Strategies and Perceptions of Students' Field Note-Taking Skills: Insights From a Geothermal Field Lesson

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ABSTRACT

Field note-taking skills are fundamental in the geosciences but are rarely explicitly taught. In a mixed-method study of an introductory geothermal field lesson, we characterize the content and perceptions of students' note-taking skills to derive the strategies that students use in the field. We collected several data sets: observations of the field lesson, hard-copy notebooks ($n = 42$), and interview data ($n = 16$). Our analysis of the notebooks revealed note-taking strategies on two dimensions, consistent with earlier findings in the literature: students' ability to write in their own words (uniqueness; *U*), and the amount of necessary information recorded (completeness; *C*). We propose several factors that influenced the students' notes: lecturer differences, previous field experience, and gender. Two different lecturers (1 and 2) taught the lesson on two different days. The note-taking task covered similar content but was not scripted, resulting in lecturer differences. Lecturer 1 included rich peripheral information, and the other reiterated the need "to think for yourself" and "focus on observations" (resulting in higher *U* scores for lecturer 2's students). We also found that students with "high" previous field experience had higher *U* scores. Interview data corroborated this finding, indicating that field experience helped students to "know what to look for." Lastly, female students generally achieved higher *C* scores than male students. Females used more words (verbosity), and this likely led to higher values achieved. To improve note-taking skills, we suggest breaking down complex field lessons into simple, manageable parts to manage students' cognitive load. © *2015 National Association of Geoscience Teachers*. [DOI: 10.5408/13-026.1]

Key words: field teaching, note-taking, geothermal geology, cognitive load theory, student perceptions

INTRODUCTION AND RESEARCH QUESTIONS

Field trips offer valuable opportunities to learn theoretical geoscience concepts (Kern and Carpenter, 1986; Kent et al., 1997; Elkins and Elkins, 2007), and instructors regard field work as "essential to learn the kinds of observations on which our entire field is based" (Butler, 2008, 6). In a recent survey, professional geologists in Canada valued practical "field skills" above all other aspects of the undergraduate curricula (Jones et al., 2010), and a larger study revealed that students, academics, and industry professionals all valued the use of field experiences in the undergraduate curricula (Petcovic et al., 2014). However, lack of funding and increased student numbers in many field-based sciences (Gold and Haigh, 1992) have led to reduced numbers of field courses and lessened the total time spent in the field, resulting in graduates with less practical field experience and skills.

Although note-taking skills are fundamental in the geosciences, many degree programs do not explicitly teach note-taking strategies, styles, and/or preferred formats (Van Meter et al., 1994). In the geosciences, like other field sciences, note-taking is commonly learned via holistic, piecemeal "best practices" passed down from various lecturers in different subdisciplines (Emerson, 1995), or through an "apprenticeship," where students study under an experienced professional in the field setting (Gold and Haigh, 1992). Additionally, rapid changes in information delivery and educational technology are causing some students and lecturers to perceive note-taking and sketching as obsolete skills (Kent et al., 1997; van der Meer, 2012). While there are several current geoscience education research initiatives that are aiming to understand field-based skills (e.g., spatial reasoning skills; Kastens et al., 2009), we have found none that has exclusively focused on the language, strategies, and perceptions of note-taking in the field.

In this exploratory study, we aimed to understand how students take notes in an introductory geothermal field lesson and to uncover students' note-taking strategies. Through analysis of the observations, notebooks, and interviews, we proposed metrics that characterize the students' performance in the note-taking task. We used interview data to uncover the students' perceptions of the value of note-taking in the field and compared the interview data to the students' notes to assess whether their strategies were consistent with their behaviors. Lastly, we explored the students' previous field and coursework experience as a potential variable that impacts students' note-taking performance and perceptions.

We used the constructs of novelty space (Orion and Hofstein, 1994) in the field learning environment and its impact on cognitive load (Chandler and Sweller, 1991; van Merriënboer and Sweller, 2005) as a theoretical lens through which to examine the results of this study. Cognitive load theory describes how cognitive "resources" are managed during learning and problem-solving tasks (Sweller, 1988). It

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suggests that when learning new material, an individual's working memory can store seven elements, but it can manipulate only two to four elements at a given time (Sweller et al., 1998). "Experts" of a given topic store information in organized, complex, rapidly accessible, "big idea" structures called schemata (Bransford et al., 2004). Consequently, experts can handle more complex working problems (van Merriënboer and Sweller, 2005), whereas "novices" do not yet have these schemata and struggle to handle many new concepts simultaneously (van Merriënboer and Sweller, 2005). The cognitive load imposed by authentic "real-life" learning tasks, such as making field observations, is often high for novice learners (van Merriënboer and Sweller, 2005). Novelty space is a measure of how unfamiliar the learning environment and tasks are to the learner, thereby adding to cognitive load (Orion and Hofstein, 1994). During a field lesson, students simultaneously encode and store information in their notebook (Di Vesta and Gray, 1972; Kiewra, 1989). In new and complex learning environments, students can become overwhelmed (i.e., high cognitive load) and cannot process the information effectively (Kiewra, 1989).

We developed two metrics to quantify the language and content of field notes, comparing individual students' notes to a lesson "dialogue" (i.e., what the whole class discussed in a field lesson): Uniqueness (*U*) is the ability of students to "write in their own words," and completeness (*C*) is the amount of "necessary information" recorded by the student compared with what the class discussed in the field lesson. The ideas of uniqueness and completeness originated from the classroom note-taking literature. In a naturalistic study on undergraduate classroom note-taking, Ganske (1981) identified that students' notes had a range of characteristics: paraphrased or word-by-word transcription; complete or incomplete sets of notes; brief or wordy notes; and the inclusion of irrelevant information. We distilled these characteristics into uniqueness, completeness, verbosity, and on-/off-task content metrics and used them as a basis for this study, allowing us to differentiate students' notes. Barnett and Freud (1985) found that learners both with and without background knowledge recorded verbatim notes, but notes by note-takers with previous background knowledge were commonly paraphrased and more unique, motivating us to explore student backgrounds as a possible influencing factor in field note-taking.

RESEARCH METHODS

Working Definition and Assumptions

Generally, the purpose of note-taking is to record information and then store it to working memory (i.e., implying that information comprehension and processing is taking place; Piolat et al., 2005). A recent study of geologic field navigation and hypothesis-making argues that field notes are "external representations of student's cognition in the field" (Balliet, 2012, 11) and that student notebooks record cognitive processes. We embrace this supposition.

It is useful to explicitly address our assumptions and working definitions of field note-taking. Our first assumption is that student note-taking strategies will differ based on the task at hand and the geological topic under study. Field geology teaching texts typically recommend general practices of being able to document a field site accurately and completely; recording observations but clearly distinguishing them from interpretations to avoid confusion in later stages of fieldwork (Compton, 1985). Generally, the purpose of field note-taking is to record data (observations), interpretations, and hypotheses. Vick et al. (1979, 16) suggest that field trips should focus explicitly on "making accurate and detailed observations and interpretations" so that students can transfer their field skills to new geologic scenarios. Additionally, in order to be effective, students should make observations that progress from the "large-scale" to the "small-scale" (Vick et al., 1979, 16). Butler (2008, 24–25), on the other hand, takes a more holistic approach, describing the notebook as: "...a document of scientific research, where hypotheses, methods, data, observations, interpretations, hypothesis modification, and planning the rest of the task are distinctly and systematically laid out... and can also serve as a reflective teaching and learning diary." Lastly, the approach, measurements, items of interest, and descriptive language recorded at a given geologic locality can be quite specific to a geological subdiscipline. Therefore, we consider it reasonable to assume note-taking strategies, style, and format will depend on both disciplinary and personal values. However, given that note-taking is typically an integral part of the assessment in a field course (Clark, 1996; Butler, 2008; Maskall and Stokes, 2009; Pyle, 2009), these values are typically set by the instructor, not the student. We thus further assume that students adapt their personal note-taking styles (influenced by previous experiences in the field or transfer from classroom note-taking skills; see later herein) to better match the implicitly or explicitly stated instructor expectations and grading criteria for the notebook. Consider for example these three commonly heard statements from instructors: (1) "Write everything you can see in this sample," (2) "The best geologists are those that cover the most ground/describe the most rocks," (3) "It is your responsibility to write what you see, not what you think I see," The first expresses focus on detail, the second on quantity, and the third on independent observations.

The second assumption we make is that note-taking in the field differs from classroom note-taking in several important ways. We propose that encoding (i.e., transcription of notes) is of a greater complexity in the field setting, as observations must be first understood and verified, and then organized and recorded. Students review their notes (i.e., storage) in the field setting differently from the classroom. Field notes are reviewed on-the-fly, informally (i.e., students may not revisit their field notes in the same meaningful fashion that they study their notes while preparing for an exam), and sometimes not at all. Additionally, we argue that language and delivery of information (i.e., observations made) in the field are typically less formal, linear, and organized than the classroom. Finally, we propose that the purpose of note-taking in these two settings is different. Field notes are used primarily to record data collection and to formulate working hypotheses, whereas lecture notes are predominantly used to record information presented or discussed in class. In the field, observations, processes, and interpretations can be discussed simultaneously throughout a lesson, and it is often assumed that the student should recognize and be able to discriminate between observations and interpretations. We think it reasonable to assume that these additional cognitive processes and field environment complexities increase the intrinsic cognitive load of note-taking.

