AAPG Search and Discovery Article #90172 © CSPG/CSEG/CWLS GeoConvention 2010, Calgary, Alberta, Canada, May 10-14, 2010

What are the cognitive processes that students experience as they learn to use a stereonet?

Boggs, K.J.E., Bennett, D., and Gale, R.

Most geologists experienced some difficulty when acquiring the 3D visualization skills involved with learning to use a stereonet (low/medium initial spatial capability), while some students just "get it" (high initial spatial capability). What instructional techniques or experiences work in transforming "low/medium spatial" capable students into "high spatial" capable students? Do all students experience a transformative moment while learning to use a stereonet, or are transformative moments confined to students with initial "low/medium spatial" capabilities?

This study represents a SoTL (Scholarship of Teaching and Learning) exploration of the student learning experience in an Introductory Structural Geology course at Mount Royal University (MRU). Participation in the inaugural MRU SoTL scholars program has brought SoTL techniques from Nursing, Social Work, Engineering, Mathematics and Cognitive Psychology into this project. This program is modeled after the CASTL (Carnegie Academy for the SoTL) and has proven incredibly powerful for the development of SoTL research (Hutchings, 2000).

Specifically, one minute and end-of-term reflective essays (used in nursing and social work) were used throughout the Fall 2009 term to document personal journeys through the learning process regarding how the students mastered the stereonet. These essays were intended to guide the students towards taking ownership of their personal learning experience, which has been documented by psychological and educational theory researchers to guide students towards improved personal learning experiences (Pintrich, 2002). "Think alouds", were borrowed from cognitive psychology, educational theory and mathematic/engineering education research. "Think alouds" involve participants verbalizing their thought process as they solve a problem. Ericsson & Simon (1980) demonstrated that "think alouds" are a valid method that can be treated as any other data acquisition (Ennis and Gyeszly, 1991).

Anecdotally, from personal experience, observation of the student learning process, and from student feedback, the importance of hands-on work had been documented during the student learning experience. Light (2001), with his work on the Harvard Assessment Seminars, had emphasized the importance of group work towards personal satisfaction in science and engineering students. This study was structured to permit the exploration of these, and other, instructional/learning experiences while the participants mastered stereonet skills.

Pilot Study: In February, 2009, six structural geology students (Fall 2008 class) completed a questionnaire exploring learning modalities (here: visual, auditory, kinesthetic), preferred instructional styles, confidence levels with stereonet skill retention, and the achievement of transformative moments. A Likert scale from 1 (not helpful or no confidence) to 5 (most helpful or high confidence) was used to evaluate the preferred instructional technique(s) and confidence level in stereonet skill retention. Statistical analysis of midterm and final laboratory exam marks were completed over a four year period in order to establish which steronet skills are basic, intermediate and advanced for the "think aloud" exercises.

Pilot Study Results: Of the six students that completed the questionnaire, three students were assessed as having a visual learning modality, two as visual-auditory-kinesthetic and one as visual-auditory.

The participants were asked to evaluate the helpfulness of the different instructional techniques used in this course. These Likert scale results are reported as an average of the six responses with (5) being the most helpful and (1) being the least helpful. Class Exercises (5.0), Lab Problems (4.8) and old exam/quiz problems (4.3) all had participant rankings above or equal to 4.3. Group work (4.2), lectures (4.0) and explanations by the instructor (4.0) were evaluated as between (3.0) and (4.3). These instructional techniques were given values under (3.0): target questions (2.3; these are questions that accompany reading assignments that are designed to focus the student's readings), extra problems from the textbook (2.5) and reading the textbook (2.7).

