A NUMERACY INFUSION COURSE FOR HIGHER EDUCATION (NICHE): STRATEGIES FOR EFFECTIVE QUANTITATIVE REASONING (QR) INSTRUCTION

Esther Wilder[1], Elin Waring[1], Frank Wang[2], and Dene Hurley[3]
[1]Department of Sociology, Lehman College, The City University of New York, Bronx, NY USA
[2]Department of Mathematics, Engineering and Computer Science, LaGuardia Community College, Long Island City, NY USA
[3]Department of Business and Economics, Lehman College, The City University of New York, Bronx, NY USA
Esther.Wilder@lehman.cuny.edu

Our Numeracy Infusion Course for Higher Education (NICHE) teaches best practices for effective Quantitative Reasoning (QR) instruction to faculty in a wide range of disciplines. NICHE is a predominantly online course that consists of 8 separate units of relevance to the development of statistical literacy as well: (1) QR and Making Numbers Meaningful; (2) QR Learning Outcomes; (3) The Brain, Cognition and QR; (4) QR and Writing; (5) Discovery Methods; (6) Representations of Data; (7) QR Assessment; and (8) QR Stereotypes and Culture. This paper describes the key components of NICHE and shows how we employ the same strategies recognized as effective methods for teaching QR to our training of faculty as QR instructors. Examples from course activities, interactive discussions, and assessment data are presented.

NUMERACY ACROSS THE CURRICULUM AND THE DEVELOPMENT OF NICHE

Whether called numeracy, Quantitative Literacy (QL) or Quantitative Reasoning (QR), infusing quantitative material throughout the curriculum is an imperative of higher education. Many scholars have called for a multidisciplinary, active learning approach to QR instruction (see, for example, Bressoud, 2009; Briggs, 2006; Diefenderfer, Doan & Salowey, 2006; Fink & Nordmoe, 2006; Gordon & Winn, 2006; Haines & Jordan, 2006; Hartzler & Leoni, 2006; Hillyard et al., 2010; Johnson 2006; and Taylor 2006). As Ganter (2006, p. 13) has pointed out, "QL must be everywhere in the curriculum, in all disciplines and all courses." Indeed, a multidisciplinary approach is central to many QR initiatives. "Like learning to write well or speaking a foreign language, numeracy is not something mastered in a single course…. Thus quantitative material needs to permeate the curriculum, not only in the sciences but also in the social sciences and, in appropriate cases, in the humanities…." (Bok, 2006, p. 134). Similarly, Steen (2004) notes that QL programs should involve faculty from multiple disciplines. The social sciences may be especially well-positioned to take the lead in QR initiatives (Steen, 2002).

The recognition that QR is the responsibility of *all* faculty provides the impetus for the Numeracy Infusion Course for Higher Education (NICHE). NICHE is an outgrowth of a QR faculty development program that has been in place at Lehman College of the City University of New York (CUNY) since the 2010–2011 academic year. In 2011, faculty from Lehman College and LaGuardia Community College (also of CUNY) received support from the National Science Foundation to develop NICHE, a QR faculty development program structured primarily as an online course to serve CUNY faculty from across the disciplines. The CUNY system includes eleven senior colleges, seven community colleges, the Macaulay Honors College, and five graduate and professionals schools located throughout New York City. It is the largest urban university system in the country, with a Fall 2012 enrollment of approximately 269,000 part-time and full-time students (CUNY OIRA, 2013).

Research on effective pedagogy informs NICHE and provides a foundation for each unit of the course. Enrollees not only review the relevant literature, but engage in activities and prepare instructional materials that are anchored in these approaches. A more comprehensive review of these strategies can be found on the NICHE website. (See "Best Practices for Quantitative Reasoning Instruction" at www.teachqr.org.)

In K. Makar, B. de Sousa, & R. Gould (Eds.), *Sustainability in statistics education. Proceedings of the Ninth International Conference on Teaching Statistics (ICOTS9, July, 2014), Flagstaff, Arizona, USA.* Voorburg, The Netherlands: International Statistical Institute. iase-web.org

THE STRUCTURE OF NICHE

The objectives of NICHE are to provide instruction on best practices for teaching QR; to foster the development of instructional materials that make use of effective strategies for teaching QR; to infuse QR into a wide range of disciplines and CUNY colleges; to increase faculty interest and comfort in teaching QR, to strengthen the faculty's own QR skills, if necessary; and to establish a network of faculty who are committed to improving students' QR skills.