Note-Taking Study Design

We examined a single, 1 h field lesson at a geothermal hot pool (a.k.a., hot spring), which was part of a longer field trip (see "Geothermal Field Setting and Lecturer Pedagogy" section). The note-taking and the lesson occurred simultaneously (i.e., students recorded notes while the lesson was ongoing). We used a mixed-methods approach to collect three types of data to characterize this event: observations (video recorded), student-made artifacts, and postlesson interviews. Later, we transcribed and coded the lesson (i.e., cohort dialogues), the students' notebooks, and the interviews utilizing ATLAS.ti coding software (Friese and Ringmayr, 2011).

First, we analyzed videotaped observations of the field lessons (for language, gestures, and teaching style). We then compared the observations to the content recorded in the students' notebooks. We used the guiding principles of phenomenography (i.e., the study of direct experiences taken at face value; examining behavior as determined by the experience of the phenomena; Cohen et al., 2007) to analyze and interpret these data. For example, in the analysis of interview data, the researcher sets out to understand what the interviewee is saying rather than what the researcher expects that person to say. We analyzed the three data sets independently, which is consistent with the "discovery" approach to phenomenography (Walsh, 2000). However, we also limited the topics of discussion in the interviews, which of course leads to "predetermined" categories (more appropriate for the "construction" approach to phenomenography; Walsh, 2000).

At each step, the researchers discussed the emerging themes to ensure that interpretations of the themes were sound. Each of these data sources was used to check the other two to ensure that any interpretation was internally coherent and consistent, and to minimize the risk of overinterpretation or other forms of bias. The risk of overinterpretation is important in this case, because coding was done by a single researcher (Dohaney), who is both a geologist with more than a decade of field experience and an education researcher. Brogt (2009) pointed out that interpretation done by a science education researcher who is also a science content expert (a "hybrid" researcher) carries a risk of overinterpretation because the researcher may fall into the trap of thinking, "I know what participants mean," during the coding process, when that interpretation is not strictly corroborated by the data. Recognizing this risk is important in the coding process, and the use of multiple data sources is one of the safeguards against overinterpretation. That said, we considered that the most valid coding and data interpretation were best done by a hybrid researcher rather than by researchers who are more single-subject specialists (geology or education). Our experiences in previous studies (e.g., Dokter, 2008; Brogt, 2009; Buxner, 2010) suggest that hybrid researchers often are better able to see relevant discipline–education links than single-subject specialists. Spot checks on data coding and interresearcher consultation took place between subject specialists and hybrid researchers on each of the individual data sources as an informal triangulation, but no formal intercoder reliability was established or calculated.

It should also be noted that this study was not designed to make inferences about students in the field, in general. Rather, it is a detailed description of a single event using qualitative and emerging quantitative data to explore student field note-taking strategies.

Student Participants

Student participants ($n = 42$; 18 female and 24 male) were enrolled in a 2 to 5 week field course on advanced undergraduate and postgraduate field techniques in volcanology and geothermal topics. The participants came from a variety of countries: Netherlands (1), United Kingdom (1), New Zealand (9), United States of America (31). Most students were 19–21 in age, but seven students were older (22–46). Student backgrounds included environmental science (8), engineering (8), and geology (26). Some students had no formal field or coursework geology training, whereas many of the geology students had either "low" or "high" field experience. These latter categories were based on a combination of the number of field trips, the number of days in the field (total), and whether they had independent research experience (e.g., summer internships) prior to the study. The students in the "high experience" category had more than three field trips and/or more than 20 d in the field (total) and any independent field experience. Several students reported having previously completed research internships ($n = 9$), either in New Zealand or the United States. This range of experience provided a rare opportunity to test a breadth of geology undergraduate skill sets and perceptions. Additionally, six of the participants had previously taken a hydrogeology course, which contained a module focused on geothermal concepts but did not have a field component.

Geothermal Field Setting and Lecturer Pedagogy

The note-taking lesson was embedded in a week-long module on geothermal geology techniques at a well-known New Zealand geothermal tourist site. Primary and secondary learning goals of the lesson are listed in Table I. This module covers topics like regional geology, geophysics, alteration mineralogy, geochemistry, hydrogeology, and physical volcanology. Prior to the note-taking lesson, information about the study was read out to the students (please see online Supplemental File 1A and 1B, located at http://dx.doi.org/10.5408/13-026s1), and consent was obtained in accordance with the University of Canterbury's Human Ethics procedures. The note-taking lesson was the first "stop" of the day and was a foundation for the rest of the field day. The students were asked to take notes onto a piece of paper that they were given (Supplemental File 2A; this can be found online at http://dx.doi.org/10.5408/13-026s2), so that we did not have to collect their normal field notebooks. These notes were not graded. Students were told that they could ask questions, interact with their peers, and behave normally as they would in the field. The information collected at the first stop (the lesson) and the other field stops that day was used to create a conceptual cross section (i.e., a cross section that denotes geothermal features, dominant lithologies, major structures, and fluid pathways in a geothermal system), which was assessed as 5% of their field grade (the field grade consisted of 40% of the course grade). Students were instructed that they could use those notes (from the field lesson) as reference for the rest of the

TABLE I: Note-taking lesson learning goals.

A. Primary Learning Goals After participating in the field note-taking activity, the students will be able to...	
Goal 1	*Locate* themselves on a map, recording the relevant location information.
Goal 2	*Make* and *record* visual observations at a geothermal hot spring.
Goal 3	*Define* minerals, textures, and features that are unique to the geothermal setting.
Goal 4	*Draw* and *annotate* sketches in order to *illustrate* the overall and detailed features of the geothermal hot spring.
Goal 5	Take *measurements* as a group (e.g., conductivity of the waters) at a geothermal hot spring.
Goal 6	Perform goals 1–4 in order to fully *characterize* a hot spring, recording it into their geologic notebooks.
B. Secondary Learning Goals (Other learning goals, which the lecturers used to enhance the field lesson)	
Goal 1	*Describe* and *explain* the geologic and hydrologic processes that lead to the manifestation of surficial features (e.g., how a geyser forms, or how silica sinter forms).
Goal 2	*Explain* how different parts of the Earth system *interact* at a geothermal feature.
Goal 3	*Illustrate* the distribution (location and elevation) of surficial features in a geothermal field at present, and in the past. *Explain* the processes that contribute to their location (present and past) and *predict* how they can be used to understand the hydrologic evolution of the field.
Goal 4	*Define* and *explain* the classification of geothermal waters by composition. *Match* and *interpret* the composition of the waters to specific chemical processes that occur in a geothermal system.
Goal 5	*Explain* how minerals precipitate from geothermal fluids. *Match* the chemistry of the system to the minerals that are present and *predict* the temperature, pH, and solubility of the fluids.

day, and the paper copy notes were not collected until the end of the day, when they were no longer used for the cross section.

In previous note-taking studies, it has been pointed out that students' awareness of their collected notes being used for research purposes may trigger a Hawthorne effect (i.e., where unexpected results could arise when subjects in a study are aware that they are part of an experiment and are receiving extra attention, thereby altering their behavior; Merrett, 2006). In this study, the Hawthorne effect could result in spurious or "artificial" note-taking, resulting in content that is not representative of a student's normal note-taking style or behavior. While we acknowledge that possibility, we had no reason to assume that this would be a major effect justifying the use of deception in the study design.

The class size necessitated splitting the student population into two groups (cohorts). Two different lecturers led the class on either day. Both lecturers were discipline experts and were familiar with the students prior to the field trip. A graduate student tutor also assisted the lecturers. The content presented to the students was organized ahead of time and discussed with the lecturers, so that the observations that students should cover were roughly the same (Supplemental File 1C; this can be found online at http://dx.doi.org/10.5408/13-026s1). A summary of the lesson protocol is below:

1. Preparatory activities, such as an introduction to the geologic context and geographic area and the general field environment, were done prior to the exercise (in the week leading up to and the day before) to reduce novelty space effects.
2. Lecturers were asked to present linear, manageable tasks (Chandler and Sweller, 1991; Pollock et al., 2002) in a learning-goals–focused, organized way to reduce cognitive load (Chandler and Sweller, 1991; van Merriënboer and Sweller, 2005).
3. Lecturers used the Socratic method (Overholser, 1993a, 1993b) and encouraged peer interaction and support.
4. Prior to the lesson, students were introduced informally to field "best practices" taken from Compton (1985) in several ways: (a) comparing their notes to expert notes; (b) practicing a top-down strategy (large scale to the small scale; Vick et al., 1979) in the week prior; and (c) emphasizing separating observations from interpretations.
5. Students were encouraged to use their own words and to not concern themselves with geologic jargon (to avoid the "show and tell" effect [Haigh and Gold, 1993] of more traditional field trips).

Coding the Cohort Dialogues

Two observers videotaped the field lesson in order to capture dialogue and behaviors of students and instructors (i.e., cohort dialogue). The dialogues of the two different cohorts were different as they were taught by different lecturers and had different students. We transcribed the cohort dialogues in several passes in order to capture the entire dialogue and the behavior of the lecturers and students. The primary learning goals for the lesson (i.e., observations, measurements, and annotations to accompany the field sketches and drawings; Table IA) largely guided the first pass of coding the cohort dialogue. Lecturers covered additional content (i.e., secondary learning goals; interpretations of observations; ad classification of geothermal systems through chemistry; chemical and physical processes in geothermal systems; procedural notes; Table IB) during the field lesson that was not specified in the primary learning goals. We identified, coded, and tallied this additional content. The second pass of coding focused on the observation category. Both cohorts made detailed observations, and so we broke them down into subcategories (e.g., water clarity, water color, activity of water, smell of the pools, color of the sinter, etc.). The excerpts that captured each observation subcategory were identified and assigned a code; then, the number of total observations was calculated. This value is later referred to as the total observations (T) in Eq. 2 (see Completeness subsection of "Note-Taking Strategy Metrics: Uniqueness and Completeness" section). The two different cohorts had different T values, as the dialogues were different.

