John Schmeelk, Virginia Commonwealth University Qatar Branch

Dr. John Schmeelk is a Professor of Mathematics at Virginia Commonwealth University, Doha Qatar Branch, where he is engaged in applied mathematics, generalized functions, image processing and educational pedagogy. He received his PhD from George Washington University in Washington, D.C. He was awarded many summer faculty grants to go to Fort Rucker, Alabama implementing procedures utilizing generalized functions. He has been an invited speaker to conferences in Australia, Brazil, Bulgaria, Canada, China, Hungary, India, Qatar, Turkey, United Arab Emirates and many other countries.

Jean Hodges, Virginia Commonwealth University Qatar Branch

Since Fall 2004, N. Jean Hodges has been an Assistant Professor of Writing and Writing Center Instructor at Virginia Commonwealth University Qatar (VCUQatar) in Doha, Qatar. Hodges works on writing assignments individually with VCUQatar students in all three of the university’s design majors as well as in the liberal arts courses. She earned her degrees in North Carolina: a Master of Science in Technical Communication from North Carolina State University; a Bachelor of Arts in Business Administration, magna cum laude, from Queens College (now Queens University); and an Associate of Applied Science in Executive Secretarial Science from Catawba Valley Technical Institute (now Catawba Valley Community College). Her work experiences in legal, medical, executive, and academic positions and her business training have informed her understanding of writing in the workplace, and her interdisciplinary Master’s program inspired the focus of her research and academic work: how we learn—the psychology of writing and creating. She has presented on this topic in professional meetings and academic venues and has published several poems and articles. Since 2005 she has been collaborating with Dr. John Schmeelk on a series of studies of MATH 131, Contemporary Mathematics, students at VCUQatar. Results from these studies have been presented in Abu Dhabi and Qatar, as well as at previous annual meetings of ASEE.
The Transformation of a Mathematics Course: 
Discoveries Along a Five-Year Journey

Abstract

This paper concludes a five-year multicultural study that gradually transformed a mathematics course that was “Western” in both content and presentation methods into a “Middle Eastern” course offered in an American university overseas to non-native speakers of English. In addition to tracing the development of user-friendly content presentation, it tracks the development of a technique the authors call “project-directed mathematics” and its incorporation with writing as a learning strategy. Data gathered from mostly female students taking courses in Contemporary Mathematics over the five years support the authors’ claims, which include new observations and recommendations that may be adapted to transform other “Western” courses into culturally-appropriate studies.

Introduction

Virginia Commonwealth University. Virginia Commonwealth University (VCUR) is a state research university located in the heart of metropolitan Richmond, Virginia’s capital since 1779. Over 32,000 students enroll on its two Richmond campuses. VCUR’s mission is to educate “full-time and part-time students of all ages and backgrounds in an atmosphere of free inquiry and scholarship so they may realize their full potential as informed, productive citizens with a lifelong commitment to learning and service.”

Virginia Commonwealth University in Qatar. In addition to the Richmond campuses, VCUR also has campuses in Northern Virginia; in Charles City County, Virginia; and in Doha, Qatar. Virginia Commonwealth University in Qatar (VCUQatar) is the flagship school of Education City, an innovative, expanding community of US universities invited to operate branches in Doha, the capital city of the Middle Eastern State of Qatar. Education City is the brainchild of Qatar’s Emir and his Consort, Sheikha Mozah Bint Nasser Al Missned, who chairs Qatar Foundation, the organization that manages Education City, among other projects. Initially supervised solely by Qatar Foundation, VCUQatar began in 1998 as Shaqab College of Design Art, but in 2002 the school became an official branch campus of VCUR, began to operate more fully under its direction, and was officially renamed Virginia Commonwealth University in Qatar.

VCUQatar’s approximately 200 students come not only from Qatar but from all over the world. Regardless of their nationality, all must study in English because the country’s rulers recognize English as the lingua franca of global business.

VCUQatar undergraduates may major in Fashion Design, Graphic Design, Interior Design, or Painting and Printmaking. The curriculum imposes specified Liberal Arts and Sciences (LAS) requirements, and MATH 131, “Introduction to Contemporary Mathematics,” is the required LAS math course. As the mathematics professor teaching this course since 2001, Dr. John Schmeelk from the start has been concerned with tailoring it to fit the unique needs of
VCUQatar’s diverse students, which has led to the series of studies preceding and including this one.

**The Original MATH 131.** For many years MATH 131, “Introduction to Contemporary Mathematics,” has been a three-credit math *option* taught at VCUR. To qualify for the course, students must pass either a mathematics placement test or an alternative, no-credit prerequisite course in algebra. MATH 131 introduces “optimization problems, data handling, growth and symmetry, and mathematics with applications in areas of social choice. Major emphasis is on the process of taking a real-world situation, converting the situation to an abstract modeling problem, solving the problem and applying what is learned to the original situation.”

In Richmond, any of the approximately 3,000 VCUR students needing a three-credit math course during any given semester take MATH 131. In typical “Western” style, university professors deliver lectures to necessarily large classes, and graduate students conduct small group work.

In contrast, VCUQatar *requires* all students to take MATH 131. Approximately 50 students take it per academic year. Arab child rearing and pre-college education, especially in Qatar, differ significantly from typical American practices: children are seldom disciplined for any reason; attention spans and patience seem unusually short (we suspect many cases of undiagnosed Attention Deficit Disorder); critical thinking skills of young Qatars entering college are generally poor; and, until recently, lower level math has been taught via rote memorization of definitions and formulas. In addition, until Education City emerged, females had significantly fewer college opportunities because they were not allowed to leave Qatar alone, and the strong cultural influence emphasizing traditional female roles continues to label mathematics as a “male” discipline. All of these factors complicate the teaching of MATH 131 at VCUQatar.

This study, the fifth in a series examining ways to motivate learning of contemporary math among VCUQatar’s design students, summarizes the preceding studies and extracts from them observations and recommendations that may be adapted to transform other analytical courses into culturally-appropriate studies.

**The Evolution of MATH 131**

**The Journey.**

*Year 1 (2005-2006, “Making Connections Among Culture, Personality, and Content In Analytical Courses”).* MATH 131 at VCUQatar began with a textbook, graphic calculator, white board, and markers. Several lectures delivered each textbook topic. VCUQatar was a female-only institution of mostly Qatars, who were difficult to motivate into studying and understanding the math principles. During this year, the authors investigated

- the effects of tying mathematics to the local cultural aspects of Qatar’s history, religion, and views about education;
- ways of appealing to students’ learning styles and brain hemispheric preferences; and
- linking new course information with students’ prior knowledge.

In addition to incorporating (1) a tour of the local Ritz-Carlton Hotel to examine its Arabesque illustrations of such math concepts as symmetry and (2) in-class design samples, the authors (3)
began studying Ricki Linksman’s “super links.” Linksman, an accelerated learning expert who founded the National Reading Diagnostic Institute in the US, popularized her research on accelerated learning in How to Learn Anything Quickly. Basically, Linksman claims that students learn best when new material is presented in ways that appeal to their favorite learning style (visual, auditory, tactile, or kinesthetic) and brain hemispheric preference (i.e., right-brain, left-brain, mixed, or integrated preference). She identifies the combination of learning style and hemispheric preference favored by an individual as that person’s “super link,” and appealing to someone’s super link is the fastest way for that person to learn.4

In this first study, the authors observed female MATH 131 students, predicted that the majority would be right-brained visual or tactile learners because of their interest in design, and suggested effective teaching strategies for these types of learners that related the course’s mathematical concepts to the students’ culture (prior knowledge) and to their design majors.

