Incorporating Concept Sketching Into Teaching Undergraduate Geomorphology

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ABSTRACT

Constructing concept sketches (diagrams annotated with short captions in which students demonstrate their understanding of form, process, and interactions) provides a new and different way to teach Earth surface processes and assess the depth of student learning. During a semester-long course in Geomorphology, we used concept sketches as an icebreaker, as a means to help students place field observations in a spatial context, and as a catalyst for understanding complex graphical presentations of data. For the mid-term and final assessment components of the course, we required students to consider a historic aerial photograph of a local site they had not visited previously in order to strengthen their abilities in landscape interpretation based upon imagery alone; a task many of them will be required to undertake in their future endeavors. Anecdotal student response to the use of concept sketches in Geomorphology was uniformly positive with students self-reporting that the sketches helped them to synthesize large amounts of seemingly disparate information. As instructors, we found concept sketches particularly useful for motivating students and for identifying misconceptions and knowledge gaps.

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Key words: assessment, interpretation, fluvial, hillslope, undergraduate education

INTRODUCTION

Geomorphology, the study of Earth surface processes and history, is one of the most integrative of all geologic sub-disciplines. For students to complete successful undergraduate coursework in Geomorphology, they must not only understand the intimate linkages between physical processes, landforms, and geologic history, but also understand and have the ability to apply principles of physics, chemistry, and in many cases biology (Rhoads and Thorn, 1996). In addition, understanding the behavior of Earth's surface requires students to conceptualize change over time and to make predictions into the future as well as hypothesize about past forms based on their understanding of process (Baker, 1988). These abstractions and interconnections are difficult to teach and often seem to stymie novice learners unaccustomed to synthesizing material from disparate fields. The societal relevance of geomorphology in such arenas as natural hazard mitigation and resource management demands that its practitioners are able to communicate difficult scientific concepts to lay audiences in a visually attractive manner (Merritts et al., 2010), adding yet another challenge for learners.

In order to assist Geomorphology students in making this challenging set of connections, we introduced the process of concept sketching into the undergraduate Geomorphology course at the University of Vermont. Concept sketching is the use of annotated visual prompts (diagrams, photographs, or graphs) as a tool for students to organize information (Tewksbury et al., 2004; Johnson and Reynolds, 2005; Reynolds and Johnson, 2005). In constructing the sketches, students are forced to acknowledge and consider the spatial relationships and interactions between geomorphic form and underlying process. They also gain the opportunity to study geological information in a visual manner (Reynolds et al., 2005; Yin et al., 2010). In this way, the concept sketch acts as a map enabling students to organize otherwise disparate pieces of information into a more coherent and comprehensive picture. In this paper, we present the three different ways in which we integrated concept sketches into a Geomorphology course, providing examples of their use in the classroom, in the field, and as a final assessment tool.

BACKGROUND

In 2008, we added concept sketches to an established undergraduate Geomorphology course at the University of Vermont. The course has been taught since 1993 and includes field, laboratory, and classroom components and stresses techniques of data collections and analysis of real-world data (http://uvm.edu/geomorph). In 2008, with the 19 students, we focused the class on fluvial and hillslope processes illustrated through local field trips as well as indoor modeling and experimental laboratory exercises. Many students taking Geomorphology are majors in Geology or Environmental Science; others have backgrounds in Natural Resources and Geography. Each week of the course focused on a key concept in either fluvial or hillslope Geomorphology, with successive weeks building upon concepts explored in the previous weeks. The course met three times a week: a 1-h lecture period on Monday introducing students to the theoretical framework of the material to be covered; a 5-h field-based laboratory period

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TABLE 1: At the beginning of the course and before each assignment, students were given detailed instructions on how to create an effective concept sketch. We helped them achieve these goals by discussing them in class, making ourselves available for questions, and providing detailed written and verbal feedback on all assignments.

