Geologic mapping strategies of novices and experts as evidenced through GPS track and map analysis

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ABSTRACT

Strategies of experts and novices during mapping of two field localities were examined to better understand the nature of expert cognition in the geological sciences. Two day-long (4-8 hour) mapping projects took place at field locations near Marquette, Michigan. Each field site required a different mapping approach; at one site, participants mapped cross-cutting relationships between rock units exposed in intermittent outcrops in a ~100 meter by 300 meter area, whereas at the second site, participants mapped rock units that form a structurally complex syncline exposed in vertical cliffs of a quarry and road cut over a horizontal distance of 1.5 km. Seven participants representing a continuum of prior geologic study and field mapping experience, ranging from none to 10+ years, took part in the study. Three undergraduates and a master's student mapped sites during normal activities in a required field methods course, and the remaining participants (a PhD student, professional geologist, and college professor) mapped the following day.

We recorded complete GPS tracks of participant movement during the mapping activities, and collected both paper maps and field notes produced by participants during the exercises. Participant maps were converted to digital format and matching polygons or polygon groups between maps were paired for analysis. We also compared participant maps to a USGS bedrock map though the analysis of polygon shape and centroid distance metrics. GPS tracks collected during mapping activities were analyzed for specific hot spots of participant activity, as well as general trends in spatial pattern. Finally, participant activity as evidenced in the GPS tracks was associated with specific mapped features. Comparison of tracks from novices and experts showed marked differences in track simplicity, hot spot location, and general trends, suggesting preconceived strategies. A wide range of map features, mapping accuracy, and mapping strategies were apparent among both novice and expert geoscientists.

RESEARCH QUESTIONS

The goal of this project is to characterize the strategies and cognitive processes used by both novice and expert geologists engaged in bedrock field mapping tasks.

1) What strategies do students and experts use to complete geology field mapping tasks?

2) Can we measure/compare these strategies via analysis of (a) spatial patterns exhibited by participants during mapping; and (b) participants' maps?

PURPOSE

WHY SHOULD WE STUDY THE EXPERT-NOVICE CONTINUUM?

- Increasing attention is paid to student (novice) cognition in geosciences, particularly concepts and skills that are thought to be intrinsic to geological expertise.
- We are forced to make assumptions about the nature of geological expertise since we know very little about how novices become experts, skills important to gaining expertise, and how traditional education shapes thinking of geoscientists.
- Understanding the transition of novice to expert is a necessary prerequisite to developing effective learning environments for students at all levels.

WHY SHOULD WE STUDY EXPERTS AND NOVICES IN THE FIELD?

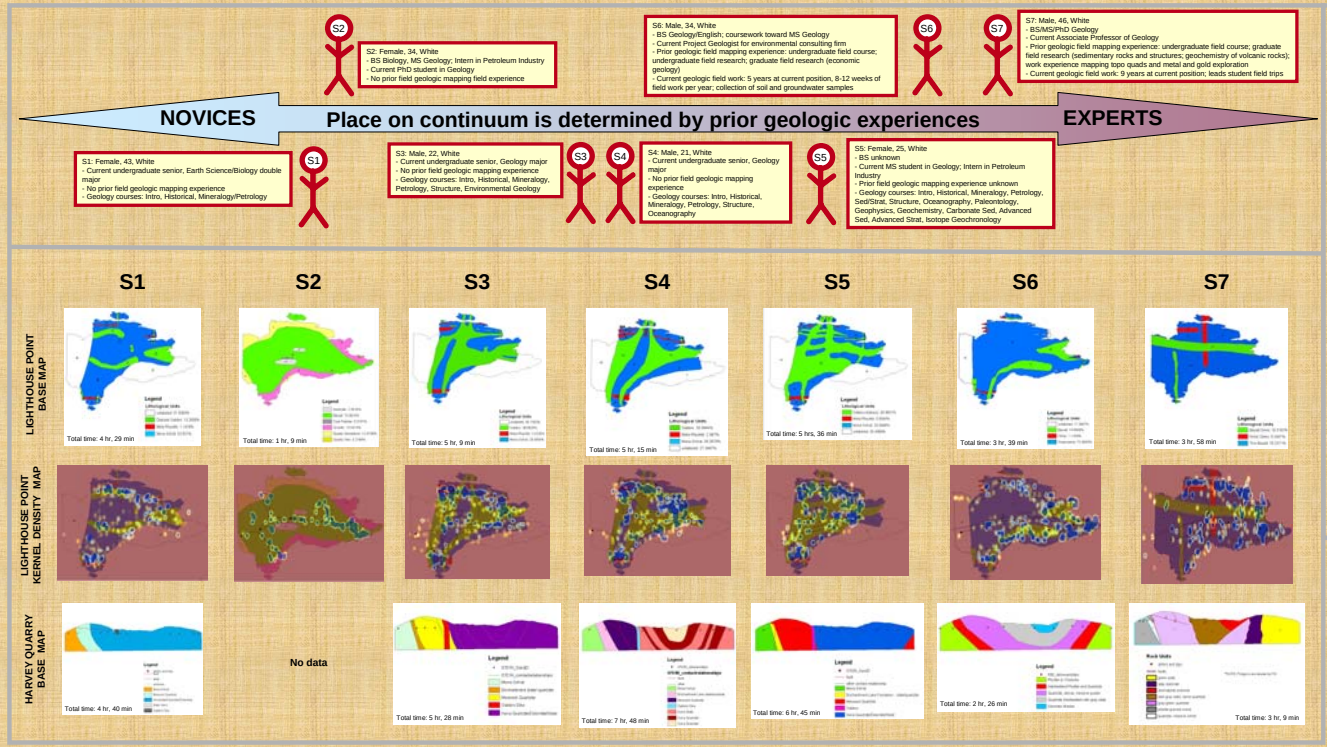
- Geological data, whether in the form of physical samples or instrumental measurements, are gathered in the natural world. Even lab experiments, computer simulations and theoretical models are designed to understand natural processes.
- Despite the wide variety of disciplines within the geological sciences, nearly all professional geoscientists receive some field-oriented training.

