STEPing to Sustainability in a Graduate K-12 Partnership

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Abstract - **The Science and Technology Enhancement Program (STEP) at the University of Cincinnati (UC) links university faculty, graduate students, secondary teachers, and secondary students in an effort to enhance student competence and promote awareness in STEM disciplines. Graduate-student Fellows gain valuable experience assisting and teaching in urban high schools. This NSF-funded project has generated hundreds of STEM lessons suitable for use by secondary school teachers. The sustainability of the program is the focus of this paper as viewed through the lessons, students, teachers, website, and the STEP Fellows. Over the past eight years, Project STEP has interacted with all of these groups to create and implement a successful community partnership. Conclusions are presented and concerns addressed. Project STEP students, teachers, and Fellows demonstrate increased awareness of the requirements and challenges of effective STEM education.**

Index Terms – Engineering, Partnerships, Sustainability, STEM, Teachers

INTRODUCTION

A project that lasts beyond funding, can obtain new funding, or can branch into new projects is considered sustainable. The University of Cincinnati's (UC) Science and Technology Enhancement Program (STEP) is a NSF (National Science Foundation) GK-12 (Graduate teaching Fellows in K-12 education) grant, currently in the eighth year of a ten year grant life. Since 2001 Project STEP has employed UC graduate students in the STEM (science, technology, engineering, and mathematics) fields to be liaisons of current STEM research to the surrounding GK-12 community. Here we focus on the last three years (2006 to present) of STEP, which represent the second phase of funding. The primary focus of this phase is on the effectiveness of the training and its impact on the participating graduate students, or STEP Fellows.

PROJECT STEP

The chief goal of this project is to produce scientists, engineers, and secondary mathematics and science educators who are experienced in developing and implementing authentic educational practices. The graduate students, called STEP Fellows, are the main focus of the grant. The STEP Fellows, 15 in the last three years, are trained to bring their complex graduate research to an understandable and interesting K-12 level. This process instills better communication skills in the STEP Fellows and breaks any reservations of working with the K-12 environment once employed as a university faculty member. The secondary goal of Project STEP is to impact student learning by relating STEM content to urban city issues through the use of hands-on, technology-driven, inquiry-based projects that also relate to desired curriculum standards. Students need an understanding of STEM and the reasons to pursue STEM careers; over 3,000 students have been exposed to STEM lessons in the past three years with STEP. Teachers of these students are involved in this process as well, and 36 different teachers have participated in the STEP program since 2006. Lastly, Project STEP focuses on the sustainability of the program itself. The university faculty participants, six primary investigators and four coordinators, play a large role in facilitating the promotion of community partnerships with teachers, K-12 students, and Fellows. In this paper, we outline the sustainability of this program beyond the initial funding and the time allotted for the grant based on collaboration between the STEP Fellows, teachers, students, website, and university faculty that work with this program.

Recall, sustainability is a three-pronged idea where current projects can promote ideas and programs that last beyond funding, new funding can be acquired, or new projects created as parts of the original begin to flourish. Searches in the literature for "sustainability" provide examples of environmentally correct buildings or practices, medical procedures, engineering topics, and various programs both outside and inside of the US. Historically in education, project sustainability has not been studied outside of the confines of reports to the grant providers. Perhaps this happens from lack of use of the terminology "sustainability." Sustainability, defined here as longevity of a program past funding, is of vital importance to GK-12 community partnerships as the form can become a model for the promotion of STEM content that permeates the various levels of the education process.

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THEORETICAL FRAMEWORK

We embrace a socio-cultural theory as the framework of this research. We look to the process of learning, not the product produced. Socio-cultural theory has grounding in the work of Vygotsky[1] and Bandura[2]. There is an emphasis on the interaction between learners and learning tasks. Since STEM education is currently in the spotlight, gaining insights into Project STEP's sustainability using a socio-cultural perspective is important. Working with the urban youth in Cincinnati, Roth and Lee's [3] statement that "a researcher… does not separate the poverty or culture of urban students' home lives from conditions of schooling, consideration of the curriculum, problems of learning, or learning to teach under difficult settings" (p. 218) becomes vitally important. Wertsch [4] also shows the relationship between all aspects of the mind and setting as inseparable in the process of learning. In this way socio-cultural theory is about the whole scene of learning, the process, not the individual parts in isolation that create the scene. This "whole scene" approach will sharpen our understanding of how STEM research, taught by present day graduate students (of which most will become future university faculty), can translate and then activate knowledge through Project STEP lessons, students, teachers, and Fellows.

