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Context in an Interdisciplinary Algebra Writing Assignment

Teaching mathematics in real-word contexts is a strategy to make math relevant for undergraduate students. However, very little research exists on students' methods of integrating contextual and mathematical knowledge through writing. This study uses an interdisciplinary writing assignment to investigate the relationship between students' written portrayal of context and mathematical argumentation. A qualitative analysis of 41 essays found that writing contextual details was associated with the use of multiple data sources and with the mathematical support of an argument. Writing about contextual details allows a student to create a sense of cohesion between mathematics and the thesis of the essay. The study suggests that pre-writing activities connecting context and mathematics may help students integrate interdisciplinary knowledge.

Traditional algebraic word problems set mathematical tasks in a terse, minimalist real-world scenario. In contrast, some contemporary curricula embed mathematical investigations in complex, interdisciplinary situations. Students may investigate whether needle exchange programs reduce HIV infections among drug users (Stocker, 2006), design efficient snow removal routes (Hadlock, 2005), or learn about symmetry through multicultural artistic practices (Ascher, 1991). Ideally, students will use mathematics to form nuanced opinions about the situation, but instead, they may treat mathematical and contextual analysis as separate domains of knowledge without creating an integrated understanding. Very little research has addressed the ways in which students themselves react to learning math in context.

Writing assignments are flexible and authentic ways to investigate the

connections students make between mathematics and real-world situations. Writing a response to an interdisciplinary math lesson requires students to write about the details of context that they found most compelling. Incorporating contextual information into mathematical writing is a complex skill. The depth of contextual detail, the quality of the mathematical work and the degree to which students relate this work to the context are likely to vary a great deal. Interdisciplinary math writing assignments will allow teachers of connected math curricula to determine their students' ability to synthesize different areas of knowledge.

Writing in mathematics classrooms usually directs students to reflect on the process of solving an assigned problem. Students may document their learning, questions, and feelings in a math journal; write explanations of mathematical ideas for their classmates; or describe their own learning processes (Burns, 2004; Nahrgang & Peterson, 1986; Pugalee, 1997). The write-to-learn movement has produced two major outcomes. First, writing assignments can produce small positive gains in test scores and other traditional measures of students' learning, particularly for conceptual and procedural competencies (Bangert-Drowns, Hurley, & Wilkinson, 2004; Jurdak & Abu Zein, 1998). Second, assignments that strengthen metacognitive skills have the greatest impact (Bangert-Drowns, Hurley, & Wilkinson, 2004; Pugalee, 2001).

Math writing assignments are likely to become important components of first year curricula that are structured around service learning classes and learning communities. Classes that involve a service-learning component (Hadlock, 2005) help students see math as a connected and purposeful subject as they become critical participants within their communities. Learning communities help struggling learners by giving them a supportive cohort of peers and by creating meaningful links among academic disciplines (Malnarich, 2005; Tinto, 1998). Because learning communities support students in high-risk classes, mathematics may be a priority for many restructured first-year undergraduate programs.

In addition to these organizational shifts, several approaches in mathematics education depend on interdisciplinary content. Ethnomathematics (Ascher, 2002; D'Ambrosio, 1985) and culturally relevant teaching (Ladson-Billings, 1995) connect mathematics to students' own cultural heritage. The mathematics for social justice approach (Gutstein, 2003; Gutstein & Peterson, 2005; Stocker, 2006) asks students to use mathematics to reveal inequalities in their communities or in global contexts. While these perspectives are not always framed as interdisciplinary, they require teachers to introduce topics from various fields of study, including anthropology, sociology, political science and economics. In-

terdisciplinary math prepares students to become critical and engaged adults who can use math to question social practices (Skovsmose & Valero, 2001).

Student-centered, interdisciplinary math writing assignments can help students express connections among varied curricular experiences. They can address recommended interdisciplinary learning outcomes, such as improving content knowledge, relating different fields of knowledge (Ackerman & Perkins, 1989), and connecting mathematics to personal values (Field, Lee, & Field, 1994). Most importantly, interdisciplinary math writing creates an inclusive learning opportunity through an asset model of student abilities rather than a deficit model (Green, 2006); students can apply all their knowledge and experiences to the task of understanding mathematics. Teachers and learning support professionals who work in programs that emphasize interdisciplinary learning will need to consider how to design interdisciplinary math writing assignments and how to scaffold students towards associated learning goals.

