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# "HOW DID YOU LEARN TO MAKE GEOLOGIC MAPS?" THE IMPACT OF EMBODIMENT, COMMUNITY, AND INSTRUCTION


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## PURPOSE AND GOALS

- Fieldwork is a key component of gaining expertise in geology (Petcovic et al., 2014)
- Learning bedrock mapping has long been a cornerstone of field instruction
- As part of a larger naturalistic study of mapping strategies (Hambrick et al., 2012; Baker et al., 2012; Baker & Petcovic 2012; 2016), undergraduate through professional geoscientists were asked during semi-structured interviews to reflect on experiences that promoted their personal competence and confidence in mapping
- This study gives voice to the experiences of a sample of geoscientists as they reflect on how they became competent in geologic mapping
- Describing the range of instructional and community experiences can add to our knowledge of the role of fieldwork in developing geologic expertise

## METHODS

### PARTICIPANTS

| Demographics | N=67 |
|---|---|
| Gender (no., % female) | 31 (46.3%) |
| Age (range, mean) | 20-68 (36.4) |
| Yrs since highest degree (range, mean) | 0-29 (7.3) |
| Current undergraduate student (no., %) | 14 (20.9%) |
| Current graduate student (no., %) | 19 (28.4%) |
| Current or former professional geoscientist (no., %) | 36 (53.7%) |
| Took undergraduate field methods/mapping course (no., %) | 64 (95.5%) / 50 (74.6%) |
| Graduate field/mapping research experience (no., %) | 44 (65.7%) / 32 (47.8%) |
| Professional mapping or teaching mapping experience (no., %) | 21 (31.9%) |

### DATA COLLECTION & ANALYSIS

Participants were recruited and selected for the larger study (2009 & 2010)

Participants completed cognitive tests, a mapping task and a post-mapping interview. Part of the interview asked "How (or where) did you learn to make geologic maps?"

Responses to mapping and experience questions were isolated for analysis

Authors independently each read a random sample of 10 interviews and generated potential codes. Codes were compared and consolidated.

Mogk and Goodwin (2012) was used to identify three key themes: embodiment, immersion, and community of practice. The fourth theme (instruction) emerged from analysis.

Authors iteratively applied codes to a sample of 5 transcripts, compared results, and refined the coding scheme until a final coding scheme was agreed upon

Transcripts were divided for coding among all authors. One author identified text passages to code and coded these. A second author independently coded each passage. Mean 76.5% agreement was achieved.

All disagreements were discussed and resolved to reach 100% agreement

Coded text segments were compiled using NVivo 11.0

Coded segments were reviewed by all authors and an independent peer group to identify key ideas within each theme. This poster focuses on our analysis of theme four (Instruction) and five codes within this theme: structured instruction, ill-structured instruction, metacognition, practice and mastery, and struggle.

## RESULTS FOR THEME FOUR: INSTRUCTION

### STRUCTURED INSTRUCTION

**Feedback is used to improve learning and performance**

**Students get regular and timely formative feedback that is used to improve work**

- 2KITTIES: She was always checking our field books. And it was more of a later; she would look at our field books and point out where we were wrong.
- MITCHELL: And then they graded it in an hour and gave it back to us, so we had this immediate feedback … it forced us to put stuff on the page because we had this very limited time. And we had feedback on the area to see if we knew what we were doing and – so that really helped quite a bit.

**Students get informal feedback through instructor interaction and questioning**

- FIAMME: And we would go out in teams of two or three and we would have, every week, one of the TA's or the professors would go out with a team and just be with them and answer questions and such.
- ZIGGY: … you have a good TA and professor for your intro classes too, and they really are good at teaching you how to do it.

**Scaffolded experiences bridge classroom to field**

**Students read/learn about concepts in the classroom and apply their ideas in the field**

- ANN: … talk about the local stratigraphy in the classroom and then we'd go out and actually look at it and then start mapping.
- MELCHIOR: Yeah, we started the field course with, of course, some series of lectures about the area. And then we looked at the general geology of the area and what to expect, what type of rocks to expect.

**Scaffolding exercises from simple to difficult creates a gradual shift of responsibility from instructor to student (first I show you, now it is your turn).**

- DINGO: a lot of the early ones they just sort of walked you through the structure the first day or so but then most advanced ones, then you get to work in pairs and stuff which is fun and nice to have someone around.
- FIAMME: It was guided from the standpoint that they provided a template that, okay let's go to an area that we've mapped. Let's look at some contacts. What the rocks look like. So we spent a day doing that and then we would often then do a traverse to look at rocks and then they would say, "Now it's your turn."

**Instruction teaches specific skills**

**Learning how to perform a technique that will be used during mapping gives students tools that are authentic and critical to the practice of geological mapping**

- GECKO: but we spent an entire week walking through each and every step of making a map, like learning how many strides in 100 feet and how to do rough triangulation with your Brunton and so it was a super intensive week in the field after we did all these little background exercises leading up to that …
- FRANCES: ... here's how to go out and put – not make a map, but like, put a few contacts on a map. Here's how to measure a strat section using a Jacob Staff. Here's how to do a pace and compass very detailed map.