To put the contents of this paper in proper context, it will be appropriate to first briefly describe the teacher training provided to the Fellows as they mature to develop STEM lessons and implement them in secondary school mathematics and science classes. The up-front preparation occurs in "Instructional Planning," a formal three credit hour course offered by the College of Education, taught primarily by the Grant Coordinator (primary author) with support provided for a College of Education faculty member who is a Co-Principal Investigator on the grant. The course addresses a wide range of topics: STEM achievement standards, lesson and unit planning, instructional models of teaching, instructional management, the nature of students, skills of connecting with students at a personal level, understanding student cultures and responding appropriately, and assessment or evaluation of student learning and instructional efforts. The course is scheduled during the summer before the Fellows enter the classrooms, but while they are engaged with upper elementary to high school students in an enrichment summer academy held at UC. When the school year begins, Fellows enroll in another Education course, "Field Practicum," which is a one credit hour course taken in the fall, winter, and spring quarters. This course supports Fellows as they encounter (frequently) unfamiliar territory upon their entry into the schools. They are required to focus on important aspects of the teaching-learning situation and the culture of the school and students as well as their relationships with the teachers. Structured and focused discussion sessions are managed by the Grant Coordinator. This conversation leads to community building among the group of Fellows, especially since returning Fellows (in their second year) are included. Continued preparation and the refinement of the skills of Fellows for their roles in schools is accomplished through the weekly Field Practicum seminars in the spring quarter where they share and discuss school experiences and collaborate on current and future efforts as a team. These seminars are managed by the Grant Coordinator along with university faculty and guest presenters.

METHODOLOGY

Data for this paper was generated from a lesson rubric which was used to evaluate the STEP lessons taught over the past three years. Two online surveys, one for the STEP teachers and one for the STEP Fellows, also supply information that covers the last three years. Student (K-12) feedback forms, filled in after STEP lessons, are also included in the analysis.

STEP LESSONS

Each STEP Fellow creates at least five major STEM lessons, most including several days of teaching, during one academic year. Most of the lessons that have been created since 2006 focus on secondary STEM content. In order to address parameters critical in contributing to the sustainability of STEP lessons, a rubric was created to evaluate 34 STEP lessons taught from 2006 to 2008, which are presented in Table 1. Each lesson was assessed based on whether it addressed, partially addressed, or did not address the following components: science, technology, engineering, math, assessments, misconceptions, educational standards, real-world applications, social impacts, and career connections.

The results obtained by reviewing the lessons in Table 1 are presented in Table 2. Evaluations indicate that 59, 62, 66, and 78% of STEP lessons analyzed contain components of mathematics; engineering, technology, and science, respectively (see Table 2). Interestingly, 97% of lessons at least partially contain components from at least three of these disciplines. When evaluating lessons that definitely contain elements from, science, technology, engineering, and/or math, 82% contain content from at least two of these four STEM areas, suggesting a trend that STEP lessons are interdisciplinary.

More than 97% of lessons address or partially address the use of multiple learning styles, and more than 93% of STEP lessons contain a real-world application. While nearly 60% of lessons deal with societal or social impacts, less than one-third of the STEP lessons focus on connecting the material to potential careers. Of interest is that only 16% of STEP lessons address potential misconceptions associated with lesson content, which may be explained by the evolution of the lesson plan development requirements as Project STEP has itself evolved over the last eight years.

STEP lessons are created by the Fellow, but are enhanced by both the university faculty working with the grant (Principal Investigator or PI and Co-Principal Investigators or Co-PI) and the university faculty working directly with the graduate Fellows on their studies (Research Advisors). These university faculty groups can have a big impact on the Fellows' research, the level of participation in the project,

and the quality of the lessons. Support from university faculty is essential. The well being of the Fellow, including discussions concerning the frustrations that they face, can be impacted if the advisor views the Fellowship as a completely separate job and not part of the graduate educational experience of the Fellow. Each Project STEP Fellow has one of the project's Co-PI as her/his advisor and is scheduled to meet with the Co-PI biweekly. The impact of these meetings and the guidance that both the PI's and the research advisors provide is another area of future study for this grant.