**Year 2 (2006-2007, “Project-Directed Mathematics”).**5 Again using Linksman’s research, the second study
- tested the researchers’ prediction of learner types and
- examined the effectiveness of incorporating projects into the course.

Shortly after introducing the course and its project-directed concept, the authors (1) gave students Linksman’s tests for determining learning style and brain hemispheric preferences. They (2) recorded students’ super links, (3) discussed the results with students, and (4) distributed handouts of Linksman’s characterizations and recommendations for each super link.

Also in this study, (5) students were shown previous student projects submitted in the earlier MATH 131 courses to introduce each new topic visually and (6) were required to complete a much more comprehensive project component (hence the term Project-Directed Mathematics).

The authors discovered that students’ documented super links did not confirm the previous assumption, that most design students by nature would be visual or tactile right-brained learners, thus identifying the necessity for testing students’ preferences (see Figures 1 and 2). Tests of 37 students in 2006-2007 revealed that 33.33 percent of the students exhibited kinesthetic and auditory preferences, an unexpectedly high deviation from the prediction (Figure 1). Neither did observations alone suggest that 50 percent of these design students would prefer left-brain, linear strategies, leading the authors to underestimate the

![Figure 1: 2006-2007 Learning Style Preferences](image)
movement (kinesthetic) preference overshadowing students’ tactile tendencies (Figure 1). Thus, allowing students to handle and examine sample projects and to create their own projects proved to be an effective learning tool that spoke to this movement preference.

Finally, while students’ responses strongly favored the sample projects, their reported preference for taking a test rather than creating their own projects was surprising given their visual, tactile, and kinesthetic learning style preferences. One explanation may lie in the high number of left brain hemispheric preferences, which would find the linear style of a test more appealing. Another explanation may be that design students find themselves creating numerous projects in their design courses, so the novelty of creating projects is diminished, and producing numerous projects may make completion time a serious consideration when students are faced with creating yet another required project. In addition, although the tradition is changing, precollege Qatari students traditionally have learned by rote memorization and recitation, so test-taking may represent a familiar habit that is preferable to unfamiliar creative requirements. Finally, because classes are small (usually 8 to 12 students) and naturally collaborative (a cultural norm), one ringleader student may influence other students’ choices by expressing her preference. The authors concluded that more research was needed to determine the actual factors resulting in this choice.

**Year 3 (2007-2008, “Techniques Motivating Project-Directed Mathematics”).** The third study extended the second study in three primary ways:

- it continued tracking the students’ super links by adding new data,
- it observed the effectiveness of using projects more extensively as both samples and assignments, and

![](image1.png)

**Figure 2: 2006-2007 Brain Hemispheric Preferences**

![](image2.png)

**Figure 3: 2007-2008 Learning Style Preferences**
• it examined individual and group techniques for effectively motivating project-directed mathematics by engaging students in high-level thinking and mathematical problem-solving.

As in Year 2, this study revealed that most of the 30 participating design students were visual and tactile learners (67 percent), with kinesthetic learners ranking 17 percent (see Figure 3). Again, the auditory preference was low; however, a surprising number of students (17 percent) displayed closely combined learning preferences, which had not appeared before (“Other” in Figure 3).

Although left-brain hemispheric preferences diminished in this study (from 50 to 33 percent), at 40 percent the expected right-brain preferences were remarkably close to those in the previous study (42 percent) and were lower than originally anticipated. The remaining hemispheric preferences (24 percent, as shown in Figure 4) were mixed and integrated, with 3 percent of the students reporting no score for this part of the super link tests.

In both the 2006-2007 and 2007-2008 studies, the significant numbers of left-brain learners were surprising. These students process information linearly and prefer working with symbolic language, such as numbers, which is advantageous for studying math but not typical of artists.

Again, allowing students to handle and examine sample projects and to create their own projects proved to be an especially effective learning tool offering versatility that appealed to most of these super link types.

In response to the need for additional research regarding the test-taking preference revealed in 2006-2007, this year students were queried about their test-taking preferences and the reasons behind them. Initially 47 percent preferred taking a final exam over completing a final project because, among other factors, they anticipated the project would take excessive time, and certainly more time than studying for a test. Of 12 responses to these queries, the results showed
that students were equally divided in the time taken to study for a test or to complete their final project (refer to Table 1 below): five reported that they spent three hours or less studying for the final test, and five reported that they spent less than three hours completing their final projects. Although most students expected completing a project to take longer than studying for a test, only one student reported actually spending over three hours on the project, revealing the students’ lack of accurate perceptions concerning the time they spend at various tasks because they are not self-monitoring. (In contrast, Spring 2010 students unanimously voted to complete a final project instead of taking a final exam because they feel more comfortable about imbedding projects into mathematics.)

<table>
<thead>
<tr>
<th>n = 12</th>
<th>Studying for the Test</th>
<th>Creating/Finishing the Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 hours or less</td>
<td>4 + 1(^1)</td>
<td>5</td>
</tr>
<tr>
<td>Over 3 hours</td>
<td>4 + 1(^2)</td>
<td>1 + 2(^3)</td>
</tr>
<tr>
<td>No Response</td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>
| Other | ● “Half an hour, for one week” \(^1\)  
● “Before 4 hours” \(^2\)  
● “During the weekend”  
● “I usually study for 2 hours and then have a brake [sic] and then start again” | ● “I didn’t really start in any one yet be [sic] I think it would take nearly 5 hours or even day It depends on the project” \(^3\)  
● . . . about 2 days”  
● “No project yet” |

\(^1\)Includes the ambiguous response in “Other”: “Half an hour, for one week”  
\(^2\)Includes the non-native English speaker response; “Before 4 hours” (meaning “Less than 4 hours”)  
\(^3\)Includes the two comments superscripted \(^3\) in “Other”

Table 1: Students’ Self-Reports of Time Spent

Year 4 (2008-2009, “Writing Techniques for Implementing Project-Directed Mathematics”).\(^7\) By the fourth year, the College of Humanities and Sciences at VCUR had marked MATH 131 to participate in its evolving Writing Across the Curriculum (WAC) initiative. (VCUR’s WAC program emerged through the establishment of its Center for Teaching Excellence in 2001.) This meant that VCUQatar’s MATH 131 also needed to incorporate WAC, as VCUQatar must duplicate VCUR’s curriculum and requirements insofar as is possible.

WAC emerged with studies of writing as a learning method during the 1960s. Writing researchers James Britton\(^8\) and Janet Emig were instrumental in converting the observation that writing enables the writer to capture and clarify thoughts into pedagogy during the 1970s, and this movement gained substantial momentum with Emig’s 1977 seminal article, “Writing as a Mode of Learning,” in which she proposed that “writing is neurophysiologically integrative, connective, active, and available for immediate visual review,” making it a uniquely effective learning tool (p. 58).\(^9\) Britton and his colleagues argued that language is a powerful tool for
organizing experience and substantially strengthened the idea of using cross-curricular expressive writing (in which the writer captures, investigates, and reflects upon his/her ideas) to enhance students’ learning (pp. 57-58). Throughout the 1980s and 1990s, Emig’s and Britton’s work became the basis for recognizing writing as a primary learning method. (For a more complete discussion of WAC history, refer to Chapter 5, “Writing to Learn,” of Reference Guide to Writing Across the Curriculum, by Charles Bazerman, et al.]