Coding the Students' Notebooks

In the primary pass of coding of the students' notebooks, we assigned every phrase in the notes to the learning goals (primary and secondary) and then further subdivided the observation learning goal content (Table I, Goal 2) into subcategories (Supplemental File 2D; this can be found online at http://dx.doi.org/10.5408/13-026s2). We defined a phrase as a single descriptive word (i.e., a color, a texture, an adjective in a sentence) or a string of words describing one singular type of observation (e.g., "the water appears still"). When coding the student's notes for the learning goals, we considered each student's work individually, and then we exported their entire work into a quotation list. The quotation list included all of the phrases from the individual's entire notebook and which phrases/quotes were assigned to which code. For example, "translucent" would be under "Observation: water clarity" and "Primary learning goal," while "Yellowstone has carbonate sinter" would be under "Context: analogous geothermal systems" and "Secondary learning goal." The quotation list also included frequency counts, which are the number of times specific codes showed up in the individual's and the cohort's notebooks. A detailed method of how, and in what order, we counted the phrases in the notebooks is included in Supplemental File 2D.

Students recorded information in the main text box and around the field sketches (i.e., annotation; Supplemental File 2A and 2B; this can be found online at http://dx.doi.org/10.5408/13-026s2), and some repetition of specific observations within the text and annotation was apparent (i.e., students would mention the same observation in different parts of their notebooks). We used frequency counts and "network views" (Supplemental File 2C; this can be found online at http://dx.doi.org/10.5408/13-026s2) to check for any repetition. Network views allow us to see all the phrases (from all the students in the cohort) for one observation type and manually sort them to identify any repeats and cluster them in terms of exact wording. Duplicates were relegated to the annotation category mentioned above, so as to not inflate the uniqueness and completeness metrics. In very few instances, students applied clearly incorrect or irrelevant terms to an observation. We put these in annotation category as well.

Next, we considered and assessed each phrase for whether it was in the student's own words (unique) or the same as the cohort dialogue (verbatim). We then directly compared the student's terminology to the dialogues, using network views to sort and assign the new codes (unique or verbatim) to every phrase (Supplemental File 2C). To better explain the unique and verbatim codes, we provide here an example of the lesson dialogue, describing a geothermal feature called sinter, and examples of the students' work (below):

> Lecturer 1: *... How would you describe it?* [Points to sinter rock texture directly in front of the students.]
>
> Student response A: *It's white*.
>
> Lecturer 1: *It's white. And what else would you say about that? Over there* [doesn't point]. *What's the texture of it?*
>
> Student response B: *It's chalky*.
>
> Lecturer 1: *It's chalky, Ok. So it's white and chalky. What else? Any other textural words you can come up with to describe just on the other side* [gestures, flattens his hands and points to sinter terrace] *this white stuff?*
>
> Student response C: *It's cracked*.
>
> Lecturer 1: *Yea, it looks like it has little cracks in it. Really simple word maybe to describe it...?*
>
> Student response D: *It's a rock*.
>
> Student response A: *Laminated*.
>
> Lecturer 1: *Yea it's a rock, it's laminated. But then even more simply. You're always good with these,* [student name]*? A word that describes this really, cracky, laminated stuff....* [Pause for approximately 6 seconds.]
>
> Student response E: *Scaly*.
>
> Lecturer 1: *Scaly. Exactly, that's the word that I was thinking of. Ok, so it's looks really scaly*.
>
> *(Cohort 1 Dialogue)*

The observations within this excerpt would be coded into subcategories of: "visual texture of sinter terraces" (chalky, cracked, and scaly) and "color of sinter terraces" (white). Examples of students' notes, illustrating these codes, are below:

> Verbatim: *"... other side [of the terrace] is white + chalky, cracked, scaly" (student notes, low-performing student, cohort 1).*
>
> Unique: *"[sinter looks...] blistered" (student notes, unique student, cohort 1).*

The first example illustrates that the student used all verbatim terms (i.e., four verbatim terms in consecutive order), when describing the sinter texture and color, while the other student used a unique term that was not expressly used in the cohort dialogue.

Note-Taking Strategy Metrics: Uniqueness and Completeness

The metrics presented here are not finite values, which represent all the observations that one can make at an outcrop. They are merely a reflection of the quantity, type, and language of information that is recorded during an introductory field lesson. It is important to stress that we do not suggest that these metrics should be used as a student assessment tool or for other evaluative purposes. Rather, they simply serve as a quantitative indicator of student note-taking strategies in the field.

Uniqueness

Uniqueness is a measure of independent observation making, active questioning, and information processing. For each individual student, uniqueness (Eq. 1) is defined as the percentage of original information (U) to the total information recorded by that student ($U + V$). We associate high uniqueness values with active information processing (i.e., filtering, considering, critiquing, etc.). Unique phrases include and can be broken down further into two categories: paraphrased phrases, and extra phrases (E). Extra phrases are additional observations that were not included in the cohort dialogue. For example, when describing the activity of the water in the geothermal pools, one student noted that the "outflow" from one pool appeared to be slower than another adjacent to it. This was not discussed during the cohort dialogue. This was an additional and unique observation made by that student. Paraphrased terms are the replacement or synonym for the same item. For example, when describing the pool activity, one of the lecturers noted that it was "bubbling frequently," but one of the students paraphrased to "bubbling a lot."

Equation 1: Uniqueness of a student's written notes compared with a cohort dialogue, where U represents the total number of unique phrases, and V represents the total number of verbatim phrases:

$$\frac{\textit{unique observations made by that student}}{\textit{total observations made by that student}} = \frac{U}{U+V} \times 100\%. \quad (1)$$

For example, if a student recorded 25 unique observations (including 20 paraphrased and five extra phrases) and 25 verbatim phrases, THEIR uniqueness value would be 50%. This means that 50% of the observations that they wrote down were unique (either paraphrased or extra to what the cohort had discussed). Uniqueness is something that would strictly apply to a situation where out-loud descriptions are being used. If a student is in the field by themselves, they would produce 100% unique phrases. We should also acknowledge that in circumstances where lecturers become highly descriptive in their dialogue (aloud, to the class), fewer unique terms could be "available" to use for each observation. A closer look at lecturer's use of adjectives and synonyms in future work will allow us to explore this aspect. We suggest that the research value of uniqueness is that it is evidence for processing of the information provided in the field lesson.

Completeness

Completeness is a measure of the ability to collect detailed notes in the field. For each individual student, we compared their total observations (made by them in their notebooks) to the total observations for their cohort (Eq. 2). The numerator contains the total observations made by the student ($U + V$) subtracted by extra observations (E; those phrases represent additional information rather than being part of the lesson dialogue). For example, if a student's notes showed 30 unique observations, five extra observations, and 50 verbatim observations, while their cohort had a total of 100 observations, their completeness would be 75%. This means they covered 75% in their own notes of what the cohort discussed but also included five extra phrases that the cohort had not discussed. Students who excel at completeness are likely mimicking classroom note-taking techniques. For instance, when an instructor states something in the field, there may be an inherited (conscious or subconscious) "classroom contract" where the student does not question what has been said and simply writes it down. Students who record complete notes are typically more capable of transcribing information (Ganske, 1981).

Equation 2: Completeness of a student's notes is represented by the number of phrases the individual student has recorded, as compared to the total observations (T) made in the cohort dialogue. Note: Completeness is not an absolute value (representing all of the possible observations than can be made).

$$\frac{\textit{total observations made by that student} - \textit{extra observations}}{\textit{total observations made by their cohort}} = \frac{(U-E)+V}{T} \times 100\%. \quad (2)$$

It may be obvious to students and teachers that recording as much information as you can (i.e., completeness) in an introductory field lesson is beneficial; however, uniqueness may be a less obvious "best practice." We argue that observation making is fundamentally an individualistic task, and therefore, it is beneficial for students to practice making their own observations and recording them in their own words. So a guided lesson in which the student considers the content discussed as a class and filters and records their individualized version is a step towards wholly independent observation making.

Though we use the metrics as proxies for student success with the note-taking tasks and to reflect their ability to process information (inferred cognitive processes; Balliet, 2012), we do not imply that high scores on either or both metrics equal note-taking mastery. Nonetheless, students who excel at both completeness and uniqueness would theoretically be effective processors and transcribers, and so we do propose that students who can use both strategies exhibit more expert-like performance.

Additional Metrics

We also defined a metric that compares the proportion of different types of information that are matched to specific learning goals. In our study, we used this metric to indicate which learning goal content was included and which was filtered out (proportion of primary to secondary learning goals; Table I; Eq. 3). For example, a student recorded 40 observations about hot springs (primary goals) and 10 statements that were data interpretations (secondary goals) from the cohort dialogue. The proportion of primary learning content recorded (over the total content recorded) for this student was 80%. Overall, we used this metric to indicate a student's preference (and filtering ability) for including different types of content (e.g., observations, interpretations, or extraneous information) that was discussed as a class during the introductory lesson.

Equation 3: Proportion of primary learning goals to total content recorded, calculated by dividing the total number of primary goal phrases (P) by the total number of phrases recorded ($P + S$; secondary learning goals):

$$\frac{\textit{total primary goal phrases made by that student}}{\textit{total phrases (i.e., primary and secondary learning goals) made by that student}}$$

$$=\frac{P}{P+S}\times 100\%. \tag{3}$$

Note: Annotation is not included in this calculation.

