and soil, organic compounds, and iron and aluminum oxides. The reflective spectra may act as a tool in analyzing many soil properties. Organic carbon is one of the foremost soil properties estimated by satellite images and spectroscopic technologies with high precision because of the accumulated organic carbon in the surface layer of soil. This property has various spectral behaviors because of the existing complexity of organic matter (Viscarra, Walvoort, McBratney, Janik & Skjemstad, 2006). The most absorbent characteristics from organic carbon often occur at the wavelengths about 1730 nm and 2330 nm, while the little absorbent is at wavelengths about 1150, 1670, 1765, 2070, 2110, 2140, 2190, 2280, 2310, and 2390 nm. The absorbent bands adjacent to 1400 and 1900 nm may be due to the existing water in organic compounds (Babaeian, Homaee, Montzka, Vereecken & Norouzi, 2015). The carbonate minerals often possess strong absorbent characteristics near 2345 nm and are relatively weaker adjacent to 1860, 1990, and 2140 nm (Viscaraa et al., 2006). Particle size noticeably affects soil spectral behavior as the size of particles becomes sizable with an increase in the light path through soil particles is more absorbed, and reduced reflection leads to spectral curves. In reduction, the size of soil particles increases soil reflectance with faded color minerals like silicates and carbonates. Oxide and hydroxide minerals have small spectral reflectance, and the level of soil spectral reflectance decreases as the size of soil particles decreases (Summers, Lewis, Ostendorf & Chittleborough, 2011). The spectral behavior of soil is a function of its constituent elements, and its chemical components like oxygen, silica, and aluminum lack strong absorbent characteristics within visible and near-infrared ranges. However, the soil's pieces, such as iron oxides, clay, and organic substance, may highly affect spectral curves and absorbent characteristics. The iron oxides influence the reflectance in the visible zones of organic carbon and clay in the infrared zones (Summers Lewis, Ostendorf & Chittleborough, 2011).

In recent research studies, soil chemical properties used spectral reflectance to achieve favorable results related to the soil structures and other components like clay, silt, and organic matter that can estimate by soil spectral data with very high precision (Summers, Lewis, Ostendorf & Chittleborough, 2011). This study used spectral data for the information on soil components present in the area of study for Iloilo Province to monitor the physical and chemical properties of soil in the flooded area.

In general, the findings of other research studies indicate that using soil spectral data may be employed as an indirect technique for the estimation of the physical and chemical properties of soil. The present study only focuses on the area in the province of Iloilo, and properties in other places in the Philippines with different effects on soil's spectral behavior are not part of the study. It also incorporates technology through an experimental approach to promoting student understanding of concepts associated with landslide parameters by geosciences and earth teachers.

1.3 Soil Settling and Water Holding Capacity

During landslides, debris flows are a transport that results in large amounts of material delivered rapidly downstream. It has destructive capabilities because of its high impact force due to the velocities reached and the mass in transit that lifts and carries large objects such as boulders and trees, resulting in fluidization of the surface soil layers (Luino et al., 2022).

Nowadays, the knowledge of the physical and environmental factors influencing landslide activation within the Panay, especially in Iloilo Province, is still lacking and incomplete. Recent studies have investigated soil settling and holding capacities and their relations with landslide occurrence, making this study a source of information and additional information for other researchers. According to Luino et al. (2022), several empirical and physically based approaches define thresholds for hydrological conditions—including rainfall, soil water holding, and settling capacity that results in landslides. Several authors have proposed different methods to identify rainfall thresholds for the possible initiation of landslides where soil can hold. Dariagan, Atando & Asis (2021), the predominant soil types in the region are clay loam of Sta. Rita and Alimodian Series, sandy loam of Sara, Umingan, Louisiana series and clay for Panay Island; Guimbalaon clay, Silay fine sandy loams of volcanic origin for Negros Occidental while for Guimaras, it is Faraon clay, gravely loam, and Sara sandy loam. This type of soil is moderately deep and has a high degree of permeability that has connected pore spaces that allow water to flow from one to another. Low permeability soil has isolated pore spaces that trap waters within them, while in a lump of clay, most pore spaces block the water where it cannot flow easily. Recent studies have only considered rainfall variables as the most vital and easy-to-quantify landslide-triggering factor for the landslide (Dariagan, Atando & Asis, 2021).

Most works find difficulties in correlations between soil water settling and holding capacity and landslide occurrences, especially when the investigation is on warning systems aimed at mitigating the possibly severe consequences and damage to property and population. These works have considered soil water settling and holding capacity as one of several variables for landslide occurrence.

On the contrary, several studies have investigated landslide-conditioning factors, including the activation of mass movements that affect soil water settling and holding capacity. Based on recent research, the researchers presented different simulations and mathematical models to estimate the rainfall conditions that affect settling and water-holding capacity leading to the activation of landslides. Infinite slope stability analysis or modeling of water infiltration dynamics and groundwater pressure in soils causes a landslide (Luino et al., 2022). Places in Iloilo Province (Barotac Viejo, Leganes, Oton, and Miagao) where the researcher conducted three different methods to investigate the occurrence of shallow landslides to mitigate its effect and give accurate information to these communities are the focus of this study.

Based on the works of Alamanis, Papageorgiou, Xafoulis & Chouliaras (2020), the activation of mass movements is due to soil moisture (settling and holding capacity), soil type, and slope acclivity. In this paper, the researcher will present a study based on three methods that use soils from four places in Iloilo Province as data for the possible occurrence of shallow landslides that have occurred in the past, with the aim of (i) identifying the soil properties that most significantly influence the activation of flood and landslides in the study area, (ii) differentiating soil water settling and holding capacity within the study area, (iii) identifying slopes or elevation angle for the possible occurrence of shallow landslides and mud-debris flows in the five different study area, and finally (iv) comparing the soil settling and holding capacity based on Imhoff cone test.

2. METHOD

2.1 Purpose of the Study

The current study wanted to determine how parameters like soil textures, soil water holding capacity, and settlement ability are factors for landslides and uses the results to give information to geology and earth science teachers. Through these, the study wants to develop a module from this experimental approach for landslide parameters that motivate students learning in earth science and geology courses.

2.2 Context of the Study

Barotac Viejo, Oton, Leganes, and Miagao are places in the Province of Iloilo prone to landslide and flooded areas. The researcher tried to improve the landslide monitoring from these areas and give accurate information on how soil textures, soil settling, and water-holding capacity can be parameters of a landslide which was one of the priorities identified by the local government of Iloilo and their respective municipalities. Developing and implementing advanced education for earth science and geoscience teachers' plans incorporating technology through experimental methods was done as the first step of the study.