In teaching faculty how to infuse QR into their courses, NICHE uses the same approaches that have proven effective in teaching college students: collaborative learning and discovery methods, for example. The course includes a 2-day in-person introductory session as well as 8 online instructional units, each lasting one week. The units themselves are asynchronous, but there are deadlines for each unit. In addition, we require that faculty participants complete pre- and post-NICHE questionnaires and assessments. Our online instructional units, delivered through Blackboard, serve as a complement to the NICHE website (www.teachqr.org).

The 8 online units of NICHE are (1) QR and Making Numbers Meaningful; (2) QR Learning Outcomes; (3) The Brain, Cognition and QR; (4) QR and Writing; (5) Discovery Methods; (6) Representations of Data; (7) QR Assessment; and (8) QR Stereotypes and Culture. Each unit can typically be completed in 6–8 hours and includes a set of readings, videos, hands-on activities and interactive discussions. In addition, faculty develop materials for their own courses whereby they:

- Articulate a set of QR learning goals, provide peer feedback on QR learning goals, and develop a revised set of QR learning goals in response to peer feedback.
- Create/adapt a QR lesson plan/exercise, provide peer feedback on QR lesson plans/exercises, and develop a revised QR lesson plan/exercise in response to peer feedback.
- Create/adapt a QR assessment plan/instrument, provide peer feedback on QR assessment plans/instruments, and develop a revised QR assessment plan/instrument in response to peer feedback.

For each key task, we provide detailed instructions and guidelines for peer review, which we urge participants to use as they develop/adapt their own instructional materials. Faculty are compensated up to $1,800 for successful completion of all materials associated with NICHE.

ANALYSIS OF DATA FOR THE 2013 NICHE COHORT

Altogether, 20 faculty enrolled in NICHE during the summer of 2013. The 20 enrollees represented 4 community colleges (n=8) and 7 senior/comprehensive colleges (n=12) as well as 8 disciplines: African American studies (1), biology (4), economics (1), mathematics (7), political science (1), psychology (2), public affairs (1), and sociology (3).

Prior to beginning NICHE, faculty were asked to complete an online pre-NICHE questionnaire/skills assessment that consisted of 44 questions, including 20 skills questions and several others that focused on socio-demographic characteristics, motivations for enrolling in NICHE, and experience/attitudes towards teaching QR. The post-NICHE questionnaire/skills assessment (also online) consisted of 46 questions, including 20 QR skills questions (addressing the same topics as the pretest) and additional questions about participants' attitudes regarding NICHE and QR instruction. Altogether, 12 faculty provided feedback on both the pre- and post-NICHE questionnaires/assessments. (Fifteen faculty completed NICHE, but our post-NICHE assessment data exclude the 3 individuals on the NICHE core development team.)

This paper presents data from the course activities and discussions as well as our pre- and post-NICHE assessments. In analyzing the latter, we have drawn on both quantitative and qualitative approaches. In comparing faculty performance responses on the skills portion of the assessment, we have made use of McNemar's test as well as the Wilcoxon signed-rank test. (McNemar's test is appropriate for nominal data and is applied to a 2 x 2 contingency tables with a dichotomous trait—e.g., correct vs. incorrect—and matched pairs of subjects. The Wilcoxon signed-rank test is the appropriate non-parametric statistical test for comparing repeated measurements on a single sample to assess whether the population mean ranks differ.) We used thematic analysis in evaluating responses to the open-ended questions (our qualitative data).

NICHE ACTIVITIES AND DISCUSSION

As mentioned earlier, the NICHE course includes a range of hands-on activities (approximately 3 in each unit) that promote self-reflection on QR pedagogy and/or allow participants to engage in effective strategies for teaching QR. For example, faculty enrollees undertake hands-on activities working with data and QR problems, review students' work, and evaluate assessment materials. They also participate in discussions about the activities, the course readings, and the videos. For example, in an exercise designed to get faculty thinking about ways of blending QR and writing in their own instruction, participants were asked to graph a course they teach along a QR/writing continuum. The graph was made available through Google Documents and participants were given instructions on how to add a shape to the graph. The resulting graph can be seen in Figure 1.