**Positive influences of good instruction**

**Instructor creates a positive learning atmosphere through intentional questioning, clear explanations/guidance, challenging students, and modeling geologic habits of mind**

- VACHOT: If the instructor wouldn't have been there our maps would have been all over the place. But there were a couple of areas where it was really clear and I thought really meaningful.
- IVY: So the person who I think of most as the person who taught me how to map was a structural geologist, and had been a professor for many years, and had a good excitement about being out in the field...

Can provide

### PRACTICE AND MASTERY

**Learning is cumulative - accumulation of experience and building on prior experiences and knowledge leads to mastery**

- CARLOS: And I think that starting [mapping] when people are undergrads is really important, because at least for me, it didn't all come together until I had accumulated a lot of experience. And it's still evolving. Like I still feel like I'm taking steps forward with my mapping.
- FIAMME: So you'd learn as you – it's a cumulative thing. So as the more you see, the more opportunities, the better you are of recognizing relationships and so on and so.
- ZIGGY: Because it's just compounded over years of doing it, it's just I feel like there's no one moment where I was like I know how to map now.

**Practice, practice, practice - the more you do it, the better you get, especially if you have a range of experiences**

- 2KITTIES: I've had field classes where we go out and do little maps of things similar to this, perhaps maybe not this big even, but its practice, practice, practice.
- FRANCES: And then once I ... TA'd as many different field schools as I could to kind of get out there and practice making maps in different areas and different ways of thinking.
- WILLIAM: I guess every time I went out into the field I feel like that had a big difference. It definitely helped me become better at mapping. Like, the first map that I made wasn't that great, and the last one I did I felt, like, was a lot better than the first one. So it's by practicing it, pretty much.

Can teach

### METACOGNITION

**The learning environment is set up in a way that fosters students to become more independent learners and take ownership of their work**

- HONEYBEE: ... you know, not just regurgitate information. It really makes you apply what you've been given in the class and then try and pull it altogether and think on your own.
- DINGO: I think being forced to just walk in the field for a whole weekend by yourself and come back with something that you're going to hand in and say 'hey this is what this area is like'. I guess that gave me the most confidence.

**The learner has ownership of their learning - it is up to the individual to step up and figure things out, make progress, and learn from mistakes**

- 2KITTIES: …. where you have to take some control and say what am I going to do first to make this work? And I've learned to try a few different things and go down the line and stop, orientate yourself, pick something you know to do, execute that and then plan on from there"
- CARLOS: ... it's almost like learning how to play a guitar. It's like if you're teaching yourself, you try different things that work and things that don't work. And I think that, for me at least, the experience has been what's put together for me.
- PEAT: But I did a lot of reading and just looking at different field guides, different hand books to see what's, is there a certain method that you go into this with, like what's the first thing you do, what's the second thing you do, is there some sort of a checklist that you could say?
- PAIRIGUE: So you can think about what you did and why you did it wrong. How you might have recognized what the real answer is. That certainly is the most helpful way for me to learn. I guess the most helpful way would be to do it, to see how I did it wrong, or how to do it right, and then to do it again right. But that's of course time consuming.

**Just get out there and do it**

- 2KITTIES: … you don't know a darn thing about this area and you go out and you just start. You start looking at the rocks and you measure sections, and you figure out the different units that you're going to be working with and then you try not to get overwhelmed with it.

Can develop

Can develop

### ILL-STRUCTURED INSTRUCTION

**What does ill-structured instruction look like?**

- MITCHELL: They threw us out there with a Brunton and a map and a pencil, and – that's what they do.
- REDBEARD: Pretty much you just made a bunch of crappy maps and I got yelled at until I figured out how to do it better.
- SAMSON: First, he kind of turned us loose out there, and we flailed.
- 2KITTIES: But it was pretty hands of, sink or swim sort of thing.
- ASPIDISTRA: And then the professor who I had for field camp wasn't very hands on, he would sort of let us go out in the field and do our thing. So, it was trial by fire.
- KAYA: He just kind of asked us a lot of questions and kind of encouraged us to figure out for ourselves how to do it I guess.

**Why ill-structured?**

**A case of a "bad instructor"**

- 3DHP: I had an instructor who was very knowledgeable and not necessarily super approachable.
- DAFFY: He didn't feel like teaching.

**It is difficult to teach mapping in a way other than just getting out there and doing it**

- 2KITTIES: I don't know how you teach that actually.

**It created an inquiry-based type of learning scenario**

- VACHOT: Probably maybe a little bit more inquiry-based where you kind of learn by doing and making mistakes and learn what kind of questions to ask.

Can lead to

### STRUGGLE

- **The physical setting and environment in which the learner is working is challenging (e.g., complex structures, rocks that all look alike to a novice, difficult terrain, poor exposure, vegetation obscuring rocks and structures), causing the learner to struggle**
  - APES: And so it was kind of hard because you'd have to walk away from the structure into the woods and come back somewhere else to take another strike and dip of it. And there were outcrops that looked similar that weren't the same thing. So it was kind of confusing because I didn't have any experience of well okay, but maybe there's a syncline and then it's coming back up over there.
  - GEOSTRUCT: We were looking at a lot of the glacial systems … the challenge of it was trying to identify all the faults and they were everywhere and it was a struggle because you just - all of a sudden a rock disappeared and you're like, where is it? And it's under the heather.