In the last year of 2022, the Province of Iloilo opened its doors to improve their landslide monitoring and share this information with teachers for learners to know about landslides and floods. The researcher used a hybrid approach, combining experimental methods, modular modality (developed module), technology, and face-to-face classes. Students learned theoretical concepts through the modules provided by teachers, followed up with lectures and skills during face-to-face meetings. This approach allowed students to better understand the lessons and ideas explored to make their learning more relevant. It allowed learners to bridge the gap between the concepts learned through the module and the help offered by the teachers during the short face-face classes. The pilot test has five (5) earth science teachers and additional ten (10) earth science teachers and their respective students from senior high school, with only fifty (50) students participating in this study and taking 1.5 hours of face-to-face classes. The same students went through the modules. These ten teachers are assigned to facilitate face-to-face learning in all phases of the course.

2.3 Developed Module

The researcher developed a module that allowed learners to use this as a self-learning module (SLM) to help the earth science teachers apply the shared information to the learner. Three earth science teachers from the University of the Philippines and two graduate students from the same school who teaches the same course were participants in the pilot testing and as content validators. Teachers went through the developed module and asked for their comments on the content of the module. The module was revised after the collaboration of ideas from the content validators. The revised module was pilot tested on the five teachers and the researcher's students.

The printed module examined students' performance and only resource material in learning landslide parameters of earth science/ geosciences courses. Lessons were delivered via module and assisted and supplemented the teachers' instruction. A series of topics in a module was part of the subject teaching, and students answered the assigned activities in the module. In addition, the module has text and graphics that consists of learning objectives. The content and context of the modules were results from the experimental approach done on the first steps in the research study that promotes critical thinking skills and enhance the core content of the earth science subject with the concepts of landslide parameters used by the teacher to design the content subject.

At the end of each module, students answered a short multiple-choice test to assess their understanding of the key concepts in the module. This assessment verified the student's completion of the unit of study and part of the research-based learning outcome. Students received grades for each module.

2.4 Instrument

After the module lesson went through, students answered survey questions that were administered to science students anonymously from November to December 2022 and after a class discussion of the module as teaching resource materials for the STEM second quarter of the year. The survey included learners' perspectives on the developed module, the experimental method applied, and earth science teaching that incorporates technology instruction that improves learners' performance. It also indicates how helpful teachers facilitate learning of landslide parameters and provide honest feedback on learners' experiences using the experimental method. A total of 50 Senior High School students of UP Visayas participated in the trial and completed the survey based on improvements in actual results. The study took place in the first week of October 2022, the second quarter of face-to-face interaction after nearly two years of distance learning. Pretests, posttests, and survey questions verified how technology instruction and experimental methods improve learners' performances in earth science and geology. The descriptive statistics and T-test analyzed the statistical significance of the various measures in this study.

2.5 Participants

For pilot testing, the participants are the three (3) teachers teaching earth science from the University of the Philippines Visayas, and the two graduate students from Tacurong Sur National High School and Janiuay National High School. For final testing, the sample class was determined using a random sampling technique from the senior STEM classes that attended the earth science and geology course. It was because each student (class) has relatively the same character, academic ability (preliminary test results), access to information (learning modules), and advanced technology (FTIR spectroscopy and Imhoff cone).

The subjects of this study were 50 STEM participants. This study of an experimental learning approach used printed modules, advanced technology, and face-to-face meetings as part of learning materials and data sources that answered the researchers' questions. The characteristics of the participants are in Table 1.

Table 1 Participant's characteristics

	Gender	Frequency	Percent	valid Percent	Cumulative Percent
valid	Male	31	62.0%	62.0%	62.0
	female	19	38 .0%	38 .0%	100 .0
Total		50	100 .0 %		
	Grade Level	**Frequency**	**Percent**	**valid Percent**	**Cumulative Percent**
valid	grade 11	17	34.0%	54.0%	34.0
	grade 12	33	66.0%	66.0%	100 .0
Total		50	100 .0%		

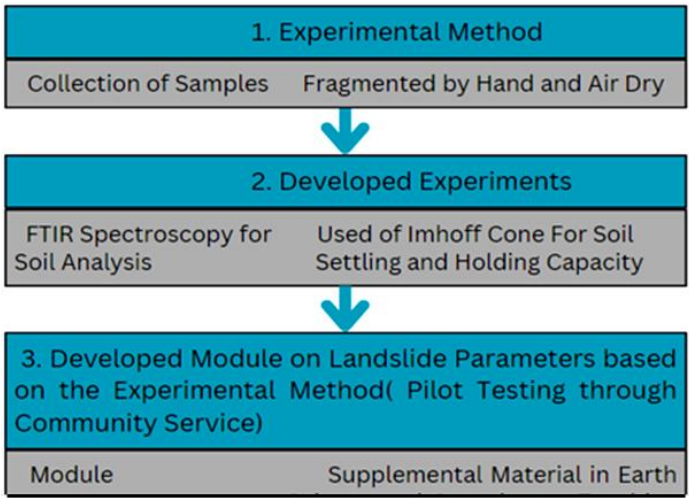


Figure 1 Procedural flowchart of the research study

2.6 Data Gathering Procedure

There were five stages in this research (Fig 1): 1) Experimental Approach, 2) Developed Experimental Procedure, 3) Developed and Validate Module, 4) Revision of the learning module as teaching materials, carrying out a pretest to determine students' prior knowledge; 5) Measuring student-learning outcomes through post-test and analyzing teachers' perceptions from answered survey questions.

First is the experimental approach, which divides into two. The first method is the collection of samples which are fragmented by hand and dried for 14 days, and the second is the soil testing through mid-FTIR spectroscopy. The chosen areas in the Province of Iloilo are prone to landslide areas according to the National Mapping And Resource Information Authority (NAMRIA), particularly in Barangays of Barotac Viejo and flooded areas such as Oton, Leganes, and Miagao. The sand was from UP Visayas Miagao instead of the soil because the Miagao is partly coastal, and most soil has a sand content in that area. The sand and five different soil samples were collected, gently fragmented by hand, and air-dried for ten days without sieving. Figure 2 contains five different soils and sand from flooded and prone landslide areas of Oton, Leganes, Barotac Viejo, and Miagao. Textures and properties of soil were analyzed using Fourier transform infrared spectroscopy. Soil organic matter was determined using the infrared wave ranges. An electronic balance identifies the weight of soil grains from 0.0000 g to 0.0200g.

Second, under the experimental method, samples of each soil were placed in an Imhoff cone with 1000ml running water to test the settling and water holding capacity. The PH paper determines the acidity or alkalinity of a liquid used. For the settling ability in Figure 3, each soil suspension was hand stirred for five minutes then a timer took time for the soil to settle. Each sample and the sand underwent a settling test as one of the parameters for floods and landslides occurrence.