Note-taking efficiency is a ratio that is determined by dividing the total number of observations made by the student by the number of words used (i.e., verbosity; W; Eq. 4; Williams and Eggert, 2002). Efficiency is a strategy that is perceived as an asset to have in applied or industrial settings. Shorthand, abbreviated, and tersely composed text results in efficient notes. For example, if a student's notes showed 50 observations total, and they used 100 words to describe those observations, their note-taking efficiency ratio would be 0.5 (Eq. 4).

Equation 4: Efficiency of a student's notes is calculated by dividing the total number of observations (made by them in their notebooks; all observations including verbatim and unique phrases; $U + V$) by number of words used to do so (i.e., verbosity; W).

$$\frac{\textit{total observations made by that student}}{\textit{total words used for describing observations}}=\frac{U+V}{W}. \tag{4}$$

We did not calculate or explore this attribute further because the experiment was not set up to measure efficiency. We anticipate that the efficiency of an individual's note-taking would likely be influenced by the purpose and context of the task, for example, a repetitive core log versus a comprehensive hand sample description for classification purposes. Additionally, it is not necessarily an appropriate note-taking strategy for introductory lessons in field note-taking. We presume that the goals of an introductory lesson might be about exploring all of the features, rather than encouraging students to be terse.

Statistical Tests

We calculated uniqueness and completeness values for each student and explored different factors that may have influenced their scores. For example, we looked at how different amounts of field experience (with subpopulations of "high," "low," and no previous experience) influenced students' uniqueness and completeness scores. We also calculated and compared mean scores using a Student's *t*-test and effect sizes (Cohen's *d*) when significant differences were found. For more details on these statistical methods, please see Cohen et al. (2007). It should be noted that because of the small sample size and the associated low statistical power, our statistical results should be interpreted with caution.

Student Interviews: Questions & Coding

We used student interviews ($n = 16$) to capture student reflections on the lesson and describe perceptions of their note-taking strategies. We conducted the interviews 5 mo following the lesson in a one-on-one and focus group format (five different focus groups, and three one-on-one interviews). The focus group sizes ranged from pairs up to four students per session. The participants (nine female, seven male) interviewed represented the range of geoscience field experience. We used a semistructured format where predetermined questions were posed, and follow-up questions were used to probe into specific attitudes and accounts:

> Researcher: *Think back to the day that we visited [the field site]. That day we had you fill out a paper notebook, which we called the note-taking activity.*
>
> a. *Do you remember that day? What was the most memorable part of that day in the field? Why?*
> b. *Did you feel challenged by the note-taking activity? Why?*
> c. *What do you think you've learned from that note-taking activity? Why?*
> d. *What is the best setting to learn note-taking and/or observations skills? Why?*
> e. *In hindsight, would you have taken notes differently or changed your behavior (based on what you know now)? Why?*

We transcribed the interviews and used qualitative analysis to isolate emerging themes based on the previously defined research questions (Creswell, 2007). We used data coding procedures analogous to those described in "Note-Taking Study Design" section. Deeper analysis revealed several themes, which included: strategies of note-taking, difficulties and challenges with note-taking, factors that distract from note-taking, and student-provided suggestions to improve the learning of note-taking. We assigned these major themes to code categories, and then we subdivided them into subthemes, which represented the range of individual's experiences and perceptions. We did not perform quantitative analysis on the interview data beyond frequency counts of themes, as the number of students was small. The main purpose of interviews was to obtain a rich data set illustrating the range of students' views, and to triangulate the field observations.

RESULTS AND DISCUSSION

Note-Taking Strategies Diagram

A plot of uniqueness (U) against completeness (C) data for all students shows the extent of note-taking strategies. We plotted the results onto a diagram that is broken into four quadrants of strategies (Fig. 1): students who wrote everything down (complete-type; high C), students who wrote in their own words (unique-type; high U), students who excelled at both strategies (dual-strategy; high U and C), and students who did not succeed in either (low-

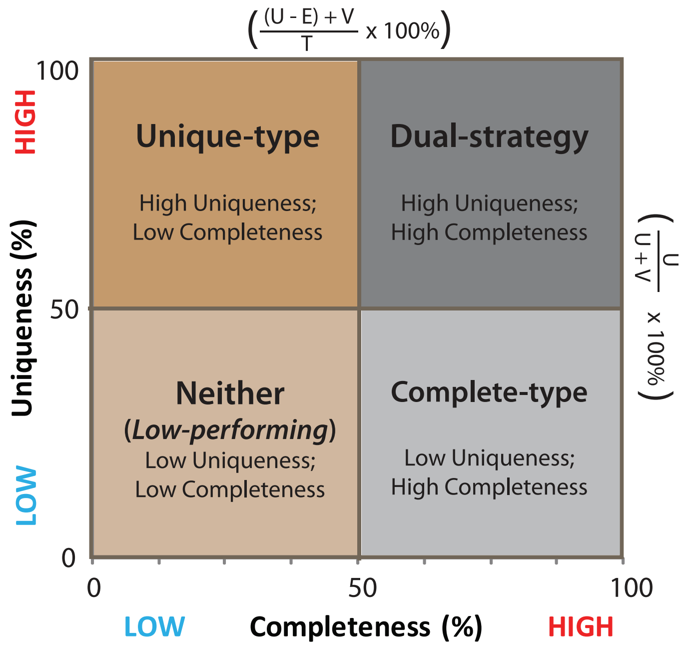

FIGURE 1: Note-taking strategies diagram: a plot of completeness versus uniqueness. Students are broken into quadrants which show unique-type, complete-type, dual-strategy, and low-performing note-taking behavior. We have defined here that dual-strategy students are those who display high *C* and high *U*. Low-performing note-takers illustrate the opposite. Students who excel at uniqueness (writing down predominantly independently derived content) are unique note-takers, while complete-type are students are dominantly focused on and essentially writing down what was said in the lesson, verbatim.

performing; low *U* and *C*). The boundaries between the quadrants in this figure are arbitrarily chosen at the 50% mark for both axes. Students plotted in all quadrants of the diagram with overall average *U* and *C* values of 39% and 48%, respectively.

We found several factors that influenced the students' success with note-taking (as defined by the *U* and *C* metrics): lecturer differences ("Lecturer Teaching Style and Pedagogy" section), amount of previous geosciences field experience ("Previous Geosciences Field and Coursework Experience" section), and gender differences ("Gender Differences" section). Descriptive statistics of the results are included in Table II. We elect to focus on these three possible factors but note that other factors could exist as well. Additionally, we reveal students' self-reported difficulties and strategies when taking notes ("Note-Taking Strategies and Influencing Factors for Success" section) and their suggestions for improving note-taking training ("Suggestions for Note-Taking Pedagogy" section). We report the results and discuss implications in a combined fashion. Also, the interview data are displayed with reference to their cohort and where they plotted within the note-taking strategies diagram. For example, (interview transcript, unique-type 1, cohort 2) would be a student 1 from cohort 2 (taught by lecturer 2) who plotted within the unique-type quadrant on the diagram.

Lecturer Teaching Style and Pedagogy

We instructed the two lecturers to use a specific approach (Supplemental File 1C) and focus on the learning goals. However, they illustrated differences in the content taught and subtle differences in emphasis and language (evidenced from the video observations and cohort dialogues). Lecturer 1 included lengthy descriptions of supplementary information (i.e., secondary learning goals, e.g., processes, interpretations, etc.; Table I). An example of this is illustrated by the following excerpt where Lecturer 1 describes how a hydrothermal eruption occurs, which is relevant to the formation of the hot spring.

> Lecturer 1: *So you are dissolving the rock beneath* [referring to the hot spring] *and stuff just caves in* [makes a 'funneling' gesture with their hands]. *Or you can have an explosion maybe* [gesturing upwards, cone] *in a really vigorous geyser event that it is so powerful that it actually rips out the rocks. For the geologists, we have talked about these before. What types of explosions are those?*
>
> Student response: *Phreatic?*
>
> Lecturer 1: *Yea, phreatic explosions. Phreatic is a fancy word for water. So if you build up enough pressure and you decompress that and you release that pressure rapidly, you can cause a rapid phase change—from water to steam, that expands—and can trigger one of these phreatic eruptions.*
>
> *(Cohort 1 Dialogue)*

This information is quite peripheral to the primary learning goal (Table I, Goal 2: Make and record visual observations at a geothermal hot spring) but provides rich, contextual information about the larger geologic processes that give rise to geothermal hot springs. However, cognitive load theory suggests that load is increased by including nontask information while students are performing a task (Chandler and Sweller, 1991; van Merriënboer and Sweller, 2005). In contrast, Lecturer 2 provided much more procedural instruction at the field location and restated the primary learning goal to the students, several times. For example: "So now the important part of the task, or the bit that we are here for, is to learn how to describe the features in front of you, Ok?"; and "Ok, so we just want to be sticking to our observations" [Cohort 2 Dialogue, Lecturer 2]. Providing instructive or procedural information during a task can decrease cognitive load (Kester et al., 2001; Pollock et al., 2002). More importantly, Lecturer 2 also encouraged students to think and write independently and explained why note-taking is important:

> Lecturer 2: *Yea, nice, a [hot] spring. A [hot] spring or a "leaky pool." It's actually fine to use normal words in your notes. You don't always have to use a fancy geology word. You are just describing in whatever the best way possible. If it's easier for you to describe it as "a leaky pool," then describe it as a "leaky pool."*

TABLE II: Note-taking strategies results summary.

