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Use of Mobile Devices for Spatially-Cognizant and Collaborative Fieldwork in Geography

Kalyani CHATTERJEA[1]

Nanyang Technological University, SINGAPORE

Abstract

Fieldwork is an essential component in Geography education. Learning through research in Geography involves generating substantial data and data manipulation. In order to make geographical inquiry a worthwhile learning experience, researchers require a seamless system that allows data collection and analysis without being distracted by the multiple methods and equipment used. NIEmGeo is a mobile application that is developed with an aim to support integrative geographic learning, both during fieldwork and during subsequent data analysis. The system has been used successfully by more than 100 students in several undergraduate courses. The paper discusses the salient features of the application, analyses the usage of field researchers, and discusses the viability of the application as a field and post-field support system for field-based learning in Geography. Some observed limitations and future research directions are also discussed.

Keywords: Fieldwork, field-data, context-rich data development, geo-referenced data, location-aware data, geo-tagging, mobile field assistant

Introduction

Fieldwork and Geography have essentially been thought of by most Geographers, as coexisting, complimentary, and an indivisible media for conveying a comprehensive understanding of the environment. Geographers do not argue about whether it is good to have fieldwork as a part of geographic learning, rather they discuss the various aspects of it to examine the comparative effectiveness. Kent *et al* (1997) provided comprehensive review of issues related to effectiveness and importance of fieldwork, while Gerber & Goh (2000) related fieldwork to making sense of the environment. Gold *et al* (1991) also went to mention that fieldwork is intrinsic to being a geographer.

[1] Associate Professor; Humanities and Social Studies Education Academic Group, National Institute of Education, 1, Nanyang Walk, Singapore 637616. E-mail: kalyani.c[at]nie.edu.sg

Therefore, it can be said that fieldwork is an integral part of geographic education, to make sense of what is learnt in the classroom, as well as to make sense of what learners see when out in the field. Fieldwork, therefore, completes the circle of learning that may be initiated in the classroom, to allow the students to apply the concepts, understand and interpret the unknown environment, to analyze the issues involved, by using appropriate techniques of enquiry in the field, to substantiate and support the hypothesis to arrive at a subject-specific decision. If this idea is supported, then fieldwork cannot be taken as a complimentary part of geographic learning, but it should be taken as an integral component.

Chatterjea *et al* (2008) placed a model of geographic education where fieldwork is preceded by conceptual and theoretical knowledge-building in class to create an image of the environment, with relevant models and hypothesis to develop experimental designs. This is followed by comprehensive data collection in the real authentic environment through fieldwork. The final stage is analysis and explanation of observation to substantiate, justify, and adjust the pre-determined image of the environment. This model emphasizes the integral role of fieldwork in geographic education. All studies, therefore, place fieldwork as a step towards effective geographic understanding.

The 'Field' in field-based learning is, according to Lonergran & Andreson (1988), a place for authentic learning and Wagtendonk (2003) remarks that field is a place remote from the classroom where a suite of instruments are used as tools by the researcher. While traditionally a notebook, a pencil, and human senses provide the essential tools, increasingly more sophisticated instruments are being introduced in an effort to bring learners up-to-speed with the existing technology as well as to enhance the understanding through the use of quantitative and qualitative evidences from the field sites.

This paper looks at a tool developed to be used on mobile phones that has built-in features to facilitate intensive field work and substantial collaborative data set development, without making such a task too difficult and time-consuming. The paper also examines how, through the use of the developed mobile application, fieldwork can contribute towards collaborative knowledge building and individual knowledge creation and meaning making through analysis of collaborative data.

Objective and Scope of Research

The fieldwork component within a Geography programme, according to Kent *et al* (1997: 319), 'should be compatible with the educational experience and state of progress of the students', and should be 'integrated into the structure and learning objectives of the complete degree that it supports'. To this effect, the undergraduate courses in Geography at the National Institute of Education (NIE), Singapore, has fieldwork as integral parts of all Physical Geography courses. Additionally, in the final year, all Geography major students have to do a full course on fieldwork, which typically is held in overseas field locations and lasts for two weeks. To engage students in analytical discourse, in both the types of field exposures, students are expected to collect sizable amounts of data from field locations and later use these to write in-depth reports as research outcomes.

Typically, first to third year students have 50% of their course grades allocated to the field reports, while the final year fieldwork course is fully graded on the written thesis, dealing with issues that are based on analysis of field-based data. This prevalent practice of integrating fieldwork into the courses requires each student to do extensive fieldwork, which is, however, difficult to achieve within the constraints of limited curriculum time. Further, the final year fieldwork course requires students to go mostly to remote locations and get primary field data, sometimes under trying environmental conditions within a pre-determined time. In order to maintain the rigour of field data collection and effectiveness of learning from fieldwork, a system needs to be put in place, so that such intensive fieldwork can easily be incorporated without hindering the learning process, so that students can get the benefit of learning from authentic learning situations, without compromising the quality of learning, and also be able to synthesize the theoretical concepts with practical observations and from collecting empirical data.

With these requirements, several strategies were experimented (Chatterjea *et al*, 2008, Chang *et al*, 2012) to integrate technological affordances to facilitate fieldwork. These focused on, among other things, collaborative data collection, and collaborative knowledge development, through the use of server-based data sharing and tag and search. However, there were several issues that needed further investigation and further developmental initiatives. In the G-Portal project, students had to negotiate cumbersome software issues before much work could be done, although data could be shared and used for mapping (Chatterjea *et al*. 2008). Later, the MobiTop development used a mobile platform. But the first generation Smart phone platform used in the development was too slow and had too many steps to follow to make learning smooth. In addition, the system required uninterrupted internet connectivity and, therefore, was either very slow or unavailable for much of the outdoor work. Another problem was that the device chosen for the development (Nokia N95) was an expensive phone and few students owned such a device at the time of research. These two efforts, thus, did not deliver the expected seamless system to enrich students' field learning experience.

The current paper is the outcome of a development of a mobile application that has been developed and used solely for the purpose of facilitating fieldwork in the Physical Geography courses at NIE. Geography fieldwork commonly requires quantitative data acquisition, photographic records of methodology as well as site-specific details, qualitative descriptions in addition to or in the absence of quantitative data. There is also a great need for geo-spatial reference for all data collected, so that the observed and measured indices can be mapped for formulating a spatial reference and spatial dimension essential for any geographical analysis. In order to acquire the quantitative data, usually fieldwork involves use of many instruments, each for a specific purpose. Photographs are used for keeping photographic records, GPS receivers are used for geo-tagging and note pads are used for recording all proceedings in the field. This leaves a researcher with more than just a few pieces of equipment and fieldwork can become a cumbersome exercise.