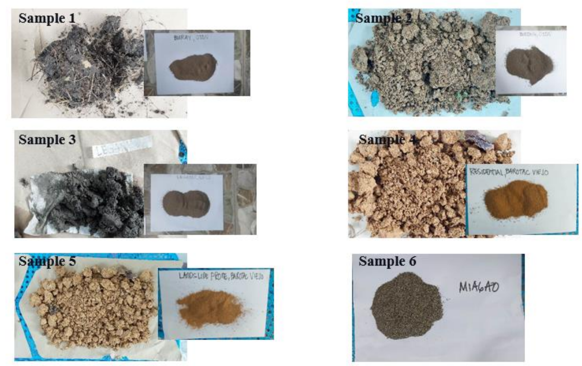
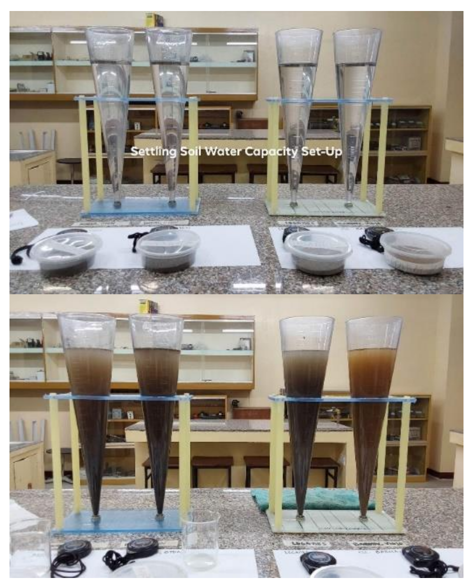


Figure 2. Five different soil samples and sand from Iloilo Province



(a) (b)

Figure 3. (a). Soil water settling Set-Up.(b) Four different samples underwent a settling test.

With a PH number of 7 and using the same Imhoff cone apparatus and a timer, 100 g of each five different soil

Figure 4. Soil water holding set-up

samples and sand tested its soil water holding capacity with 250 ml of water added. The Imhoff cone measured the sediment volume that settled after 4 hours. The reading volume of settled sediment required gentle leveling of the surface of the settled sediment in the Imhoff cones with one-finger taps at the bottom of the cone. The contents were carefully decanted and reweighed using weight-balanced (hardened). Air dry the soil within 24 hours to remove water. Filter papers were removed, dried at 37 °C overnight, and reweighed to determine sediment weight. This process was done three times for each soil. The 100 g soil contained in 1 L of water was the independent variable, where the maximum settling volume is four hours for landslide soil settling ability. This approach uses the Imhoff cone for a given mass of soil in volume suspension that could vary, ensuring no residue was lost in the filtering process; the suspended soil mass was an absolute parameter for each sample. In determining the soil water holding capacity for every 100 grams of each soil sample, 250 ml water was added to the Imhoff cone and set for four hours for each soil sample to absorb the water added (Fig 4).

The third process is the researcher's development and validation of a module. The module contains the results of soil textures, settling, and water-holding capacity information. A pilot test ensures the validity of the developed module. The module was try-out by five earth science and geosciences teachers for content validity. A survey questions about the content and how a module can help motivate students in learning about landslide parameters.

The fourth process was revising the learning module as teaching materials, and carrying out a pretest to determine students' prior knowledge. The module was revised based on the content validators' suggestions and recommendations. A pretest test was conducted on fifty (50) participants of the University of the Philippines Visayas, Janiuay National High School, and Tacuyong Sur National High School.

The last remaining process is measuring the effectiveness of the developed module based on the collaboration of experimental research and technology. Measuring student-learning outcomes through post-test and analyzing teachers' perceptions from answered survey questions. Final testing was on another ten teachers and their respective students.

Students from each school participated in their own specific discussion time to discuss the same topics (definitions, context, and content of modules). The module in landslide parameters was a teacher follow-up through face-to-face meetings. Students performed module activities, and if students needed clarifications on the lessons, an online platform was available where students exchanged ideas with definitions, context, and content and followed up with teacher assistance during a short face-to-face class. For the third week, the teacher prepared and conducted an actual study inside the classroom. The collected data of both groups were analyzed, interpreted, and concluded using frequencies, mean-standard deviation, T-test, and ANOVA. The results of the research were in favor of a student's learning and teaching approach. The researchers suggested that collaboration between advanced technology and experimental method were an alternative to teaching to help students adjust to the new classroom environment due to the Covid-19 pandemic.

2.7 Data Analysis

Quantitative and qualitative data were collected from respondents and analyzed separately using the Excel program and the PSPP application, open-source software or program for statistical analysis of sampled data (PSPP) intended as a free alternative for IBM SPSS Statistics. The frequencies of nominal variables and descriptive statistics like percentages, standard deviations, and means of categorical variables were analyzed using PSPP also. T-test was used to test the relationships of variables. The 50 respondents of Grade 11 and Grade 12 STEM tracks students answered all parts of the research questionnaires and no missing value from the participants' answers.

3. RESULT AND DISCUSSION

3.1 Fourier Transform Infrared (FTIR) Spectroscopic Analysis of Soil Properties.

In Figure 5, sample one had peaks containing a single bond area (2500-4000 cm^{-1}). No hydrogen bond in the material because there is no broad absorption band presence. A sharp at 3423 cm-1 is an Alcohol and hydroxy compound, especially a Hydroxyl group, and H-bonded OH stretch is present, and 3621 cm^{-1} replies to the existence of free alcohol hydroxyl compound(OH). No aromatic structure because there are no peaks between 3000 and 3200 cm^{-1}. A narrow sharp of less than 3000 cm-