Concept sketch guidelines
1. Effective concept sketches will be neat, with clear diagrams and readable, concise captions.
2. Every caption should include four specific levels of thinking.
(a) The caption should identify geomorphic feature in concise terms.
(b) The caption should explain the relevant processes and/or history.
(c) The caption should identify inter-relationships and linkages with other features.
(d) The caption should make predictions about the future evolution of the feature.
3. Effective sketches will avoid numerical keying of observations and instead use arrows and balloons to link ideas to locations on the sketch.
4. Effective sketches will be well-organized, visually pleasing, and easy to read and understand.

on Wednesday during which students collected data at local sites relevant to the topic at hand; and a 2-h guided data organization and analysis session on Friday preparing students to pull together their work into a laboratory report and/or concept sketch to be handed in the following Monday.

METHODS AND IMPLEMENTATION

During the semester, we assigned multiple different concept sketches starting with a simple in-class concept sketch done in groups on the first day of the semester. During the next several weeks, concept sketches were assigned in lab and along with those sketches, we gave specific content guidance (Table 1) in the form of a handout that was explained and posted on-line. Mid-term and final student learning assessments were based on the creation of large concept sketches done in teams of two over a period of a week each.

Of particular importance was our insistence that each concept sketch caption include four distinct levels of thinking: identification, process, linkages or interactions, and predictions for the future (Fig. 1). These levels generally follow Bloom's taxonomy for learning (Bloom et al., 1956). In order to help students become more aware of underlying interconnections and to encourage thinking at a higher level, we challenged them to think beyond simple, narrative labels. We encouraged students to embed small, annotated sketches within their larger concept sketch as a means to illustrate their understanding of more complex and detailed concepts such as specific physical processes of the evolution of forms over time. We stressed the importance of clear communication by encouraging keyword highlighting, suggesting the use of titles, and by stressing the importance of purposeful layout and clear spatial referencing with arrows and connecting lines to show identification and interconnection.

Some sketches were done alone so that we could assess each student's individual knowledge and understanding; others, including both the mid-term and final assessment sketches, were done in two-person teams so that students could practice collaborative work. We used detailed rubrics to assess student performance on the mid-term and final sketches (Table 2). The final concept sketch incorporated revision of the student's mid-term work; our detailed rubrics allowed students to perform revision in response to constructive critical commentary.

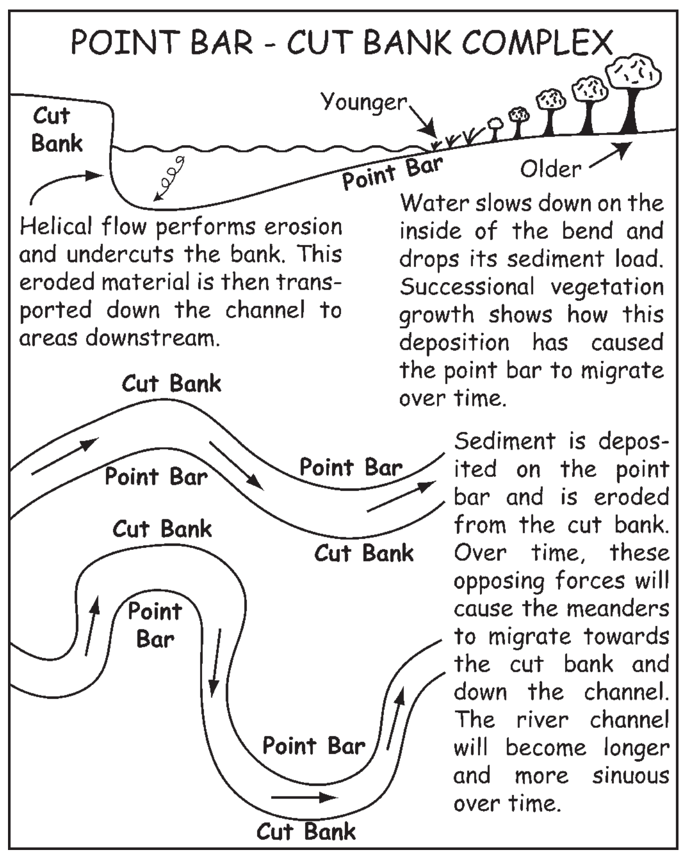

FIGURE 1: Small example of what a concept sketch is and what elements it should include. This example includes both sketches and captions, along with clear labeling of key features. It exhibits the four levels of thinking: identification, process, linkages or interactions, and predictions of the future.