These quoted mark ranges of averages are from the assembled midterm and final exam marks over the four year period, fold analysis and fault plane diagrams were only covered after the midterm and are therefore only quoted as one value. Stereonet skills such as plotting the pole to a plane (84 to 93%), calculating the line of intersection between two planes (91 to 94%), measuring a plane's orientation when given two apparent dip directions (86.5 to 89.4%), and measuring the rake of a linear feature on a plane (89.6 to 90.5%) all had averages greater than 80%. Stereonet skills such as calculating true thickness from oblique traverses (63.2 to 69.2%), unplunging or unfolding a fold (57.8 to 68.2%), analysis of folds (cylindrical versus conical, orientation of principal stresses; 73.8%) and fault plane diagrams (74.2%) all had averages greater than 60% and less than 79.9%. The stereonet skill of calculating the original orientation of features beneath inclined unconformities (49.5 to 56.3%) had an average below 59.9%.

The participants were also requested to report their confidence level on some stereonet skills (Likert scale from 1 (no confidence) to 5 (complete confidence)). Stereonet skills with an average above 80% had a reported average confidence of 4.5 to 4.8, and those with an average above 60% and below 79.9% had a reported average confidence of 3.5 to 3.7. The steronet skill with an average below 60% was not included in this pilot study, but will be included in the "think-aloud" exercises.

Pilot Study Discussion: All six participants had a visual component to their learning modalities. This leads to the additional question: "Do all geologists have a visual component to their learning modality?"

The top three most-helpful instructional techniques were Class Exercises (5.0), Lab Problems (4.8) and old exam/quiz problems (4.3), which all involve a "hands-on" component. This acknowledges the anecdotal observation of the importance of "hands-on" exercises for deep learning. Anecdotally, it had been thought that one of the most important advantages of the small class sizes at Mount Royal University (≤25 in geology major classes such as Structural Geology) is that laboratory exercises are interwoven with the lecture material. New material is introduced in the lecture portion, as a group the class works through a Class Exercise, then the students work through independent appropriate laboratory problems. These six students acknowledged the helpful nature of this approach, which supports past feedback from the students in student evaluations and comments to the instructor.

The next three most-helpful instructional techniques were Group Work (4.2), Lectures (4.0) and Explanations by the Instructor (4.0). These three techniques all involve personal interactions with the instructor or between the students. These relationships between students and faculty/other students were emphasized by Light (2001) as being very important for positive student learning experiences. Typically most Geology Major students at MRU take Structural Geology immediately after the Introductory Field School (last two weeks prior to the fall term). Both courses are taught with a concerted effort to form the students into a strong cohesive group that works well together in smaller study groups. The nature of the field school promotes the development of strong student cohorts. We do not have graduate students at MRU, instead instructors may select students to act as peer tutors. The Learning Skills department at MRU provides these peer tutors with various workshops designed to develop their tutoring skills (such as communication, mentoring, etc). Group work had been commonly acknowledged by past students as an important component of the student learning experience in both courses. These questionnaire results supported this observation.

The three least helpful instructional techniques were target questions (2.3; these are questions that accompany reading assignments that are designed to focus the student's readings), extra problems from the textbook (2.5) and reading the textbook (2.7). Even though all participants had a visual component to their learning modalities they all ranked reading and answering theoretical questions as being the least helpful instructional techniques. This suggests that reading-writing should be assessed separately as a learning modality as per the VARK (visual, auditory, reading-writing, kinesthetic) questionnaire (Fleming and Bonwell, 2008).

One puzzling point is that "extra problems from the textbook" were ranked so low as a helpful instructional technique. This is a 'hands-on' problem solving instructional technique similar in nature to the three instructional techniques chosen as being the most helpful. It is possible that student focus on GPA resulted in a preference for old exam/quiz problems over more random extra problems from the textbook.

Typically students are very comfortable with basic skills (averages > 80%) such as plotting the pole to a plane (84 to 93%). Some students experience some difficulty with the intermediate skills (averages between 60 and 79.9%). Many students experience greater difficulty with the advanced skill (average less than 59.9%) of calculating the original orientation of features beneath inclined unconformities (49.5 to 56.3%). These statistical results confirmed what had been observed anecdotally in the classroom; the exception was that all rotation problems were previously thought to be advanced.