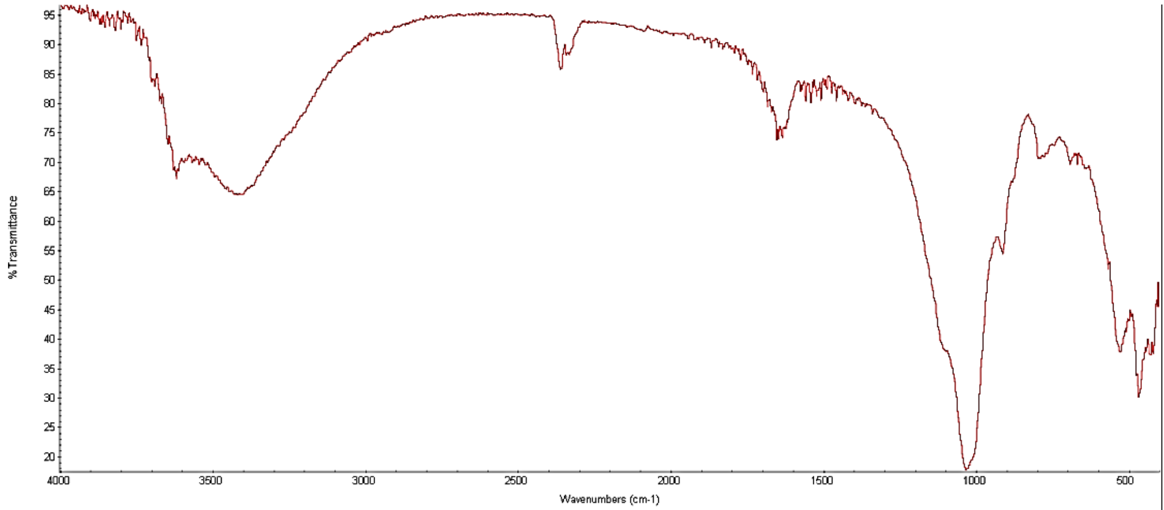


Figure 5. Buray, Oton FTIR Analysis

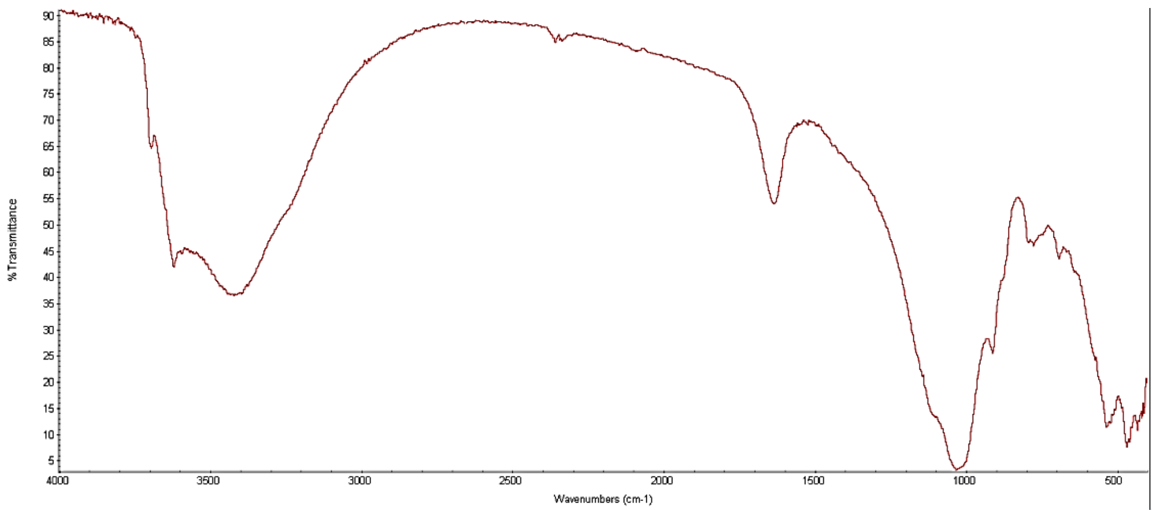


Figure 6. Botong, Oton FTIR Analysis

1, especially at 2360 cm^{-1}, indicates the presence of carbon dioxide. No specific peak for aldehyde has between 2700 and 2800 cm^{-1}. No triple bond region (2000-2500 cm^{-1}) was detected, informing no C≡C bond in the material. Regarding the double bond region (1500-2000 cm^{-1}), the sample has some organic nitrates from the soil or ammonia at about 1652 cm^{-1}. There is no specific peak for aldehyde between 2700 and 2800 cm^{-1}. This material has Thiols and a thio-substituted compound. Since the peaks were only about eight, the material should be a small organic compound. The result showed that several peaks were detected, informing the complex structure material. In addition to the single bond area (2500-4000 cm^{-1}), there are several peaks. In the double bond region (1500-2000 cm^{-1}), several peaks were also detected: In the fingerprint region (600-1500 cm^{-1}), a sharp at 1033 cm^{-1} informed the Alkyl-related compound present.

In Figure 6, sample two had peaks containing a single bond area (2500-4000 cm^{-1}). No hydrogen bond in the material because there is no broad absorption band presence. A sharp at 3442 cm^{-1} is a secondary amino, especially Heterocyclic Amine, is present from ammonia decomposition, and 3621 replies to the existence of an alcohol hydroxyl compound or free O-H. No aromatic structure because there are no peaks between 3000 and 3200 cm-1. A narrow sharp of less than 3000 cm-1, especially at 2360 cm-1, indicates the presence of carbon dioxide. No specific peak for aldehyde has between 2700 and 2800 cm-1. No triple bond region (2000-2500 cm^{-1}) was detected, informing no C≡C bond in the material.

Regarding the double bond region (1500-2000 cm-$^{1)}$, the sample has some organic nitrates from the soil or ammonia at about 1637 cm^{-1}. Samples from the residential area so urea or carbamide compound formed as the end product of the metabolism of protein and excreted in the urine of mammals. It is synthesized in large quantities from ammonia and carbon dioxide for use in fertilizers, animal feed, and manufacturing polymers known as urea-formaldehyde resins, used in making plastics. There is no specific peak for aldehyde between 2700 and 2800 cm^{-1}. Since the peaks were only about eight peaks, the material should be a small organic compound. The result showed