Three major goals for incorporating VCUR’s WAC program into VCUQatar’s project-directed approach became

- to develop students’ metacognition about their learning and thinking processes,
- to convince students that using knowledge of the personal super links in all of their courses (not just in MATH 131) is beneficial, and
- to deepen their understanding of how the MATH 131 concepts apply to them personally and professionally.

The Classes. The 2008-2009 MATH 131 classes involved 15 female students, only two of whom were freshmen: five were seniors, three were juniors, and five were sophomores. Two of the seniors were older than typical, one by a year or two and the other by one or possibly two decades.

Method for Incorporating Writing. During the second class meeting students received a handout explaining why journal entries were being required and how those entries would be assessed. The authors discussed this handout and the writing component of the course at length, answering students’ questions in class, including an explanation of the research being conducted and the project-directed approach evolving from it. As previously, Linksman’s learning style and brain hemispheric preferences tests were given early in the term, and the results were discussed with students, who received handouts of Linksman’s characterizations for each of the learning styles and brain hemispheric preferences. Also, students received composition notebooks, individualized by name and super link on the front cover, to use as their personal journals. In addition to three sets of three specific journal assignments each, students were encouraged to record any of their thoughts about the course in their journals and were reassured that such additional comments would be regarded as private and would not affect their grades.

In addition to the journals, “one-minute papers” were used to identify students’ understandings, misunderstandings, and questions (providing timely feedback to the professor) as well as to promote their metacognition. These papers consisted of a half-sheet of paper listing a writing prompt, such as “what I didn’t understand in today’s lesson was _____,” that students wrote about for literally one minute. Depending upon the specific prompt, one-minute papers were completed at either the beginning or the end of a class session.

As in previous studies, during class each new topic was introduced visually by showing students sample projects. Students were allowed to handle the projects and were encouraged to think about and ask questions about the comprehensive final project that they would be required to complete.
Finally, students were asked to complete a survey at the end of the course to help assess whether they remembered and used their “super link” information as well as their reactions to the journal assignments.

Results. As in previous studies, Figure 5 shows that the students were predominantly visual, tactile, kinesthetic learners, yet again confirming the suitability of using sample projects to appeal to their learning styles. Writing in journals also appealed appropriately to these styles.Talking about these sample projects and discussing journal entries and one-minute paper responses in class addressed the few auditory preferences. In addition, both students and professor were involved in writing and illustrating concepts during class on the white board, and students were encouraged to illustrate their journal entries.

Figure 6 below reveals that the hemispheric preferences of these classes were particularly interesting because Linksmans’s work, which focuses on US students, suggests the mixed and integrated preferences are rather rare. The mixed preference results when the hemispheric scores are within one or two points of each other. This means that the individual uses each hemisphere for appropriate tasks regularly but slightly prefers the approach of one over the other and occasionally uses the techniques of that hemisphere to perform tasks better suited to the opposite hemisphere. When this happens, learning is more difficult. The integrated
preference means that these scores are tied and suggests that the individual is using the two hemispheres most appropriately for all tasks. In other words, functions that are easily handled by the left side of the brain (such as linear, step-by-step processing of information) actually are handled by that hemisphere, and vice versa. Such development enables the individual to take better advantage of innate potential and to learn easily in either a right- or a left-hemispheric environment. The unexpected frequency of mixed and integrated preferences throughout this research series suggests a future line of research to investigate how and why American and Gulf students are developing so differently along these lines.

Three notable differences occurred between the fall and spring classes:

1. Length of class. The fall class consisted of two 75-minute sessions per week, but the spring class had three 50-minute sessions per week. The shorter classes made incorporating students’ whiteboard activity more difficult.

2. Students’ hemispheric preferences. During the spring, the hemispheric preferences were more equally split between right and left than during the Fall Semester, and a noticeable distinction between the two preferences occurred in students’ class attendance: the two Spring Semester students with a right hemispheric preference, normally expected to have greater difficulty with mathematical tasks, exhibited markedly poor attendance, although they did complete the course and create good final projects.

3. Journal use. The Fall Semester students seemed to really like having their own journals and immediately asked to include their homework and one-minute paper responses in them as well as their journal assignments and private musings. Throughout the semester, several students used their journals for all of their math-related work, while others reserved them solely for their journal assignments. All of the students handwrote or printed their journal work, deriving tactile benefits from putting pencil to paper and suggesting more personal involvement with the journal. One senior frequently recorded her self-reflection on the homework assignment she had just finished. However, during the Spring Semester, no students included homework or notes in their journals, and two students typed, rather than handwrote, their responses to the journal assignments. One freshman pasted her typed responses into the journal, and a senior submitted typewritten sheets rather than the journal itself. This class seemed to make less use of the journal overall, usually gave shorter answers to journal assignments, and lacked the overall enthusiasm of the fall students. We believe these differences are attributable to students’ different personalities and the generally older students in the fall class rather than to super link differences. (In the fall class, seven of the nine students—nearly 78 percent—were juniors and seniors; in the spring class, five out of six students—about 83 percent—were freshmen and sophomores.) Often the fall students seemed to be following the lead of one much older senior who had returned to school when her children were in high school and who exhibited strong leadership skills.

Students’ written responses to the journal assignments were especially revealing for three fundamental reasons:
In responding to them, all of the students at some time moved beyond the basic levels of knowing and understanding to the higher cognitive domains of applying, analyzing, synthesizing, and evaluating. For example, in response to the assignment to “observe the teaching of any one of your professors during two class periods and note what he/she does that fits in with your preferred learning style and hemispheric preference,” one student with mixed-right and tactile preferences wrote:

Over two class periods I have observed my Experiential Design class professor explain and teach the class about sustainable packaging. . . . I got the feeling that it was easy to soak up and understand information from this teacher. I began to ask myself why? . . . I realized that part of the reason . . . is because I am a tactile person, which means I use my sense of touch a lot, and this really relates to the 3D and 4D packaging class. I noticed I was very imaginative and thinking of what does not yet exist.

My professor was really good at using descriptive words, ones that simply made me imagine or understand what she meant. The tone of her voice and the pace she spoke in really made a positive impact on my learning. . . . I noticed the professor uses hand gestures a lot when trying to explain a matter. She was also enunciating each word clearly, which made it easier for me to grasp that knowledge. It made me have a visual memory of how the information was said and how it related to the project, how it could even relate to several other projects.

These were some of the aspects in my professor that really caught my attention . . . Although I do think that there are some things that could be added to the way of teaching in order for me and people with my same or similar hemispheric preference is to not stand too close to me with eye contact as she is explaining something because it can be uncomfortable at times. . . . maybe introducing some more materials and bring in examples and samples to class when explaining instead of just saying it orally would make a big difference to my learning. (B. Al-M.)

Another student, who was visual and kinesthetic with a mixed-left preference, applied what she was learning about symmetry to the shape of a door, synthesized her new mathematical information with her existing knowledge of doors, and evaluated the outcome:

I choose a shape of a door. Symmetrical, right side is a reflection of lift [sic] side. Axis of reflection, if I apply reflection, the b’ reflection of b shape will not change. Any point on the axis of reflection is reflection to itself. . . . If we apply rotation, then we can’t have a practical door any more. If we apply translation on the door we may have a problem in a given house. . . . (N. Al-K.)