TABLE 2: We used detailed grading rubrics to assess students' performance on the mid-term and final concept sketches. These rubrics helped us to grade consistently, and ensured that students knew where they had done well and where they needed improvement. The example shown here represents only a small part of the rubric used to assess the mid-term exam.

Example grading rubric							
Grading rubric: Geomorphology mid-term exam							Names:
	Sketch present (1 pt)	Feature identified (2 pts)	Process described (4 pts)	Interactions discussed (1 pt)	Predictions made (2 pts)	Sum (10 pts)	Comments
(A) Interpreted cross-section through the channel from A to A′.	1	2	2.5	1	1.5	8	Overall, well done. Could have improved by including more information about process and prediction.
(B) Soil profile at location B.	1	1	3	1	2	8	Nice sketch. Could have improved by identifying individual soil horizons and discussing, their formation.

APPLICATIONS OF CONCEPT SKETCHING IN GEOMORPHOLOGY

We used concept sketching in several venues for different purposes and with different prompts or underlying graphics. Concept sketches were used in the classroom to build confidence, involve students in lecture, and encourage idea sharing. In several laboratory write-ups, we used concept sketches as the means by which students explained their understanding of the material and spatially located field data. For both the mid-term and final assessment projects, we used large and intricate concept sketches as a means of evaluating student learning at the completion of the course. Prompts or underlying graphics varied and included photographs, line drawings, remotely sensed data, and graphs. In each instance, we reinforced the importance of understanding not only the underlying geomorphic concepts, but also the ways in which humans interact with landscapes and affect geomorphic processes.

Application #1: Concept Sketching in the Classroom

We introduced the idea of concept sketching on the first day of class. As an icebreaker, we provided three different poster-sized, remotely sensed images as prompts: one of the world, one of North America, and one of the area around Portland, Oregon. We broke the 19 students into three groups and showed them a few examples of concept sketches. We then provided them with a pad of blank post-it notes and gave them 15 min to create geomorphic annotations regarding either specific landforms or general landscape patterns visible on each map (Fig. 2). At the end of the exercise, we hung the maps on the classroom walls and student groups presented their work to the rest of class.

We had multiple goals in using concept sketches in this way during the first day of class. Early on, we wished to establish the importance of collaboration between students and to build comfort with impromptu public speaking between groups. We specifically wanted the groups to compare their sketches and discuss the similarities and the differences determined largely by the scale of observation, another key concept we focused on over the duration of the course. Working in class allowed students to become familiar with concept sketching under the supervision of several instructors and ensured that they understood what concept sketches were from the start. The freeform exercise clearly set the precedent that we were going to maintain an open classroom where movement, discourse, and questions were welcome and expected.

During this first exercise, students identified major landforms familiar to at least one person in each group. We found that the students often noticed and labeled features that resulted from both solid Earth processes (volcanoes, plate boundaries, and faults) as well as human impacts on the environments (development, clear-cutting, and agriculture), thus providing a wonderful catalyst for us to emphasize the synthetic nature of geomorphology as well as its importance to society.

Application #2: Concept Sketching as a Laboratory Assignment

During the second week of class, we had our first laboratory period and immediately introduced concept sketching as a means by which to organize and report field data in a place-based, geospatial context. The field trip involved a 5-h canoe trip down a local river. Each student was given laminated, georectified aerial photographs of the river and the adjacent bottomlands overlain with UTM gridlines. Each canoe carried a hand-held GPS unit so that locations visited in the field could be marked on the photograph, reinforcing students' map reading and GPS skills. At the conclusion of the trip, the lab assignment required the students to create two concept sketches [Figs. 3(a) and 3(b)]. The first sketch was based on the aerial photograph of the area they actually canoed and their assignment was to explain how large, lowland, meandering rivers work by citing examples from the trip. The second sketch was based on a tracing of the channel and associated cut off meanders along a reach of the same river that we did not canoe, and thus required students to extrapolate what they had seen and learned on the trip to areas they had never visited. This second sketch was designed to prepare

