# Design and Assessment of an Interactive Digital Tutorial for Undergraduate-level Sandstone Petrology

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## ABSTRACT

A digital interactive tutorial has been created to provide undergraduates a 'virtual microscope' resource for learning sandstone petrology. The tutorial does not replace hands-on laboratory experiences with the petrographic microscope, but lends efficiency and breadth to the learning process. Students are able to obtain practice with identification of a wide array of sandstone components outside of the laboratory and independently of the instructor.

The efficacy of traditional petrography instruction versus instruction supplemented by the tutorial was assessed in two semesters of GEO 416M, "Sedimentary Rocks" at the University of Texas at Austin. Students in the first semester were not provided with the tutorial, providing a baseline or control for comparison. In the second semester, the digital tutorial was provided to all students on CD and assigned as a required resource in laboratory exercises. Investigation of student attitudes towards the tutorial demonstrates a high level of approval, and subject matter attainment appears to improve with tutorial use. Individualized, one-on-one instruction should remain a key element in effective teaching of petrography. Digital materials have a clear benefit in terms of enhancing the quality, availability, and breadth of the demonstration materials that can be provided to students. Based on this preliminary assessment, there are benefits in student learning as well.

Key words: petrography, sandstones, sedimentary petrology, educational assessment, digital imaging

## INTRODUCTION

Hands-on experiences with earth materials are a vital aspect of earth science education. The need for petroleum explorationists or mining geologists to have extensive first-hand knowledge about the natural variations of rock properties is obvious. In fact, it is difficult to imagine an area of earth sciences for which knowledge and understanding of rock properties is irrelevant. Interestingly, as undergraduate earth science departments adopt an increasingly broad view of their curricular needs, the most intensively hands-on study of earth materials, perography, is being squeezed from the curriculum. Despite this trend, students of even the most broadly defined earth science areas, for example, hydrologists, environmental scientists, and geo-physicists, have considerable stake in obtaining a detailed understanding of earth materials.

We have developed and tested an interactive digital tutorial in sandstone petrology. The goal of this tutorial is to provide students exposure to the highly visual subject matter of petrography outside the confines of organized laboratory exercises. Our hope is that widespread use of such digital interactive formats will allow students to gain high levels of expertise with description and interpretation of earth materials despite the reduced amounts of hands-on laboratory practice that are allowed by modern curricula.

## PETROGRAPHY INSTRUCTION IN THE MODERN EARTH SCIENCES CURRICULUM

It is inescapable that instruction in petrography is labor-intensive, and therefore expensive. Further expense relates to the cost of microscopy equipment and thin sections. Expertise with microscopy is attained through repeated exposure to large amounts of visual information. Teaching of petrography necessarily depends upon the involvement of an instructor who has already attained this expertise. In a typical laboratory session, an instructor with extensive experience in the identification and interpretation of microscopic features, conveys this information by demonstrations to a small group of students. After having received the instruction on how to locate and identify a given feature, the student is then called upon to make independently such identification and to have the correctness of their interpretation confirmed by the instructor. Typically, this proceeds through a repeated exchange in which students locate a feature, question the instructor about it, and in turn are interrogated about other features located by the instructor. Extensive practice outside of the laboratory is a key element to gaining petrographic expertise, but especially at the beginning of this process, individualized attention from the instructor is indispensable. Accomplishing petrographic instruction depends not only upon the availability of an experienced petrographer and but also on the availability of suitable demonstration materials (thin sections) and working petrographic microsocopes.

Cost aside, the principal reason that petrographic instruction is disappearing from the modern curriculum relates to the fact that it must compete for time within an increasingly diverse list of required courses (e.g., Fitz, 2000). Experiences in the Department of Geological Sciences at the University of Texas at Austin are illustrative of the challenges for retaining petrography in the curriculum. Until the mid-1980s undergraduates in this department took two required courses in