The participant reported confidence level also confirmed these rankings (Likert scale from 1 (no confidence) to 5 (complete confidence)). Basic skills had a reported average confidence of 4.5 to 4.8, and intermediate skills had a reported average confidence of 3.5 to 3.7. The advanced skill of unconformity rotation was not included in this pilot study.

The Structural Geology course at Mount Royal University was adapted from the course taught by Dr. D.A. Spratt at the University of Calgary. This original course was designed to incorporate the scaffolding steps strongly recommended by de Caprariis (2002) as being an effective method for teaching the challenging 3D visualization skills involved while using the stereonet. The statistical analysis confirms that the basic skills are the ones that are introduced early and then built upon for the intermediate and advanced skills.

Main Study Fall 2009/Winter 2010: The VARK questionnaire (Fleming and Bonwell, 2008) was used to establish personal learning modalities. During the Fall term 2009, all students in Structural Geology at Mount Royal University completed 4 x one minute papers and an end-of-term reflective essay that documented their personal journey through the learning process regarding how they mastered the stereonet. All students will have the opportunity in January 2010 to create electronic posters entitled "How I learned to use a stereonet". These posters and the reflective papers will be used as props/guides/prompts for the participants during the "think aloud" semi-structured interviews. The "think aloud" portion of the interviews are designed to document individual thought processes as the participants answer the question 'How I learned to use the stereonet' and solve the basic, intermediate and advanced problems using the stereonet as "think-aloud" exercises. The semi-structured interview questions were designed to prevent simple yes or no responses and solicit more in-depth answers from the participants.

The Fall 2009 term was the first time that all students in Structural Geology (not just the participants in the study) completed a learning modality questionnaire, the one minute papers, and the end-of-term reflective papers. The effectiveness of these techniques will be evaluated during the "think-aloud" semi-structured interviews. It is also possible that the reflective nature of the poster, the interviews and the "think-aloud" exercises may exert a beneficial learning influence on the participants (as per Pintrich, 2002). This will be assessed by a follow-up questionnaire after the interviews have been completed. The students will be given the opportunity to participate in any portion(s) of this study.

It is hoped that the results from this study and a future study comparing the thought processes of geology students with experienced professional geologists will significantly improve upon the comprehension of the cognitive processes involved while geology students master challenging concepts such as the 3D visualization skills involved in using the stereonet. Improved understanding of these cognitive processes may lead towards improving how we teach similar challenging skills.

Acknowledgements: I am very fortunate to be one of the inaugural MRU SoTL scholars. Discussions with the members of our group (Business, Engineering, English, Journalism, Nursing, Policy Studies and, Social-work Professors) during retreats, monthly meetings, coffee, etc were exceptionally valuable during the incredibly steep learning curve of the past year. Specifically the "think-aloud" concept was introduced by Dr. Miller-Young (engineering), the reflective essay concept by Dr. Bennett (social work) and Dr. Gale (mentor) proposed the poster. Dr. Bennett will be conducting the "think-aloud" semi-structured interviews.

References

de Caprariis, P.P., 2002. Developing successful learning strategies in structural geology. Journal of Geoscience Education, 50 (2), 145-149.

Ennis, C.W.Jr., and Gyeszly, S.W., 1991. Protocol analysis of the engineering systems design process. Research in Engineering Design, 3, 15-22.

Ericsson, K.A., and Simon, H.A., 1980. Verbal resports as data. Psychological Review, 87, 215-251.

Fleming, N.D. and Bonwell, C.C., 2008. VARK: a guide to learning styles. www.vark-learn.com.

Hutchings, P. 2000. Opening Lines: Approaches to the Scholarship of Teaching and Learning. The Carnegie Foundation for the Advancement of Teaching. Menlo Park, California, USA.

Light, R.J., 2001. Making the Most of College: Students Speak Their Minds. Harvard University Press, Cambridge, Massachusetts, USA.

Pintrich, P.R., 2002. The role of metacognitive knowledge in learning, teaching and assessing. Theory into Practice, 41 (4), 219-225.