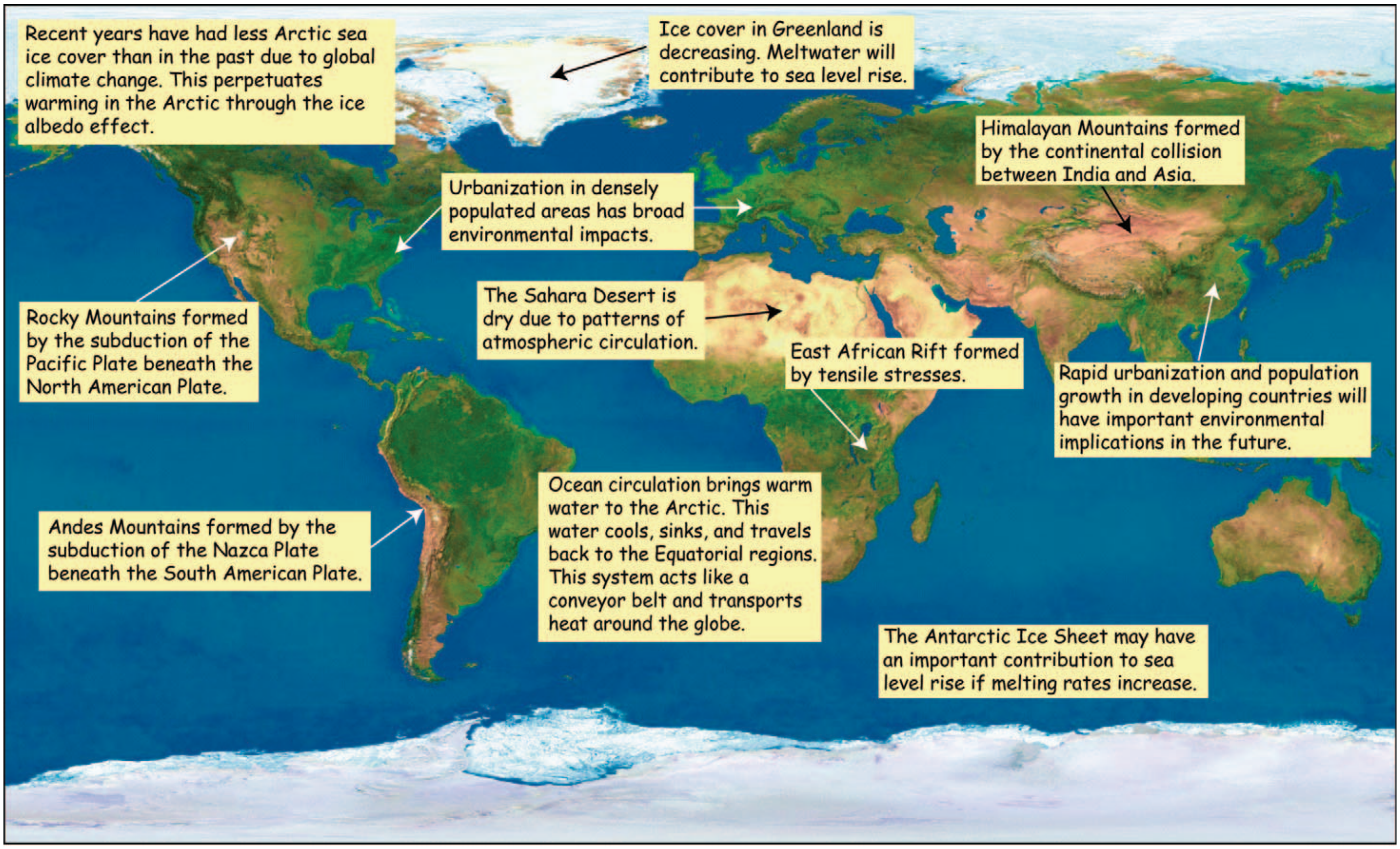

FIGURE 2: Satellite imagery of planet Earth overlain with examples of student observations from our ice-breaking exercise on the first day of the semester. We divided the class of 19 students into three groups, provided each with a different scale image of somewhere on the planet and a stack of post-it notes, and asked them to conceptually annotate the image they had been given. Student groups then presented their initial concept sketch to the class.

them for the mid-term and final concept sketches based on imagery from a local site that they would not see first-hand during the semester.