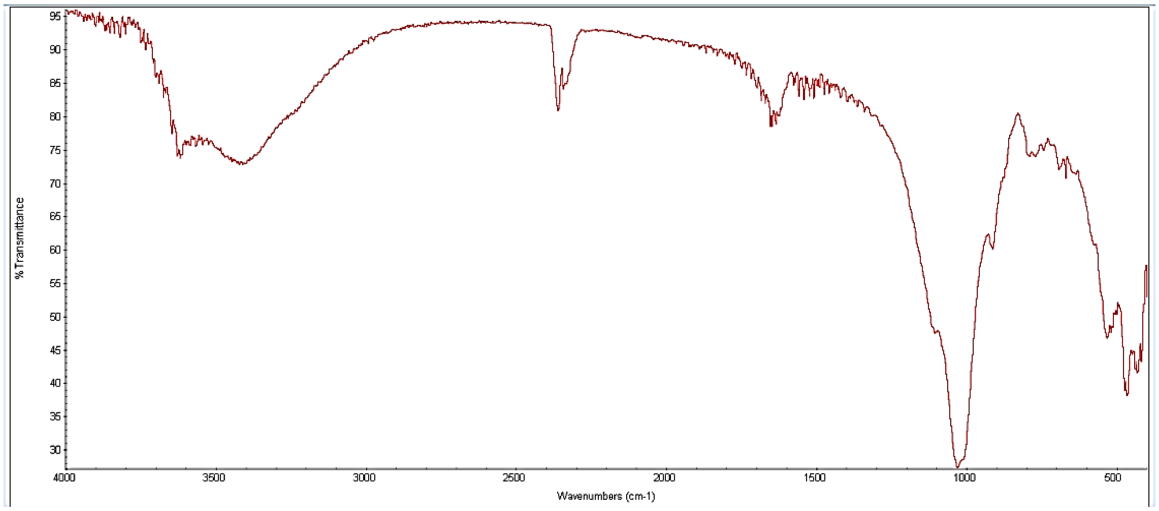


Figure 7. Leganes FTIR Analysis

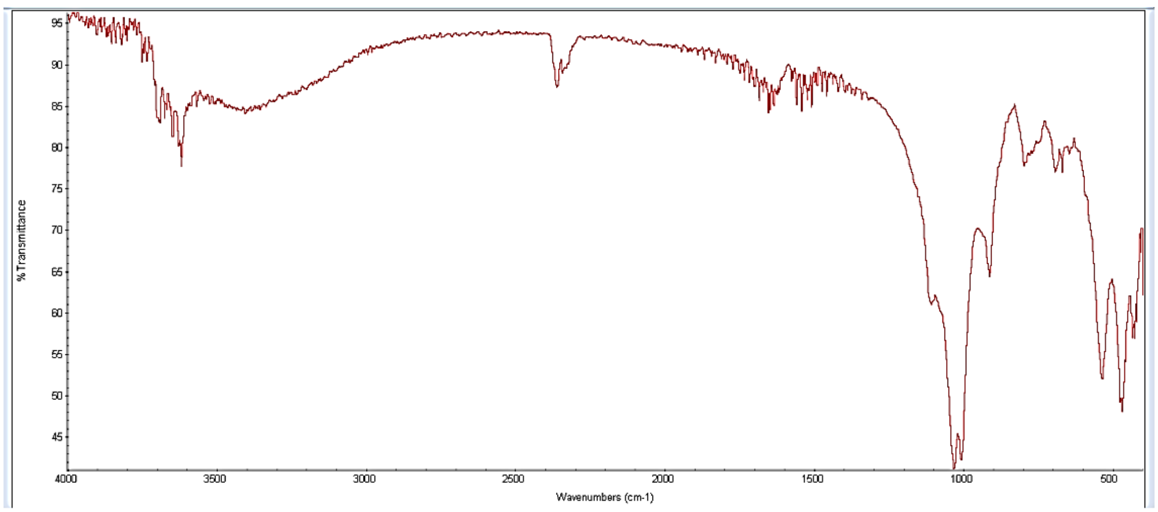


Figure 8. Barotac Viejo Residential Area FTIR Analysis

that several peaks were detected, informing the complex structure material. In addition to the single bond area (2500-4000 cm^{-1}), there are several peaks. In the double bond region (1500-2000 cm-$^{1)}$, several peaks were also detected: In the fingerprint region (600-1500 cm-^{1}), a sharp at 1033 cm^{-1} informed the Alkyl-related compound present.

In Figure 7, sample three had peaks containing a single bond area (2500-4000 cm-^{1}). No hydrogen bond in the material because there is no broad absorption band presence. A sharp at 3419 cm^{-1} is an Alcohol and hydroxy compound, especially Heterocyclic Amine is presently produced by the reaction of water with nitriles, and 3621 replies to the existence of an alcohol hydroxy compound. No aromatic structure because there are no peaks between 3000 and 3200 cm^{-1}. A narrow sharp of less than 3000 cm^{-1}, especially at 2360 cm^{-1}, indicates the presence of carbon dioxide. No specific peak for aldehyde has between 2700 and 2800 cm^{-1}. No triple bond region (2000-2500 cm-$^{1)}$ was detected, informing no C≡C bond in the material. Regarding the double bond region (1500-2000 cm^{-1}), the sample has some organic nitrates from the soil or ammonia at about 1652 cm^{-1} (Olefinic (alkene)). There is no specific peak for aldehyde between 2700 and 2800 cm^{-1}. This material has Thiols and a thio-substituted compound. Since the peaks were only about eight, the material should be a small organic compound. The result showed that several peaks were detected, informing the complex structure material. In addition to the single bond area (2500-4000 cm^{-1}), there are several peaks. In the double bond region (1500-2000 cm^{-1}), several peaks were also detected: In the fingerprint region (600-1500 cm^{-1}), a sharp at 1033 cm^{-1} informed the Alkyl-related compound present. At 464 cm^{-1}, the Thiols, and thio-substituted compounds, especially Aryl disulfides (S-S stretch are present in the sample.

In Figure 8, sample 4 had peaks that contained a single bond area (2500-4000 cm^{-1}). No hydrogen bond in the material because there is no broad absorption band presence. A sharp at 3419 cm^{-1} is an Alcohol and hydroxy compound, especially Heterocyclic Amine is present, and 3691 replies to the existence of an alcohol hydroxy compound. No aromatic structure because there are no peaks between 3000 and 3200 cm^{-1}. A narrow sharp of less

