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QMRA Wiki: An Educational Tool for Interdisciplinary Teaching of Risk Modeling in Engineering Curricula

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Dr. Jade Mitchell is an Assistant Professor in the Department of Biosystems and Agricultural Engineering at Michigan State University. She received her B.S. from the University of Pittsburgh in Civil and Environmental Engineering, M.S. in Civil Engineering and Ph.D. in Environmental Engineering from Drexel University. Dr. Mitchell is keenly interested in supporting environmental and human health decision making through the use of integrated risk and decision frameworks. Her work includes development of new frameworks, models and data sets toward this end. Dr. Mitchell has specific experience in quantitative microbial risk assessment (QMRA) and she conducted her graduate research under the multi-University, multi-disciplinary, Center for Advancing Microbial Risk Assessment (CAMRA), a jointly funded US EPA and DHS Center of Excellence. After joining MSU, she became affiliated with CAMRA as a principal investigator. Her lab conducts both computational risk modeling research and fundamental research. Her current work and future interests lie at the intersection of chemical and microbial stressors where understanding trade-offs, benefits and risks deviate from existing risk paradigms and require new data, tools and frameworks. Her future research goals include applications of risk-based decision making to water infrastructure management, and emerging hazards such as antibiotic resistance. She is managing editor and a developer of the QMRAwiki, an interactive, online tool for the QMRA community. Dr. Mitchell has also been involved in developing and teaching training workshops in QMRA for several years. She was recently awarded a nearly $1M grant from the National Institutes of Health to develop a new course, models and tools to support interdisciplinary engagement in QMRA.

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Abstract:

Quantitative microbial risk assessment (QMRA) is a paradigm that has demonstrated itself as a valuable tool in assessing the efficacy of engineering interventions through modeling and data analysis. One of the values of the QMRA paradigm is that in building the exposure scenario or conceptual model, the engineer understands their system better and can also predict changes to the system. The challenge in teaching QMRA to undergraduate and graduate engineering students is that QMRA is an interdisciplinary field that requires transdisciplinary approaches. What this means for QMRA instruction, is that the faculty member is faced with the formidable challenge of conveying essential concepts and guided implementation of the paradigm. This includes critical information from the fields of: microbiology, mathematics, physics, statistics, public health and engineering. Considering these needs the QMRA Wiki (qmrawiki.canr.msu.edu) was developed. It serves as an online location for a suite of educational material, tools, applications, data and models. Surveys conducted during a QMRA institute were analyzed to determine the efficacy of the QMRA Wiki for instructional success for QMRA.

Introduction:

Quantitative Microbial Risk Assessment (QMRA)

Quantitative microbial risk assessment (QMRA) has proven itself as a modelling paradigm to simulate health effects from environmental and anthropogenic exposures to pathogens [(1–4)]. QMRA is a growing field that is developing as a trans-disciplinary science that incorporates concepts and knowledge from: physics, microbiology, pathology, public health, engineering, biochemistry, mathematics, communications, epidemiology, biostatistics and sociology. Unfortunately there is a dearth of experts in fields not related to engineering, mathematics and microbiology in current QMRA expertise. Therefore, there is a need to expand the breadth of scientists engaged with QMRA modellers and scientists. In order to facilitate the training of these scientists in QMRA science and modelling the QMRA Wiki was developed.

QMRA Wiki

The genesis of the QMRA Wiki was within the joint USEPA[1] and DHS[2] center of excellence – Center for Advancing Microbial Risk Assessment (CAMRA). The CAMRA QMRA Wiki was developed as a central database for the CAMRA center but then began to develop itself as an educational tool. This CAMRA QMRA Wiki facilitated two main aims of the center: 1.) to support the research mission and collaboration of the core projects that comprises the CAMRA center and 2.) support the CAMRA Summer Institutes, a set of short summer courses outlined to allow for the training of future QMRA modelers and experts.

The QMRA Wiki was first developed as a standard MySQL database the implementation of which was managed using MediaWiki (http://www.mediawiki.org/). The overall value of the QMRA Wiki was discovered as an educational tool that also houses the majority (and in the case of dose response modelling all) of the discovered QMRA research and data. These beginnings were unfortunately not overtly successful based on the trans-disciplinary nature of QMRA. Rather than being able to browse specific topics and areas of knowledge as can be performed in a standard Wiki or other scientific field-centered Wiki, QMRA is different. In order to develop an

[1] United States Environmental Protection Agency
[2] Department of Homeland Security

understanding of how the specific core areas of QMRA (figure 1) related to each other and affect each other, a smart means of managing the data was required.