We used a very different prompt for a laboratory session focused on identifying and surveying river terraces. In order to help students place their survey of one vertical section of river terraces in the context of the river's long profile, we provided them with a plot showing the contemporary profile and a series of Holocene-aged terrace profiles (Wright et al., 1997). The graph was relatively straightforward but the underlying geologic history represented by the terrace profiles is complex and has always been a challenge for students to grasp. The older terraces were created by a series of base level falls related to progressively lowering glacial lakes; the younger terraces reflect episodic incision driven by climate and sediment/water loading through the Holocene; the youngest inset terrace reflects the effects of changing land use over the past 100 y (Wright et al., 1997). In this case, the concept sketch instructions required the students to annotate the graph and include inset sketches as a means to explain river dynamics and relevant processes over time and space related to the deglacial and post-glacial history in Northern Vermont with the aid of a fieldtrip guidebook chapter we provided to them. While many students successfully made connections between rivers in cross-sections and in long-profile form, this exercise proved quite difficult for others, requiring us as the instructors to reconsider what types of guidance the students needed.

We found that the use of concept sketches as a method for laboratory synthesis was particularly powerful because sketching encouraged students to link data and ideas from a laboratory assignment to larger ideas and overarching concepts discussed during the semester. The use of a standardized base prompt with the inclusion of smaller (inset) concept sketches allowed students to experiment with making their own free-form concept sketches while providing a uniform basis for grading. By assigning concept sketches as lab reports several times over the course of the semester, we intentionally prepared students to create larger and more complex sketches as their mid-term and final course assessments. Using the same assignment type (with varying prompts) multiple times throughout the semester gave the students repeated opportunities for feedback from us allowing them to improve their work through experience. Through this style of feedback, the students gained an understanding of what we were asking and expecting of them, while we learned what was required from us as

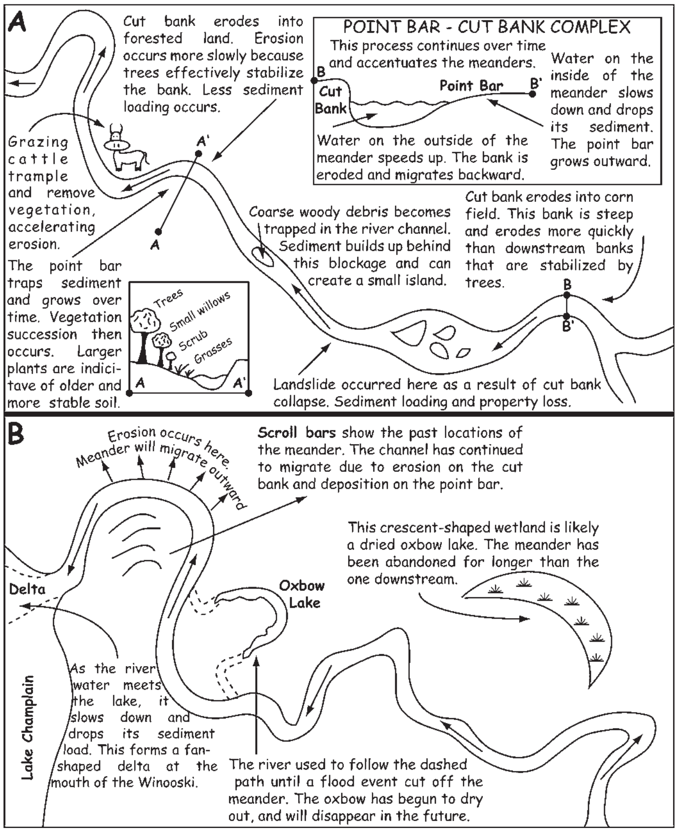

FIGURE 3: Example of a final laboratory concept sketch assignment from the Winooski River canoe float trip, northern Vermont. Comments and sketches shown represent those typically provided by the students. (a) Annotated trace of the reach of river that the students canoed during a laboratory field trip. We made frequent stops to discuss germane fluvial processes and forms, and well as human modification of the channel. (b) Length of river farther downstream, where students did not visit. For this exercise, students were required to make geomorphic observations and interpretations based on aerial imagery alone, preparing them for the more complex mid-term and final assessment sketches.

instructors to enable them to successfully assemble their sketches.