Note-Taking Strategy	Variable	Mean	SD	Two-Sample *t*-Test	Cohen's *d* Effect Size
Uniqueness	**Lecturer differences**			$t = 2.31$ $p = 0.02$ Significant	0.72 Medium
All students ($N = 42$)	Lecturer 1 (19)	34.89	8.96		
	Lecturer 2 (23)	41.84	10.29		
Primary goals content	**Lecturer differences**			$t = 4.24$ $p = 0.0001$ Significant	1.28 Very large
All students ($N = 42$)	Lecturer 1 (19)	84.4	7.5		
	Lecturer 2 (23)	92.3	4.3		
Uniqueness	**Prev. field experience**			$t = -2.34$ $p = 0.02$ Significant	0.78 Medium
All students ($N = 42$)	Low (21)	35.76	11.18		
	High (17)	43.41	8.32		
Lecturer 1 ($N = 19$)	Low (11)	31.87	7.77	$t = -2.06$ $p = 0.056$ Significant[1]	0.97 Large
	High (7)	40.23	9.36		
Lecturer 2 ($N = 23$)	Low (10)	40.04	13.11	$t = -1.18$ $p = 0.26$ Not significant	–
	High (10)	45.63	7.16		
Completeness	**Gender**			$t = -3.15$ $p = 0.003$ Significant	0.98 Large
All students ($N = 42$)	Female (18)	51.71	7.66		
	Male (24)	44.41	7.27		
Lecturer 1 ($N = 19$)	Female (7)	56.32	8.29	distributions of both groups were not normal	–
	Male (12)	45.83	6.80		
Lecturer 2 ($N = 23$)	Female (11)	48.77	5.86	$t = 2.01$ $p = 0.058$ Significant[1]	0.84 Large
	Male (12)	42.99	7.73		
Verbosity	**Gender**			$t = 2.3$ $p = 0.03$ Significant	0.72 Medium
All students ($N = 42$)	Female (18)	156	37		
	Male (24)	130	36		
Lecturer 1 ($N = 19$)	Female (7)	170	46	$t = 2.94$ $p = 0.02$ Significant	1.51 Very large
	Male (12)	115	25		
Lecturer 2 ($N = 23$)	Female (11)	147	28	distribution of male group was not normal	–
	Male (12)	145	40		

[1]*t*-tests that resulted in *p* values near the 0.05 threshold were considered significant for this study.

Lecturer 2: *Ok, so do people agree with* [student A]*? So don't just copy where* [student A] *has put it, because [he/she] might not be right. Where did you put it?*"

Lecturer 2: *So make sure you are thinking about this information and that you are not just writing this down.*

Lecturer 2: *So it's not only good to write down the* [observations], *write something stupid down, that can help you remember. Just wanting to be thinking about ways to embed this into your brain. So that when you come back home and your notebook is covered in water and half rubbed out—at least some information is there that can help you relate to where you've taken your notes.*

(Cohort 2 Dialogue)

Another observed difference in style was in the verbal confirmation of specific terms during the dialogue by Lecturer 1. The coding example from Section 2.6 illustrates a commonly used teaching method that occurs during discussions with students. The lecturer holds a descriptive term in their mind that is suitable for the phenomena being observed; asks the students to describe what they see ("What's the texture of it?"); hears some responses and selects the one that matches what they think ("scaly"); and reinforces the phrase using tone and spoken rewards ("scaly. Exactly, that's the word that I was thinking of"). This may communicate to the students that this term (scaly) is the right, and it is the only word to describe what they see.

In an attempt to understand whether the lecturer's style of teaching impacted the students' *U* or *C* values, we plotted students' results onto the note-taking strategy diagram and sorted the students by Lecturer 1 or Lecturer 2. Figure 2A illustrates that the *U* values differ between the different

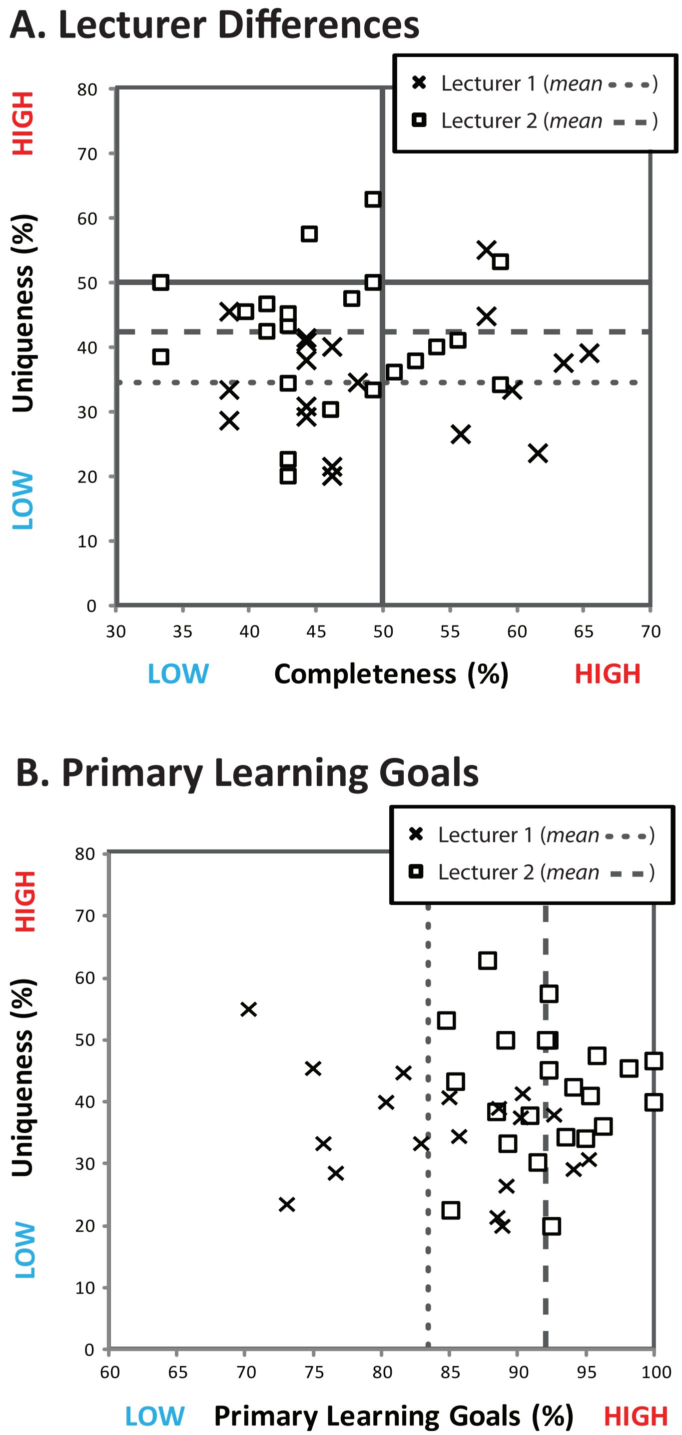

FIGURE 2: Lecturer differences in uniqueness and primary goal content. (a) Students taught by Lecturer 2 achieved higher U scores. (b) A plot of uniqueness versus the proportion (in %) of primary learning goals (to total phrases). This plot illustrates that a significant portion of Lecturer 1's students had low primary goal % values, corresponding to low U values.

lecturers (i.e., between cohorts of Lecturer 1 [$n = 19$] and Lecturer 2 [$n = 23$]). An independent sample t-test showed the difference to be statistically significant ($p = 0.02$, $d = 0.72$). The C values of the two cohorts were statistically equivalent. Based on these teaching style differences, we suspected that students would have more difficulty "filtering" through the interpretation-focused dialogue of Lecturer 1. Figure 2B shows the students' U values against the proportion of recorded phrases related to the primary learning goals over the total content recorded (Eq. 3). Lecturer 1's students illustrated much lower proportions of primary content (statistically significant; $p = 0.0001$, $d = 1.28$), which we attribute to inclusion of secondary goal content (i.e., interpretation and context-focused) and less explicit focus on independent-thinking and metacognitive strategies prompted by Lecturer 2.

The emphasis placed on content and strategies was an unanticipated difference, rooted in the different approaches specific to the lecturer's teaching style. Both lecturers systematically addressed each type of visual observation and commented on the relevance of that particular observation (i.e., the importance of including each data set), which was outlined in the note-taking lesson protocol (Supplemental File 1C). However, these observed differences appear to affect the students' cognitive load (in Lecturer 1's cohort), which in turn affects the content of the information recorded, and thus the success with writing in their own words (i.e., uniqueness). Furthermore, neither lecturer declared that the primary goal was to "write everything down" and did not specifically emphasize the value of completeness. However, Lecturer 2 explicitly impressed upon the students the importance of thinking and writing independently and using their own language. This "talk-aloud" style (i.e., actively explaining aloud what they were thinking and what they were writing down) modeled to the students a metacognitive strategy (e.g., Flavell et al., 1985; Schunk, 2008) when making observations and taking notes.

Finally, the lecturer's teaching styles did not seem to alter the overall proportion of students within the different note-taking strategy categories. However, it is possible that the differences we observed may occur due to a lack of explicit instructions on note-taking best practices. The lecturers were not asked by the researchers to explicitly state these best practices because as the purpose of the study was to replicate a common field teaching lesson. Therefore, it is possible that if the lecturers had both explicitly stated the importance of U and C, then the results of this study may be different.