While specialised equipment, e.g., streamflow meters, pH meters, thermometers or similar environmental monitoring gadgets cannot be replaced because of the requirement of data precision, equipment such as digital cameras, voice recorders, even GPS receivers, compass, clinometers etc. can be replaced by using built-in applications and affordances in today's mobile phones. This makes a mobile phone, not just telecommunication equipment, but an integrated field assistant, especially because of its pervasiveness and ease of use. It was, therefore, an easy choice when it came to deciding on a device platform, to choose the mobile phone for developing an application to facilitate fieldwork processes and also to prepare a base for collaborative data development and subsequent problem analysis and problem solving. In order to make the exercise useful and meaningful, certain provisions were deemed as essential requirements:

1. Geo-tagged photo records: to record the location of the site, for subsequent mapping
2. Customizable quantitative data recording: to allow any type of data from any instrument, useful for a wide range of physical data collection
3. Qualitative inputs as descriptions of processes, observations etc.: deemed essential for recording researcher descriptions, observations that cannot be quantified
4. Recording of specific comments: to facilitate researcher's work
5. Collaborative dataset development: to allow more learners to contribute data for developing a sizable data set
6. Internet usage, but without the need for roaming data use: to allow offline work in remote areas and upload data at the researcher's convenience
7. The ability to develop customizable context-rich data set that has specific learning goals
8. All these to be incorporated in one single system for ease of use in the field and also on a platform that has little or no learning curve

With these goals, the platform selected was smart phone, for its pervasiveness and for the built-in affordances. SMART phones also allow programming to enable customized data entry and management. It is affordable and omnipresent. An informal survey in the university revealed that during this research project, more than 50% of the students used iPhone, and that they were extremely conversant with the built-in affordances. This made iPhone the chosen platform for the development of the fieldwork application, NIEmGeo, which was made available at the Apple Store for free public downloading in early 2012 (Figure 1.).

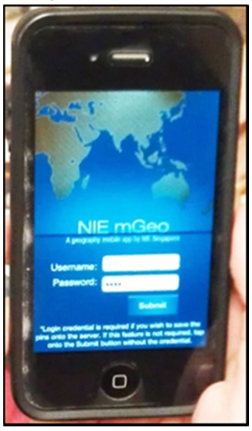


Figure 1.
Opening page of NIEmGeo Application

NIEmGeo is customized to facilitate the fieldwork processes and subsequently, the analysis process in order to integrate the learned concepts with the field observations, to formulate a thesis. In this respect, the application is not just a tool for complimenting fieldwork processes but one that supports integrated learning during post-field work. Following the model discussed in Chatterjea (2010), NIEmGeo is geared to cater to Stage 4 (Fig. 2), during fieldwork to facilitate in the field data recording and data management, and subsequently, in post-fieldwork phase, (Stage 5 in Fig. 2), during the analysis and integration of knowledge and field observation. Therefore, the objective of this development is to scaffold student-driven, inquiry-based learning in Geography.

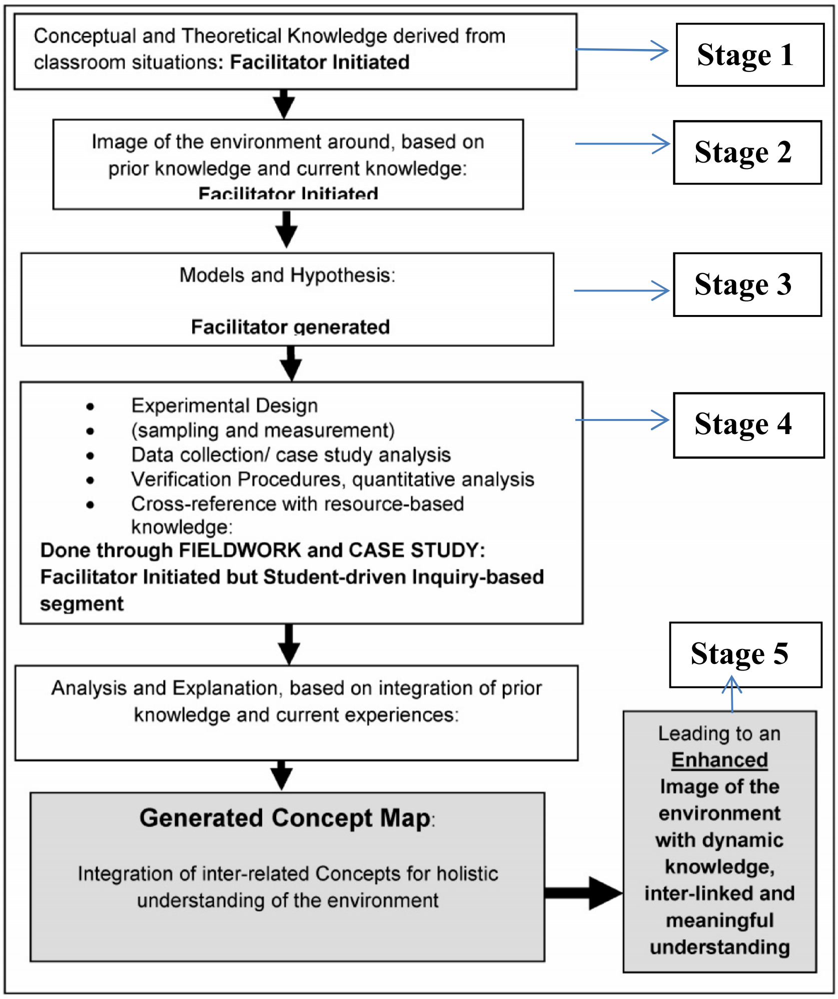


Figure 2.
A framework for synthesizing geographical understanding (adapted from Chatterjea, 2010)

This research looks at the ways this application has assisted in integrating field experiences with geographic analysis in inquiry-driven learning environments.

Views on fieldwork and the place for integration of Information Technology: a review of existing literature

While fieldwork has been hailed as an integral part of Geography education, with the advent of mobile technology, many researchers have been involved in examining the place of such integration and if such introductions actually assist in enhancing the way fieldwork may contribute to better work and understanding. Kaasinen (2003) looked at the various aspects of location-aware services on mobile phones to assist users to access information while in the field. Such location-aware services, however, are aimed at providing information to the user on the go, rather than catering to the actual needs of the individual user. The main objective of such location-aware services is to make information available to the user, be there any need, but these are not necessarily customized to the user requirement. Pascoe *et al* (1999) and Baldauf (2007) examined the issue of users authoring in context, rather than retrieving, to do field tasks.