Application #3: Concept Sketching as a Final Assessment

We used structured concept sketches as the primary synthetic assessment tool for the course. For the mid-term assessment, we gave the students a week off of formal lecture and laboratory activities and provided them a 36″ by 24″ blank poster that included at its center an oblique aerial photograph of a large river and adjacent uplands (Fig. 4). We provided a detailed list of topics that needed to be included in the concept sketch. This list formed the basis of our grading rubric (Table 2) for evaluating the sketches. The mid-term assessment focused on rivers and included soils, which acted as the bridge between the fluvial (first half of the semester) and hillslope (second half of the semester) sections of the course. To complete the assessment, the students worked in pairs. The questions required the students to sketch and annotate active processes, cross-sections, long profiles, and soil pit profiles. We returned the mid-term assessments in person, providing detailed written and verbal feedback to the student pairs. To protect student work, and maintain privacy, no comments were made on the actual posters. Instead, we provided each group with a detailed rubric that served as a means for them to address misconceptions when revising the fluvial section as part of their final assessment. For several weeks after the mid-term posters were completed, they hung in a common hallway, allowing students to see and learn from the work of their peers.

For the final assessment, we used the same image as a prompt but expanded the poster to a 42″ square and provided a second set of questions related to hillslopes in addition to the fluvial questions. This meant that part of the final assessment included focused revision in response to our critique of the fluvial components of the poster, while the other part included new material related to the hillslope processes. The revision process allowed students to correct their misunderstandings of fluvial systems instead of simply charging ahead with new material. Again, we gave the students a week to prepare their final posters, but we structured the week by requiring students to be present and working during class and laboratory periods. These meetings became consultancy periods during which the students freely and repeatedly approached us as instructors with questions about both content and poster design. To conclude the course, the students presented their work in a poster session during which half the class circulated while the other half stood by and explained their posters; we then rotated so all students experienced both presenting and observing (Fig. 5).

Our observations and student feedback both suggested that concept sketches were pedagogically useful as a summative assessment tool. Students reported that preparing both the mid-term and final concept sketches encouraged engaged review of course materials (readings, notes, and lectures posted online). We heard repeatedly from students that the process of creating the final concept sketch helped them synthesize material they had learned over the semester, allowed them to link large and small concepts together, and provided a means to understand the course material in its entirety. Students took pride in creating a visually pleasing representation of their knowledge and commented that the preparation process was a difficult but satisfying replacement for the “memorize and regurgitate” trap into which most final exams fall. Because the posters contained so much information, we used a detailed rubric for evaluation. Honoring the large amount of time the students put into their final sketches, we handed posters back in scheduled face-to-face meetings and provided a detailed review of our assessment. These meetings allowed us to correct any lingering factual misconceptions, provided us with insight into the strengths and weaknesses of our efforts in designing the assignments, and identified improvements that can be made in future semesters.

