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Community mapping in geology education and research: How digital field methods empower student creation of accurate geologic maps

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The synthesis paper on learning in the field by Mogk and Goodwin (this volume) is an impressive discourse on historical and modern perspectives of geology field education. Their paper serves as both an affirmation of the continued importance of field education as well as a call to arms for necessary action to enhance its future relevance for geoscience education. In this commentary, I will address and expand on one particular topic in Mogk and Goodwin's "Recommendations for Future Research" section, specifically: "What is the appropriate role of instructional technology in field instruction?" This commentary will make the case for the importance of including instruction in digital equipment and techniques within a field geology curriculum and will use a community mapping example to show how undergraduate geology students can create accurate and complete geologic maps by using digital technologies in the field.

The question of whether to include instruction in digital field methods within a field geology curriculum has become increasingly relevant as mobile computing has entered the phase of widespread popularization through the use of smartphones and tablets (e.g., De Paor and Whitmeyer, 2009). Though the complexities of using ArcGIS on fairly bulky field computers have not been completely alleviated at present, it is not difficult to envision a near future where data collection and editing of geologic maps can be efficiently accomplished in real time in the field with mobile devices. However, the relentless progression toward increased power and miniaturization in mobile devices has not changed the basic necessities for geologic field mapping, which include accurate measurement and characterization of lithologic units, real-time editing of a working geologic map while in the field, and detailed sketching of geologic features that have relevance to the mapping task at hand. Traditionally, these basic components of field mapping have been facilitated through the use of hardback field notebooks and paper topographic maps and aerial photos. To a large extent, digital methods are only effective when they improve the efficiency of these traditional components of fieldwork. As such, instructors in field methods have to weigh the relative merits of traditional versus digital techniques, and whether the ultimate improved efficiency of digital methods outweighs the additional cognitive load on students as they combine learning the technology with learning the geology.

Many field courses now include some element of digital methodologies in their field curricula (Whitmeyer et al., 2009; Pavlis et al., 2010), recognizing that most geoscience professionals now use digital equipment to collect data in the field (De Paor and Whitmeyer, 2009; Whitmeyer and Mogk, 2009). A common approach is to teach students the rudiments of ArcGIS, ArcPad, or some other geographic information system (GIS) software, so that students can use this software in conjunction with tablet personal computers (PCs) and/or ruggedized pocket PCs (e.g., Trimble GeoExplorer series) with built-in global positioning system (GPS) receivers to map geology in the field (Brodaric, 2004; Knoop and van der Pluijm, 2006; Pavlis et al., 2010). Since ArcGIS is the industry standard for cartographic applications, students can realize long-term benefits from exposure to this software, though field exercises are often limited in scope due to time constraints. Unfortunately, the fairly steep learning curve currently associated with GIS software often elicits some frustration on the part of students, as many of them feel that, at least initially, the technology inhibits their ability to cover ground quickly and efficiently in the field. One way to address this issue is to use the cumulative quantity of field measurements obtained by a whole class of students digitally mapping the same region to create a group geologic map. This approach can alleviate some of the pressure students feel regarding time conflicts between learning new techniques and tackling a new field area. This concept of combining the data-collection efforts of many individuals within a single map project is often called "community mapping" or "crowd sourcing," and it has proven to be effective in quickly creating highly accurate maps of crisis areas, such as earthquake disaster zones (e.g., the 2010 Haiti earthquake; Zook et al., 2010)