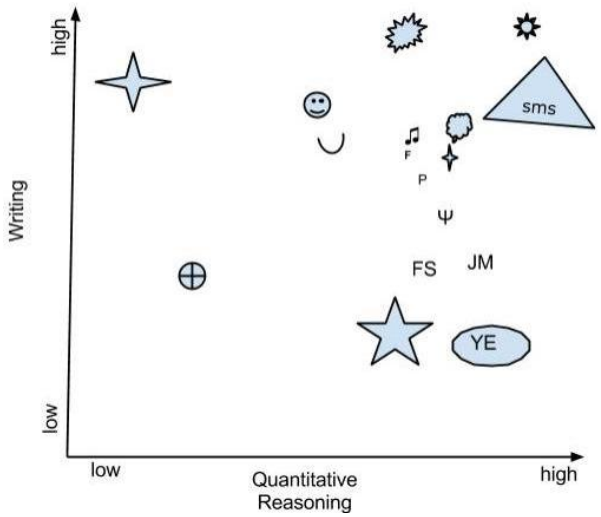
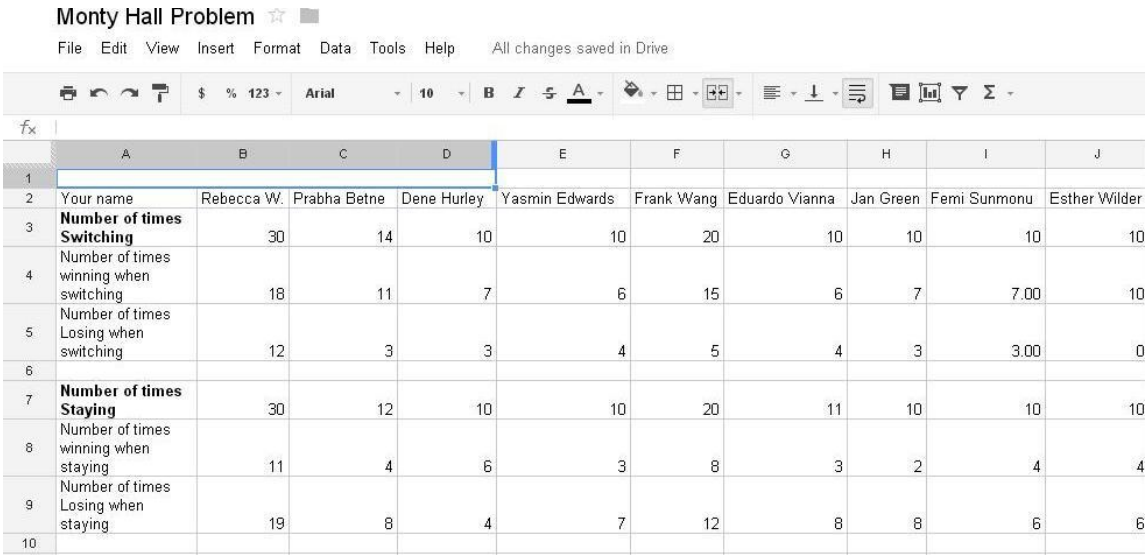


Figure 1. Faculty graph their courses on the "QR and Writing" spectrum

After graphing their courses, faculty were instructed to "go to the bottom of the graph and identify yourself, indicate the symbol you used, noting what course it represents and why you graphed it where you did." A biology faculty member at Bronx Community College replied, "My symbol is the circle with 4 quadrants, which I chose because Intro Biology 2 has 4 major topics: development, genetics, evolution, & ecology. It has a fair amount of writing, as each week students participate in either a discussion board or a wiki…. It's relatively low on the QR scale currently, as the only QR-heavy topic is genetics and only 3 lab require mathematical and QR skills. The same topics could be taught with a heavier emphasis on QR."

In another exercise designed to show the advantages of discovery methods and group work, participants were asked to pick a partner and to undertake an empirical test of the Monty Hall exercise, the classic probability problem. They were instructed to undertake at least 20 trials, 10 with switching and 10 without switching. Afterwards, they posted their results on a shared Google spreadsheet, a portion of which is shown below (Figure 2). (Another page shows a bar chart with the likelihood of winning (stay vs. switch) drawing on these data.) Finally, they were asked to reflect on the results of the exercise and on the ways in which discovery methods might be useful in teaching QR. A faculty member in mathematics at Guttman Community College wrote, "The benefit of discovery methods is that students get to accept or refute their own assumptions based on evidence. A simple example that I have used is the probability of getting heads or tails in a coin toss. All the students will indicate that there is a 50% chance of getting heads or tails, but when they do the actual tosses they see that while this is the expected probability it may not be what is observed. They then have to explain why, and they are able to determine how sample size affects expected ratios."