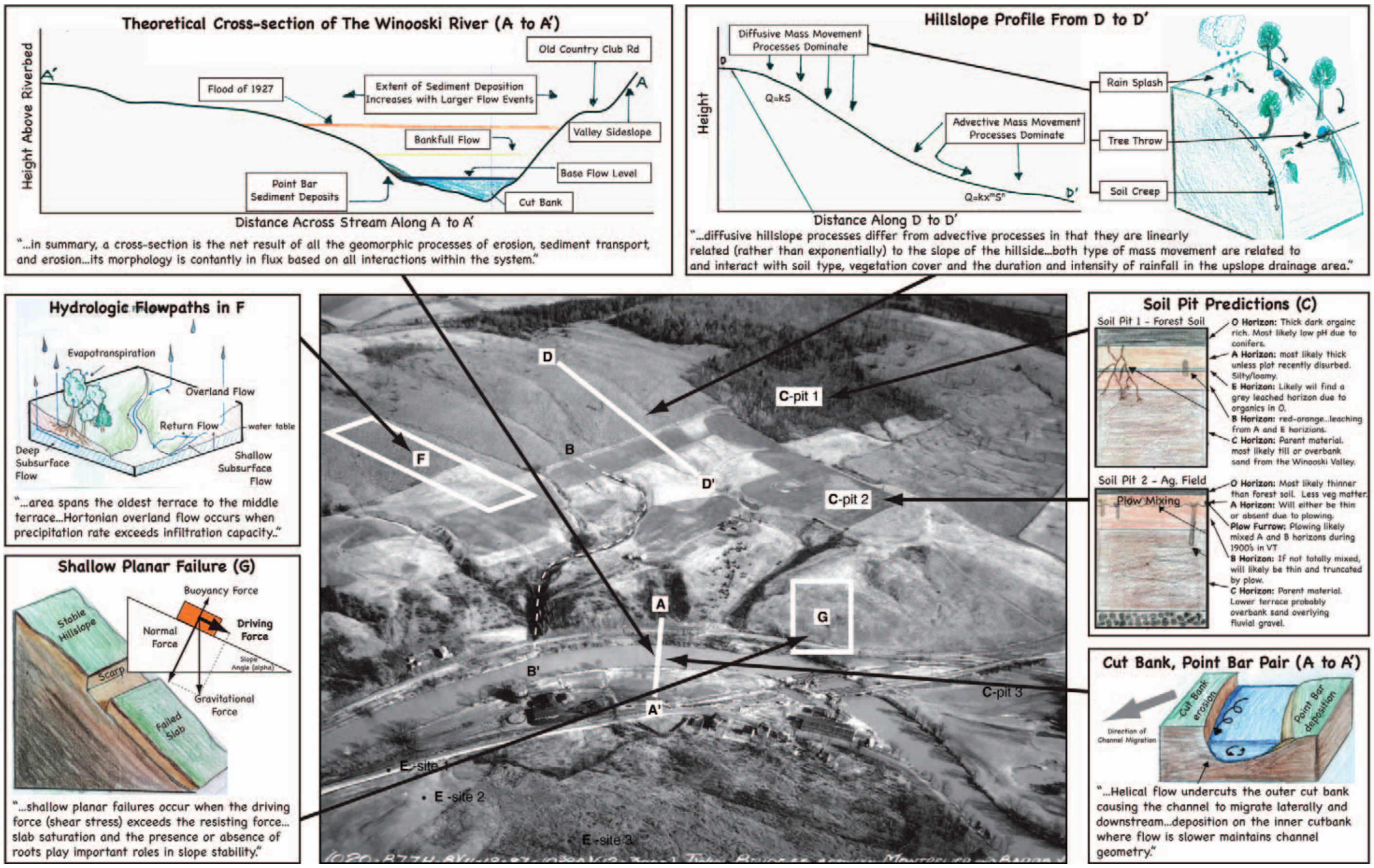

FIGURE 4: Compilation of examples of sketches and annotations generated by the students for their final concept sketch project. We required the students to analyze and interpret a variety of hillslope and fluvial concepts exemplified in the oblique aerial photograph taken in 1927 following the flood of record along the Winooski River in northern Vermont. The image provided the students with the opportunity to convey their understanding of the interrelationships between all major concepts covered during the semester. In addition, the section of river and time at which the photograph was taken required students to acknowledge the influence human activities and land-use practices have on geomorphic process and form, as well as to consider the role extreme events, such as flooding, have on fluvial and hillslope processes.