Semantic MediaWiki (https://semantic-mediawiki.org/) is a means of linking the pages in a Wiki and specifically provides the ability to link data embedded in one page for easy access and use by multiple others. This use of a semantic MediaWiki has allowed for the development of QMRA apps and tools [(5)] that would not be possible without the central location of QMRA specific data.

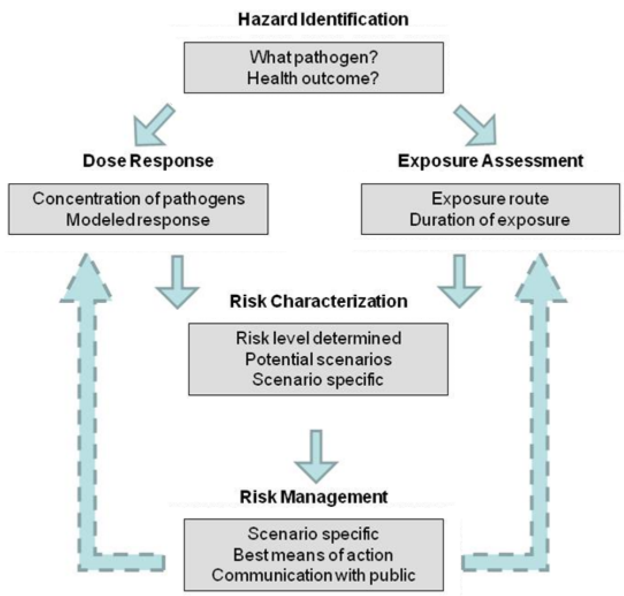

Figure 1. QMRA paradigm, the feedback arrows show the important communication that QMRA modelers and teams need to have with their own knowledge base (if working alone) as well as the QMRA modeling team.

Evaluation Study Methods

QMRA III – QMRA Interdisciplinary Instructional Institute

QMRA III is a National Institute of General Medical Sciences[3] (National Institutes of Health) funded education and research program. QMRA III aims to develop further interest and training of experts in the fields not currently represented in QMRA (*e.g.* sociologists, clinicians *etc*.). To

[3] NIGMS/NIH, Award Number R25GM108593

these ends QMRA III is developing the QMRA Wiki into a more potent educational tool and has taken the reigns of it from CAMRA. In addition to the redevelopment of the QMRA Wiki, QMRA III is seeking to test it's efficacy in educational development and support, as well as develop apps to further support QMRA education.

Survey Development

Surveys were developed to assess the capabilities of the students given specific tasks in an undergraduate risk class. The purpose was to determine if completion time and accuracy of the completed answers can be improved by using the QMRA Wiki. Since the standard other than the QMRA Wiki is to issue publications regarding terminology and basics of risk and QMRA at the outset of the class, reading from the open literature was used as a comparison point.

The students were timed to determine how long it took them to complete the tasks. The first and second tasks were identical to each other, students were grouped into one of 4 groups: literature first (lit first), literature second (lit second), QMRA Wiki first (wiki first) or QMRA Wiki second (wiki second). The survey then asked three fundamental knowledge questions regarding QMRA: 1.) Please define 'k', 2.) Please define 'dose' and 3.) Please define 'risk'

Survey Analysis

Student's responses were then rated from 1 to 3 for how accurate they were to the correct answers. In the case of defining 'k', this is a dose response parameter for the exponential model. If the student responded that it is a dose response parameter and/or mentioned that it was for the exponential model, then this resulted in a 1 for the rating, distance away from this response resulted in a worse rating. The maximum for all ratings is 3. For the define 'dose' question the optimal response for a rating of 1 was that dose is the amount of pathogen that the host is exposed to. Lastly for the define 'risk' question, the optimal response for a rating of 1 is that risk is the likelihood of a deleterious effects post exposure to a pathogen of known dose.

From these responses and after coding, descriptive statistics and violin plots were developed to analyze the results. All plotting and statistics were performed in R (www.r-project.org). Violin plots were chosen since they are essentially a mix of boxplots and kernel density plots. It is important to highlight and examine the density of the distribution of results from these surveys, an directly compare the density of different interventions to each other in one plot.

Results

Table 1 shows the summary statistics from the surveys. Overall the results are fairly consistent. The second group of students had better median and mean completion times for the task than the first set. It is interesting that when the QMRA Wiki is used first, that the completion time is faster as compared to all other scenarios.

When the QMRA Wiki was offered first there was also a marked but not overly significant improvement in success ratings. When the QMRA Wiki was offered second there was a slight improvement in defining dose when looking at the mean success rates. However, the QMRA Wiki being offered first did allow for a statistically significant difference in means when considering a Kruskal-Wallace test ($p<0.05$) on the data for defining k. The Kruskal-Wallace test was chosen since for each group we remained under the threshold for the central limit theorem and normality could not be proven to allow for the use of a t-test or ANOVA.