While the location server purely focuses on providing location details, Pascoe *et al* (1999) discussed the development of a context-aware fieldwork tool that aimed to provide various details in a template, which is not possible using the traditional paper-based recording methods. Lim *et al* (2006A, B) discussed using learner guided fieldwork by using mobile phones, while Chatterjea (2008), Chatterjea *et al* (2008), Goh *et al* (2006, 2008), Kim *et al* (2008), Chang *et al* (2012), Nguyen *et al* (2008, 2009), Puspitasari *et al* (2007), Quach *et al* (2010), Razikin *et al* (2009), Theng *et al* (2006, 2007), Vo *et al* (2007), and Vuong *et al* (2007) discussed the use of applications developed on mobile devices to do collaborative, synchronous field to classroom learning, with geo-referenced locations, multi-media elements, and multi-layered tagging as well as grouped fieldwork using maps on servers, to enhance field observation and field-assisted learning. Ally (2009), Lim *et al* (2004, 2005) discussed how mobile phones can be used to engage students in guided field investigation where students develop the context for collaborative learning. Hall and Gray (2004) discussed the use of a multimedia based, location aware system to support team-based field studies in archeology. In this study, field workers shared their locations and activities with other groups of workers. All these studies looked at the use of building up location-aware context, suited to the specific needs of the field researcher that are designed to enhance the understanding of the issues at hand. However, points raised by researchers are issues of unfamiliarity with the equipment used and the problems of using multiple equipment to perform various tasks. They mentioned the disadvantages of using multiple devices such as GPS receivers, digital cameras, compass and other field devices and noted that use of so many devices make fieldwork rather lengthy, troublesome and error-prone. The study using HP iPAQs for fieldwork in archeology also had handling problems due to users being unfamiliar with the device. Research points to the usefulness in realizing team work and use of a common surveyor tool and the potential and applicability of such a system for studying other scientific domains, such as geographical or environmental studies.

With the advent of Web 2.0 tools, the possibility of users to customize, edit, share information from online device becomes a reality (Soon *et al*, 2008) and Rost and Holmquist (2010) in their research on mobile fieldwork commented that use of a mobile device to do out of classroom studies satisfy the working style of today's learners and mobile phone is indeed useful as a tool to incorporate IT facilities in their learning process. Following the same trend of thought, Tarumi *et al* (2007) mention that students have difficulty linking authenticity to classroom knowledge but provision for input of location-aware information provided a meaningful outcome for students involved in collaborative knowledge development in the field using mobile phones.

They mentioned that since students already are conversant with the various uses of the mobile phone for their communication tasks, using this device becomes a logical choice. The widespread use of mobile devices for creating and sharing of digital information is a lifestyle for the present generation of learners, and with the emerging trend of flat rate subscriptions and good transfer speeds of data, use of mobile devices is becoming more common and affordable. Welsh *et al* (2012) mention using SMART phones in the field to geo-tag photographs as a measure to enhance students' field investigations in both Human and Physical Geography. However the authors point out that there are specific locations where mobile services may be below the desirable levels and also that the usage of such services may incur costs, thus somewhat restricting the usage. It is to be noted that researchers still talk about data plans for data sharing while in the field and this could be an issue – not just for charges involved, but because reliable connectivity can be an issue while working in remote areas, such as done in most field based sciences.

Mobile devices have been deployed as learning tools among all age groups and Clough *et al* (2008) mention that although there has been research on how mobile devices can support and enhance collaborative learning, there is relatively little discussion on whether this is used for collaborative learning in the pursuit of learners' own specific learning goals. They also mention that introduction of unfamiliar devices do disrupt the learning process and points out the need for using a platform which all are comfortable to use. In fact, this was one of the key issues that hindered progress of the field study in archeology, where students were not fully conversant with the use of HP iPAQS (Hall and Gray, 2004). Using omnipresent equipment gives control over the goals and processes of learning, and the expected learning outcome, rather than wasting time and diffusing the learners with the procedures of use of the equipment. Research also shows (Chang *et al*, 2012) that even when familiar equipment is used, design of the application and sub-optimal network connectivity (slow internet connections) may hinder the free flow of work and thus reduce the effectiveness of the initiative.

It may be summed up that use of multiple data recording devices on multiple field equipment can be laborious, and are prone to data loss. It is also confirmed, while devices are necessary for collecting quantitative data, unfamiliarity with the equipment leads to less than optimum quality of work and cause confusion, and hence, reduce the quality of fieldwork. While research shows that fieldwork is definitely enhanced through provisions for subject-specific context development through use of input devices, such devices should have a gentle learning curve, be versatile in their affordances to reduce number of equipment required for field use, and ideally be an acceptable feature of the learners' mode of work. Clough *et al* (2008) also reinforced the view of Patten *et al* (2006) that educationally appropriate application should be built on a combination of collaborative, contextual, constructionist and constructivist principles' and that mobile devices can particularly support constructivist learning through data collection, site-initiated customizable inputs, location awareness and collaborative work.

As a response, mobile devices, with the built-in advantage of being ubiquitous have been the choice of some fieldwork. But their work-flow designs and the sub-optimal connectivity have not provided the intended outcome so far. So far, there is, therefore, an agreement that working in the field requires a device that can do multiple tasks to facilitate learning and that mobile devices do have the advantage of being small, integrative, multi-tasking, and ubiquitous to learners. But there is still a need for an integrative platform that can allow the required features of mobility, ubiquity, gentle learning curve, versatility of allowing constructivist learning through customizable inputs and location-aware, collaborative work. The current development aims at filling in these gaps to provide fieldwork an integrative learning tool.

NIEmGeo design considerations and features

In response to the widely-held idea that effective fieldwork requires a system that is easy-to-use, integrative, multi-featured to support spatial analysis, able to support constructivist learning, a mobile application was developed as a part of this research, for use in SMART phone, specifically the iPhone. This application, NIEmGeo, registered with Apple Store, has the capability to support geographic field-based investigation, specifically to cover the requirements for fieldwork in remote areas, in the absence of reliable internet connection. Several design considerations were put in place to make this application useful as a geographic field assistant.