For at least one student the journal assignments helped her discover new information while wrestling with the mathematical concepts. In response to the assignment question, how could geometric and arithmetic sequences be applied in Fashion
Design, Graphic Design, or Interior Design, she began her entry with doubts about their applicability to Fashion Design, then considered the meaning of the terms, and finally arrived at a relationship to her major:

Using these kind of sequences in fashion design might be a little unusual. I’m trying to figure out how these sequences can be used in fashion but I can’t figure it out.

Arithmetic is a sequence which goes from one term to the next by always adding (or subtracting) the same value (common difference, d). Geometric is a sequence which goes from one term to the next by always multiplying (or dividing) the same value (common ratio, r).

A way to use this in fashion would be when sizing patterns, going up one size, each time adding a certain amount to a certain part of the pattern. (S. C.)

This student had a left, visual and tactile super link, and it is easy to see her using the left hemispheric strategy of linear, step-by-step thinking to determine her answer to the question.

(3) Finally, the responses to the journal assignments revealed information about the students’ efforts and growth in the course that the professor otherwise would have never known. Some students reported really struggling with some of the concepts and repeatedly seeking additional outside help or conducting online research. Many of the students’ responses revealed sudden engagement with the mathematical concepts as students discovered a relationship to their interests and passions. For example, in her discussion of symmetry, one student chose the capital letter \textit{H} to illustrate symmetry, rotation, and glide reflections. As she concluded her answer, her enthusiasm became evident:

Overall, the letter H in Helvetica has tons of different kinds of symmetry.

A nice re-design I see for this where it would still be very symmetrical is adding equilateral triangles to the H, like this:

I think it’s pretty cool. (S. C.)

Similarly, a sophomore with a visual/left super link began to merge her instinctual analysis of fractals (left hemispheric preference) with the creativity of a designer (right hemispheric preference) when she wrote in her journal:

I was very attracted to it [her illustrated fractal from Chaoscope Website]. I find it inspiring because of the mergeded [sic] colors of green and purple. It looks subtle,
but with a twist of un-easiness. Something I like to call a beautiful madness. 😊
(E. S.)

We also learned of one student’s personal struggle with being in Doha from her selection of an illustration for her symmetry journal entry:

I chose *Symmetry in Nature* [a photograph showing trees, hills, and clouds reflected in a lake]. There is nothing more beautiful than nature. I am from a beautiful country that has a beautiful nature; throughout the 4 seasons, it blossoms and changes differently, but all amazing. Here in Doha, there is nothing. The green is handmade and to me really not impressive. This is why I chose this picture with symmetry in nature. I am naturesick. . . . (M. H.)

Using journal writings also uncovered the uneasiness with, or limited ability of, a couple of students to think analytically, deeply, or self-reflectively. For example, one studious, bright freshman, whose family was instrumental in establishing the lower level educational system in Doha in the early 20th Century, responded meagerly to the prompt about observing her personal super link at work (or not) in other classes:

In the math classes, the instructor shows us how to solve a problem in steps. I understand the problem easily. After that, when I go home and revise I found that the notes that I was take it in class covers everything, and I don’t have a question. My notes are pretty good because the professor is so clear in what he is explaining. In addition, sometimes he shows us some models and the students’ projects in order we can see pictures of what he is explaining. I think the pictures help me to understand the lesson more. When we have any graph to draw, drawing with the professor step-by-step teaches me easily. (A. D.)

Not only was this one of the shortest responses to this journal prompt, but also this student unexpectedly chose her math professor to observe (probably for convenience). We had orally recommended that students observe a professor in one of their other classes without announcing their assignment to that professor. Neither did this student follow the instructions to state her super link, to identify the professor’s activities that appealed to her super link or that failed to do so, and to discuss alternative things the professor might do that would be more helpful to her. Although she was one of the few diligent note takers in the class, her thinking failed to extend beyond observing and reporting surface events and praising the professor.

This problem is relatively common among Qatari students in particular because of the curricula and delivery of their pre-college programs that have historically encouraged rote memorization rather than critical thinking. (These methods are being changed to better prepare students for college, but the process will take time to become fully operational.) By the time these students are upperclassmen, many of these problems have been overcome through their college training. Using journals in MATH 131 contributes positively toward this process by providing opportunities to begin thinking critically for underclassmen and by reinforcing them for upperclassmen.
Using one-minute papers was less successful than expected. During the fall, students convinced the professor to alter the plan for their use by including the responses in the students’ journals. This resulted in a few responses being recorded in the journals but not reviewed by the professor until well after the class discussion, as well as in some students’ failure to complete the responses at all. This experience emphasized the necessity of immediately collecting these responses after one minute of writing.

During Spring Semester, one-minute papers were assigned in class about three times. As noted, these were the less mature students, and their responses were less helpful than anticipated because they tended to give polite, vague responses. Also, the professor was unable to use this strategy as often as desired because he asked students to complete a one-minute response at the end of the class. With the shorter class periods during Spring Semester and the students’ eagerness to leave on time, this final activity often was sacrificed. More work on timing of the delivery and content of the writing prompts is needed before this strategy will prove helpful in MATH 131.

By mistake, no course surveys were conducted at the end of the Spring Semester, but four of the nine students completed the survey at the end of the Fall Semester. All four students recalled their brain hemispheric preference and learning style correctly with the exception of one student who forgot that her hemispheric preference was actually mixed-right and reported only the right portion of that preference. All four students agreed that (1) they did pay attention to their learning and hemispheric preferences in both math and other courses this semester, and (2) super link information should continue to be included in MATH 131. Their comments on the latter response were positive, ranging from “helps a bit” to “and I believe it should be given in freshman year so we can implement it in all other courses. Maybe it should be a separate course. This way we learn more about it.”

Three of the four students reported that the journal assignments were helpful to their understanding of topics in MATH 131. Two students reported that the first assignment regarding their super links was the most helpful. The fourth student, who did not find the journal assignments helpful, commented that students “need to work on it in class, too.” She also identified four journal assignments (although only one was requested) as being least helpful to her because “I didn’t understand it much.” (It should be noted that this student failed to submit much of her work and had poor attendance.) The remaining respondents found different journal assignments least significant, because the related math concepts were complicated or the assignment seemed irrelevant or unnecessary.

Surprisingly, all four respondents said that journal assignments should continue to be included in MATH 131 because “it gives the student a chance to analyze his/her understanding in math,” “it does help in relating math to real life and to my major,” the journal assignments “helps understand the topics a bit,” and it is “helpful and good for students to write.” These comments seemed surprising because only two of the four reported that they thought differently after taking MATH 131. One of the affirmative respondents said the course had made her think of real life applications, and the other reported thinking differently about her major after taking MATH 131. The two negative respondents gave similar personal reasons for their responses:

(a) “I’m sorry to say this, but I never enjoyed math, and I never will.”
Three of the four respondents found the sample projects “somewhat helpful” for giving them ideas about what the professor expected in the final project. The fourth student responded “very helpful” because “It is like history. If you read history, you avoid a lot of mistakes and you learn from other people’s experience. And it helps you also by not starting from zero point and opening a lot of possibilities for you.”