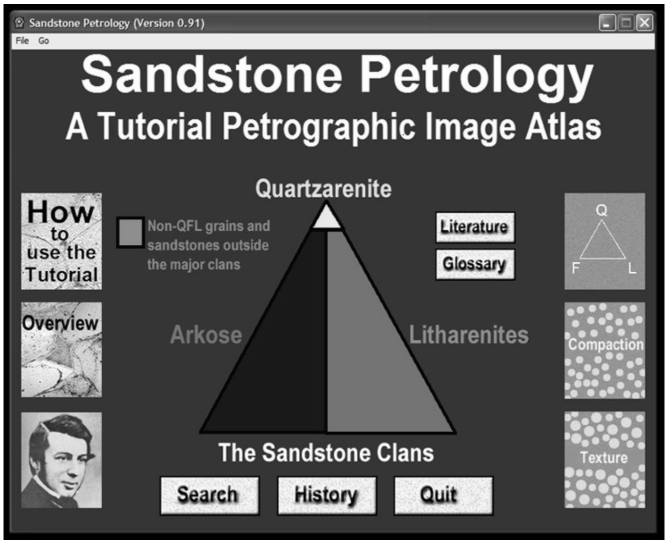


**Figure 1. Top-level page of the tutorial. Provides entry into all the major sections.**


**Figure 2. Images from the feldspar diagenesis section of the tutorial. The small text box was called up by clicking on the large blue area in the center of the field of view. The glossary entry was called up by clicking on the hyperlinked text in the small text box. This particular image contains 11 additional scripted area and 10 additional hyperlinks for the student to explore, click, and learn.**

sedimentary materials. The first course, offered to sophomores, was GEO 416M, “Sedimentary Rocks”. This course covered hand specimen petrology, measured sections and core description, and depositional environments for both siliciclastic and carbonate sediments and rocks. Two laboratory sessions a week gave the students hands-on experiences. A second course, GEO 336K, “Sedimentary and Metamorphic Rocks” was offered to juniors and seniors. Prerequisites were a semester in mineralogy and a semester in igneous petrology both including a substantial component of optical crystallography. The GEO 336K course devoted a half-semester to the petrography of siliciclastic and carbonate sediments and rocks. Again, students attended two laboratory sessions each week, for totals of six sessions devoted to siliciclastics and six to carbonates. These materials were examined with respect to provenance, geochemical history, and porosity evolution. In the wake of added departmental requirements for undergraduates, including courses in geophysics and hydrogeology, the sedimentary rocks curriculum contracted. Today, petrology instruction is subsumed under GEO 416M and students only receive 3 laboratory exercises in petrography of sandstones and 3 in carbonates (shales and evaporites are completely omitted). One disadvantage to this arrangement is that students are introduced to microscopic observations without grounding in mineralogy, crystallography, or crystal optics.

## PREVIOUS ASSESSMENTS OF DIGITAL INSTRUCTIONAL MATERIALS

The finding of ‘no significant difference’ is recognized as the most common outcome of attempts to assess the relative efficacy of distance learning (Russell, 1999; http://teleeducation.nb.ca/nosignificantdifference/index.cfm). On the other hand, a meta-analysis of 254 previous studies showed that students exposed to computer-assisted instructions learned more material, learned the material faster, and liked their classes more than students in traditionally structured classes (Kulik et al., 1983; Kulik and Kulik. 1989). These studies mostly relied on testing for recall of factual knowledge and surveys and pre- or post-interviews, and seem to indicate that computer assisted instruction can be very effective at promoting rote memorization (Renshaw et al., 2000). Other studies point out that, whereas computer assisted instruction can be as effective as traditional teaching methods for rote memory, it is not always shown to be *more* effective . Our results, described below, support the findings of the Kulik papers.

### Goals and Features of the Digital Sandstone Tutorial

The current tutorial module is a demonstration version made with Macromedia Authorware Version 5.1, for the Windows PC platform. The module is delivered on a single CD-ROM disc as a stand-alone application and could be executed from the CD without installing any components to the user’s local hard disk. Minimum hardware requirements for running the tutorial is Intel Pentium 120 Mhz processor equivalent or faster, 64 MB of RAM or greater, a 1024 by 768 pixel display setting, 64MB of RAM or greater, and a CD-ROM drive.