A good list of requirements for geographic field work can be:

1. Geo-spatial reference of the field sites
2. Photographic records of field evidences and features
3. Records of large number and variety of quantitative data
4. Customizable data recording field
5. Facility to record qualitative data
6. Facility to record personal reminders and comments for assistance in the field

Further to these, in order to perform a good geographical investigation, researchers need to share and access data collected by other co-workers in the field, for the sake of using a larger database for effective analysis. To attain this, the researcher would require:

1. A system that allows data upload and data download from a sharing location. This enables use of others' datasets and eases individual workload without impinging on the limited time, and without putting excessive pressure on individual researcher.
2. A system that provides spatially cognizant data sets, that can be visualized on maps, to provide the much-required geographic information, without all researchers venturing into the entire difficult terrain individually.
3. A system that can be used with internet-based sharing, even if such facilities are not available at remote field locations.
4. A system that can assist research, through collaborative analysis and sharing of comments.
5. A system that allows post-field data management, editing to allow subsequent data inputs, if necessary.

With these perceived requirements, the application, NIEmGeo was developed, providing all the above on-site and post-field facilities to the researcher. The foremost design consideration for this application was to make it user-friendly, with almost no learning curve. To this end the application is well set as it uses the much-commonly used iPhone platform (with more than 50% students at the university using iPhone). This encourages more focus on the actual field work, as the user is able to concentrate more on the data collection and observation, rather than moving through the maze of the application. A smart phone is light, easy to use, and has several in-built features, such as a camera (both still and video), hosts applications that measure heights, angles, distances, and other similar useful field applications, has geo-referencing capability that is very accurate, as long as mobile network is available (which is mostly available and usable even when dedicated GPS receivers do not work). The application, NIEmGeo, was developed to incorporate the specific requirements, as stated above, to make it useful for students working in remote mountainous areas during their two-week intensive fieldwork on fluvial, slope processes. The application was also used by another group of students who worked separately in different parts of Singapore but shared the data, to save individual work time, and yet gain access to sizable data sets, developed collaboratively. The specific features incorporated in the application are as follows:

1. NIEmGeo is a synthesized platform for recording all kinds of data in the field and takes out the need for reliance on pen and paper. This reduces the risks of data loss.
2. The application allows customizable data field, to suit all types of field investigation. The user is able to input data in any form. This helps in keeping it open for various types of field investigation, particularly since Geography is a multi-disciplinary subject and may involve different type of data for different situations.
3. Photographs and even videos form important parts of field evidences and photogrammatic surveys for landscape evaluation, process analysis and geographic understanding. The application uses the mobile phone’s in-built system to generate and then record such evidences.
4. All data, quantitative, qualitative, photographic, are geo-tagged, to enable information to be geo-spatially mapped using free software Google Earth, and Google Maps. This takes out the need to use proprietary GIS applications such as ArcGIS, which are expensive, has steep learning curve, requires dedicated computer facilities and are not universally available. NIEmGeo, thus is equipped to provide spatially referenced locations of field sites, with terrain and other details, for learners to analyze the geographic processes operating there, without having to learn how to use GIS software. The use of the application is therefore, inclusive enough to allow field-based learning for all without additional costs and additional affordances over what is already available.
5. Finally, fieldwork in Geography often involves working in remote locations where internet connections may not be available. Using data transfers and uploads that require internet connectivity can render the exercise futile or at best extremely expensive when roaming data access becomes a necessary requirement.

Use of 3G network can also be unreliable in remote locations, even when the researcher is willing to spend the additional money. Therefore, it was thought to be of utmost importance that the application be able to work even when internet connections were not available in field situations. An essential requirement set for NIEmGeo, therefore, was the ability to store all data inputs till affordable and reliable internet connection is available to upload to the server. Data transfer is set through using WiFi connections, when that is available.

All these features target to make fieldwork more user-friendly, focused, reliable, and totally customizable for any type of geographical investigation. In addition to being a reliable data recording system, it provides a unique way to visually locate the field sites by using geo-referencing. This feature makes NIEmGeo a useful geographical tool. NIEmGeo incorporates a two-tiered geographical analysis system, (i) during fieldwork as well as (ii) in the lab/ classroom during post-fieldwork and analysis. The details of these features and the rationale are discussed below in the order as they are used in the field and subsequently during data analysis:

Fieldwork phase

Before students embark on the fieldwork, the lecturer has to assign userids and passwords to each group and also assign specific coloured pins to each group, so that the individual group inputs can be easily identified. Currently the application can take up to ten groups, with ten different coloured pins. The application requires students to login with their userids and passwords before they go to the field, particularly if network is not available at the field location. This loads the maps on the mobile device. However, if this is not done, students can still use the application as usual, although the background map is not available while the work is done. While in the field, students generate data from their field locations.

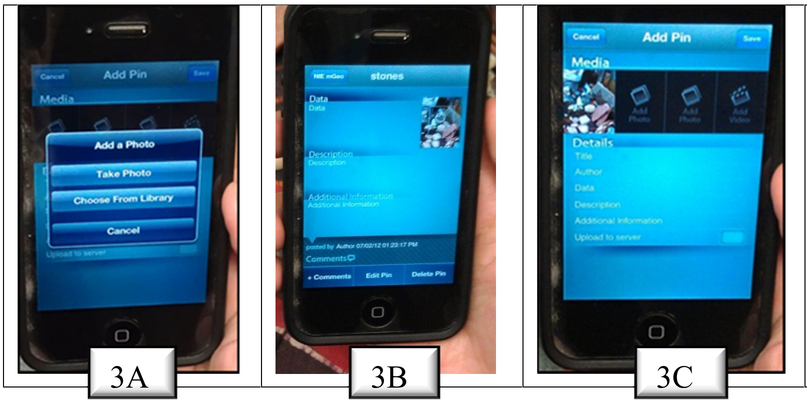


Fig. 3a. *Photographic data entry on NIEmGeo*

Fig. 3b. *Photograph recorded at a field site*

Fig. 3c. *Adding data and other details from the field location*

1. The first data input feature is the photogrammatic recording. NIEmGeo allows three photographic data and one Video data for each location. (Fig. 3a and 3b).
2. Each of the photographic inputs are geo-referenced, using the built-in affordance of the mobile phone, and the information is ready to be uploaded to the server, for future use in mapping of the study locations.
3. Once photographic data are created, other types of data are recorded, creating a contextual data set base. NIEmGeo offers the field researcher complete freedom to input any type of data, as the field is customizable, depending in individual

requirement. The data field allows quantitative data, in any preferred order, with no limitations on the number of entries (Fig 3C) as long as individual inputs are separated by a comma.