Previous Geosciences Field and Coursework Experience

The lecturer differences noted in the previous section prompted us to examine the other note-taking variables within subpopulations (Lecturer 1's cohort and Lecturer's 2 cohort). Figure 3 represents plots of the students' results when sorted by general field experience and independent research experience. Figure 3A shows that students with "high experience" (as defined earlier; $n = 17$) achieved higher U results than those with "low experience" ($n = 21$). Comparing the "low experience" group to "high experience" group, we find a statistically significant difference in the mean ($p = 0.02$, $d = 0.78$), indicating that students with more experience tend to have employed more unique-type and dual strategies. Interestingly, the C values are statistically equivalent ($p = 0.37$). Figure 3B illustrates that the students who had any independent research experience (nine of the 42 students) have above average U and trend

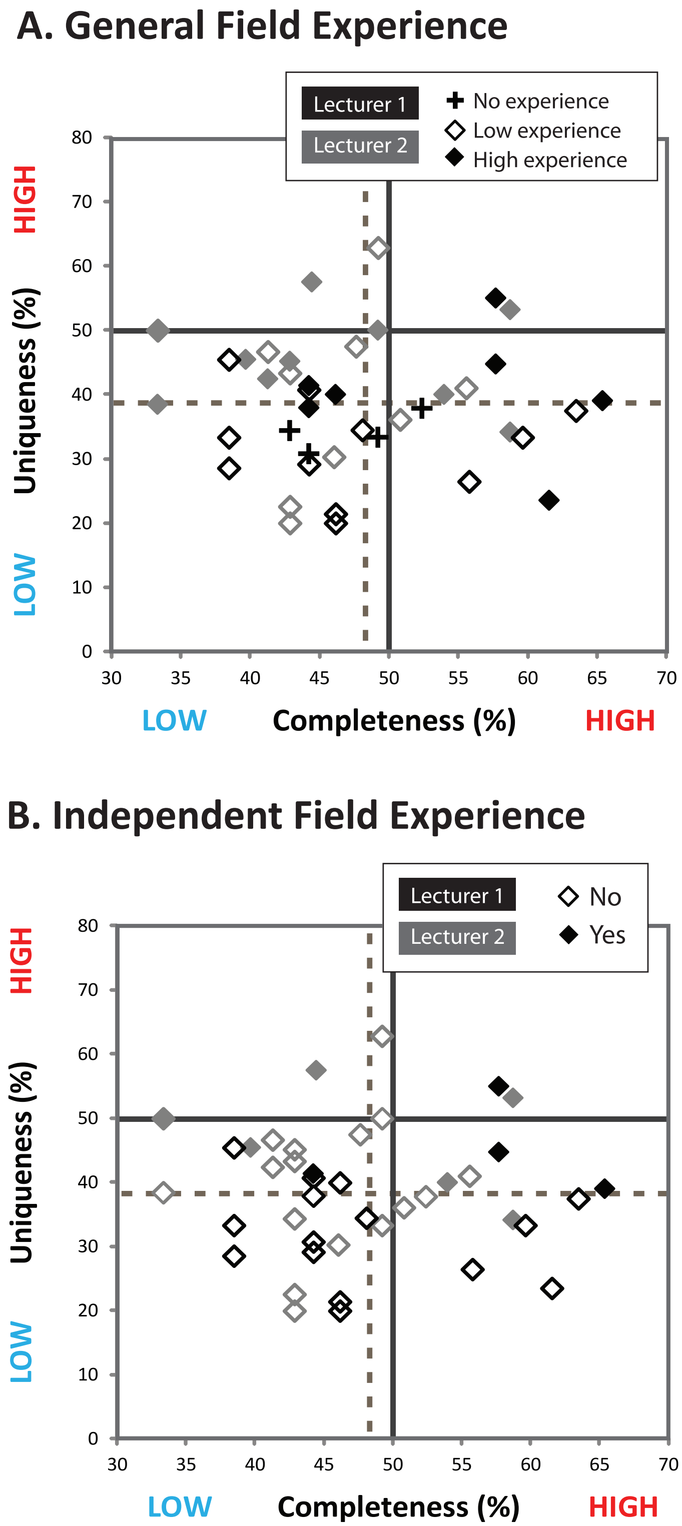

FIGURE 3: Previous field experiences and uniqueness. A note-taking strategy diagram filtered by the amount of the student's previous field experience. Solid lines represent the 50% threshold, and the dashed lines represent the averages of each variable for the whole student population. (a) Students with "high experience" plot closer to, and within, the unique and dual-strategy fields and achieved statistically higher *U* values. (b) All the students who had independent research experience were shown to have higher *U* than those who did not.

towards the unique and dual-strategy fields as well. The subpopulations (within the two different cohorts) revealed similar findings, with less convincing statistical significance, which is most likely due to the loss of statistical power (see Table II). These findings are in agreement with research by Barnett and Freud (1985), who found that students with previous experience will more commonly record unique information. We interpreted this effect to be due to more developed note-taking and observation-making schemata in students with field experience. Students with more experience are paraphrasing the content while listening and making new observations, indicating sophisticated thinking and freed-up cognitive resources; students with less experience do not have established complex schemata, become overloaded easily, and resort to encoding the cohort dialogue verbatim.

Interestingly, interview data revealed mixed student perceptions on whether previous geologic field experience reduced the task difficulty. Several students indicated that previous field experience positively affected their note-taking strategies (4 of 16) and felt that they needed to know "what to look for" in order to reduce the difficulty. One student remarked: "Yea, I definitely think that you need a background before you go out into the field. You need to know what you are doing. And what you are looking for. That's what I found for the [another field assignment]. I struggled so hard with that" (interview transcript, complete-type 1, cohort 1). This matches with research on novelty space, which suggests that preparatory activities (in this case, providing student's with knowledge of the expected phenomena) prior to the field trip reduce the effects of novelty space (Orion and Hofstein, 1994) and cognitive load in order to allow students to perform the academic task. However, two students were unsure of whether previous field experience lessened the difficulty. (Note: Prior field experience was not an explicit interview topic; 10/16 students did not explicitly mention prior experience.) One student noted: "… [the note-taking activity] was kind of difficult… even after our 5-week field course, I am still not comfortable taking notes" (interview transcript, unique-type 1, cohort 2). Students also felt that encountering the "new geologic scenario" contributed to the difficulty of the task: "It was a little bit challenging in that it was really different from other stuff we have been doing. It was geothermal instead of sedimentary or metamorphic or whatever…" (interview transcript, low-performing 2, cohort 1). We feel this is an interesting finding, potentially hinting at other confounding or interacting variables, and an interesting avenue for future research.

We also explored whether the students had "high," "low," or "no" previous geoscience coursework as a possible factor that influenced students' *U* and *C* values. Research in the area of skills and situated learning implies that successful performance of domain-specific skills should be taught in an embedded, authentic curricula (i.e., information must be embedded in the situation in which it is used for effective recall and performance—in this case, in a field environment, not a classroom environment; Schon, 1983; Roth and Roychoudhury, 1993). We compared students' *U* and *C* scores by the number of geology courses, but no statistically significant differences were found. Some students with very little geology-specific background had higher *U* and *C* values than students with substantial geologic coursework back-

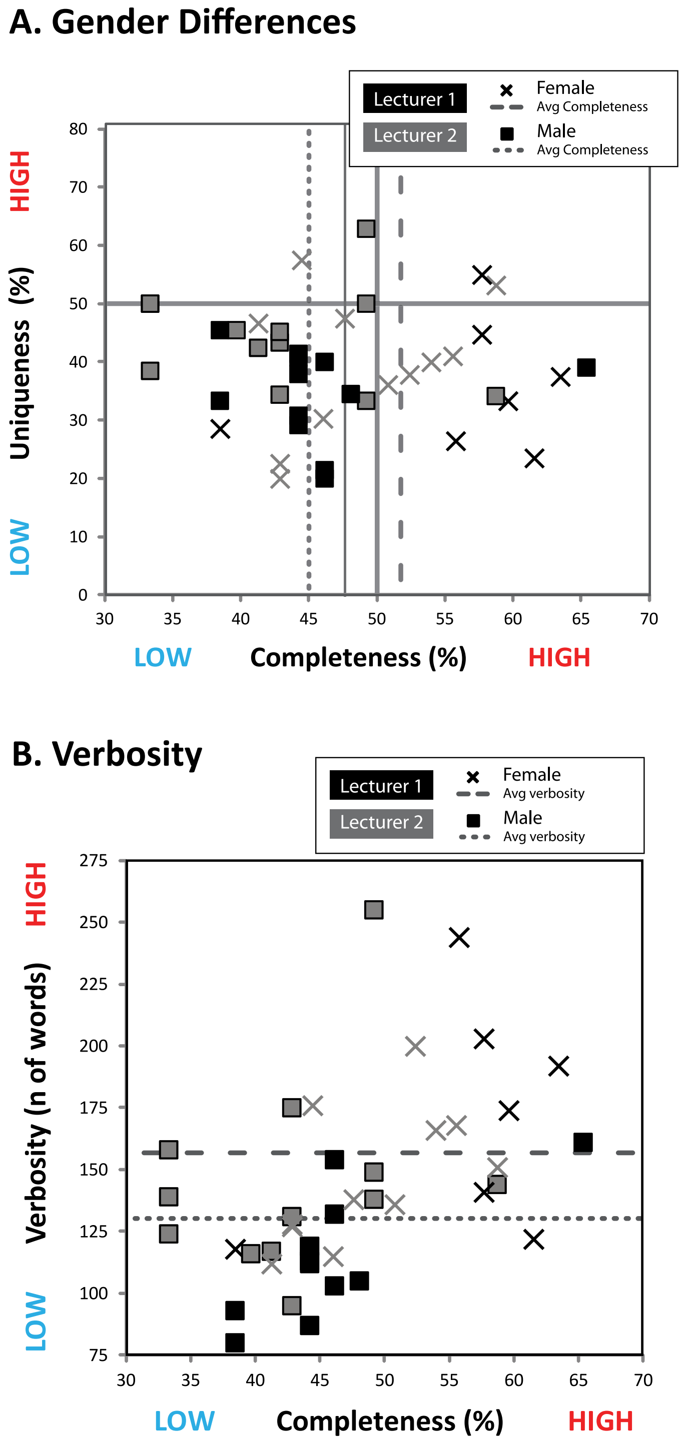

FIGURE 4: The note-taking strategy diagram sorted by gender. The lines represent the average of completeness values (all students, solid line), for men (dotted line), and for women (dashed line). (a) Women achieved statistically higher *C* values. The dual-strategy students were both women, and more men generally fall within the low-performing category. (b) Verbosity plotted against completeness illustrates that females used more words on average than male students.

ground (e.g., an environmental science major with little geology coursework, but "high" field experience, achieved high *U* and *C* values). Additionally, six participants had been introduced to geothermal concepts in a previous semester-long hydrogeology course but showed a range of *U* and *C* values.