Two students found creating their own projects “somewhat helpful,” but neither commented on her answer. One student found this “not very helpful” because “we’ve got far too many deadlines already but it was fun making them [the projects].” The fourth student did not answer this question because “I cannot say because I did not finish yet.”

All four students reported elements from the course that they would be able to use in their careers and/or daily lives.

The authors concluded that incorporating writing into MATH 131 helped most of the students become aware of their learning and thinking processes and apply the MATH 131 concepts to their personal and professional lives, satisfying two of the three goals for this course. Evidence of convincing students to apply their super link knowledge in all of their courses was less apparent, but the unanimous response of the fall students to continue including journal assignments in the course suggests that the students did find the information helpful personally.

The authors’ hypothesis that requiring students to write more in MATH 131 would improve both the professor’s delivery of instruction and the students’ mastery of the MATH 131 concepts by requiring deeper and more diverse mental engagement with them was primarily supported; however, problems with younger students’ limited critical thinking abilities and with strategizing the one-minute paper process also were revealed. The different class scheduling for the two semesters proved that three 50-minute classes were more beneficial for most students than two 75-minute classes because the material could be presented in smaller chunks and, theoretically, one-minute papers could be used more frequently, although this did not happen because the papers were given at the end of class when students were too eager to leave. Consequently, the professor is considering a recommendation that

- future MATH 131 classes be scheduled three days a week for 50 minutes each and be restricted to junior and senior students,
- students be required to pass a specialized test of critical thinking ability before being allowed to register for the course, or
- that a basic course in critical thinking skills become a prerequisite for MATH 131.

In addition, the delivery timing, the collection, and the content of writing prompts in the one-minute papers need to be reviewed and revised.

The unexpected frequency of mixed and integrated preferences throughout the authors’ research series concerning MATH 131 students suggests a future program of research is needed to investigate how and why American and Gulf students are developing so differently along these lines.
Finally, journal writing gave the professor another method for “talking” individually with each student and providing positive, reinforcing, and encouraging comments. It showed concrete evidence of most students’ movements into the higher cognitive domains of Bloom’s Taxonomy of learning cognition, confirmed the use of writing as a means of discovery, and revealed information about the students’ struggles and enthusiasms that the professor otherwise would not have discovered and been able to address. Incorporating writing within a project-directed approach shows great promise as an effective strategy for teaching contemporary mathematics to design students.

**Year 5 (2009-2010, “Discoveries”).** Because both Education City and VCUQatar continue to grow, record numbers of co-ed students participated in this year’s studies. During Fall Semester, 37 students enrolled for three classes of MATH 131, swelling class sizes to the maximum limits we feel are advisable in this culture, which is very close-knit, socially adept, and collaborative. An additional 20 students enrolled in the spring. As these numbers continue to increase, we predict that the impersonality of large lecture-room classes will prove both non-motivating and detrimental to most Qatari students, who constitute 53 percent of VCUQatar’s 217 students this year.

**The Method.** This year MATH 131 incorporated everything learned from our previous research:
- linking new information (math topics) with prior knowledge by establishing connections among the Arab culture, students’ preferred super links, and the course content;
- testing, teaching, and emphasizing the importance of knowing and using one’s individual super link;
- using a variety of teaching methods to appeal to diverse super links;
- incorporating sample projects extensively;
- involving students in more active classroom work (to better appeal to tactile and kinesthetic students);
- examining individual and group techniques to engage students in high-level thinking and mathematical problem-solving;
- incorporating writing to develop students’ metacognition and critical thinking as well as to deepen their understanding of how the MATH 131 concepts apply to them personally and professionally; and
- proactively seeking information and feedback from students through one-minute papers, journal entries, and course surveys that can make the classroom experience more productive for both professor and student.

In addition, numerous quizzes, both announced and unannounced, were introduced, and one-minute papers were used more extensively and more effectively than previously.

As in Year 4 previously described, students first received
- a course syllabus and schedule,
- both written and oral explanations of the course writing component, and
- an oral explanation of the authors’ research program and handouts on the roles that different super links play after students had taken the Linksman preference tests.

Although the professor explained the syllabus and schedule, the Writing Center Instructor visited the class to discuss the research program and journal assignments, to administer and discuss the
preference test results, and to return and comment on journal assignments once they had been reviewed and commented on by both professors within the journals.

The cartoon illustration in Figure 7 helped visual learners understand differences between the left- and right-brain super links, and the professor further illustrated the concept using two differently-preferenced former student’s posters, shown in Figure 8, to portray vividly their contrasting approaches to the same assignment. A left-brained student illustrated the Fibonacci spiral in the left poster as a composite of smaller geometric pieces having a linear feel, while the more organic, intrinsically united version on the right was completed by a student having a strong right-brain preference.

In addition, the math professor introduced course topics by relating them in various ways to the students’ cultures and prior knowledge as well as by using sample projects created by previous students to illustrate the concepts. Together with a rubric, these sample projects also helped clarify expectations for the students’ final math project, which carries the weight of a final exam. As the preceding four years’ studies have shown, sample projects and required project assignments both motivate students and facilitate their mastery of the MATH 131 concepts. Following are topical illustrations of this method.

**Sequences, Series, and Fibonacci Numbers.** Geometric designs strongly influence Arab art and architecture, so MATH 131 includes several chapters that expand upon rotations, reflections, and translations. Students first study mathematical formulas that describe geometric shapes, followed by an intense development of the Fibonacci sequence and several of its properties illustrating its “real-life” utility. To help motivate students’ interest, the professor connects these topics with elements of Muslim culture, since most of the students are Muslims studying in a Muslim country.
The Fibonacci sequence is presented first because it enjoys a rich history. The professor and students consider Fibonacci as an Italian mathematician, and the students research him on the web. The corresponding journal assignment requires students to think about Fibonacci’s discovery in greater depth by discussing how his being European yet learning the Hindu-Arabic system of numbers and arithmetic contributed to his discovery of the Fibonacci sequence.

Past students’ Fibonacci projects, such as the poster shown in Figure 9, illustrate the classroom discussion of the Fibonacci sequence (1, 1, 2, 3, 5, 8, 13, 21, …). Similarly, the love seat in Figure 10, designed by an interior design student using a double Fibonacci spiral, was used to motivate computing and working problems on the white board.
Applying their artistic talent to assigned math projects, the students created several Fibonacci Spirals, such as the unique one displayed in Figure 11 completed in Fall Semester 2009. Taking the concept even farther that semester, an interior design student created a Fibonacci coffee table (Figure 12). When students saw this project, several of them commented that “I didn’t know what these numbers mean, and now I know I understand them.”

The Fibonacci numbers also occur in nature. Schilling and Harris’s chart shown in Table 2 below illustrates the presence of the Fibonacci sequence in flowers in an organized way that appeals to left hemispheric preferences, and several flower illustrations taken from a web site are projected on a screen to appeal to right hemispheric preferences and visual learning styles. Similarly, the Nautilus seashell in Figure 13 also has the shape of a Fibonacci Spiral and aids students with visual learning styles.