4. NIEmGeo also has provisions for recording qualitative information regarding the field location, researcher's personal views, comments, which usually help in further analysis, especially if there is some incoherence in the data and if there is some special issue that cannot be captured just by quantitative data. All field geographers would agree that such a facility is considered essential, as field conditions cannot be pre-conceived and often field conditions can be erratic and unexpected from before.
5. In addition to the quantitative and qualitative inputs, field conditions often require researchers to note specifics down, sometimes as reminders, or as special notifications. This comes of use, particularly if the data is unique, unexplainable, or if more observations are required. Usually such recordings are done on the field data sheets. Since NIEmGeo takes pen and paper recording out of the field exercise, it has incorporated a section where the researcher can input some personal comments, reminders or notes – that are only seen by the specific researcher, and not by the others in the research community.
6. All data from the fieldwork phase are saved in the mobile device, if internet is not readily available. This is especially useful in field locations located in remote areas, where either internet can be erratic or could involve high data roaming charges. NIEmGeo only allows uploading to server using WiFi, because of its reliability in data transfers (Figure 4.).

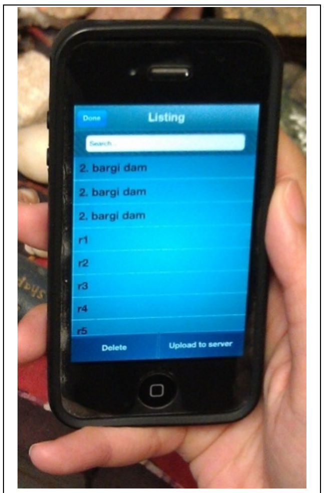


Figure 4.
Data uploading option on the application when WiFi is available
Note: This option is unavailable when WiFi is not available

Once the researcher arrives at a location with available WiFi facilities, data can be uploaded to the server for subsequent use. Even after the upload all data still remains in the mobile device and any further updates for the same location replaces the older data, to reduce confusion. This feature incorporating in-phone storage, choice of data upload time, as well as subsequent uploading to update data is aimed at covering the need for safe data storage, and data editing and updating as required by the researcher.

Post-Fieldwork, Data Analysis phase

1. Data from the field is uploaded in the dedicated server (currently the university offers that service), through a userid and password verification process.
2. To encourage collaboration in data set development, different groups are given separate userids and passwords to upload the data, to build a combined data set, even on the same topic. However, the data set is only editable by the developer group, and "Read only' access is provided to all other groups. This is an important requirement to support development of vast data sets, essential for an in-depth analysis, rather than some minimal data generated by just one group of students. The system, therefore, allows for development of big data sets collaboratively by various groups, and the data is also available to all, allowing for detailed analysis, based on the collective data set. Collaboration in the field and as well at analysis stages is supported by the application (Fig. 4).

Figure 5.
Data uploaded by groups doing research in Forest Boundary Environment

3. All entries can be viewed and commented on by the lecturer, as well as others. This not only allows the lecturer to keep track of students' work, but also becomes a potential platform for negotiation and collaboration (Fig 6). Peer-reviewed and collaborative development of the geographical understanding, thus, is the focus of the development.

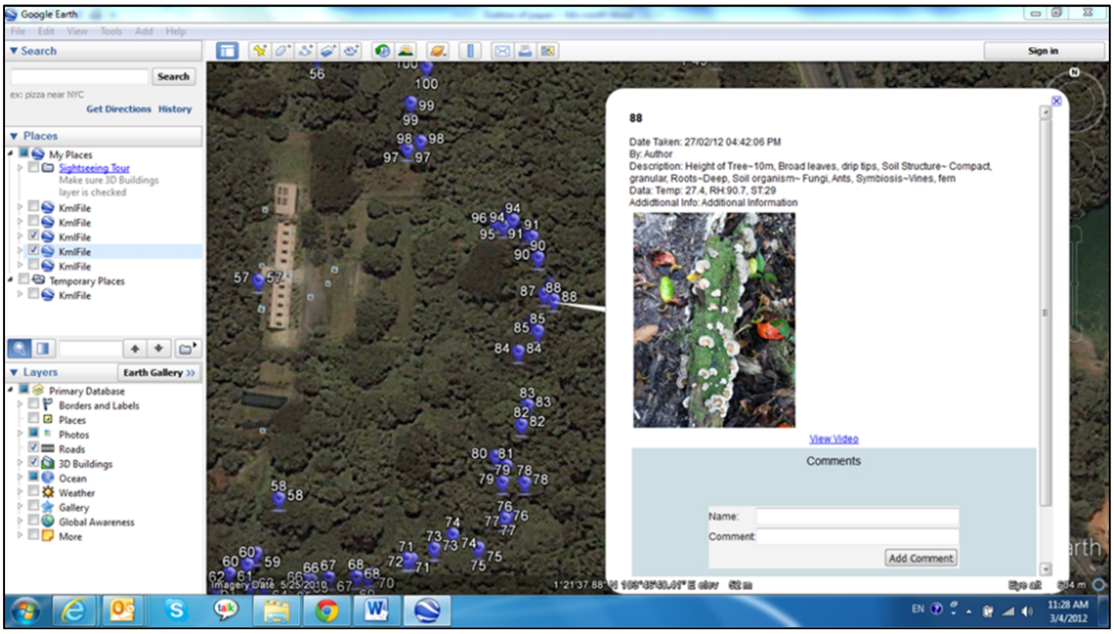


Figure 6.
Data mapped on Google Earth, with inset showing data and comments field from others

Both the during field session and the post-fieldwork workflow, using NIEmGeo, make geographical analysis useful and more far-reaching than single group's work, using multiple equipment, and depending solely on their own data.

Examples of Location-aware and context-rich data collection by different field groups

Before NIEmGeo was officially launched in February 2012, in December, 2011, a Final Year class of 21 students (working in three groups) used the application as a pilot study, to conduct fieldwork in remote areas, (1) along Narmada River on Vindhya Mountain in Central India and (2) along Kosi River on Himalayas in North India. The field sites were remote, on difficult terrain and along deep, rough rivers. Data collection, under ordinary conditions, using multiple equipment, would have to be reduced to minimal number of data entries, as working conditions were not conducive to extensive work, especially since the time available was very short. Internet was not available and terrain excluded possibilities of communication between the groups during the field work.