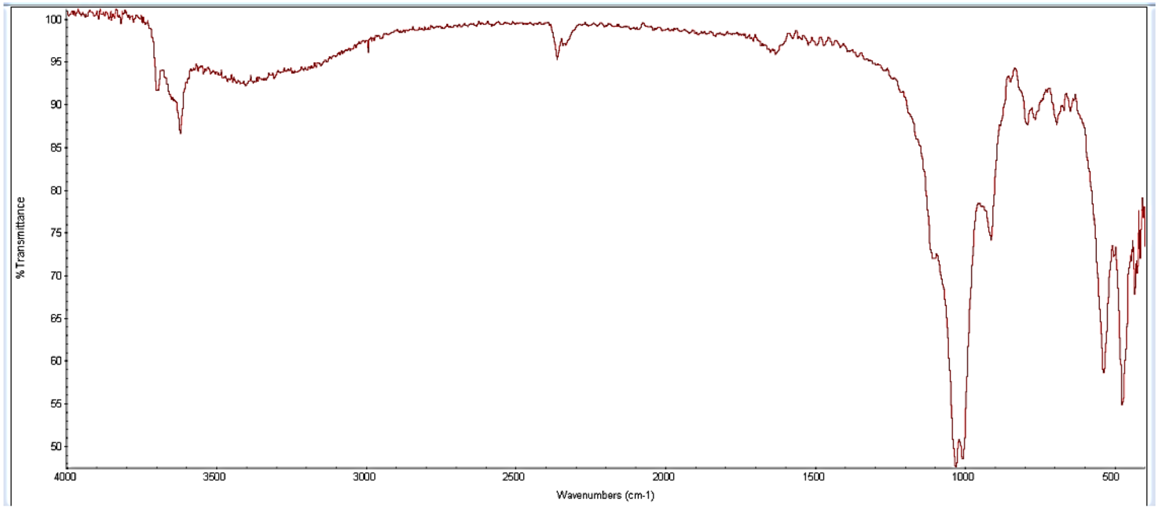


Figure 9. Barotac Viejo Landslide Prone Area FTIR Analysis

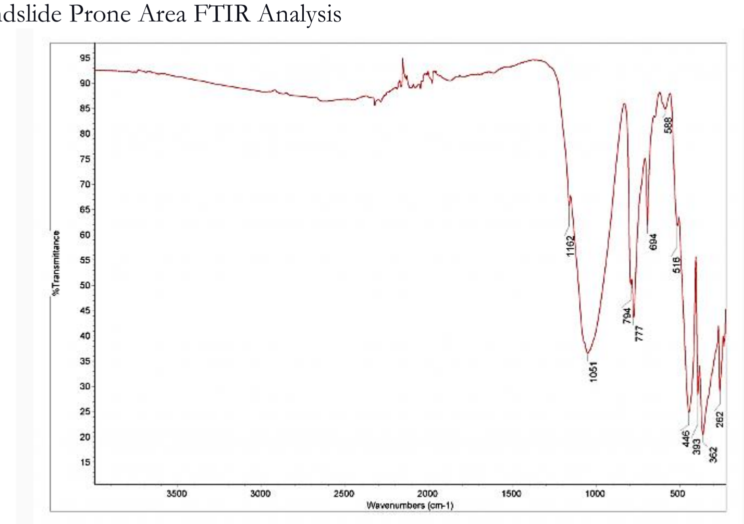


Figure 10. Sand FTIR Analysis (SiO_2) from the Department of Geology at the University of Tartu (https://spectra.chem.ut.ee/paint/fillers/sand/).

than 3000 cm^{-1}, especially at 2360 cm^{-1}, indicates the presence of carbon dioxide. No specific peak for aldehyde has between 2700 and 2800 cm^{-1}. No triple bond region (2000-2500 cm^{-1}) was detected, informing no C≡C bond in the material. Regarding the double bond region (1500-2000 cm^{-1}), the sample has some organic nitrates from the soil or ammonia at about 1683 cm-1 (Aromatic ring (aryl). There is no specific peak for aldehyde between 2700 and 2800 cm^{-1}. Since the peaks were only about eight, the material should be a small organic compound. The result showed that several peaks were detected, informing the complex structure material. In addition to the single bond area (2500-4000 cm^{-1}), there are several peaks. In the double bond region (1500-2000 cm^{-1}), several peaks were also detected: In the fingerprint region (600-1500 cm$^{-1)}$, a sharp at 1029 cm^{-1} informed the Alkyl-related compound present. At 466 cm^{-1}, the Thiols, and thio-substituted compounds, especially Aryl disulfides (S-S stretch are present in the sample.

Figure 9. shows the analysis of Sample Five, the soil from the landslide-prone area of Barotac Viejo. The results conclude as follows: (1) Regarding the number of peaks, there are more than five peaks, informing that the analyzed chemical is not a simple chemical. (2) The peaks contained a single bond area (2500-4000 cm-$^{1)}$. No broad absorption band was found, indicating no hydrogen bond in the material. There is a sharp bond peak at about 3623 cm-1 and 3697 cm^{-1}, replying to the existence of secondary alcohol and OH stretch. No peaks between 3000 and 3200 cm^{-1} indicate no aromatic structure. No specific peak for an aldehyde is between 2700 and 2800 cm-1. (3) One triple bond region (2000-2500 cm^{-1}) was detected, indicating a carbon dioxide bond in the material. (4) Regarding the double bond region (1500-2000 cm-^{1}), a sharp peak at about 1633 cm^{-1} informs some simple hetero-oxy compounds, especially the organic nitrate, which can be from artificial fertilizer and ammonia. This peak at about 1633 cm^{-1} informs a C=C bonding in the material. And at the fingerprint region (600-1500 cm-^{1}), there is an Aliphatic organohalogen compound from an industrial product that comes from pesticides. Based on the above interpretation, conclusions on ample five has to do with farming due to a

compound found in pesticides and fertilizers used by farmers for their plants and animals. The material should be a small organic compound since the peaks were only about ten spikes.

In Figure 10, the infrared spectrum of the clean sand sample depicts an adsorption peak at 830 cm^{-1} depicting the symmetric and asymmetric stretch vibration for Si—O, respectively. Absorption peaks around 620 cm^{-1} characterize the bending of the Si—O functional group in asymmetric and symmetric vibration regions with the presence of pure silica as the chief component in the sand sample. The clean sand particles show peaks at 2,851.85 and 2,924.64 cm^{-1}, which indicates the symmetric and asymmetric -CH2 stretch. The absorption band around 2,920, 2292, and 2236 cm^{-1} in the three spectrograms shown in Figure 9 depict the C—H symmetric vibration of the saturated hydrocarbons and O—H band due to stretching vibration at 3,435 cm^{-1}. C¼O stretching peaks appeared between 1,627 and 1,870 cm^{-1}, confirming carbonyl components like acids and aliphatic esters in the sand particles (Saxena, Kumar & Mandal, 2018).

3.2 Soil Settling and Water Holding Capacity

Imhoff cones with dry soil to determine the settling time for five soils and sand. This settling time was affected by the agitation method (handshaking and stirring). The information on the soil settling capacity of the samples and sand conducted in the laboratory is in Table 2. Compared to other soil samples, the results revealed that soil from a landslide-prone area has a lesser settling time except for the sand that settles fastest due to larger masses. Granulated soil samples have a longer settling time required. A soil with higher clay contents had more suspended clay-sized particles after hand stirring for 5 minutes. With different particle size distributions, the slope of the settling relationship is difficult to determine because of the inability to account for the mean aggregate size of the soil sample or the sample's aggregate stability due to the limited functions of the instrument used. These properties may vary from soil to soil and change with time and exposure to various environmental influences.

A 100g of soil and sand were placed inside the Imhoff cone to determine the soil-water-holding capacity. Using the Imhoff cone, the accuracy of these methods is good, but they are very time-demanding. Results revealed that the soil water holding capacity depends on soil texture (particle sizes) and organic matter. Soil texture, smaller particle sizes, such as in clay, have a larger surface area. The larger the surface area, the easier the soil to hold onto water leading to a higher water-holding capacity. Compared to sand, which has large particle sizes but a smaller surface area. The sand has a smaller surface area leading to low water-holding ability. Also, sand is gritty and therefore does not hold more water because pores are so large that water can rapidly move through it.

Soil organic matter is another factor that can help increase water-holding capacity (Reichert et al., 2009). Soil organic matter has a natural magnetism to water. Botong and Buray Oton is farm area causing an increase in the percentage of soil organic matter leading to an increase in soil water holding capacity due to a decayed material from a living organism (plant or animal material) (Table 3).