Monty Hall Problem

File Edit View Insert Format Data Tools Help All changes saved in Drive

	A	B	C	D	E	F	G	H	I	J
1										
2	Your name	Rebecca W.	Prabha Betne	Dene Hurley	Yasmin Edwards	Frank Wang	Eduardo Vianna	Jan Green	Femi Sunmonu	Esther Wilder
3	**Number of times Switching**	30	14	10	10	20	10	10	10	10
4	Number of times winning when switching	18	11	7	6	15	6	7	7.00	10
5	Number of times Losing when switching	12	3	3	4	5	4	3	3.00	0
6										
7	**Number of times Staying**	30	12	10	10	20	11	10	10	10
8	Number of times winning when staying	11	4	6	3	8	3	2	4	4
9	Number of times Losing when staying	19	8	4	7	12	8	8	6	6
10										

Figure 2. Faculty input data for the Monty Hall Problem

RESULTS AND DISCUSSION OF ASSESSMENT DATA

Table 1 shows NICHE completers' responses to a series of questions asking them to reflect on the effects of NICHE in a variety of domains. As shown in the table, 84% of NICHE completers indicated that they would be placing a heavier emphasis on teaching QR in their courses as a result of their participation in NICHE; 75% agreed that they had become familiar with new tools for teaching QR, and 92% indicated that they had become engaged in a network of CUNY faculty committed to QR instruction.

An additional open-ended question asked faculty to reflect on how their approach to teaching QR "has changed (or will change) as a result of NICHE." One respondent, an assistant professor in African American studies at a four-year college wrote, "I am much more confident in my understanding of QR in terms of philosophy, pedagogy and goals. …. We all know that QR is essential to preparing our students for the 21st century, but the rise of digital humanities suggests that QR is also essential for preparing 21st century students to study centuries past. I spent countless hours this summer blazing a google trail inspired by our readings, videos, and assignments, and I discovered an abundance of resources applicable to my teaching of African American literature that are now available to my students through Blackboard."

Similarly, an associate professor of psychology at a community college wrote, "I am now familiar with a wide range of strategies so that my teaching repertoire has increased significantly. But most importantly, through NICHE I acquired a systematic method for infusing QR in my courses, beginning with establishing and ending with assessing clear goals…. I want to gradually turn all my lessons into active learning ones wherein students can actively work with data."

Table 1. *As a result of my participation in NICHE, I…*

	Strongly agree	Somewhat agree	Neither agree nor disagree	Somewhat disagree
Plan to place a heavier emphasis on QR in my course instruction	58.3%	25.0%	0.0%	16.7%
Have become familiar with new strategies and tools for teaching QR	66.7%	8.3%	25.0%	0.0%
Have become engaged in a network of CUNY faculty committed to QR instruction	83.3%	8.3%	8.3%	0.0%

Note: No respondents chose the "Strongly disagree" response.

Indeed, a more deliberate emphasis on teaching QR through the use of best practices was a recurrent theme in faculty members' comments.

Although improving the faculty's QR skills is not the key objective of NICHE, we did hope to see such an effect for some faculty who were less adept at QR. We therefore developed two versions of a QR skills tests that we administered to faculty both before and after NICHE. Table 2 shows a pretest/posttest comparison of NICHE faculty performance on the QR skills test, broken down by question. The mean score on the pretest was 16.45 out of 20; on the posttest, 17.72 ($p<.05$). For the pretest, faculty obtained perfect scores on 12 of the 20 questions, so no improvement was possible on some parts of the test. (Our NICHE cohort was somewhat biased towards faculty who were already committed to and knowledgeable about teaching QR, and many of the participants were involved in leading QR programs.)

CONCLUSIONS

The Numeracy Infusion Course for Higher Education (NICHE) is associated with a significant improvement in the QR skills of participating faculty. It has a notable impact on changing the way that faculty plan to approach teaching QR. The overwhelming majority of faculty who participated in NICHE plan to place a heavier emphasis on QR in their course instruction and have become familiar with a wide range of tools for teaching quantitative reasoning and improving statistical literacy. In particular, many faculty plan to place a more deliberate emphasis on teaching QR, to incorporate more data analysis and real-world examples into their teaching, and to employ best practices that include articulating learning goals, providing learning opportunities, and undertaking assessment to improve teaching.