Table 1. Statistical breakdown of survey results regarding the time to complete tasks and success rates.

		Time to Complete Task	Define 'k'	Define 'dose'	Define 'risk'
Literature First	***Median***	15.00	1.00	2.00	2.00
	Mean	15.07	1.24	1.66	1.57
	Standard Deviation	7.65	0.64	0.55	0.92
	Minimum	4.00	0.00	0.00	0.00
	Maximum	30.00	3.00	2.00	3.00
	Skewness	0.22	0.66	-1.36	-0.23
	Kurtosis	-0.83	1.18	1.04	-0.63
		Time to Complete Task	**Define 'k'**	**Define 'dose'**	**Define 'risk'**
Wiki Second	***Median***	15.00	2.00	2.00	2.00
	Mean	15.68	1.49	1.49	1.71
	Standard Deviation	10.09	0.98	0.78	0.94
	Minimum	3.00	0.00	0.00	0.00
	Maximum	50.00	3.00	2.00	3.00
	Skewness	1.39	-0.16	-1.13	-0.53
	Kurtosis	2.48	-0.94	-0.34	-0.44
		Time to Complete Task	**Define 'k'**	**Define 'dose'**	**Define 'risk'**
Wiki First	***Median***	10.00	1.00	2.00	2.00
	Mean	11.74	1.10	1.55	1.62
	Standard Deviation	7.79	0.66	0.69	0.82
	Minimum	4.00	0.00	0.00	0.00
	Maximum	30.00	2.00	3.00	3.00
	Skewness	1.27	-0.11	-0.56	-0.42
	Kurtosis	0.71	-0.56	0.16	-0.11
		Time to Complete Task	**Define 'k'**	**Define 'dose'**	**Define 'risk'**
Literature Second	***Median***	10.00	2.00	2.00	2.00
	Mean	12.46	1.33	1.59	1.70
	Standard Deviation	7.43	0.78	0.80	0.87
	Minimum	3.00	0.00	0.00	0.00
	Maximum	40.00	2.00	3.00	3.00
	Skewness	1.89	-0.69	-1.07	-0.50
	Kurtosis	5.96	-0.99	0.30	-0.14

The violin plots shown in figures 2 – 5 correspond to results for time to completion, success rating for k, success rating for dose and success rating for risk respectively. We can see from the results shown in these violin plots that there is a good spread overall for the success rates throughout all intervention types. For the completion time (figure 2) we can see that not only did the peak completion time change but the density is skewed to the low end for the QMRA Wiki being used first, as is corroborated by the skewness (table 1). When investigating the success rates for defining k (figure 3) we see that there is the start of a second level of density for the literature first, however, this is not significant and the preponderance of results was ratings of 1. When the QMRA Wiki was used first the density shown in figure 3 for the ratings of 1 demonstrate the effectiveness of the QMAR Wiki for instructing this fundamental part of the dose response assessment in the QMRA paradigm.