TABLE 1
STEP LESSONS REVIEWED

13 Mathematics Lessons	21 Science Lessons
1. Fuel Cells	1. Alternate Fuels
2. Geometry Surface Area	2. Antibiotics
3. Logarithms in Science and Engineering	3. Ants to People
4. Pre-Calculus Log	4. Atomic Inquiry
5. Real World Budgeting	5. Bridge Building
6. Skittle Statistics	6. Computer Evolution
7. Slopes of Cincinnati 1	7. Drinking Water Dilemmas
8. Slopes of Cincinnati 2	8. Exploring How Urbanization Affects the Water Cycle
9. Survey Engineering Inclinometer	9. Food for Thought
10. Suspension Bridges	10. Genetic Engineering
11. Tantalizing Triangles	11. Heat Transfer/Surface Area
12. Triangle Transformations	12. Ionic Covalent
13. Trigonometry Super bowl	13. Movie Making and Podcasts
	14. Planetary Processes
	15. Polymer Properties
	16. Range of Motion
	17. Starr Minors
	18. Tolerances in Eng. Design
	19. Vectors
	20. Wastewater Treatment
	21. Watershed Model Design

STEP Lesson Characteristics

We begin our analysis of sustainability with STEP lessons which are the most universal and accessible parts of our program. All the STEP lessons, regardless of content or engineering discipline, whether they deal with Wastewater Treatment, Vectors, Genetic Engineering, or Fuel Cells, include elements that address the "ASC" acronym that STEP lessons are built on. Emphasized through course content, "A" stands for "Applications to the Real World," "S" stands for "Societal Impact," and "C" stands for "Career Connections." In some of the lessons these three are explicitly stated in the summary of the lesson, but in other lessons "career connections" and "applications to the real world" are made in the main activity/demonstration of the lesson. Societal impacts, even when they are not explicitly stated, are clear throughout the lessons (how does the subject matter relate to us as students, our schools, our families, our communities and society as a whole). Another consistent characteristic is that most of the lessons address multiple learning styles or intelligences. Regardless of the subject content, most lessons addressed visual-spatial, interpersonal and bodily-kinesthetic activities where students are engaged in activities, moving around the classroom, working inter-dependently and referencing either power-point slides or other visual media throughout the lesson. Addressing common secondary student misconceptions is an additional strength of the STEP lessons. Drawing student attention to their misconceptions in the content or in the presentation of new information is vital for the lesson to be truly effective. Misconceptions of students are often implied, but not explicitly stated in the lessons, and this aspect of lesson development deserves more STEP Fellow attention. Specific instructions (expectations for Fellows) about content and format of STEP lessons have evolved over the years that the program has been in existence. Currently, the customary STEP lesson format includes specific details regarding standards, objectives, misconceptions, applications, societal impact, career connections, and learning diversity. Earlier written lesson plans may not explicitly mention these elements, but often include them implicitly throughout the student lessons and activities presented.

Generally, multiple STEM components are well addressed in the lessons that have more clearly defined mathematical content (such as "Logarithms in Science and Engineering") compared to lessons where mathematics is incorporated in basic calculations such as computing runoff volume when using a model of the urban water cycle (in "Exploring How Urbanization Affects the Water Cycle"). Despite differences, all STEP lessons contain STEM components that are useful for teachers, available around the globe (via the website), and contribute to the sustainability of Project STEP.

STEP STUDENTS

We move our attention from the lessons to the students that Project STEP hopes to inspire. Working with nine different schools since 2006, and 36 different STEM teachers, over 3,000 students have participated in STEP lessons. Students are involved in this STEM-promoting community partnership because their school participates as a STEP school; however, student activity feedback forms collected after every STEP lesson display the impact of the program on these students. Future scientists and engineers must have access to scientific information, the imagination to explore innovative ideas, and the unyielding pursuit of solutions that will address global multidisciplinary concerns in an ecologically responsible manner. Over 1,500 of the students responding to the student activity feedback form report that the STEP program affects their opinion about engineering in a positive manner. Nine out of every 10 students feel that they learned "something new" from the STEP lessons. Over 2,000 students believe that the program improves their confidence in mathematics and science abilities. A few student comments that cement the ideals of Project STEP include: "*It opened up our minds to a whole new different way of doing things. We learned the background of what it takes to make something*" and "*I liked that it was a challenge*

and didn't come as easy as everything else." Therefore, the increase in student ability and self-efficacy in STEM content is another aspect of Project STEP sustainability.