3.3 Student's Perception of Developed Module

As technology changes, the living styles and tendencies of people toward social communicational, economic, and educational aspects, people need to reach information or any resources fast and easily. In addition, they need to exchange and share resources on an informational base. With the help of technology, today it is easy to reach

Table 2 Soil settling time

Soil Settling Capacity			Time(hrs.)		
Samples	**Type**	**Location**	**Trial 1**	**Trial 2**	**Trial 3**
1	Soil	Buray, Oton	4 .333	5.167	5 .75
2	Soil	Botong, Oton	3.333	2.16	2.75
3	Soil	Leganes	2.16	2.43	4.33
4	Soil	Residential, Barotac Viejo	3.11	3.167	4.33
5	Soil	Landslide Prone Area, Barotac Viejo	2.19	2.42	2.15
6	Sand	UP Visayas, Miagao	0.45	0.35	1.15

Table 3 Soil holding capacity time

Soil Water Holding Capacity			Time(hrs.)		
Samples	**Type**	**Location**	**Trial 1**	**Trial 2**	**Trial 3**
1	Soil	Buray, Oton	1.54	1.5	2.46
2	Soil	Botong, Oton	2.07	2.3	2.2
3	Soil	Leganes	0.5	1.2	2.46
4	Soil	Residential, Barotac Viejo	0.56	1.41	2.3
5	Soil	Landslide Prone Area, Barotac Viejo	1.41	2.16	2.3
6	Sand	UP Visayas, Miagao	0.035	0.0235	0.038

Table 4 Gender group statistics

	Gender	N	Mean	Std. Deviation	S.E. Mean
How do you feel overall about the module?	Male	31	1.19	.40	.07
	Female	19	4.47	.70	.16
Do you like learning landslide parameters from the develop module?	Male	31	4.23	.67	.12
	Female	19	1.42	.61	.14
How much do you learn about landslide parameters using the module?	Male	31	1.26	.51	.09
	Female	19	4.16	.37	.09
How helpful have your teachers been while you've been studying landslide parameters through module?	Male	31	4.19	.40	.07
	Female	19	3.74	.99	.23
Are you satisfied with the modules you're using for discussing landslide parameters?	Male	31	3.68	.83	.15
	Female	19	1.21	.42	.10

Table 5 Grade level group statistics

		Sum of Squares	df	Mean Square	F	Sig.
How do you feel overall about the module?	Between Groups	6.35	1	6.35	18.43	.000
	Within Groups	16.53	48	.34		
	Total	22.88	49			
Do you like learning landslide parameters from the develop module?	Between Groups	.02	1	.02	.06	.814
	Within Groups	14.86	48	.31		
	Total	14.88	49			
How much do you learn about landslide parameters using the module?	Between Groups	1.38	1	1.38	11.08	.002
	Within Groups	6.00	48	.12		
	Total	7.38	49			
How helpful have your teachers been while you've been studying landslide parameters through module?	Between Groups	12.62	1	12.62	23.41	.000
	Within Groups	25.88	48	.54		
	Total	38.50	49			
Are you satisfied with the modules you're using for discussing landslide parameters?	Between Groups	.01	1	.01	.09	.771
	Within Groups	7.99	48	.17		
	Total	8.00	49			

information and share it with others with technology instruction like an online module that motivates learners. In this study, conventional learners are responsible for building connections between the knowledge they acquire and the situation in which they apply this knowledge; however, some learners do not use much of the knowledge they have gained from learning experiences but through experimental methods that help them remember. In Table 4, according to gender group statistics, females have a very satisfactory rating in reading the module that discusses landslide parameters, with an average mean of 4.47. The male participants, with a mean average of 4.23, liked to learn in the development module. Female participants with a 4.17 mean average learn about landslide parameters using the development module. And same female participants are satisfied with the learning modules.

In Table 4, in the grade level group statistics, the developed module significantly affects to participant's learning method that primarily influences learning, allowing students to explore and find relevant information to solve problems embedded in a complex social context. This application of experimental approaches with technology instruction allowed students to associate their knowledge of solution procedures with real-world-like problem situations.

3.4 Student Performances on the Developed Module

In Table 5, more than 50 percent of the participants got the answer wrong during the pretest, and after they were users of the development module (table 6), students

Table 6 Pretest frequencies of student

		Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
1	The movement of earthy materials from a higher region to a lower region due to the gravitational pull	wrong	0	34	68.00	68.00	68.00
		correct	1	16	32.00	32.00	100.00
		Total		50	100.0	100.0	
2	Downhill movement of the earth is mainly caused by	wrong	0	34	68.00	68.00	68.00
		correct	1	16	32.00	32.00	100.00
		Total	50	100.0	100.0		
3	Movement of heavy materials on the unstable sloppy region creates	wrong	0	41	82.00	82.00	82.00
		correct	1	9	18.00	18.00	100.00
		Total	50	100.0	100.0		
4	Device that detects landslide	wrong	0	25	50.00	50.00	50.00
		correct	1	25	50.00	50.00	100.00
		Total	50	100.0	100.0		
5	To prevent landslide, improving soil cultivation prevent the effect of	Wrong	0	43	86.00	86.00	86.00
		Correct	1	7	14.00	14.00	100.00
		Total	50	100.0	100.0		

Table 7 Posttest frequencies of student

		Value Label	Value	Frequency	Percent	Valid Percent	Cum Percent
1	Downhill movement of the earth is mainly caused by	Wrong	0	25	50.00	50.00	50.00
		correct	1	25	50.00	50.00	100.00
		Total	50	100.0	100.0		
2	Movement of heavy materials on the unstable sloppy region creates	Wrong	0	20	40.00	40.00	40.00
		Correct	1	30	60.00	60.00	100.00
		Total	50	100.0	100.0		
3	Device that detects landslide	Wrong	0	11	22.00	22.00	22.00
		Correct	1	39	78.00	78.00	100.00
		Total	50	100.0	100.0		
4	To prevent landslide, improving soil cultivation prevent the effect of	wrong	0	18	36.00	36.00	36.00
		Correct	1	32	64.00	64.00	100.00
		Total	50	100.0	100.0		
5	The movement of earthy materials from a higher region to a lower region due to the gravitational pull	Wrong	0	17	34.00	34.00	34.00
		Correct	1	33	66.00	66.00	100.00
		Total	50	100.0	100.0		

increased their scores by more than 50 percent. Technology and experimental methods can help learners construct knowledge and deduce meanings by providing rich learning environments. As one of the most widely used and easily accessible technologies today, FTIR spectroscopy has many intrinsic capabilities that can complement the methods of instruction. The interactivity of the module is to engage mental processes and enhance performance and productivity. The learner using the module actively participated in the teaching and learning process. With the abilities of advanced technology, the module can enable a case-based approach wherein learners encounter real-life problem cases and solve them using appropriate knowledge or concepts. Research and development of technology and experimental method have evolved recently to provide learners with environments that enhance the application of knowledge.