The tutorial is constructed largely around the tripartite Folk sandstone classification (Folk et al. 1970; Folk 1980), displayed on the top-level tutorial page (Figure 1; Choh et al., 2001a, 2001b, 2002). An additional section addresses grains other than quartz, feldspar, and lithic fragments and also sandstones dominated by these exceptional grain types. For each of the major sandstone ‘clans’, there are tutorials containing petrographic images related to both provenance and diagenesis. Within each sub-section of the tutorial the student is provided with introductory text describing the major learning goals for the particular section. The tutorial images themselves may be entered either directly from the second-level tutorial pages, in which case they may be viewed sequentially. Alternatively, the tutorial can be entered through thumbnail pages that allow access at

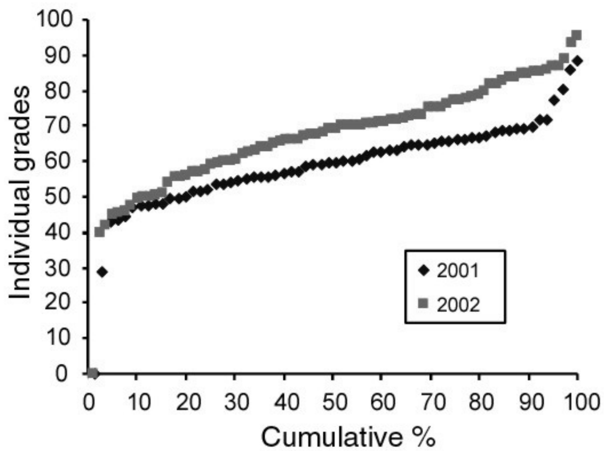


**Figure 3. Cumulative distributions of individual grades on the laboratory examination in siliciclastic petrography in fall 2001 and spring 2002 semesters of GEO 416M.**

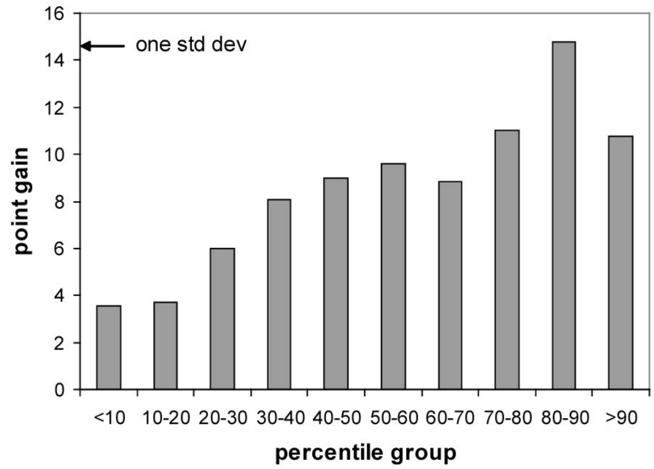


**Figure 4. Improvement in grades on the laboratory examination in the spring 2002 semester as compared to the fall 2001 semester. Every percentile grouping shows a gain, but students ranked in the higher percentiles of the class show greater average gains.**

any point in the tutorial sequence, or by using the search engine.

The principal educational approach of the tutorial is an interactive "virtual" microscope experience using a non-intrusive user interface (Choh et al., 2001a, 2001b, 2002). A key element of the tutorial is that the petrographic images fill a substantial portion of the available screen area (approximately 96 % of 800 by 600 pixels used; Figure 2). Each image, as in a true microscope view, is basically unadorned until the student actively calls up information that is temporarily displayed over the image. In passing the cursor over the image with the mouse, the cursor appears as either an arrow or a hand. Areas of the image where the pointing hand appears are scripted such that clicking on the region calls up either a small amount of text that identifies the feature displayed beneath the cursor, or a larger box of text that expounds upon the key concepts conveyed by the image (Figure 2). On clicking again, text boxes disappear and the student can continue to explore the image or move to another. In effect, the student is forced to search for information and to actively "ask" to be informed with a mouse click.

A variety of buttons appear on a bar on the image frame. These buttons allow navigation options, toggling between different image types of the same field of view (for example it is possible to switch between plane- and cross-polarized views of some images), call up general information about the sample, and activate the search engine or history function which can appear in a separate pop-up window. The search engine allows the user to generate a list of images referring to a given term which are subsequently hyperlinked to the images. In addition, all images contain a unique alphanumeric identifier that can allow instructors wishing to utilize only a small portion of the tutorial images (e.g., in introductory-level courses) to assign a list of specific images to be viewed. The 'history' function allows the user to generate a list of pages visited and to return immediately to any of them with a double-click.