The assignment described here differs from the write-to-learn approach. In our study, undergraduate algebra students wrote a position paper on funding malaria intervention programs in Africa and supported their views with mathematical arguments. Students were free to choose any mathematical work—a calculation, a graph, or an equation—that would support the position they took on the malaria issue. Presumably, students incorporated math that they had already learned and that they believed they understood. In this sense, students were not writing to learn, but rather, writing to create meaning.

Our study used a qualitative research design to analyze students' strategies for integrating knowledge in an interdisciplinary math writing assignment. We assessed the level of contextual detail that students presented in their essays, their use of multiple sources of data, and their success in supporting their opinion with a mathematical calculation. The purpose of our study was to determine whether there was an association between students' written portrayal of a contextual issue and their use of mathematics to express an opinion. This mirrors what we hope students will do as adults: to create an informed position on social issues incorporating both situational and mathematical knowledge.

Method

Participants and Assignment

The students in this study ($N = 41$) were enrolled in an introductory developmental algebra class at a large, midwestern university. The class was ethnically and linguistically diverse. Many students from Southeast Asian and East African immigrant families knew of international health

issues from personal or familial experience. Several algebra topics during the semester were presented using international public health data as part of an on-going research project on teaching standard algebra topics through anthropological contexts (Staats, 2006, 2007). Interdisciplinary learning goals for these units included the geography and transmission of infectious diseases and measurements of disparities in quality of life in various countries.

The assignment was a take-home essay attached to an otherwise standard, in-class algebra test. Students read an article by Jeffrey Sachs (2005) in which he claims that an annual funding level of $3 billion would be sufficient to control the malaria epidemic in Sub-Saharan Africa. They wrote a paragraph in response to the article using the grading rubric in figure 1.

Figure 1. Interdisciplinary algebra assignment and grading rubric.

According to a professor who advises the United Nations, $3 billion dollars in international aid each year would be adequate to control malaria in Africa. Would you support this effort? Is $3 billion dollars a realistic funding goal? Feel free to express your honest opinion, but please use *data and mathematical calculations* in your answer.

Grading:	You express an opinion:	2 pts.
	You cite data:	2 pts.
	You perform a calculation:	4 pts.
	Your calculation supports your opinion:	4 pts.

References (please indicate your sources of information)

- ❑ Achieving the Millennium Development Goals—The Case of Malaria, J. Sachs.
- ❑ Fact Sheet on Infectious Diseases
- ❑ U.N. Human Development Indicators handouts
- ❑ Other: _____

By this point in the class, students had studied percents, proportional reasoning, graphing lines, and making predictions using linear models. The open-ended, unstructured character of the assignment allowed students many options for using mathematics from the classroom in developing a position statement. Verbal instructions emphasized the importance of using data to perform a calculation rather than simply reporting statistics. In addition to data provided in Sachs' article, students could use a fact sheet on infectious diseases and a summary of economic performance of countries around the world (Human Development Report, 2003) that were handed out in class.

Procedure

We collected and analyzed 41 student essays using a qualitative research design that employed content analysis (Bryman, 2004; Neuendorf, 2002) to identify co-occurring features within students' essays. Coding required three stages: developing a shared coding scheme, assessing inter-rater reliability, and conducting a chi-square analysis of the coded essays.

We developed a coding scheme by analyzing five essays jointly. We coded whether students used more than one data source, wrote about the context in a detailed way, and supported a verbal argument with mathematics. We also classified the types of arguments that students presented.

Once we established a coding scheme using five essays, we independently read and coded the remaining 36 essays. The original five essays were removed from the analysis of inter-rater reliability to avoid overestimating the level of agreement. Given the small sample size of 36 essays, we coded each category as present or absent. The Cohen's kappa for our level of agreement was 0.70 ($N = 36$), an adequate level of agreement (Bryman, 2004, p. 174). We discussed differences in our coding of the essays until we were able to reach a consensus for each category of each essay, and we reassembled the collection of 41 coded essays.

Chi-square independence tests were used to determine whether there were significant relationships among students' use of detailed contexts, multiple data sources, and of mathematics to support an argument. We checked to ensure that expected values for all cells were greater than 5, so that the tests were valid.