STUDY AREA

The study utilized two field locations near Marquette, MI in the Michigan Upper Peninsula. Rocks exposed at both sites are distinctive enough that a detailed knowledge of the local geology and stratigraphy was not crucial to mapping the field sites.

Lighthouse Point: Cross-cutting relationships between three rock units on a topographic base map (100 meters x 300 meters).

Harvey Quarry: Seven distinct rock units in a structurally complex syncline exposed in vertical cliffs of a quarry and roadcut. Exposure over a horizontal distance of 1.5 km; site flagged every 100 meters.



METHODOLOGY

PARTICIPANTS:

- Participants created bedrock maps of both sites on consecutive days.
- S1, S3, S4, and S5 participated as part of normal activities in 2-week geologic mapping course, and had ~8 hours to complete each map (plus supplemental course assignments).
- Participants S2, S6, and S7 participated one day after other subjects. Time was unlimited, but all participants finished each tasks in under 4 hours.

METHODOLOGY

DATA:

- Data collected from all participants: Draft and final maps, field notes including lithologic descriptions, continuous GPS track record (modified from Lieder, 2005), background survey, and Novelty Space Survey (J. Elkins, personal communication).
- Data collected from S2, S6 and S7 only: Audio recordings of thoughts during mapping, digital photographs taken by participants, follow-up interviews.

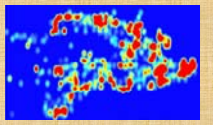
METHODOLOGY

ANALYSES:

- Maps were analyzed in ArcGIS 9.2. Polygon and other analyses provided information about total map area devoted to specific rock units.
- GPS tracks analyzed via kernel density analysis and examined for trends. GPS tracks and associated time stamps were used to create a density map for the time each participant spent mapping Lighthouse Point. Kernel density in ArcGIS was used to calculate the accumulated density of time spent by each participant in the vicinity of each feature.

DATA NOTES

- Participants are positioned along the Expert-Novice continuum based upon relative levels of prior geologic, bedrock mapping, and other field experience.
- Digitized versions of participants' maps from Lighthouse Point and Harvey Quarry are shown for all participants (S2: Lighthouse Point only).
- Kernel density plots with simplified GPS tracks (black lines) from Lighthouse Point are shown for all participants.



Average Kernel density map of Lighthouse Point, GPS tracks for all seven subjects. Red indicates areas where subjects spent the most time; blue are regions that were not visited.

NOVELTY SPACE SURVEY RESULTS

SUBJECT	SOCIAL NOVELTY	COGNITIVE NOVELTY	GEOGRAPHIC NOVELTY	PSYCHOLOGICAL NOVELTY
S1	44%	31%	41%	16%
S2	---	25	57	38
S3	22	34	31	28
S4	13	28	38	34
S5	56	22	47	31
S6	---	16	61	25
S7	---	16	7	25

Novelty Space Survey courtesy of J. Elkins; Score of 0% suggests complete familiarity; score of 100% suggests complete unfamiliarity.

LIGHTHOUSE POINT POLYGON ANALYSIS

Percentage of Total Map Area Assigned to Each Unit by Participant

SUBJECT	Schist, greenstone, amphibolite	Diabase, gabbro	Meta-rhyolite, felsic porphyry	Other rock types	Unmapped area
S1	54%	13%	1%	0%	32%
S2	0	71	14	16	0
S3	27	39	2	0	31
S4	36	33	3	0	27
S5	29	39	1	0	31
S6	73	15	1	0	11
S7	76	19	5	0	0

RESULTS

- Cognitive and psychological aspects of field work become less novel with increasing expertise.
- Total map area devoted to different units is similar for experts.
- Expert maps display more contacts between units and structural complexity than novices (tentative - more data needed).
- Experts display economy of movement during mapping by having simpler movement tracks and less backtracking than novices.
- Kernel density analysis suggests that expert mappers spend more time in key areas, such as contact relationships, faults, etc., than novices.

IMPLICATIONS

- GIS analysis of maps and movement is a powerful tool for understanding the expert-novice continuum in the field.
- Student field experiences might benefit from explicit instruction about mapping strategies. Physical modeling of expert behavior on the part of students might be helpful.
- Much more research on the expert-novice continuum in geosciences, is needed: How do experts compare across disciplines? How do students compare at different points in undergraduate and graduate training?

ACKNOWLEDGEMENTS

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REFERENCES

Lieder, C., 2005, Problem solving strategies of geology students during independent field examinations shown by GPS tracks: MS Thesis, San Diego, San Diego State University.