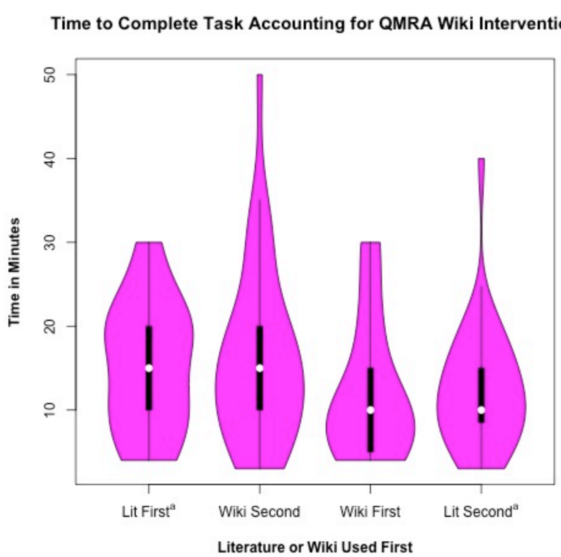

Figure 2. Violin plots for completion time, a – Lit refers to literature

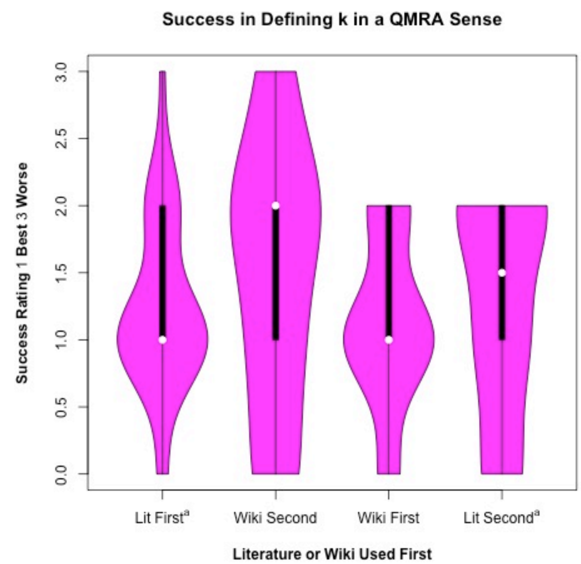

Figure 3. Violin plots for success at defining k, a – Lit refers to literature

Figure 4 shows that when the QMRA Wiki was used first for the interventions, that there is a great similarity to the results from the literature second group. It is also interesting to note that there is a second level density also being developed at the rating of 1 similar to what was seen in figure 3. However, while not significant with regards to this density region in the Wiki first group, there is some level of improvement that can be seen as compared to literature first. When being asked to define risk (figure 5) we can see that there is no significant difference in response success rates between any of the interventions. The literature first has its density spread over more of the range of ratings, however, there is not a significant difference to outline for these results.

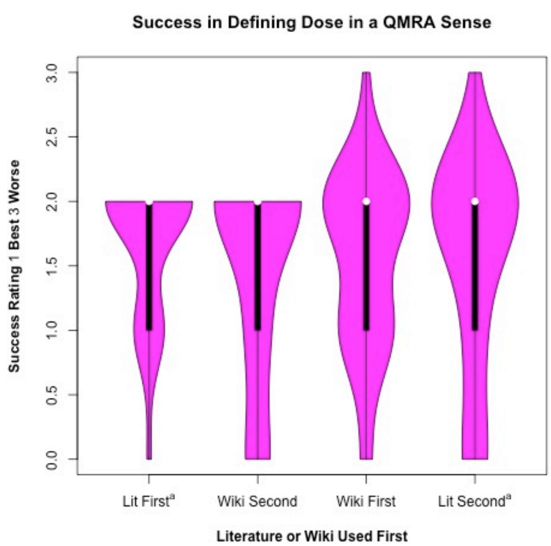

Figure 4. Violin plots for success at defining dose, a – Lit refers to literature

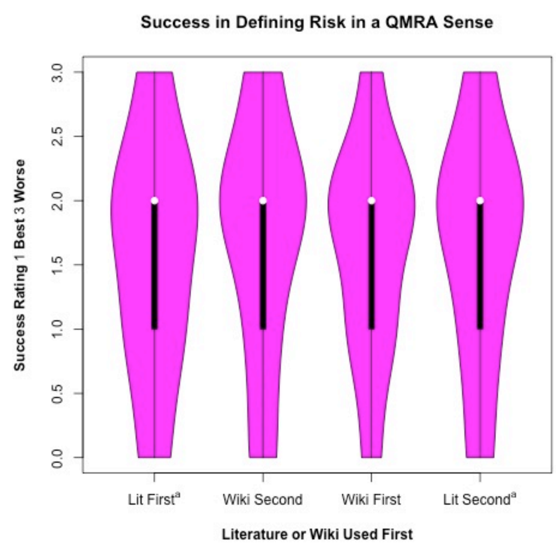

Figure 5. Violin plots for success at defining risk, a – Lit refers to literature

Conclusions

Overall there is small improvement in the student's abilities in QMRA after the Wiki intervention. Additional comments in the survey and in the class demonstrate that the QMRA Wiki as it is now is hard to navigate and pull information from. The search does not respond as expected (default expectation in Wikipedia) and browsing large tables can be arduous and inefficient. The success rates are not consistent but comparing the changes in density in success ratings (figures 2 – 5) and completion time when the Wiki was used first gives credence to its efficacy in a classroom environment.

The QMRA Wiki is currently in the beginning stages of a complete overhaul. Given the transdisciplinary nature of QMRA a traditional Wiki using the MediaWiki or Semantic MediaWiki environment is too constrictive. There is not the availability to allow for smart searches and adaptive responses from the database. For these reasons a new content management service is being developed for the third iteration of the QMRA Wiki.

A similar study to this one will be performed using graduate students and QMRA III participants. We will determine if there is a trend of improvement in using the QMRA Wiki. However, it should be noted that the QMRA Wiki should be introduced as early as possible so the students are not confused in how to interact with it before beginning instruction.

Acknowledgements:

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