Results

The chi-square tests returned two significant relationships. First, there was a significant relationship between students' use of contextual details and their use of multiple data sources, $\chi^2\,(1, N = 41) = 4.67$, $p < 0.05$. Students who used multiple data sources also tended to write their essays with several contextual phrases. Second, there was a significant relationship between students' use of contextual details and successfully supporting their argument using mathematics, $\chi^2\,(1, N = 41) = 10.1$, $p < 0.005$. Students who interpreted their argument in terms of their calculation were also likely to include specific contextual references.

Discussion

The results suggest that students' portrayal of contextual details was associated with specific mathematical choices. Writing vividly about the context was linked to the use of multiple data sources or to the use of mathematics to support an argument. Students' use of contextual

details, however, did not co-occur simultaneously with use of multiple data sources and effective mathematical argumentation. This co-occurrence took place in only 13 of 41 essays. Some students, for example, used contextual details and multiple data sources but did not use math effectively in their essay. An essay could support one of the significant results and serve as a counter example for the other.

Coding Issues

As we coded the essays, we identified specific words and phrases that justified each rating. This introduced several issues. At the outset, we tried to identify phrases that represented students' sense of values in order to present evidence of students' personal engagement with contextualized mathematics assignments. However, we were unable to agree on a coding scheme for the expression of values. In some essays, students' values emerged globally, without specific phrases that could be used as evidence. So we abandoned this category and focused instead on the more bounded categories of specific contextual words, data sources, and connections between thesis and mathematical work.

To rate the level of contextual detail, we identified phrases that referenced life in Africa, malaria prevention and treatment, and associated social, political or economic issues. Because the terms *Africa* and *malaria* are mentioned in the question statement, we did not consider these words as references to the context. Nor did we count high-frequency phrases like *developed countries*, *third world*, and *United Nations* because we considered these as too general or vague to represent a detailed engagement with the situation. An essay was rated as using a detailed context only if it made several specific references to issues or stakeholders associated with malaria in Africa.

Because many students selected similar data as the basis of their mathematical argument, almost all the essays could be coded in terms of four argument types.

1. *Attainability*. This argument considered the feasibility and methods of raising funds to control malaria.
2. *Investment*. Some students wrote about whether donor nations would have their loans repaid and whether assistance money would produce substantial economic growth.
3. *Cost per Case.* Many students constructed a ratio for the amount of money needed per person to reduce the risk of malaria or the amount of money that could be spent for each diagnosed malaria infection.
4. *Need.* This argument addressed the number of people who are at risk for malaria infection. Some students using this

argument simply cited data on the magnitude of the malaria epidemic, and many used rates of change to predict future levels of malaria.

An essay was rated as using mathematics to support an argument if two conditions applied. First, the student had to actively engage math rather than cite statistics. Performing a calculation, writing an equation or expression using mathematical symbols, and drawing a graph are all examples of active mathematics that students used in their essays. Second, once we had defined the argument types used in the essay, we identified written phrases that interpreted the mathematics in terms of one of the argument types. This process was independent of the level of contextualization in the essay because students were able to present an argument using very general terms.

We took care to define each category neutrally so that students' opinions and skills would not affect the rating given for the category. For example, two students could use the same argument type without agreeing with each other. Similarly, we emphasized students' rhetorical use of mathematics rather than its correctness. Incorrect use of mathematics affected the grading of the assignment, but not the analysis of students' writing that we present here. So, if a student performed a calculation incorrectly but used the result to further his/her argument, the essay was coded as one that used mathematics effectively to justify the argument.

Contextual Detail and Rhetorical Cohesion

A student's decision to include situational details in an essay may seem quite distinct from the mathematical choices of selecting data and performing calculations. A student who chooses to exemplify her opinion by listing, for example, several wealthy countries or effective malaria interventions is, in an immediate sense, making a writing choice. On the other hand, using multiple data sources and supporting an argument with mathematics are more immediately mathematical decisions, expressions of the student's quantitative literacy. We must account for why certain mathematical choices co-occur with imaginative and distinct descriptions of the malaria epidemic in Africa.