Traditionally this work could have been done in geographically separated locations, but would entail recording various types of data on field sheets, subsequently copying these manually by other groups (to make use of each other's data), and then using GIS software (ArcGIS) to draw the maps for doing spatial analysis. Even then, the photographs and data would have to manually tag with the location, as such things would not be spatially cognizant, by themselves. However, these three groups of students engaged in the fieldwork using NIEmGeo for all their data recording as well as subsequent data analysis. For the Narmada River segment of the work, the students were assessing the flow conditions, flow volumes, and the water quality of a river that flows through a rift valley on marble rocks, to examine if the country rock had any implications on the dissolved load and if the topographic and geologic restrictions of the containing valley influenced the flow characteristics of the river. They collected 500 sets of water temperature, water pH values, channel depth readings, streamflow velocities, channel morphological data, such as channel shape, width, and other descriptive bank characteristics from two separate boats plying different routes along the gorge, using the same procedures and entering data using the application. Data was collected synchoronously to eliminate influence of weather changes.

At another two sites on the Himalayan locations, students collected field data related to atmospheric temperature, relative humidity, rock characteristics along stream valleys, stream bedload, stream channel morphology, streamflow velocity, water temperature, bank erosion hazard indices, from three geographically separated locations to assess the relationships between river and the country geological and topographical characteristics to assess how the river adjusted its flow conditions to the given environment. Each of the three groups of 7 students managed to collect as many as 662 sets of fluvial-related data, such as streamflow velocities, channel configurations, bedload, water quality, data related to bank erosion, bank materials. All data was recorded using mGeo and data recording included geo-referenced photographic evidences, quantitative data of all variables measured, qualitative descriptions of field conditions, as well as researcher's comments. The use of mGeo collectively allowed them to cover far more ground in the given length of time and collect huge data sets, which was subsequently used to study the river's fluvial characteristics with more confidence, than what they could have done had they worked only on their own, using traditional field methods. Use of mGeo allowed students to use the collectively developed data sets when they did post-field data analysis. Data, photographic, quantitative and qualitative were used to do analysis of bedload characteristics, dissolved load characteristics, stream channel assessments, erosion hazard index assessments, flow characteristic assessments for the rivers visited. Upon uploading the data and transferring the information on Google Earth, they could create maps (Fig. 7a), that showed the exact routes followed, the exact locations where the various types of data were collected, which could then be used to analyze the riverine conditions.

Use of the huge data base allowed them to create isolines, charts, and tables with the help of the collective datasets, to show various parameters related to the rivers under study (Fig. 7b). Interesting part of this entire task is that, students do not need to be proficient in GIS to be able to visualize the field characteristics, as the data can easily be shown in Google Earth, using the facility in NIEmGeo. The subsequent work done by students show that they used the data collected by other groups extensively to draw maps, to infer, to analyze conditions, a feature that shows the effectiveness of the application in facilitating collaborative learning in Geography.

Figure 7a. *Pins showing locations of different groups collecting the field data on various stream parameters*

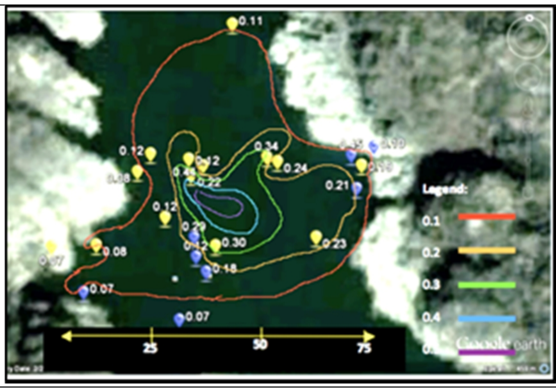


Figure 7b. *The combined data from various groups is used to draw the Isovels*

After the official launch of the application in the Apple Store, another class of undergraduate students (total 80 students) used the application to conduct field investigation of a slightly different nature. These were students from a BioGeography course and were engaged in studying the impact of urban development around a nature reserve in Singapore. The time available to do this field-based data collection was very short (2 hours for individual students) and the area had to be covered extensively to gather enough data to substantiate their views on impact of non-forested landuse at the forest boundaries on the forest floral environment. The class was, therefore, divided into eight groups, each given to cover a different section of the entire area to collect detailed, geo-referenced, environmental, vegetational, and soil data, using NIEmGeo. This provided the opportunity to collect a combined data set with 4000 quantitative information on various parameters, such as air temperature, relative humidity, soil temperature, soil moisture, ground litter, location of lianas and epiphytes, signs of forest floor erosion etc. in enough numbers to provide a good base for analysis afterwards. This also allowed the task to be completed in a short time (each student investing only two hours for the fieldwork), as the task was small for individual students. This provided the lecturer an opportunity to expose all students to authentic learning situations, do field-based tasks, and collect primary data, which is considered essential for reliable geographical analysis, without impinging on the curriculum time or compromising the quality of learning. So each student within the groups collected small chunks of data from designated areas recorded all relevant attributes, including geo-spatially cognizant information synchronously.

Subsequently, students uploaded the data to the University server and the entire data set was now available for every one's use. The final analysis of the forest peripheral environment was done by individual students, based on the varied and vast data sets developed collectively by all, gathered using exactly the same procedures and within the same time frames by all students in the course. This data sharing also allowed students to compare their own data with those of others and thus led to a more enriching analysis of the given issue. Students could also use Google Earth to draw the maps of all the field locations and analysis and explanations for certain parameters (such as high temperatures along certain sections of the forest because of locations near major roads) became easier (Fig. 8), while they could compare this data with those collected by others in the interior of the forest, to examine the extent of the impact of urban development all around the forest.