In a field lesson, a student is required to encode and vet the information provided and combine it with their own observations of the geologic environment. We show here that students with previous field experience had statistically higher *U* values, and we attribute this to several factors. Like other cognitive skills, we suggest that students with more experience may have more developed note-taking schemata. Also, students with more experience have fewer "unknowns" and expectations associated with field activities and specifically field note-taking, which in turn reduces novelty space (Orion, 1993; Orion and Hofstein, 1994). These combined factors result in lower cognitive load experienced during the task. We also believe that when students become overloaded, they abandon filtering the information in favor of writing notes verbatim (i.e., resorting to "parroting" or "mimicking") as a means of coping with the large amount of information provided. Van Meter et al. (1994) suggest that students will adjust their note-taking strategies to the perceived level of difficulty of the task. The "writing notes verbatim" strategy may be derived from the traditional classroom and examination environment, where textbook answers may elicit higher grades than unique responses. Lastly, we suggest that increased field experience may help students to test out and develop transferable note-taking strategies that can be applied in multiple geologic scenarios.

Gender Differences

During initial passes of notebooks during coding, we found that many of the female students wrote more than male students, leading us to investigate if there were any relations among gender, verbosity, and completeness. Figure 4A illustrates that, on average, *C* values for women were higher than men ($p = 0.003$, $d = 0.98$). We then plotted verbosity versus *C* (Fig. 4B), which showed that generally female students wrote more (average of 156 words, compared to 130 words for males; $p = 0.03$, $d = 0.72$), and we feel that this strategy led to a higher *C* metric. Analysis of the subpopulations (within the two different cohorts) showed similar results (Table II). We found no significant differences between the genders in the *U* metric. Additionally, we found that the majority of male students (20 of 24) scored within the low-performing category, but trended toward the unique-type note-taking quadrant, and that male students paraphrased and included many additional or "extra" observations, more so than female students.

The fact that the women in this study wrote more (higher verbosity) agrees with several classroom studies (Hartley and Davies, 1978). For example, after an introductory psychology lecture, Nye (1978) found that men used an average of 382 words, and women used 518 ($p < 0.001$), which led to a high positive correlation in the number of main "points" included in the notes by women (Pearson's $r = 0.77$; $p < 0.001$). It is possible that the male students simply valued *U* over *C* as strategy of choice and are more focused on writing in their own language and much less concerned with getting all the information, but rather, the "right" or "important" information. Van Meter et al. (1994, 327) reports that students who paraphrased the lecturer's content did so, in order to "increase [their] understanding of class content." Therefore, their note-taking strategy could be an explicit attempt to independently learn more, which could be derived from generally higher levels of academic self-efficacy (i.e., critical thinking skills) reported in undergraduate males compared with females (Lundeberg et al., 1994; Beyer and Bowden, 1997; Jordan et al., 2009). However, the note-taking categories that we defined in this study (as depicted in Fig. 1) are arbitrary and based on cutoffs at the 50% mark and require further research. Additionally, the gender differences identified in this study were not a part of our original research questions, and therefore the study was not set out to examine this variable. Further research should be carried out to fully understand gender differences with field note-taking.

Note-Taking Strategies and Influencing Factors for Success

In this section, we present the results from the focus group interviews that relate to the strategies employed by students and challenges that are purported to affect their ability to take notes.

Note-Taking Strategies

From the focus group data collected, the majority of students interviewed (12 of 16) admitted that their primary strategy was to "write everything down" (completeness). For example: "I feel like it's easier to just write down everything and anything. Because you think, 'I don't know when I will be back here,' so you just try and get down as much as you can. Yea, just write down everything" (interview transcript, low-performing 3, cohort 2). This exemplifies a need to record information without reflection, but despite valuing this strategy, the student scored one of the lowest *C* values of the study population. Another low-performing note-taker reported: "Yea, I was basically just writing down everything, because we were getting so much information thrown at us, at the time. And like, I didn't know what was important. So then, I was just writing it all down" (interview transcript, low-performing 2, cohort 2). This student additionally noted that there was "so much information," which is evidence for cognitive overload. Students who scored high *C* values also valued completeness: "[I was] trying to just get as much information down, because it might be useful to you later on. Like, the more you write the better" (interview transcript, complete-type 1, cohort 1). One of the Low-performing students explained why making observations in the field is so important. In this anecdote, they recall one of their first field experiences:

> Researcher: *What setting or style of learning, can observations best be taught? In the field? In the lab? In the classroom?*
>
> Low-performing 1: *I think being out in the field* [is the best]*, like my first year in college and we went out for a lab for whatever reason. It was like: 'Ok, get out there, take some strikes and dips and measure everything'... So [the lecturer] didn't really say anything, [the lecturer] just let us take our measurements, write everything down. And then we got back and [the lecturer] was like: 'Write a lab report on what you did and why it's important'. And we were all like: '[Shoot], we don't have any information'* [laughs] *and then like 'Why didn't we take this?'. And [the lecturer] was sort of laughing at us. And said 'Ok, now you guys learn from your mistakes. We will have another field trip next week so that you can go back out to collect data'. And I think that is so much of what it is. Knowing what you need to get from the field. Not because someone tells you what to do—or because it's in a book. But because you go out and you realize... like you need to have it down on paper or somehow documented.*
>
> *(Interview transcript, low-performing 1, cohort 1)*

This student describes a good understanding of the value of complete notes and why it is important that they should have high *C*. However, despite these insights, the student scored low *C* values. Regardless of the knowledge and understanding of the field note-taking, this student has a clear awareness of what they should be doing during a task yet fails to meet their own standards.

Two of the focus groups discussed the value of notes being "easily be read" by another geologist. One student noted: "And I've heard that you should always try and write your notes, so that another geologist can see what you are saying" (interview transcript, unique-type 1, cohort 2). This implies a use of note-taking language and approach that are intelligible by other geologists. Another noted that making observations and writing notes are difficult "because observing is an independent thing" (interview transcript, undifferentiated [did not hand-in notebook], cohort 1), implying the awareness that writing notes is a product of your own observation making, not simply to write down what others have said. Several students (five students) described having a "top-down" or a "larger to a smaller perspective" strategy (Vick et al., 1979) when making their observations (e.g., "I tried to have a strategy and record the broad stuff and then work my way down to the macro-, the meso-, micro-scale stuff" [interview transcript, unique-type 1, cohort 2]). This is not surprising as this was an explicit "best practice" that is taught in the field course the students attended. What is intriguing is the utility that the students apply to "top-down" note-taking:

> Researcher: *What do you feel that you've learned from the note-taking activity?*
>
> Dual-strategy 1: *I think just the reiteration that you have to write* [emphasis] *things* [emphasis] *down* [emphasis]*... It makes you deal with it. So you have to think "this is the larger perspective" and "this is the small perspective" and you have to really think. You can't just say "there's orange stuff here." Like there is orange stuff here, but it could be "this," or "this," and it's a process. It makes you reason more, or process the ideas more in your head. Otherwise you might just skip over things and write your picture and then you look in your picture and think "I can't skip that part, because it's in the picture."*
>
> *(Interview transcript, dual-strategy 1, cohort 1)*

Both students quoted above acknowledged using the top-down strategy, but the dual-strategy student also elaborated and explained the detailed process that one must take to characterize and understand geologic features. They explain that this strategy has utility and that it is more than just writing things down; it is a vehicle for helping students stay focused and apply a systematic approach to making observations and recording them in their notes. We propose that this top-down strategy may assist in lowering cognitive resources due to a scaffolded method or framework (i.e., observations schemata).

Based on these findings, we suggest that students are aware of note-taking strategies but have differing success (based on our criteria) with implementing them. This study examines one note-taking experience, within a specific context, with introductory lesson goals. It is unclear whether these strategies and their application in different contexts are obvious to students, and even to experts. Further research should be performed in order to better develop students' views of the purpose and appropriateness of note-taking strategies. It is clear, however, that some students are not executing strategies successfully. The following section provides explanations as to factors that may obstruct the implementation of successful strategies.