While content analysis can tell us that statistically significant relationships exist among the variables associated with student essays, it does not shed light on why students might have made these choices. A close reading of students' essays suggests that writing contextual details may serve the function of creating rhetorical cohesion. A student who cites data from two sources needs to explain the nature of the data in order to establish why they are relevant to each other. Similarly, supporting an

argument with mathematics may not directly raise the issue of context, but it does connect different parts of the essay, that is, the controlling idea and a calculation. Writing about situational details may help a student to interpret mathematical work and to explain its relevance within a written argument.

Linguistically oriented text analysis offers a more detailed description of students' strategies for linking contextual and mathematical statements (Halliday & Hasan, 1976; Witte & Faigley, 1981). Cohesion in student writing can be studied systematically by identifying phrases that reference other phrases within the text or ideas external to the text. Many types of referencing exist in any piece of writing. *Conjunctive cohesion*, for example, comes into play when words like *however* and *therefore* establish logical relationships among ideas (Halliday & Hasan, p. 230; Witte & Faigley, pp. 192-193). In this discussion, we focus on *lexical cohesion*, "the predominate means of connecting sentences in discourse" (Witte & Faigley, 1981, p. 193). Lexical cohesion acts through the associated meanings of words. *Collocation* is a form of lexical referencing that involves listing examples of a general concept (Halliday & Hasan, 1976, p. 288). A student used collocation in his sentence: "If malaria were controlled, Africa would produce about $12 billion dollars more per year which is not only a good investment to Africa but to the whole world (e.g. economics, tourism, trade, etc.)." The student creates a sense of cohesion when he explains the phrase "good investment" in terms of the positive outcomes of economic improvement, tourism and trade. Another type of lexical cohesion is *reiteration*, the restatement of a word or phrase with a "near synonym" (Halliday & Hasan, 1976, p. 288). A student commented that spending $3 billion to reduce deaths among 3 million people "is not enough because medicine/drugs, medical technology and seeing doctor cost more than $1000 for each person." In this statement, "medicine/drugs, medical technology and seeing doctor" establish reiterative cohesion because they are restatements of similar ideas.

Collocative and reiterative cohesion can describe the rhetorical role played by many contextual words that students used in their essays. Each of the following sample essays is presented as the student wrote it, with original paragraph divisions and original errors in spelling, grammar, and mathematics. Because we are concerned with cohesion, each essay is presented in its entirety.

Weak Contextualization and Cohesion

In the first selection, contextualization, multiple data sources and supporting an argument with mathematics are all rated as absent. The

author uses a *cost per person* argument based on Sachs' (2005) estimate that malaria kills around 3 million people annually, mostly in Africa. The author suggests that more than $3 billion would be necessary to have an impact on Africa's malaria epidemic.

> No it wouldn't be because if you were to maintain $3 billion dollars in each year you can't help out 3 million people. The calculations that would help is for example 2006 = $3 billion / 3 million = $1,000 each person. If this continuously keep it that way, it will not work and help out to keep the malaria under control. The cost must be higher.

Selection 1

This writer expresses her opinion clearly and offers a correct mathematical statement using data that is available in Sachs' article. She does not, however, link her mathematics to the thesis of the essay by explaining why she believes that one thousand dollars per person is insufficient funding. If she had brainstormed more details of the situation, she might have listed materials and services necessary for a malaria control program that would exceed this level of expenditure. Details of context would have helped this writer elaborate on her sense that more funding per case is needed, and they would have established stronger cohesion between her thesis and her mathematical work.

The next selection was rated as lacking a detailed context and lacking multiple data sets, but supporting an argument with mathematics. It presents an *attainability* argument through the use of a formula to calculate the level of aid that high-income countries should contribute.

> Yes, I support this effort 100% But honestly, 3 million dollars is not enough for the malaria epidemic. But I also strongly feel that the U.S should be the only one trying to help provide aid. It should be all the 1st world countries giving 3% of the countries income to aid, and not only for malaria but everywhere else. So take y = x(.03) x is for the countries income + y is the country.

Selection 2

The student seems to have meant that the U.S. should not be the only contributor of $3 billion. He has fulfilled the requirements of the question, but if he had developed further his idea of shared international responsibility for malaria funding, he might have been obliged to introduce more contextual details. If, for example, the student had tested his equation with the $10,065.3 billion GDP of the United States (Human Development Report, 2003, p. 278), he would have obtained the U.S. contribution of $302 billion, far in excess of the $3 billion that Sachs recommends as a global donation level for malaria prevention. Sample

calculations using his equation would have generated a list of examples, forming a collective cohesion link between additional data and his thesis on shared funding responsibility. If this student had followed his reasoning one step further, he probably would have needed to describe potential donor nations in a more engaged and more cohesive essay.