<table>
<thead>
<tr>
<th>Flower</th>
<th>Petals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iris</td>
<td>3</td>
</tr>
<tr>
<td>Wild Rose</td>
<td>5</td>
</tr>
<tr>
<td>Delphinium</td>
<td>8</td>
</tr>
<tr>
<td>Corn Marigold</td>
<td>13</td>
</tr>
<tr>
<td>Aster</td>
<td>21</td>
</tr>
<tr>
<td>Pyrethrum</td>
<td>34</td>
</tr>
<tr>
<td>Michaelmas Daisy</td>
<td>55</td>
</tr>
</tbody>
</table>

Table 2: Flower Petals Show the Fibonacci Sequence

The next topic is the “Golden Number,” often termed “The Divine Proportion,” leading to the golden rectangle. (For excellent additional references on this subject refer to the books, Divine Proportion and The Golden Ratio.) The Golden Number, $\frac{1+\sqrt{5}}{2}$, approximated as 1.61803…, occurs in lectures on art history, architecture, and in numerous other places, and it generates much student discussion. Two previous students’ projects, one a poster (Figure 14) and one a painting (Figure 15), illustrate these concepts using the Fibonacci sequence.

This section concludes with the standard arithmetic (linear) and geometric (exponential) sequences and series. The professor distributes formula sheets to the class and displays the linear and geometric sequences and series in pie and bar graphs using Matlab-6.7, which also introduces the students to this software package. The professor also exhibits and discusses the two graphs shown in Figures 16 and 17 to illustrate the standard geometric sequence and series, $\frac{1}{2}, \frac{1}{4}, \frac{1}{8}, \frac{1}{16}, \frac{1}{32}, \ldots$. 
The journal assignment for geometric and arithmetic sequences asks students to discover ways these concepts could be applied in their majors (or intended majors for undeclared students). Students are encouraged to think creatively, using their design skills to invent a future application if they are unable to uncover an existing one.

**Symmetry.** Symmetry is explained using photos of Doha’s mosques, relating the new concept to familiar structures in the society. Figures 18, 19, and 20 illustrate mosques that are about 75 years, 45 years, and 10 years old, respectively. Being mostly Arab Muslims, the students are very familiar with Arab designs in mosques and can immediately identify their symmetry. Since all the men in their families are obliged to go to the mosque five times daily, the young women are constantly exposed to mosque life and also are encouraged to attend mosque with their families and friends whenever possible. (Attendance obligations differ for men and women.)
In addition, the professor circulates a copy of *Architecture of the Islamic World*\textsuperscript{12} among the students so they can observe architectural structures designed by Islamic architects. Its illustrations precipitate the students’ understanding of Islamic architects’ extensive use of structural symmetry and help motivate their understanding of the underlying symmetrical principles displayed in the mosques and other buildings in Qatar.

The relevant journal assignment gives students numerous suggestions for choosing an object to examine and discuss its symmetry (or lack thereof). They are required to write about changes in their object as the terms *rotations, reflections, translations, and glide reflections* are applied to it. Finally, they are asked if any of these terms spark an interesting idea for redesigning the chosen object.
A lighting course is required for interior design students, so a lighting fixture in the Intercontinental Hotel (see Figure 21) is shown to the students to help them understand the symmetric notions of rotations, reflections, and glide reflections. The concepts of rotations and reflections are presented in the text, implementing the notation $D_n$ to indicate symmetry having exactly $n$ rotations combined with exactly $n$ reflections. The notation $Z_n$ indicates exactly $n$ rotations and no reflections. Notational requirements present problems to most novice math students, but MATH 131 students relate these ideas clearly and concisely when working with projects.

Another image used in this section is the carpet in Figure 22, which is in the Ritz Carlton. Its medallions richly illustrate symmetrical properties. Once the students are grasping the new concepts, they are asked to determine the symmetrical properties of the greeting card from Istanbul shown in Figure 23 using the notations, $Z_n$ and $D_n$. (Tactile students in particular are encouraged to handle the card if they wish to help them complete the assignment.) Student projects on symmetry using these notational conventions are shown in Figures 24-27.
One of the more creative, yet simple, student projects appears in Figures 26 and 27. Here students used two sets of perpendicular mirrors to reflect the design. Figure 26 shows the design reflection using two mirrors, while Figure 27 shows the complete, symmetrical pattern produced by four mirrors uniting two reflections.

*Fractals.* Fractal designs are introduced by showing students the famous “Stairway to Heaven” fractal selected from the web (Figure 28). Students recreate the basic Koch Snowflake and the Sirpinski Gasket fractals by plotting them on graph paper and developing the sequences contained within each illustration. They measure number of edges, lengths of individual edges, length of total perimeters, and areas on worksheets, thus developing the various aspects of fractals in an elementary manner, which leads to completing student projects such as those shown in Figures 29-33. Particularly interesting are the diverse media the students choose, including pottery, graphics, and a flashlight, among others.
Two journal assignments address fractals. The first asks students to relate fractals to their major (or intended major) by trying to mentally re-design something in their field that is typically geometric using fractals. This assignment integrates students’ creativity and design skills with math by involving students more personally with the concepts. The second assignment asks students either to research Benoit Mandelbrot’s life and answer related questions or to compare at least three fractals for similarities, differences, and inspirational design value. Either choice leads students to delve more deeply into fractals.

Next, the professor shows students the Mandelbrot set in Figure 35, guides their examination of it, and discusses the mathematical technique, implementing both real and complex numbers.
allows students to introduce artistic development by employing colors for the escaping, periodic, and attracting sequences within fractals. A short MatLab program (see Algorithm 1) generates 301 by 301 seeds and iterates each seed 50 times before it is returned to the picture displaying the color. This helps the students understand the iteration of the point and the need for computer power to obtain good fractal results. Work in progress involves using software to create some interesting fractals. Again, the students can introduce artistic creativity by employing hot and cool colors for the escaping, periodic, and attracting sequences.

**Algorithm 1: MatLab Program Code**

```matlab
%Mandelbrot Set-saved as Mandel.m
h=waitbar(0,'Computing…');
x=linspace(-2.1,0.6,301);
y=linspace(-1.1,1.1,301);
[X,Y]=meshgrid(x,y);
C=complex(X,Y);
Z=max-1e6; it_max=50;
Z=C;
for k=1:it_max
    Z=Z^2+C;
    waitbar(k/it_max)
end
close(h)
contourf(x,y,abs(Z)<Z_max,1)
title('Mandelbrot Set', 'FrontSize',16)
```

For graph theory, the course concludes with a very brief introduction of graph theory, including Euler and Hamilton graphs. The maps shown in Figures 35-36 help students visualize the famous Konigsberga seven-bridge problem. We also cover the famous Kruskal’s algorithm, which can select the best route on a graph to maximize profit. The algorithm is demonstrated in a student’s innovative board game project shown in Figure 37.

**Figure 34: The Mandelbrot Set**

**Figure 35: Map of Konigsberga Illustrating its Highlighted Bridges**

**Figure 36: Konigsberga Bridges**
Results and Discussion

Learning and Thinking Preferences. Tables 3 and 4 below show the results of students’ learning style assessments for Fall 2009 and Spring 2010 Semesters, respectively. As in the past years of this study, most students exhibited visual, tactile, and kinesthetic learning preferences (in that order). Almost no students (2 percent) exhibited an auditory preference this year, and over the five years of this study only 2.5 percent of students displayed this preference, suggesting that, for VCUQatar students, lectures are the least effective delivery system because so few students are auditory learners.