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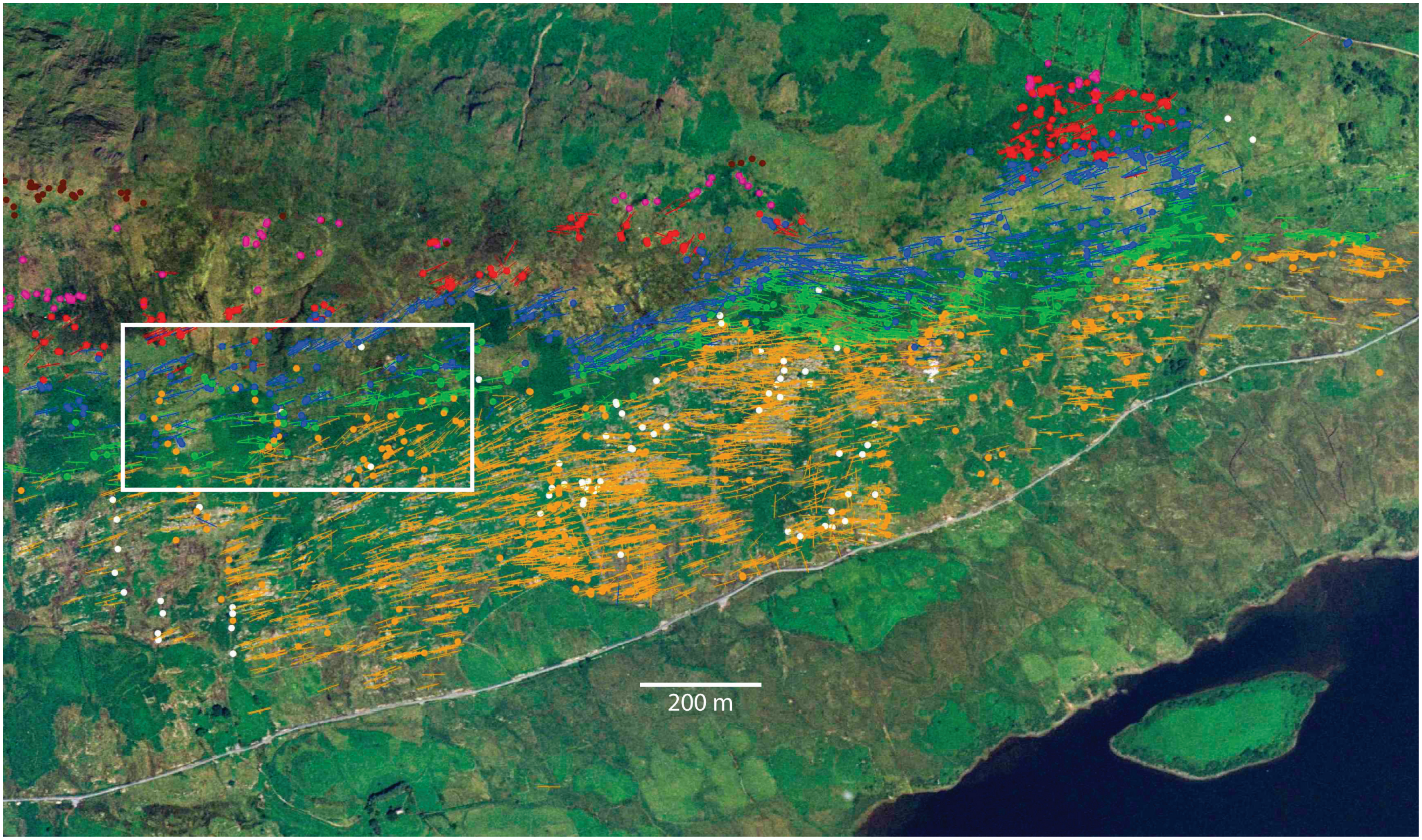

Figure 1. Collective field data from 3 years of student mapping during the James Madison University Ireland Field Course digital mapping exercise on the mountain of Ben Corragh, western Ireland. Units are represented, respectively, by colored dots and strike and dip symbols. White box shows an example region of conflicting student data. Background orthophotos are courtesy of the Ordinance Survey of Ireland (OSI). Center of image is located at approximately 53.564° N and 9.512° W. Dots are outcrop locations with lithologic data only, strike and dip symbols are outcrops with lithologic data and orientation data. Colors equate to individual lithologic units.

and wildfire-affected regions (e.g., the 2007–2009 Santa Barbara wildfires; Goodchild and Glennon, 2010).