Detailed Contextualization and Stronger Cohesion

In the third selection, a student develops a similar *attainability* argument, suggesting that $3 billion could easily be donated by five of the world's wealthiest countries. The student also uses a *need* argument when she writes that this funding "would also benfit (sic) the people in the developing country." The essay was rated as using a detailed context because it lists five wealthy countries and estimates their combined income. It uses multiple data sources and supports an argument with mathematics.

> I would support this effort because the money put together by the rich nations would not put a dent in what they are worth. It would also benfit the people in the developing country. It is a realistic goal to achieve, but a time table to achieve it would need to be set and enforced.
> Going by the 2003 economic performance handout, the top five richest countries were the U.S., Japan, Germany, U.K. and France. These five countries grossed in the thousands of millions of dollars. Just $600,000 per year donated be each of these countries would equal the $3 billion needed to assist the African countries so they can control malaria.
> $600,000 x 5 countries = $ 3 billion

Selection 3

The student seems to have meant that $600 million, rather than $600 thousand, would be required from each of the five countries. Despite this mathematical error, she uses contextual phrases to link her calculation carefully to the essay's thesis, phrase-by-phrase, using reiterative lexical cohesion. The "money required for malaria prevention" is a restatement of the $3 billion; the "wealthiest countries" of the first sentence becomes "5 countries" in the math statement; and the phrase "small portion of the combined income" refers to the $600 thousand in the math statement. Her attainability argument is supported by her calculation, and only minor revisions would be necessary to produce a mathematically correct, logical argument. In this essay, the use of contextual details allows the student to create a sense of cohesion between mathematical work and a thesis statement.

Furthermore, the student was obliged to introduce details of contextualization, listing five wealthy countries, in order to explain her use

of multiple data sources. She used the Human Development Report (2003) to identify the countries and their incomes. She suggests that the $3 billion target can be achieved through attainable contributions from each of the five countries. The $600,000 contribution of each country becomes a collocative cohesion link to the $3 billion funding level. By listing countries that are potential donors, she establishes links between the two data sources. She could not adequately describe the data that she was using without introducing these details of context.

The last selection was also rated as using a detailed context, multiple data sources and using mathematics to support an argument. The student writes about many contextual details including HIV, endemic versus epidemic diseases, medications, mosquito nets, the forty-seven countries of Sub-Saharan Africa, and relevant academic disciplines. While Sachs' article focuses on the loss of lives in Sub-Saharan Africa, this student's use of data and mathematical argumentation are based on the idea that funding could be used for prevention of malaria as well as treatment. For this reason, he considers a program that would serve a wide, regional population of healthy, but at-risk people along with those who are already ill.

> HIV/AIDS is the most important issue to me: especially in America, but since this question is regarding malaria, I will make my argument around that.
>
> With malaria being listed as one of the top three epidemics facing the world today, especially in Africa, it is important to know the population of Africa, where malaria is endemic vs. epidemic and how to best use the proposed $3 Billion.
>
> According to the CIA World Factbook the July 2006 population of the African continent was estimated to be at 910,844,133. The world health Organization lists Sub-Saharan Africa as being the most susceptible to the malarian mosquito vector. Given more time I would research (and would enjoy doing it) the population of the 47 countries in Sub-Saharan Africa. With this data I would be able to determine, approximately how much money could be spent per person by utilizing the following formula:
>
> x / 3,000,000,000
>
> x = # of people in Sub-Saharan Africa.
>
> This result would show us how much could be spent, per person in the control of malaria. Not having all of the information needed, such as the cost of medication insecticides, netting, etc. I can't, and would not feel right, in giving an answer as to whether or not the $3 Billion would be sufficient in fighting this epidemic.
>
> Epidemiology and medical geography is one of my educational

interests. Given the complexity of this situation and the lack of data available without doing further research, I can only say I would support the $3 Billion international aid if it could be proven to make a difference.

NOTE: Sorry for the length of this portion of the test. I find this information/topic intriguing and difficult to sum up in one paragraph.