<table>
<thead>
<tr>
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<th>Section 2</th>
<th>Section 3</th>
<th>Honors Students</th>
<th>TOTALS</th>
<th>PERCENTS</th>
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<td></td>
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</table>

Table 3: Results of Fall 2009 Students’ Learning Style Assessments Per Section of MATH 131

<table>
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<tr>
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<th>Section 3</th>
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<th>TOTALS</th>
<th>PERCENTS</th>
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<td></td>
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<td>7</td>
<td>1</td>
<td>18.0</td>
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</tbody>
</table>

Table 4: Results of Spring 2010 Students’ Learning Style Assessments Per Section of MATH 131
Tables 5 and 6 below display students’ hemispheric preference test results for Fall 2009 and Spring 2010 Semesters, respectively. It is interesting to note that students during these semesters exhibited the strong right hemispheric preference that the authors originally expected design students to display and predicted in Year 1 (2005-2006). Nearly one half (46 percent) of the fall students and two thirds of the spring students (66.7 percent) preferred using their more creative right hemisphere, suggesting that most students taking MATH 131 this year were not predisposed to the linear strategies that would enable them to grasp mathematical concepts more easily.

<table>
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<th>PERCENTS</th>
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<td>2</td>
<td>2</td>
<td>11</td>
<td>46</td>
</tr>
<tr>
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<td>3</td>
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<td>0</td>
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<td>0</td>
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<td>4</td>
</tr>
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<td>0</td>
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<td>4</td>
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Table 5: Results of Fall 2009 Students’ Hemispheric Preference Assessments Per Section of MATH 131

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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Integrated</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td></td>
<td>10</td>
<td>7</td>
<td>1</td>
<td>18</td>
<td>100.0</td>
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</tbody>
</table>

Table 6: Results of Spring 2010 Students’ Hemispheric Preference Assessments Per Section of MATH 131

Tables 7 and 8 below compare the results of students’ super link tests over the five years of the study. Table 7 shows that, as originally predicted, the majority of MATH 131 students have favored visual and tactile learning styles throughout the study (76 percent of students’ preferred learning styles when combined). Although the Year 2 study found that mere observation is not enough—students must be tested to accurately determine their preferences—some characteristics of students’ preferences can be observed and predicted rather well. For example, in the case of VCUQatar’s MATH 131 students, the popularity of and devotion to students’ design studio classes, in which students may observe, collaborate, and work hands-on, attests to their preferences for visual aids or live demonstrations (the visual) and for touching and feeling physically or emotionally (the tactile). On the other hand, kinesthetic preferences at times may mimic tactile behaviors, thus requiring testing to determine. Based on the results of this study, it does seem clear that successful auditory delivery of information will be especially difficult in MATH 131, making lectures the least-favored and most ineffective information delivery method and arguing in favor of the project-directed approach.
Table 8 shows that over the five-year study 49 percent of the participants have preferred the right, or artistically inclined, hemisphere. Adding in those students with mixed preferences that slightly favor the right hemisphere, this number rises to 58 percent. The implications for MATH 131 are significant: because the left hemisphere deals with symbolic processing (such as numbers) in a sequential manner, we may expect most MATH 131 students to struggle with mathematical concepts. Effective information delivery methods for these students will involve their senses and will show them the “whole picture” or the “answers” before presenting the sequential steps involved.

In short, although MATH 131 professors will need to include some teaching strategies that appeal to the left-brain auditory and kinesthetic types, to be effective for the most students, teaching strategies should target the visual or tactile right-brain students. Again, the versatility of the project-directed approach argues in favor of its use as a strategy appealing to most students.

<table>
<thead>
<tr>
<th>Year</th>
<th>n =</th>
<th>Visual</th>
<th>Auditory</th>
<th>Tactile</th>
<th>Kinesthetic</th>
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<td>predicted</td>
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</tr>
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<td>5.5</td>
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<table>
<thead>
<tr>
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Table 7: Five-year Comparison of Students' Learning Styles Preferences

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<th>Mixed-Left</th>
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<td>--</td>
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<td>4</td>
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<table>
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</table>

Table 8: Five-year Comparison of Brain Hemispheric Preferences

**One-Minute Papers.** As in 2008-2009, one-minute papers were used as a learning-by-writing strategy. Of 34 responses to a one-minute response paper asking students to explain how the Golden Number and the Fibonacci Sequence are related, all students except one gave surprisingly good answers that incorporated various elements from the classroom discussion. The one exception wrote: “I have no idea, because till this day I am sure about my understanding to these things. This weekend I’m gona sit down on my own and try to figure it out.” Although the student actually wrote that she was sure about her understanding, her context implies that this statement should have read unsure. The professor allowed her to follow her individual course of
action, and during the next class, she told the professor that she had, indeed, figured out the relationship. Her test result later testified that she had done so accurately, as she made a B for the course.

In response to another one-minute paper prompt, *The MOST IMPORTANT thing I learned from today’s lesson is ___ because ___.* 12 of 33 students stated they now understood the relationship of the geometric and arithmetic sequences to everyday life or their majors. Four of the students mentioned that they had studied arithmetic and geometric sequences before but never understood them until this lesson. In addition, the professor received such feedback from the students as:

- “. . . However, I would like to see examples of these equations written out,” written by a student with a Tactile/Right super link.
- “The most important thing I learned from today’s lesson is the graph because I’m a visual learner and I want to see an example of problem. I also like how you explain how we use it in life. Along with you writing down on the board many examples so we can have a chance to understand,” written by a student with a Tactile/Left super link.
- “I used to think that math is not really involved with day to day matters. However, when I learned that the growth of population can be observed through geometric sequences, I was thrilled. It was interesting to see how formulas & concepts apply in life.”
- “The most important thing I learned was how the Fibonacci Sequence ‘principle’ carries over to much broader areas of math in the form of linear/geom. sequences that have terrific relevance in the field of design. This was a great lesson. I’m glad we started with Fib Sequence this course because the idea really transfered [sic] over well for me today.”
- “. . . This arithmetic [sequence] is pretty fun. ☺”
- “I learned about Fibonacci’s rabbits and I found the name of the lesson a little funny. The lesson was easy and not that boring. I also knew that there is an art gallery at the Hayat [sic] and it sounded interesting from the way the instructor described it.”
- “. . . It was also interesting to see the work of other students regarding the spiral.”

The first two statements show that the students were thinking about their super links and how they process information, even if they were mistaken about their own learning style, as was the second respondent. Statements 2-4 suggest that the students were responding well to the professor’s attempts to link the new mathematical concepts with familiar ones, especially in the students’ majors. Response 5 also shows that at least one student responded to the local art gallery reference with familiarity. Statements 4-7 give the professor important feedback about the effectiveness of his classroom activities and methods for reference in future courses. Respondent 1 even suggests the method that would be most helpful to her.

Finally, the responses to a situational one-minute paper produced four unexpected responses that either demonstrated the higher thinking levels of analysis and synthesis or alerted the professor to the students’ lack of understanding arithmetic and geometric sequences. The situation required students to decide whether they preferred receiving 12 monetary gifts from “Aunt Gertrude,” one per month for the next year, using either an arithmetic or a geometric sequence. The students were to identify and explain their preference. All students except four selected the geometric sequence because of the increased money they would receive. The four students choosing an arithmetic sequence said:

- “Arithmetic sequence would be preferred by me if it grew at a faster rate. However, it is linear and would be boring. Geometric sequence increases exponentially. Nevertheless, I
would as [sic] my aunt to give me in the arithmetic sequence since I would [not] want her to spend all her money for me 😊!!"