In addition to the tutorial sections for the sandstone clans mentioned above, the top-level page provides entry to the following subtopics: "How to use the tutorial", "What we've tried to build", "Heroes of Petrography", "Sandstone Architecture and Classification", "Compaction", and "Texture". Each of these sections, to varying degrees, utilizes (or, eventually will utilize) the same interactive style and architecture seen in the sandstone clan tutorials. Finally, a 67-term glossary and an annotated reference list are hyper-linked throughout the tutorial.

## EDUCATIONAL ASSESSMENT

Assessment activities* were carried out during the fall 2001 and the spring 2002 offerings of the course, GEO 416M, "Sedimentary Rocks", co-taught by McBride (Table 1). Students enrolled in this course are geology majors and petroleum engineers, most in their second or third year of the program. Assessment was designed to examine the subjective impressions held by students concerning petrographic instruction (interviews), the functionality and utility of the tutorial (student questionnaires), and quantitative data on tutorial efficacy for student learning (grades).

During the fall semester the students were not provided with the demonstration version of the digital sandstone tutorial so as to provide a baseline for the assessment. During the spring semester, CD copies of the digital tutorial were distributed to all the students. Contrasts between the two semesters were held to a minimum: the instructor, course content, the sizes of laboratory sections, and the laboratory exercises were the same. The usual cross-semester changes were made in laboratory exams, but the style and overall content of the exams were the same. The mix of petroleum engineers to geology majors could not be controlled and differed slightly between the two semesters as did the total class enrollment. Different individuals served as laboratory teaching assistants (T.A.s) across the two semesters.

The CD was introduced during a brief presentation to the class at the beginning of the semester. The T.A.s used the CDs to demonstrate petrographic features at the beginning of laboratory exercises. A desktop computer running the demonstration version of the tutorial was

| Class Make-up | Fall 2001 (baseline) | Spring 2002 (tutorial provided) |
|---|---|---|
| Total enrollment | 68 | 83 |
| Geology majors | 33 | 33 |
| Petroleum engineers | 27 | 43 |
| Other majors | 8 | 7 |
| Males | 46 | 54 |
| Females | 22 | 29 |
| **Evaluation Instruments** | | |
| 3 lab quizzes | X | X |
| Lab exam | X | X |
| Student interviews | X | X |
| Student Questionnaires | | X |

**Table 1. Student make-up and assessment activities in two semesters of GEO 416M Sedimentary Rocks.**

available during laboratory activities. Copies of the atlas of sandstone features, AAPG Memoir 28, *A Color Guide to Sandstones* (Scholle, 1979), were also available to students during laboratory exercises. Finally, students were encouraged to utilize the CD as a study aid and to respond to a detailed questionnaire relating to their experiences with the tutorial. Because one goal was to assess the functionality of the tutorial (e.g., whether particular paths through the tutorial led to crashes or whether use of the graphical interface was self-evident), students were intentionally given little guidance into how to utilize and interact with the tutorial.

Interviews in both semesters were solicited on a volunteer basis from the entire class enrollment and conducted in a group setting by outside educational consultant Barufaldi. Interviews conducted in the fall support the notion that undergraduate students struggle somewhat with identification of sandstone components. The students did express satisfaction with the hands-on nature of the laboratory exercises. They were also pleased with the attentiveness and qualifications of the teaching assistants, but expressed a desire for having more of the T.A.'s individual assistance with identifying sandstone components. Most students described having difficulties drawing connections between hand specimens and thin sections and also problems with estimating percentages of components within thin sections. They noted that they desired more examples of structures and thin section features. Students suggested the inclusion of more photographs in the lab manual would allow them to gain a better grasp of features observed in thin sections.

Interviews with students in the spring semester repeat some of the themes that ran through the fall interviews: approval of the hands-on nature of the labs and the opportunity for one-on-one interactions with the T.A.s; discomfort with estimating percentages and learning the large amounts of identification information required. The students expressed strong approval of the digital tutorial.