Selection 4

The essay presents a *cost per case* argument through a formula that calculates the ratio of Sub-Saharan population to the recommended $3 billion funding level. A *need* argument is introduced with the observation that malaria is "one of the top three epidemics facing the world today, especially in Africa." The student's interest in malaria prevention compelled him to seek new sources of data for the population of the Sub-Saharan region, but he has only found the population of the continent of Africa. His reference to "47 countries" restates this distinction between Africa and the Sub-Saharan region. This reiterative cohesion helps him explain that the data in the article and in his source are not adequate to answer the question fully. His contextual references to the continent, the Sub-Saharan region, and its countries help him coordinate two different data sources in a critical manner.

Because he does not have the data that he thinks is necessary, the student writes a formula that is an example of a cost per case argument: "x / 3,000,000,000" followed by "x = # of people in Sub-Saharan Africa." The contextual details that the student lists after his cost per case formula—medications, mosquito nets, and insecticides—are components of a malaria control program to be covered by the $3 billion that appears in the denominator. Listing these details establishes collocative cohesion between his mathematical formula and the need argument that he introduced at the essay's beginning. In this essay as in the previous one, contextual details help create cohesion between mathematical work and the written thesis.

Conclusion

These selections demonstrate the cohesive roles that contextual references play in interdisciplinary student writing. Students who illustrate their social, political and economic imaginations with many contextual details tend also to draw mathematical information from multiple sources or explain carefully how their calculations support their argument. Contextual phrases help students explain why different data sets are relevant to a social question and help them connect mathematical work to written opinions. Creating these connections in writing is a first step

towards synthesis of different domains of knowledge, a central issue in interdisciplinary learning.

Contextualization in students' interdisciplinary mathematics writing is worthy of further attention by both researchers and practitioners. Mathematics instructors and learning center tutors who assist students in interdisciplinary math classes may find it helpful to pay attention to the ways in which students write about context. These results suggest several approaches to designing interdisciplinary writing assignments. First, the essays presented here address the value of designing assignments around multiple drafts. They are useful from a research viewpoint because they demonstrate students' original and independent writing strategies, but the final essays would have been much better if students had completed multiple drafts rather than a single take-home assignment. Second, it appears that multiple data sets create the need among students to consider the real-world situation more deeply. In many disciplines, students commonly coordinate data from different sources, but this is less common in first-year university mathematics classes. This study suggests that creating an assignment involving multiple data sets can give students a reason to imagine realistic aspects of the situation.

If interdisciplinary mathematics becomes more prominent in first-year programs through service learning, linked courses and multicultural curriculum, learning center support staff may be called upon more frequently to help students write coherent essays that involve mathematical work. Scaffolding activities may help students connect the meaningful aspects of the situation with mathematics (Mendez & Taube, 1997). Concept mapping and other pre-writing activities that build connections between context and math may help students integrate knowledge from different sources and different disciplines. A learning center tutor, for example, could ask students to brainstorm words that they associate with an interdisciplinary scenario and then annotate the list with the mathematical units that would allow these ideas to be measured. Units are the most immediate connection between mathematics and context, because they always refer to the agents and processes of observable situations. Students might then build mathematical models relating the variables, but they would need to dedicate appropriate work time to locating the data through library or Internet searches in order to test the models.

Alternatively, a writing tutor could help students develop a concept map to trace issues and activities associated with their data into the contextual situation. Students could take a more critical perspective on their data by contextualizing it with the questions:

1. Am I using the correct units for my data?
2. What real-world situations create these data?
3. What do the data measure?
4. How were these data collected?
5. What policies, problems or resources influence these situations?
6. What situations are left out of this data collection process?

This kind of concept map could help students become more critical about linking their mathematical calculations to their opinions.

Contextual descriptions represent students' imagination of a real-life scenario. When students write contextual details in an interdisciplinary mathematics essay, they describe the aspects of a situation that they think matter. In this study, students' ability to write a meaningful statement using mathematics required them to present images drawn from their knowledge of geography, economics, and international public health. Contextual description and mathematics were linked in students' writing through their attempts to make sense of interdisciplinary information. If students are encouraged to attend to context in their math writing, they are likely to sharpen their quantitative skills and their ability to express the relevance of mathematics in the world.

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