4. CONCLUSION

The present study generates the following conclusions;

1. The FT Infrared spectroscopy analysis of the contents of soil (clay) and organic matter directly affect soil water-holding capacity due to the larger surface area of the clay soil.
2. The smaller particle sizes, such as in the case of clay, have a larger surface area. The larger the surface area,

the easier the soil to hold onto water leading to a higher water-holding capacity.

3. Soil from a landslide-prone area has a lesser settling time except for the sand that settles fastest due to larger masses. Imhoff cone is not enough instrument to determine the settling ability of soil samples that has different particle size distributions. Settling relationship with other factors in landslide monitoring is difficult to identify because of the inability to account for the mean aggregate size of the soil sample or the sample's aggregate stability due to the limited functions of the instrument used. These properties may vary from soil to soil and change with time and exposure to various environmental influences.

Accurate data through any experimental approach leads to teachers' mastery of sciences. Experimentation in an investigative and communicative way provides the teacher with a different way of teaching but stimulates students to study and construct their knowledge. The experimental approach had the potential to the formation of students ability who understand and value science and its contributions to daily routines. Data results will be shared with the community of teachers handling earth science and geology classes.

ACKNOWLEDGEMENTS

The author thanks the University of the Philippines Visayas and the following; (1) the Division of Physical Sciences and Mathematics for the physics instrument and laboratory room, (2) staff and Chairman of the Department of Chemistry for the help with the execution of the FTIR soil analysis and the instrument used in the study.

REFERENCES

Alamanis, N., Papageorgiou, G., Xafoulis, N., & Chouliaras, I. (2020). *Effects of Landslides and Soil Settlements on the Built Environment: A Meta-analysis*. 7. 6-15.

Babaeian, E., M. Homaee, C. Montzka, H. Vereecken, and A.A. Norouzi. (2015). Towards retrieving soil hydraulic properties by hyperspectral remote sensing. *Vadoze Zone J*. 14(3),doi: 10.2136/vzj2014.07.0080.

Dariagan, J.D., Atando, R.B. & Asis, J.L.B. (2021) Disaster preparedness of local governments in Panay Island, Philippines. *Nat Hazards* 105, 1923–1944. https://doi.org/10.1007/s11069-020-04383-0.

Guerrero, C., Viscarra R.R.A, & Mouazen, A. M. (2010). Diffuse reflectance spectroscopy in soil science and land resource assessment. *Geoderma*. 158: 1-2.

Hassani, A., Bahrami, H., Noroozi, A., & Oustan, S. (2014). Visible-near infrared reflectance spectroscopy for assessment of soil properties in gypseous and calcareous soils. *Journal of Watershed Engineering and Management,* 6(2), 125- 138.

Iurian, A. R, Cosma, C. (2014). A practical experimental approach for the determination of gamma-emitting radionuclides in environmental samples. Nucl. is unknown and the path forwards. *Plant and soil,* 375, 1e19.

Jaggi, N., & Vij, D. (2006). *Fourier transform infrared spectroscopy. In Handbook of Applied Solid State Spectroscopy*. Boston: Springer, 411-450.

Luino, F., De Graff, J., Biddoccu, M., Faccini, F., Freppaz, M., Roccati, A., Ungaro, F., Amico, M., Turconi, L. (2022). The Role of Soil Type in Triggering Shallow Landslides in the Alps (Lombardy, Northern Italy). *Land 2022*, 11, 1125. https://doi.org/10.3390/land11081125.

Margenot A.J., Calderón F.J., Goyne K.W., Mukome F.N.D & Parikh S.J. (2017). IR Spectroscopy, Soil Analysis Applications. In: Lindon, J.C., Tranter, G.E., and Koppenaal, D.W. (eds.) *The Encyclopedia of Spectroscopy and Spectrometry*, 3(2), 448-454.

Mohamed, E., Saleh, A., Belal, A., & Gad, A. (2018). Application of near-infrared reflectance for quantitative assessment of soil properties. *The Egyptian Journal of Remote Sensing and Space Science*, *21*(1), 1-14. https://doi.org/10.1016/j.ejrs.2017.02.001.

Nandiyanto, A. B.D., Oktiani,R., & Ragadhita, R. (2019). How to Read and Interpret FTIR Spectroscope of Organic Material. *Journal of Science & Technology*, 4(1), 97-118. DOI: http://dx.doi.org/10.17509/ijost.v4i1.15806.

Pajalic, S., Peranic, J., Maksimovic, S., Ceh, N., Jagodnik, V., & Arbanas, Ž. (2021). Monitoring and Data Analysis in Small-Scale Landslide Physical Model. *Applied Sciences,* 11, 5040. https://doi.org/10.3390/ app11115040.

Reichert, J. M., Albuquerque, J. A., Kaiser, D. R., Reinert, D. J., Urach, F. L., & Carlesso, R. (2009). Estimation of water retention and availability in soils of Rio Grande do Sul. *Revista Brasileira de Ciência do Solo*, *33*, 1547-1560.

Rossel, R. V., Walvoort, D. J. J., McBratney, A. B., Janik, L. J., & Skjemstad, J. O. (2006). Visible, near infrared, mid infrared or combined diffuse reflectance spectroscopy for simultaneous assessment of various soil properties. *Geoderma*, *131*(1-2), 59-75.

Saxena, N., Kumar,S., & Mandal, A.(2018). Adsorption characteristics and kinetics of synthesized anionic surfactant and polymeric surfactant on sand surface for application in enhanced oil recovery. *Asia-Pacific Journal of Chemical Engineering*. 13(4), 1-14. https://doi.org/10.1002/apj.2211

Soares, B. C., de Campos, M. E. C., Thomaz, J. R., da Cruz Pereira, G., & Roehrs, R. (2016). The importance of experimentation in the teaching of sciences to elementary school. *Revista Monografias Ambientais*, 1-17. doi:10.5902/2236130827003.

Sojka,R. E., Carter, D. L., & Brown, M. J. (1992). Imhoff Cone Determination of Sediment in Irrigation Runoff. *Soil Science Society of American Journal*, 56:884-890.

Soriano-Disla, J. M., Janik, L. J., Viscarra Rossel, R. A., Macdonald, L. M., & McLaughlin, M. J. (2014). The performance of visible, near-, and mid-infrared reflectance spectroscopy for prediction of soil physical, chemical, and biological properties. *Applied spectroscopy reviews*, *49*(2), 139-186. http://dx.doi.org/10.1080/05704928.2013.811081.

Summers, D., Lewis, M., Ostendorf, B., & Chittleborough, D. (2011). Visible near-infrared reflectance spectroscopy as a predictive indicator of soil properties. *Ecological Indicators,* 11(1), 123-131