**Struggle due to perceived personal characteristics (e.g., not being good at 3D thinking, having a weak background in mapping, etc.)**

- CARLOS: And I just think as an undergrad, you're bombarded with so much in geology it's like a foreign language at first that you need to - I don't know, it's a struggle. Maybe it's not for some people, but for me it definitely was. I didn't understand strike and dips the first time I did it, I could not get it. It just did not make any sense to me.
- DARREL: So the fact that I don't have great knowledge in geology and mapping, it was just, it just makes it more challenging to me to figure out what was going on. And I felt like, for some reason, that I wasn't finding out what was exactly going on, so that was frustrating for me.

**Participants recognize that struggle is beneficial to learning; that having to figure out answers and solve problems ultimately leads to meaningful learning (not just rote or surface learning)**

- SAMSON: And the struggling is where we learned, I think, the most, because then we realized if you don't have a plan, if you don't know what to do, you're going to waste a lot of your time out there, and you're not going to take the observations and readings in such a way that you're going to be able to produce something like this.
- VACHOT:… sometimes it's good for students to kind of struggle a little bit and then you get the extra instruction and you get that aha moment. Maybe it's more meaningful than being told right up front …

**Seeing the instructor struggle (or as the instructor, allowing students to see you struggle) can teach how to deal with the uncertainty that is inherent in geologic mapping**

- FRANCES: You can watch me in the field be like, oh, I don't know what this is, I'm so confused. [I] think that's valuable, yeah. And watch how you work through it as opposed to, you know, sometimes you see students when they're learning. It's really frustrating. This is actually a really challenging skill
- ZIGGY: ... the way our professor ran it is that he - it's one of those areas he was doing for his research, and he's never mapped it before. So he would come out with us and map around and I heard him cuss and say I don't know what the F is going on here. So, when you're feeling frustrated and you know the professor is frustrated, it just - I don't know, to me it just felt like I was actually doing real mapping.

## DISCUSSION

Participants experienced two contrasting types of instruction:

- Ill-structured, in which they were "turned loose" to "sink or swim"
- Structured, in which the instructor scaffolds learning, teaches specific skills, and provides timely and helpful feedback

Regardless of the instructional style they experienced, participants recognized that the learner bears responsibility for monitoring their progress and learning from their mistakes.

Metacognition helps build and develop independent mapping skills that leads to mastery. This can be acquired through how instruction is designed or students taking some responsibility in the learning process.

Struggle is recognized as part of the learning process. A little struggle forces learners to take ownership of their work, but too much leads to frustration, which impedes learning.

Practice is an important component to mastering skill and developing mapping expertise. This can take multiple experiences over several years.

## IMPLICATIONS FOR TEACHING

Designing instruction that provides students the opportunity to take responsibility of their learning leads to meaningful learning. However, this opportunity should not be one that will cause excessive frustration. Finding the balance between empowering students to grapple with the process while minimizing frustration creates positive learning experiences.

Providing students with the skills they will need in the field before leaving the classroom reduces cognitive load so that students can concentrate on mapping while in the field.

Participants appreciated that "learning by doing" was critical to gaining mastery in mapping. However, they valued feedback and timely intervention when they made mistakes. Scaffolding learning with frequent "check-ins" while in the field boosts student confidence.

## REFERENCES


Baker, K. M., & Petcovic, H. L. (2016). Sensitivity to landscape features: A spatial analysis of field geoscientists on the move. *Journal of Geoscience Education 64*(3), 242-253. DOI: 1089-9995/2016/64(3)/242/12

Baker, K. M., Petcovic, H. L., Wisniewska, M., & Libarkin, J. C. (2012). Spatial signatures of mapping expertise among field geologists. *Cartography and Geographic Information Science 39*(3), 119-132. DOI: 10.1559/15230406393119

Hambrick, D. Z., Libarkin, J. C., Petcovic, H. L., Baker, K. M., Elkins, J., Callahan, C. N., Turner, S. P., Rench, T. A., & LaDue, N. D. (2012). A test of the Circumvention-of-Limits hypothesis in scientific problem solving: The case of geological bedrock mapping. *Journal of Experimental Psychology: General, 141*(3), 397-403. DOI: 10.1037/a0025927

Mogk, D. W., & Goodwin, C. (2012). Learning in the field: Synthesis of research on thinking and learning in the geosciences. In K. A. Kastens & C. A. Manduca (Eds.), Earth and Mind II: A Synthesis of Research on Thinking and Learning in the Geosciences. Geological Society of America Special Paper 486 (pp. 131-163). doi: 10.1130/2012486(24)

Petcovic, H. L., Stokes, A., & Caulkins, J. L. (2014). Geoscientists' perceptions of the value of undergraduate field education. *GSA Today, 24*(7), 4-10. DOI: 10.1130/GSATG196A.1


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