The tutorial questionnaire (Table 2) was completed by 56 of the students during the spring semester (Table 3). Confirming the results of the interviews, responses on the questionnaires indicate strong student approval of the digital sandstone tutorial. The functional and navigational aspects of the tutorial worked well for this group of undergraduates. Equally important, the students report a high level of tutorial use. Students report using the tutorial in a variety of ways: in lab, at home for practice, and for study before both laboratory and lecture exams.

The level of use is also revealed in the detailed and diverse recommendations offered by students regarding future development of the tutorial. Student input arising from the evaluation of the demonstration version turns out to be a tremendously rich source of insights into both favorable and unfavorable aspects of the digital tutorial.

**Sandstone Petrology: A Tutorial Petrographic Image Atlas**

Version 0.9 Demo Version, Spring 2002: Evaluation Form
In return for this demo CD we ask for input. The questions below point to some issues we're currently thinking about, but we'd appreciate any feedback you'd like to give us. Please share the demo (and copies of this form!) with anyone who is interested. Although we still consider this tutorial a 'demo' it contains substantial content on each of the 3 major sandstone clans. You may respond directly on this form and return it to your T.A.; you may also respond to the numbered questions via email: sand@geo.utexas.edu. Thanks for any guidance you can provide to us!

Kitty, Earle, and Suk-Joo

1.Are the various tutorial functions (e.g., navigation, searches) sufficiently self-evident? Did you have trouble with any particular ones?
2a What about image quality (For example, do you see sufficient detail compared to an actual microscope view?, or, do the images display at the correct brightness on your computer?)
2b What about the artistic 'look'? (For example, to what degree does it seem amateurish vs. "professional"?, or, does the 'atmosphere' seem appropriate with respect to the subject matter?)
2c Is the tutorial entertaining? (For example, Did you ever laugh?, Did you ever say to a friend, "Hey, look at this!")
3 Please describe how you've used the tutorial. (for example: in lab to compare to what you're seeing in an actual sample; systematically, through each subtutorial; in a "random walk" fashion guided by the thumbnail pages; outside of class for review; an hour at a time, carefully reading all the text you can find; 10 minutes at a stretch, just looking at what catches your fancy…..etc., etc.—-just tell us what you did).
4 Please compare your experiences with this tutorial to your experiences with various 'hard copy' atlases, for example AAPG Memoir 28 or the Adams and Mackenzie atlas.

**On a more general note:**
5 Things we should have included, but didn't
6 Things we've included, but shouldn't:
7 Other things you like:
8 Other things you don't like:

**Table 2. Text of the questionnaire distributed to students in GEO 416M, "Sedimentary Rocks" during the spring semester. The version of the questionnaire given to students provided spaces for their responses.**

| Questions | Respondents (n) | Positive (%) | Negative (%) |
|---|---|---|---|
| Functions of the self-study | 53 | 92 | 8 |
| Ease of navigation | 53 | 91 | 9 |
| Image quality | 53 | 64 | 9 |
| Artistic appearance | 53 | 47 | 21 |
| Entertaining | 50 | 42 | 36 |
| Level of use | 52 | 65 | 35 |
| Comparision to hardy copy atlases | 17 | 88 | 6 |

**Table 3. Responses given by GEO 416M students to the main items on the questionnaire shown in Table 2. Responses to some questions do not sum to 100% because some answers were judged to be intermediate or neutral.**

| | Fall 2001 | Spring 2002 | t |
|---|---|---|---|
| n | 65 | 79 | |
| avg. lab exercise | 75.6 | 81.1 | 2.2 |
| std. dev. | 18.9 | 10.6 | |
| avg. lab exam | 59.0 | 67.6 | 3.5 |
| std. dev. | 12.7 | 14.8 | |

**Table 4. Average grades for lab exercises and lab exams in siliciclastic petrology in 2 semesters of GEO 416M. Value is the outcomes of the student's t-test of difference between means, showing that differences in grades for lab exercises and lab exams are significant at the 98th or 99th percentiles, respectively. In other words, there is less than a 2 percent chance that these differences are due to random variation.**

Comparison of average grades across the spring and fall semesters reveals an apparent improvement in student attainment (Figures 3, 4; Table 4). Average grades on the three laboratory exercises and the lab exam in sandstone petrography rose significantly in the spring semester and students on the higher end of the grade distribution gained the most. Gains were posted for every percentile grouping and ranged from approximately 4 points for the lowest 20$^{th}$ percentile, to more than 10 points (near 1 standard deviation and equivalent to a letter grade improvement) for students in the upper 20$^{th}$ percentile.