CONCLUSIONS AND FUTURE REFINEMENTS

The 2008 Geomorphology class at the University of Vermont benefited dramatically from the incorporation of concept sketches. As instructors, we found that the sketches clearly showed the depth of student knowledge and rapidly allowed us to identify student misconceptions and confusion. Student concept sketches made it very clear which students had moved beyond landform identification and were able to consider underlying physical processes and linkages between features and disciplines. In this sense, concept sketches assigned in class and in laboratory periods became a useful rapid assessment tool to gauge student understanding and quickly adapt our teaching strategy. The concept sketches clearly and immediately showed which students understood the class material clearly enough to present it in an organized and logical fashion. We used concept sketches in a wide variety of applications (e.g., graded versus non-graded, group versus individual, and narrow versus wide focus) and found that in almost every application, the use of concept sketches greatly encouraged the synthesis of material.

Over the course of the semester, student concept sketches improved significantly. We observed increasingly proficient integration of text with graphical material as well as an increased level of sophistication in both the drawings and in the text. We also noted improvements in the students' ability to approach the more abstract parts of captioning, specifically their ability to articulate linkages and to make predictions of system behavior in the future. Through these improvements, we witnessed novice learners gaining confidence both in the material itself and in the means of presentation we required. Given the need for clear visual and written articulation of findings in the geosciences specifically and in society in general, we suspect that the written and visual presentation skills gained over the course of the semester will be of significant utility to these students wherever their academic and professional lives take them.

Anecdotal student reports, gathered during the final poster session as well as from informal conversations when

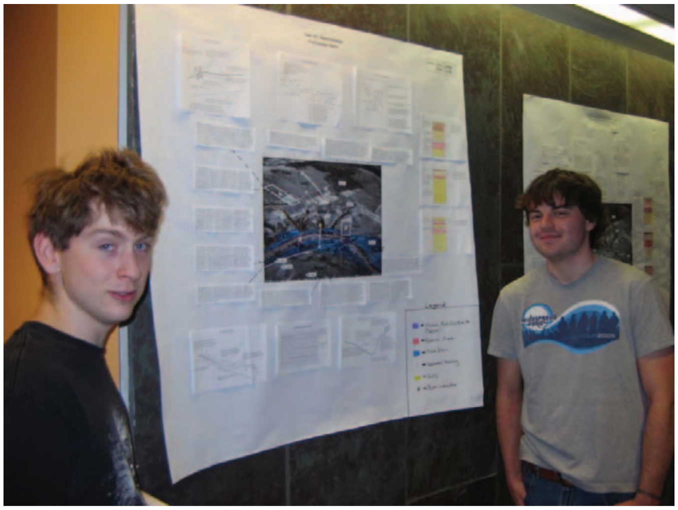

FIGURE 5: At the conclusion of the semester, student pairs presented their final concept sketches to the class. Students commented that they took pride in their final product and enjoyed having the opportunity to share their work with their peers.

we handed back graded assignments, suggest that students also felt that they benefited from the use of concept sketches in this course. The students repeatedly reported that preparing the concept sketches helped them to synthesize disparate strands of information in a way that exams or final papers did not. Many students who described themselves as learning well from the visual and spatial arrangement of information, which is fundamental to Geology, were particularly enthusiastic about these assignments. Most students reported great satisfaction with the way in which their final concept sketches turned out and felt that preparation of the sketches was time well spent in terms of integrating 10 weeks of material. There were numerous comments relating how concept sketching allowed students the opportunity to express their creativity and individuality in the context of doing science, something they considered unusual and positive.

There are several refinements we will make the next time the course is offered. Most importantly, we will add in-class and out-of-class assignments that help students focus on concise yet informative writing. We found on both the mid-term and final concept sketches that some students had trouble presenting only the most essential material and would include large volumes of superfluous information in their descriptions. Many of the students commented on the benefits of having us present during over 6 h of class time while they prepared their final posters and that they felt they would have benefited more if the mid-term had been handled the same way. An issue we encountered with nearly every mid-term poster was the lack of organization as well as the lack of clear labeling. The final posters were greatly improved in this regard, and in the future we plan to stress these elements to the students up front and incorporate them more directly into concept sketches earlier in the semester. Additional refinements we have considered include electronic creation and submission of the concept sketches as well as pairing the sketches with more traditional written essays.

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