We have used a community mapping approach for several years in the digital mapping exercise at the James Madison University field course in western Ireland. This 4–5 day exercise focuses on mapping an extensive mountainous region by targeting an original section of a mountain each year, such that over a 5 year period, the whole mountain gets collectively mapped (Whitmeyer et al., 2010). Though students are still effectively novice field mappers at this point in the course, the collective integration of data from 15 to 20 digital maps typically results in any disparate data points being overwhelmed by accurate data. The collective digital map that is produced is impressive in the sheer quantity of outcrop data represented (Fig. 1). The map can also be pedagogically instructive in that it sometimes reveals regions where students had conflicting interpretations of the geology (e.g., classification of lithologic units; Fig. 1, inset).

Our experience is that students are challenged, and sometimes frustrated, by using digital field methods to create a geologic map (Table 1). Students' initial frustration with learning how to use the equipment and GIS software can be exacerbated by not-uncommon episodes of equipment failure, which can result in a loss of digital field data. However, students appreciate the exposure to digital field equipment and GIS software (Table 1) and consistently report gains in feeling, skill level, and knowledge in the summative survey of this exercise (Table 2). They are typically quite impressed when they see the results produced by incorporating student field data from several years into a collective geologic map of the mountain (Table 1) and consider the exercise to be useful to essential (Table 2).

The conclusions drawn from several years of teaching digital mapping methods in the field, include: (1) It is possible to effectively introduce students to digital field mapping methods in a 4–5 day exercise, though typically there will be some frustration involved. (2) By using a community mapping approach, accurate original geologic maps can be produced over the course of a few years by novice geology students, but (3) digital mapping techniques do not change or replace the traditional components of effective geologic mapping in the field. Ultimately, digital methods simply improve the efficiency of a geologist throughout the process of field data collection and geologic map preparation. So, in response to Mogk and Goodwin's query on the appropriate role of using instructional technology in field instruction, I argue that effective field instructional techniques have not changed, nor have the key components of geologic fieldwork changed. What has changed is that we now have more efficient methods of collecting field data and assembling geologic maps, and we do our students a disservice if we fail to introduce them to the modern

TABLE 1. EXAMPLE STUDENT COMMENTS

Using a tablet was nice (also so, so, so frustrating).
Getting experience with ArcGIS was also nice.
Creating a digital map was fast and easy and extremely clear, so you could easily distinguish contacts and structural features.
I became far more confident through this exercise.
The tablets were ridiculously heavy; it's easier to copy your data at night and leave the tablet behind. How are you supposed to climb a mountain with a 15 pound [*sic*] thing hanging off your chest?
The programs (ArcGIS and ArcPad) are hard to use at first, and it kinda sucks to lose time in the field due to digital malfunction. I would rather spend time in the field scratching my head over geology questions rather than technical questions.
More time would be helpful. It was extremely stressful trying to learn a new program and map an extensive area at the same time.
Wow, that (composite, digital geologic) map of the mountain is great! We collected a lot of data.

TABLE 2. ASSESSMENT DATA

	1	2	3	4	5	Mean
My prior experience with ArcGIS was:	Nonexistent	Very little	Moderate	Considerable	Extensive	1.87
My prior <u>feelings</u> specific to this exercise were:	Great discomfort	Slightly apprehensive	Neutral	At-ease and comfortable	Highly motivated	2.93
My prior <u>skill level</u> with this exercise was:	Completely unskilled	Basic	Competent	Skilled	Expert	2.21
My <u>knowledge</u> gains from this exercise were:	Nonexistent	Very little	Moderate	Considerable	Extensive	3.88
My <u>feelings</u> after this exercise were:	Great discomfort	Slightly apprehensive	Neutral	At-ease and comfortable	Highly motivated	3.73
I found this exercise to be:	Not valuable at all	Only slightly valuable	Moderately valuable	Useful	Essential	4.32
My <u>skill level</u> after this exercise was:	Completely unskilled	Basic	Competent	Skilled	Highly skilled	3.57
My overall learning from this exercise was:	Nonexistent	Trivial	Moderate	Considerable	Extensive	3.91

Note: Assessment data for the 3 years of digital mapping exercises represented in Figure 1 (mean of responses, $n = 86$). Gains were consistently recorded in feelings, skill level, and knowledge. Assessment template is from Pyle (2009).

digital equipment and techniques that they will use in their subsequent professional careers.

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