Factors That Affect Note-Taking

In the postinterviews, several students (four of 16) described the social and physical environment as a distraction in the geothermal lesson. One low-performing student stated the strong desire to explore, rather than focus on the task at hand: "I wanted to let the little twelve-year-old inside of me just like, run around and look at everything and touch stuff and take pictures" (interview transcript, low-performing 1, cohort 1). Another student mentioned the social interactions as a distracting factor: "... there were a couple days in field camp where I probably did not observe anything, because I was just talking to people..." (interview transcript, undifferentiated student, cohort 1). When asked what was memorable about the note-taking activity that day, another responded: "I remember flirting with [student's name] the entire day." (interview transcript, low-performing 1, cohort 1). Observations of students during the lesson did not elucidate any gender-related patterns of behavior (i.e., if males or females were observed to more frequently exhibit flirting behaviors during the lesson); however, this attribute was not a part of the researchers' observation protocol. Field trips are acknowledged to positively influence the affective domain outside of the cognitive learning sphere (Kern and Carpenter, 1984; Boyle et al., 2007); however, as evidenced here, social dynamics can be a powerful distracter, particularly if not acknowledged by the lecturer and students.

Several students (3 of 16) mentioned "the level of detail" as an intrinsically difficult aspect of making observations and note-taking in the field. Some students said they felt they got into "too much detail": "... there's other times when I don't know, I feel like I am getting too detailed, like unnecessarily so in field areas" (Interview transcript, unique-type 1, cohort 2); "there are huge differences in the level of detail you can see... You see a lot of subtle features out in the field, compared with [other learning activities]. Sometimes seeing all those little subtleties makes it more confusing and sometimes it helps you out to understand things a little better" (interview transcript, low-performing 2, cohort 2). Knowing which objects (in the natural geologic environment) to observe and record, and which to disregard, and in how much detail, is a great challenge for note-takers. We propose that this aspect contributes to the overall cognitive load of the exercise for students and for professionals. Being exposed to similar scenarios (i.e., knowing which objects, and what level of detail that is expected, and in different contexts) would arguably lessen the cognitive load for future note-taking experiences. We feel this supports the higher *U* scores that were achieved by students with more field experience.

Suggestions for Note-Taking Pedagogy

Staying on task can be difficult in these novel environments. One student's perceptions of ways to overcome the distractions of this complex, challenging environment is stated below:

> Researcher: *Where you do think the best place is to learn observations? Where is the best place to learn these? In the field? In a videogame? In a lab? In a lecture?*
>
> Student: *I'm not even sure it matters where you are, as much as it's the state of mind that you are in. As long as you are not distracted by things, by other people. So that you can just observe. You are observing. Like, there were a couple days in field camp where I probably did not observe anything, because I was just talking to people and ya know, like off in my own little world. I definitely observed the most when the professor was like "Ok, no one is allowed to talk. You sit over there, you sit over there and you all draw and you think and you just write things down." (Interview transcript, undifferentiated student, cohort 1)*

The students were asked "In hindsight, would you have taken notes differently or changed your behavior (based on what you know now)?" We found three themes that describe tools and additional strategies for improvement:

1. Having a "cheat sheet" of important geologic observations prior to the field experience: "I really actually wish that I had a list [of geothermal observations] to bring with me, afterwards. So like if I found myself in a geothermal area again, I would have like a list of questions like that." (Interview transcript, unique-type 1, cohort 2)
2. Using technology in the field to improve the quality of their notes: "I would ask for an iPad or something [student laughs]. Because I hate [emphasis] doing it by hand. But if I had a mini-computer and then I could break it up into sections: data, observations, interpretations. It would be more organized, segmented... But I think definitely like structuring it, right in the field. That would help me so much more!" (Interview transcript, low-performing 1, cohort 1)
3. Improving organization and structure of their notes: "I would probably organize it a little better. Like I would pick some [geothermal] pools and then organize, rather than one huge long rant. I think like the same 'volume' of words, but just better organized." (Interview Transcript, complete-type 2, cohort 1)

Half of the students interviewed indicated that having an introduction to the set of criteria and "list of observations" that one should make would significantly help them to perform in a new geologic scenario. However, one of the dual-strategy students questioned the list, stating: "So [you have the list and] you go into the field and know what to write. But I'm not sure if that is a good thing. Ya know, *just* [emphasis] to have a list to *just* [emphasis] write everything down. But I guess those are the key observations and those are the ones to be writing down. So I guess it is a good thing" (Interview transcript, dual-strategy 1, cohort 1). The student questions here that note-taking is about more than just recording all the information.

Cognitive load theory indicates that students' cognitive functions will be assisted most by having procedural instructions given to them during the tasks (Kester et al., 2001). This allows them to work alongside their "recipe." We suggest that practicing with the set of criteria may enable students to internalize systematic observation making and note-taking and reduce the cognitive load of note-taking. It seems likely that using a list would increase C, but its impact on U (and thus, independent thinking) is less apparent and could produce the opposite effect. It may inhibit the student's need to think for oneself and encourage them to follow a recipe, without question. During the first note-taking lesson, we suggest using a list (as the lecturer) to follow a line of thinking that is suited to the context and purpose of the learning activity and follow up with providing the list to the students, to encourage students to be systematic and avoid missing information at new locations.

To ensure efficient encoding of notes, handheld technology can be used in the field sciences to quickly record and organize information with students (e.g., Guertin, 2005, 2006; Guertin and Bodek, 2008) and professionals (Brodaric et al., 2004; Clegg et al., 2006; Pavlis et al., 2010). Guertin and Bodek (2008) discussed the positive effect that handheld technology had on students' attitudes, particularly with respect to data collection in the field. However, they also reported that students who are unfamiliar with certain technologies can be "put off" by the additional task of learning technology while learning to write geologic notes and field map, simultaneously (thereby increasing the cognitive load). Yet, there is also merit in training students to use equipment and software that companies use (e.g., ArcPad) if that is part of your course goals.

CONCLUSIONS AND FUTURE DIRECTIONS

Learning in the field can be a complex and overwhelming experience for most students. This study is a first step in characterizing field note-taking. By coding and applying semiquantitative metrics to 42 student notebooks, we have illustrated that the completeness (C) and uniqueness (U) in note-taking strategies were affected by: the lecturer's teaching style, previous field experience, and gender.

The lecturer's pedagogy impacted the students' note-taking. Lecturer 1 included extraneous information, which the students recorded in their notebooks, significantly reducing the average C of the cohort. Due to these differences, we analyzed the other variables (field experience and gender) within the cohorts and as a whole. Geoscience field experience is associated with higher U scores, whereas there was no such association for geologic concept background (i.e., coursework). The majority of participants reported that they valued previous field experience when writing notes. Gender also appeared to be a factor in note-taking. Female students had statistically significant higher completeness values than males, which were shown to be linked to writing more (higher verbosity). However, some students achieved low scores despite describing a sophisticated understanding of what is required for good note-taking in interviews.

These findings are supported by previous studies, which suggest that students take notes in different ways (i.e., verbatim versus rephrased points or complete versus incomplete notes; Ganske, 1981) and use note-taking strategies derived from previous experiences in the classroom (Van Meter et al., 1994) with varied success implementing these strategies (Bonner and Holliday, 2006). Low C occurs when students miss information, while low U occurs when the information provided is not filtered or questioned. Both of these "failures" are likely the result of the distracting environment (social and sensory distractions; novelty space; Orion, 1993; Orion and Hofstein, 1994) and subsequently high cognitive load (van Merriënboer and Sweller, 2005) of the note-taking task. Dual-strategy students are valuing and implementing both strategies effectively. Some students are favoring one strategy over another (valuing it because it was successful from previous academic experiences) and implementing a single-strategy approach.

Based on the data in this study and the cognitive load literature, we suggest a number of "best practices" to assist students in taking good notes in the field. These suggestions aim to specifically reduce distractions and cognitive load during the note-taking task:

- Learning goals should be communicated clearly and reviewed as needed during the task.
- Specific note-taking tasks can be broken into small parts (or modules, which are meaningful to experts) in order to better manage and store information: Start with the larger perspective (the geologic region, the geographic features, the eco-biodiversity) and then progress to the smaller perspective (the textures, minerals, colors of the features you are concerned with).
- Students should take a break between the parts: to reflect and organize, or reorganize their notes.
- Establish field "etiquette," separating out "quiet time" for observations and other times for task-specific peer interaction to reduce social distractions and to initiate and maintain focus.
- Once an introductory lesson has been completed, you can proceed to other geologic sites and allow students to take notes, in their fullest complexity in order to attain authentic field observations and note-taking. Emphasis in the later lessons should be on fine-tuning these skills.

These suggestions obviously are generalizations. Professionals will have a wide variety of note-taking strategies and values that are honed over time. However, in order to prevent cognitive overload, a compartmentalized and somewhat standardized approach to note-taking in the field may be appropriate for novice learners. Modifying practitioners teaching approach to focus explicitly on the development of basic field skills should, in theory, lead to enhanced formation of schemata in novice to intermediate students and allow them to progress more readily to working on new and complex geologic scenarios.

Our measures of uniqueness and completeness align with qualities typically sought in geology graduates: the ability to independently and accurately record information in the field. New research questions have emerged from this study that require the attention of the field sciences community: What level of detail is needed to make good notes? What level of support is necessary for students to succeed in this complex task? Are these aspects context-dependent? In order to fully characterize the link between note-taking strategies (based on our classification), larger and wider ranges of participants and scenarios are required to tease out the factors that impact these strategies (uniqueness and completeness). Future studies will analyze changes in students' field note-taking over a longer duration (e.g., a longitudinal study looking at a population of students note-taking over an academic year or longer; cf. Bonner and Holliday, 2006), explore the novice to expert spectrum of note-taking strategies and formats, and investigate digital note-taking techniques.

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