- “I would prefer the arithmetic method because that would help me keep a count in numbers (of the increase).”
- “I prefer an arithmetic sequence. I love addition. It’s simple & quick. Moreover I enjoy doing arithmetic sequences more than geometric sequences. Arithmetic sequences are easy & fun to work with.”
- “I would prefer the method arithmetic because geographics [sic] does not relate to my personality and needs. This is an easier way to help to collect the money and invest it in a good way. It increase the outcome of money ($100 x each month).”

Having expected strictly mathematical reasoning, the professor was surprised, yet pleased, to see the students reasoning in unexpected ways. The first respondent allows concern for her aunt to affect her response, while Students 2-4 clearly feel that they understand arithmetic sequences better than geometric ones, signaling to the professor the need for follow-up work on both topics, but especially the geometric sequences, with these students.

**Implications**

The implications of these studies are many, and in most instances they can be adjusted to apply to other analytical courses. From the first study, during which the authors focused on relating new math concepts to students’ prior knowledge, the authors suggest these strategies:

- Investigate the components that feed into students’ prior knowledge. These are not limited to prior math knowledge, but also include cultural and life experiences that can provide an entry point into new concepts. In Qatar, a field trip to a hotel with extensive Arabesque designs and samples of designs, such as a plate bearing a symmetrical design, that can be presented in class give students an opportunity to relate math principles to the real world.
- Become familiar with the different learning styles and hemispheric preferences and develop a range of teaching strategies that appeal to each style and preference. The results of our studies show that lectures alone will appeal primarily to auditory learners, which accounted for just 2.5 percent of our students over five years.
- If possible, do not rely on observation alone to assess students’ learning styles and hemispheric preferences; rather, test these for more accurate and reliable results. Students themselves are often mistaken about their preferences, thinking they are visual learners when in actuality their favored learning style is something else.

The second study, which investigated the effectiveness of incorporating projects into the course, revealed:

- Requiring students to create projects either about or using the math principles they are studying effectively appeals to the learning styles of visual, tactile, and kinesthetic learners, which accounted for 97.5 percent of our students over the five-year period. We allowed students to choose the math topics for their projects and encouraged them to be as creative as possible, resulting in the diverse projects portrayed in this paper as well as many others. We found that creating projects either individually or collaboratively worked well, and students enjoyed the collegial competition of trying to outperform each other with their projects.
Selecting some of the earlier students’ projects to save as future teaching models the students could examine and handle worked well for introducing each new topic as well as for inspiring the current classes’ creative ideas for their final projects. Students seemed to enjoy knowing that the sample projects used throughout the semester were created by fellow students rather than purchased or produced by the faculty.

Preferring a final exam over a final project may occur when the class contains a high number of left-hemispheric preference students, when the novelty of creating projects is diminished by large quantities of projects required in other courses, when production time is perceived as too short, or when cultural/educational traditions have conditioned students to feel “safer” with the familiar form of a test.

In the third year of this study, we discovered:

- Self-monitoring skills must be taught consecutively with math skills because students’ perceptions about the time they need for various tasks as well as about their own preferences often are inaccurate. Testing, interviewing or querying students, record-keeping, and comparing results in class are good strategies for improving students’ self-awareness.

Similarly, in the fourth year we set out to develop students’ metacognition about their learning and thinking processes by incorporating writing in the form of journal keeping, completing specific journal assignments, stimulating attention and thought through one-minute papers, and completing an end-of-term survey. During this study, we found:

- Shorter classes (three 50-minute sessions per week) made incorporating students’ whiteboard participation more difficult and often meant too little time was available to use one-minute papers. We recommend two 75-minute classes per week.
- Students with a right hemispheric preference, normally expected to have greater difficulty with mathematical tasks, may exhibit poor or irregular attendance.
- Structured journal assignments can be useful tools for encouraging students to move into the higher cognitive domains of applying, analyzing, synthesizing, and evaluating.
- Journal writing can help students master math principles as well as discover new information as they wrestle with these concepts.
- Responses to journal assignments can track students’ thinking processes, revealing information about the students’ efforts and growth in the course that the professor otherwise would not have known.
- Journal writings can reveal students’ need for help with analytical or self-reflective thinking.
- Failing to use journals and one-minute papers in the recommended ways can reduce or negate their effectiveness. For example, allowing students to record math homework in their journals complicated the timely collection of both journal assignments and math homework. Similarly, recording one-minute paper answers in journals can mean that these responses are not reviewed immediately after being given, as intended, but may be delayed until well after the class discussion, thus losing their effectiveness as teaching tools.
- Intentional repetition and questioning regarding students’ super links is necessary if students are to remember them correctly. We had anticipated that discovering this
personal knowledge about oneself would be motivational enough to help students remember their super links, but this proved to be mistaken.

- Critical thinking skills of our Arab freshmen often proved too poorly developed to handle appropriately some of the journal assignments designed to move students into higher cognitive domains; consequently, in educational systems where teaching methods may not have emphasized critical thinking development during the earlier grades, we recommend requiring students to pass a specialized test of critical thinking ability before being allowed to register for MATH 131.

Continuing to incorporate varied teaching styles, writing, quizzes, and projects into MATH 131 during the fifth year taught us that:

- Our original predictions, based on typical characteristics of artistic persons, that design students would be visual, tactile individuals with right hemispheric preferences were confirmed by the five-year statistics. During this longitudinal study, 76 percent of the students were visual and tactile learners, 49 percent preferred using the right hemisphere, and 9 percent had a mixed-right preference. Although one can observe and predict some students’ preferences, testing remains necessary to identify preferences accurately and to reveal atypical individuals and classes.
- The versatility of projects both shown as examples and produced as learning tools addresses well the learning styles of visual, tactile, and kinesthetic students.
- One-minute papers are a quick means of gaining both insight and feedback from students. Knowing that they may be asked to complete a one-minute paper encourages many students to identify and focus on at least parts of a lesson to write about. Students’ responses may help professors target especially effective or ineffective teaching methods. One-minute papers also aid in developing students’ metacognition as well as in pinpointing students who are struggling and may need additional instruction.
- Incorporating periodic quizzes into the classes motivates better attendance among the students, as they want to protect their grades by not missing a quiz.
- In the collaborative Arab cultures, maximum class sizes of 10-12 students facilitate better control of students’ activities and better student-professor relationships than do larger class sizes.

Conclusions

This five-year journey began with the need to motivate female students, mostly Arabs, to become interested in their required course, MATH 131, Contemporary Mathematics. They were reluctant math students both because of cultural expectations for females and because they could not relate math principles to their future needs as designers. MATH 131 at VCUQatar started with a textbook, lectures, a graphic calculator, a white board, and markers—typical tools in a “Western” course that quickly revealed a need to motivate these students. Beginning with an investigation of Qatari culture to develop a base of the familiar upon which to build new concepts, over five years the authors progressed through diversifying teaching strategies to appeal to different learning styles and hemispheric preferences, introducing projects as examples and as teaching tools, journaling to help students build critical thinking skills, and responding to one-minute prompts and quizzes to develop students’ metacognition. The result is a uniquely “Middle Eastern” course that better motivates the students, as well as their professors.
Bibliography