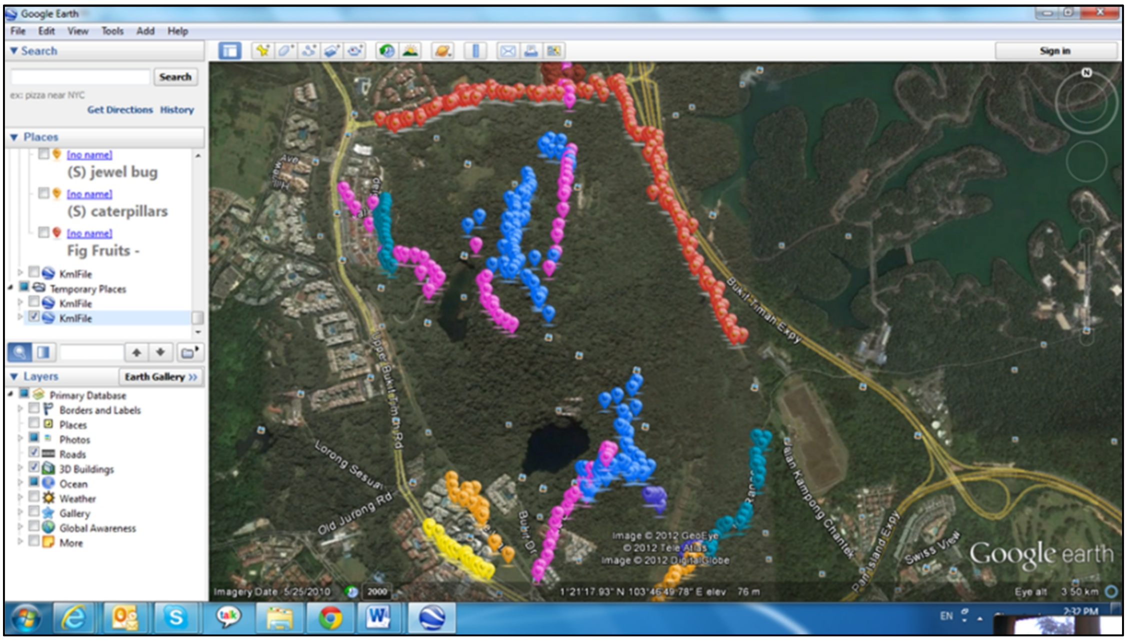


Figure 8.
Data plotted using Google Earth, showing locations of data points covered by differentgroups. Different groups' data pins are colour-coded for easy identification.

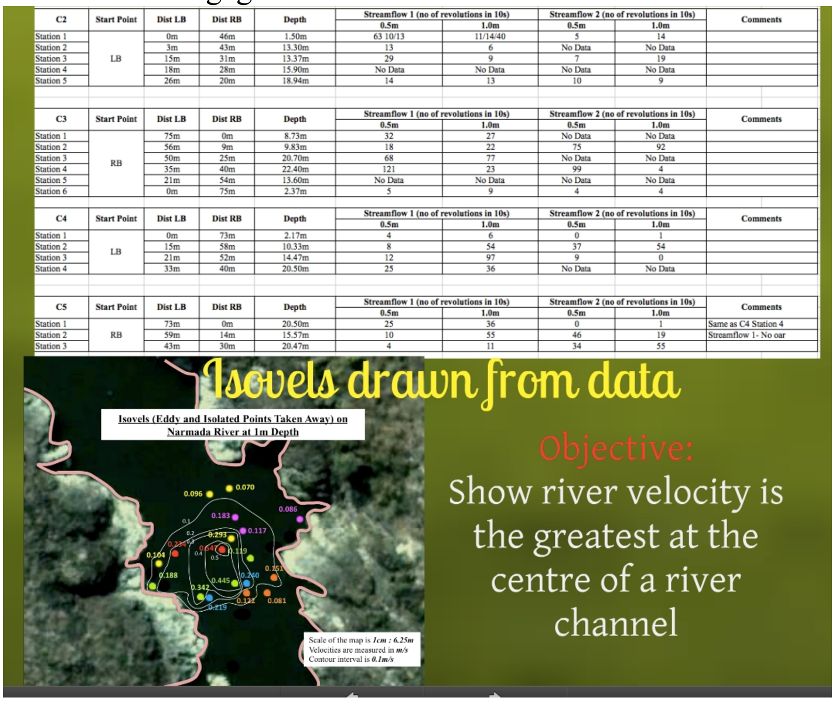
Such in-depth analysis based on sharing of wide range of data sets was possible through the use of a single platform capable of handling various types of quantitative and qualitative, spatially-cognizant data that could be accessed by all via the server. The ability to use Google Earth to draw up the maps and to see the relevant data as well as other comments on a geo-referenced map completed the geographical analysis, even though very few students had, by that time, done courses in GIS.

Figure 8 also shows how the student groups were distributed in a wide area and how each group's data could be identified through the use of different coloured pins. When opened on Google Earth, each pin shows the data collected for the specific location, as well as all comments that have been made regarding the site. This makes the location context-rich in a way that is specific to the student's use and requirements.

It can be summarized that use of the application made the following tasks possible:

1. Collaborative data set development and data sharing
2. Exposure to authentic field conditions and field analysis within the available limited curriculum time
3. Collection of only a small set of data in the short given time, yet the ablity to access a large data set developed by others, during data analysis
4. Data representation on maps for a visual understanding of the given issues.

Thus, NIEmGeo not only facilitated field data recording, but also allowed use of the collective data sets to be tabulated and mapped to perform analysis of findings during the post-field session. Figures 9 and 10 and Table 1 show the various ways NIEmGeo was used by the two classes of students, engaged in very different types of geographical locations but engaged in similar shared fieldwork tasks.



C2	Start Point	Dist LB	Dist RB	Depth	Streamflow 1 (no of revolutions in 10s)		Streamflow 2 (no of revolutions in 10s)		Comments
					0.5m	1.0m	0.5m	1.0m	
Station 1	LB	0m	46m	1.50m	63 10/13	11/14/40	5	14	
Station 2		3m	43m	13.30m	13	6	No Data	No Data	
Station 3		15m	31m	13.37m	29	9	7	19	
Station 4		18m	28m	15.90m	No Data	No Data	No Data	No Data	
Station 5		26m	20m	18.94m	14	13	10	9	

C3	Start Point	Dist LB	Dist RB	Depth	Streamflow 1 (no of revolutions in 10s)		Streamflow 2 (no of revolutions in 10s)		Comments
					0.5m	1.0m	0.5m	1.0m	
Station 1	RB	75m	0m	8.73m	32	27	No Data	No Data	
Station 2		56m	9m	9.83m	18	22	75	92	
Station 3		50m	25m	20.70m	68	77	No Data	No Data	
Station 4		35m	40m	22.40m	121	23	99	4	
Station 5		21m	54m	13.60m	No Data	No Data	No Data	No Data	
Station 6		0m	75m	2.37m	5	9	4	4	

C4	Start Point	Dist LB	Dist RB	Depth	Streamflow 1 (no of revolutions in 10s)		Streamflow 2 (no of revolutions in 10s)		Comments
					0.5m	1.0m	0.5m	1.0m	
Station 1	LB	0m	73m	2.17m	4	6	0	1	
Station 2		15m	58m	10.33m	8	54	37	54	
Station 3		21m	52m	14.47m	12	97	9	0	
Station 4		33m	40m	20.50m	25	36	No Data	No Data	