## DISCUSSION

The current version of the tutorial is a demonstration version, with content assembled with the primary goal of assessing functional aspects of the design and learning environment. In the sense that the students express enthusiasm and utilized the tutorial, the concept of mapped, "live" petrographic images works well for the students tested. The basic design elements and architecture presented no obvious obstacles to use. This is not surprising in the sense that science and math majors, in general, approve of and adapt well to computer-assisted learning (Murray and Yavine, 1998; Renshaw et al., 1998).

As previously mentioned, an unexpected outcome of the evaluation was the energy the students devoted to providing substantive suggestions regarding functional and conceptual improvements to the tutorial. Student input relating to aspects of tutorial content and design will guide major aspects of the future tutorial development (Choh et al, in press). A cyclic process of applying student evaluation results to improve the effectiveness of computer-based modules is fundamental to the successful development of such programs (Renshaw and Taylor, 2000; Choh et al., in press). Combined with a variety of content improvements to satisfy the goal of providing a balanced treatment of major subject areas of sandstone petrology, these student-driven design enhancements should lead to an educational product of considerable utility and popularity with students.

One concern is whether, at some point, the image collection will grow to a size and level of content that undergraduates feel is overwhelming and, hence, inaccessible. Interestingly, such a point does not seem to have been reached by the demonstration version (300 images), as no students raised this particular complaint. Rather, a common complaint is somewhat to the contrary—that the images are mapped inadequately. Of course, as novices, undergraduates do not generally have a reliable sense of which features within an image are important. What is interesting to note is that these students, in essence, are making demands for more information. There is no indication that they want less.

Another concern is whether students who have access to the tutorial may feel free to devote less time and effort to the hands-on laboratory activities. According to T.A. reports and the promising outcome of the grade comparison, this problem does not appear to have arisen.

This study did not assess the effect of tutorial use on individual student attainment. Programming capabilities within Authorware provide highly flexible options for tracking of use in a network-installed tutorial version. Future assessment efforts will likely focus on assessing correlations between extent and completeness of tutorial examination and individual levels of attainment.

It has been suggested that computer-assisted instruction software generally does not impact all students equally (Renshaw and Taylor, 2000) and our results show that, indeed, better students gain the most. In order to learn as much as possible about the functionality and effectiveness of the design and architecture, students in our study were intentionally given little guidance on how to use the tutorial. It is interesting to speculate that attainment gains will increase further, and perhaps less unevenly, if more active efforts are made to foster structured tutorial use.

We have no evidence to suggest that instruction in petrography can proceed without hands-on experience and the involvement of an experienced petrographer. The facility with which students interacted with the tutorial does show that it is possible to expose students to the huge variety and complexity of sandstone components, even if a thin section collection of sufficient breadth is not available and laboratory time is limited.

## CONCLUSIONS

Interactive digital images allow connection of substantial interpretive content to images, allowing both material (microscopes and thin sections) and intellectual (interpretive) resources to be widely and inexpensively shared in the geoscience community. A digital tutorial in sandstone petrology has been developed and tested to determine if this type of learning resource will be well received by students and if learning can be accomplished and even enhanced by the use of such materials. Results of this study indicate:

1. Undergraduate geology majors and petroleum engineers in a required sedimentary rocks course at the University of Texas at Austin adapted readily to using interactive petrographic images. Based on these preliminary results, student attainment of petrography improved with use of the tutorial.

2. The 300-image collection presented to these students does not appear to have been overwhelming. In fact, students seem eager for greater amounts of content.

3. Digital image collections of the type employed in this study provide an opportunity for retaining a high level of petrology training in the modern curriculum.

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