Table 2. NICHE faculty performance on the QR skills assessment: pretest and posttest

Skill	% Correct, pretest	% Correct, posttest	Dif-ference
Interpret. of rates	100.0	100.0	0.0
Conversion of money	100.0	100.0	0.0
Independence of events	100.0	81.8	-18.2
Fuel efficiency and car mileage	36.4	81.8	+45.5
% salary increase/calculation of pay raise	100.0	100.0	0.0
Interpret. of histogram	90.9	100.0	9.1
Interpret. of pie chart	36.4	72.7	+36.4
Number sense for very big numbers	90.9	63.6	-27.3
Median	100.0	90.9	-9.1
Mean/Average	100.0	100.0	0.0
Mode	100.0	90.9	-9.1
Interpret. of table on % distribution of workers	90.9	90.9	0.0
Ratio	81.8	90.9	+9.1
Interpret. of percentages less than one	90.9	90.9	0.0
Comparison of % distribution of two populations	72.7	72.7	0.0
Interpret. of line chart	100.0	100.0	0.0
Extrapolation of line chart	63.5	90.9	+27.4
Interpret. of multivariate chart	90.9	81.8	-9.1
Interpret. of qualitative chart	81.8	100.0	+18.2
Interpret. of medical testing results	18.2	72.7	+54.5*
Total average score	16.45	17.72	+1.27*

*$p<.05$

Note: *Difference* is the percentage-point difference, pretest to posttest. For individual questions, McNemar's test was used. For the total average score, the Wilcoxon signed-rank test was used.

REFERENCES

Bok, D. (2006). *Our underachieving colleges: A candid look at how much students learn and why they should be learning more*. Princeton, NJ: Princeton University Press.

Bressoud, B. (2009). Establishing the quantitative thinking program at Macalester. *Numeracy*, *2*(1), Article 3.

Briggs, W. L. (2006). What mathematics should all college students know? In R. Gillman (Ed.), *Current practices in quantitative literacy* (pp. 17–19). Washington, DC: Mathematical Association of America.

City University of New York (CUNY) Office of Institutional Research and Assessment (OIRA). (2013). *Student data book*. Retrieved from http://cuny.edu/about/administration/offices/ira/ir/data-book/current.html

Diefenderfer, C., Doan, R., & Salowey, C. (2006). The quantitative reasoning program at Hollins University. In R. Gillman (Ed.), *Current practices in quantitative literacy* (pp. 41–48). Washington, DC: Mathematical Association of America.

Fink, J. B., & Nordmoe, E. D. (2006). A decade of quantitative reasoning at Kalamazoo College. In R. Gillman (Ed.), *Current practices in quantitative literacy* (pp. 51–54). Washington, DC: Mathematical Association of America.

Ganter, S. L. (2006). Issues, politics and activities in the movement for quantitative literacy. In R. Gillman (Ed.), *Current practices in quantitative literacy* (pp. 11–15). Washington, DC: Mathematical Association of America.

Gordon, S., & Winn, J. (2006). Interconnected quantitative learning at Farmingdale State. In R. Gillman (Ed.), *Current practices in quantitative literacy* (pp. 55–62). Washington, DC: Mathematical Association of America.

Haines, B., & Jordan, J. (2006). Quantitative reasoning across the curriculum. In R. Gillman (Ed.), *Current practices in quantitative literacy* (pp. 63–68). Washington, DC: Mathematical Association of America.

Hartzler, R., & Leoni, D. (2006). Mathematics across the curriculum. In R. Gillman (Ed.), *Current practices in quantitative literacy* (pp. 69–74). Washington, DC: Mathematical Association of America.

Hillyard, C., Korey, J., Leoni, D., & Hartzler, R. (2010). Math across the community college curriculum (MAC3): A successful path to quantitative literacy. *MathAMATYC Educator*, 1(2), 4–9.

Johnson, J. (2006). Math across the curriculum at UNR. In R. Gillman (Ed.), *Current practices in quantitative literacy* (pp. 75–80). Washington, DC: Mathematical Association of America.

Steen, L. A. (2002). Quantitative literacy: Why numeracy matters for schools and colleges. *Focus, 22*(2), 8-9.

Steen, L. A. (2004). *Achieving quantitative literacy: An urgent challenge for higher education*. Washington, DC: Mathematical Association of America.

Taylor, C. (2006). Quantitative reasoning at Wellesley College. In R. Gillman (Ed.), *Current practices in quantitative literacy* (pp. 141–146). Washington, DC: Mathematical Association of America.