C5	Start Point	Dist LB	Dist RB	Depth	Streamflow 1 (no of revolutions in 10s)		Streamflow 2 (no of revolutions in 10s)		Comments
					0.5m	1.0m	0.5m	1.0m	
Station 1	RB	73m	0m	20.50m	25	36	0	1	Same as C4 Station 4
Station 2		59m	14m	15.57m	10	55	46	19	Streamflow 1- No oar
Station 3		43m	30m	20.47m	4	11	34	55	

Figure 9.
Example of analysis of streamflow velocity using data from the NIEmGeo server (Note that with many data sets available, students have the option of showing discretion in data usage)

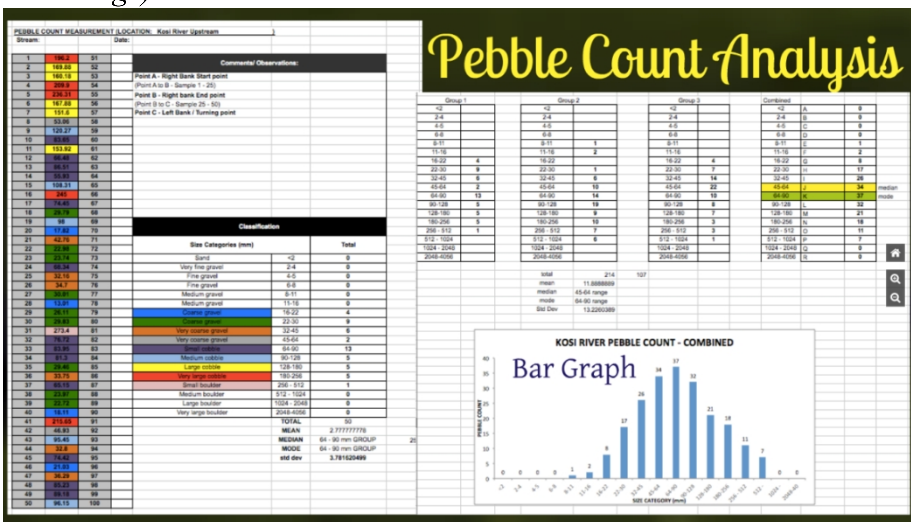


Figure10.
Example of analysis of stream bedload using data from the NIEmGeo server (Note that the bar graph is drawn using combined data)

The students did not use any pen and paper recording, using the mobile application as the only data input method. There was no data loss and although both groups of students are used to sharing information using other affordances such Dropbox, because NIEmGeo offered a system of all inputs tagged with individual locations, individual quantitative and qualitative data, students used the system for the entire suite of work, from data sharing, subsequent data tabulation, data analysis, to mapping, using the application.

Table 1.
Field and post-field use of NIEmGeo by students

Field work Phase	Course using the application	AAG232: BioGeography	AAG401: Geographical Methods and Fieldwork
	Total no. of students	80	21
	No. of groups	10 (Each group deployed in a different location to study various aspects of BioGeography)	3 (Each group deployed in a different location to study various aspects of Fluvial Geomorphology)
	Total number of coloured pins used	10	2 (for one location when there were two groups) 3 (for a location when there were three groups)
	Total no of photos uploaded	1692	1327
	Total no. of videos uploaded	4	11
	Total number of locational (geo-referenced) uploads	672	598
	Total no. of quantitative field data uploaded	4000 (each student only 50 data)	3588 (each student from 165-180 data)
	Total no. of qualitative descriptions uploaded	1237	582
Data Analysis Phase	Use of other groups' data for own analysis	80	21
	Use of other groups' photo for analysis	80	21
	Use of other groups' data for comparison	80	21
	Use of Google Earth	80	21

	and NIEmGeo to create maps (Figs. 8, 9, and 10)		
	Use of NIEmGeo as a data repository	80	21 Additionally, MS Excel files were shared sometimes through Dropbox

NIEmGeo is meant to provide opportunity for data upload with WiFi connection, to ensure that data is not lost in the process if 3G network connection is erratic. While students working in remote mountain locations in India did not comment on this because they did not have any internet while they were in the field, students doing field work in Singapore commented that this was not necessary. However, because 3G network signals can be sometimes erratic and may sometimes even be lost, this feature is still maintained, to offer total reliability in data storage and management.

Conclusion

NIEmGeo was set to solve some of the nagging problems in field work in Geography courses: too many cumbersome equipments, the problem of having to record data on paper while juggling with multiple equipment, and then having to safeguard this piece of paper from getting lost. It also aimed at providing geo-referenced data, and provide a workable solution to the common woes of a teacher trying to juggle between limited curriculum time, need for relevant and useful field experience and data collection that would be useful for actual analysis, without impinging on students' out of college time. The application provided these effectively, judging from the usage patterns of more than 100 undergraduate students in Geography (Table 1). The issue of using maps for a spatial analysis, using big data base for meaningful analysis, and cooperative database development through academic negotiations are some of the features that make pedagogically sound learning environments and make connections between the classroom and the outside world. The application has covered many features that enhance the way spatial sciences such as Geography can be learnt.

Students on the task generally responded favourably on the usability of the application, with most mentioning that it helped them visually place their data locations on the map and recording each data point details. The post-field analysis of students' work using the substantial data set was clearly an advantage for all the groups. However, just as Welsh *et al* (2012) mentioned, for the second year undergraduate group working in the forests, lack of enough iPhones among some students did cause some dissatisfaction, although that did not affect the group data collection, as all groups had some students who used iPhone. This problem can well be solved, if in future upgrades and enhancements, android platforms can also be included. This is essential as increasingly, in the coming years there is a possibility of students using mobile devices with other platforms.

Another enhancement that needs to be incorporated is to allow provisions for further data representation, merging applications for tabulating and graphing with the current

NIEmGeo. That will enhance the application as an effective research tool. Further, no Geography field tool is complete without the facility to be able to do field sketch. Field sketching allows students not just to observe but also to synthesize the observations to arrive at an educated judgment about the geographical processes operating in that environment. Since NIEmGeo is developed on a mobile phone platform, there is no opportunity for the student to perform this task, while in the field. Future developments or versions of this application, therefore, need to incorporate this very powerful and important tool most geographers would like to use, to enhance the geographical understanding. Further research can incorporate this to examine how it can enhance field-based learning in Geography.

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Biographical statements

Dr. Kalyani CHATTERJEA is an Associate Professor of Geography in the Humanities and Social Studies Education Academic Group, National Institute of Education, Nanyang Technological University, Singapore. Her areas of focus include Geomorphology, BioGeography and applications of Information Technology in Geographic Education.