TABLE 2
PERCENTAGE OF STEP LESSON COMPONENTS

Component	% of STEP lessons that address this component	% of STEP lessons that partially address this component
Science	78.13%	3.13%
Technology	65.63%	25.00%
Engineering	62.50%	34.38%
Mathematics	59.38%	21.88%
Oral Assessment	3.13%	3.13%
Written Assessment	90.63%	3.13%
Misconceptions	15.63%	18.75%
Essential Questions	31.25%	21.88%
Power Points	59.38%	0.00%
Multiple Learning Styles	59.38%	37.50%
Pictures or Diagrams	84.38%	12.50%
Application	93.75%	6.25%
Social Impact	59.38%	25.00%
Career Connection	34.38%	31.25%

STEP TEACHERS

STEP teachers, 36 different ones since 2006, are an essential part of the STEP community partnership. In an online survey recently sent to this group of teachers, the collection that responded (67%) ascribes the value of the program to widely varied attributes. On a scale of 1 to 5 for usefulness of the STEP Fellows' lesson content in the classroom where 1 is "Not at All," 3 is "Neutral" and 5 is "Definitely," the great majority of teachers answer with either a 4 or 5 (91.7%). In terms of difficulty of reusing STEP lesson content, the majority of the teachers agree that it is not difficult to use the content at all, with some even remarking that it fits perfectly into the curriculum and the kids "*love it.*" The teachers agree that the lessons are clearly written and easy to follow. In terms of the appeal of the lessons, the teachers note that they like the lessons because of the hands on activities, student engagement, real-life application and the fact that they bring a more current or new way of looking at the subject matter. Many of the teachers still maintain their relationship beyond the direct appointment as a STEP teacher. Overall, three alternate perceptions of STEP surface in these STEP teacher reactions— that of STEP as a person, referring to the STEP Fellow in the teacher's classroom, STEP as a program to be part of, and STEP as a personal opportunity. These views are not mutually exclusive, as evinced in this response, "*Students like learning from the STEP Fellows and the STEP Fellows bring real-world applications to the science content I teach. It has been WONDERFUL!*"

STEP teachers and STEP Fellows work closely together. The teachers considered STEP lesson content useful in their classroom. No one counted the content detrimental. However, a few (13%) did not change teaching styles or habits, as if the STEP addition was novel, entertaining, and mostly just a brief classroom addition. Yet, the overall implication of the program for the teachers was very positive. In terms of involvement in the STEP Program, by in large there was positive feedback with over a third (38%) of the teachers stating that they enjoy interacting with the Fellows and that the Fellows bring a lot of high-quality, fresh ideas to the classes. The teachers also generally appreciate the fact that as a result of Project STEP, the students are exposed to STEM content. Teacher use of STEP content is a sustainable aspect of this program based on the past usage of content and the enthusiasm for more lessons as they are developed.

STEP WEBSITE

Teacher use of the STEP website correlates to highly positive responses. Several of the teachers (25%) visited the website (www.eng.uc.edu/step) many times for ideas and even used many of the lessons available for download. One teacher in particular has adapted and taught most of the available physics lessons on the website. Website usage is evidence of broader integration into the program as a whole and a more consistent application of STEP lesson content with or without a Fellow present in the classroom. A full 54% of teachers have visited the website, and more than half of them downloaded lessons. Many of the teachers who use different lessons on the website also use mini-lessons, or activities that do not fill an entire class period. These mini-lessons demonstrate a higher level of STEP activity in the classroom and are mentioned in all of the most positive responses from teachers. Even where the school is in its first year of participating with STEP, teachers report benefit to their classroom from such activities accessible on the website. Figure 1 illustrates the frequency and the number of lessons used by the STEP teachers from the past three years.

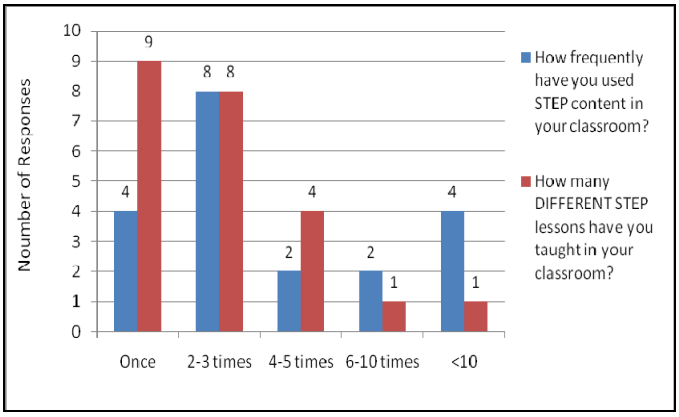

FIGURE 1
STEP LESSON USE BY FREQUENCY AND DIFFERENCE

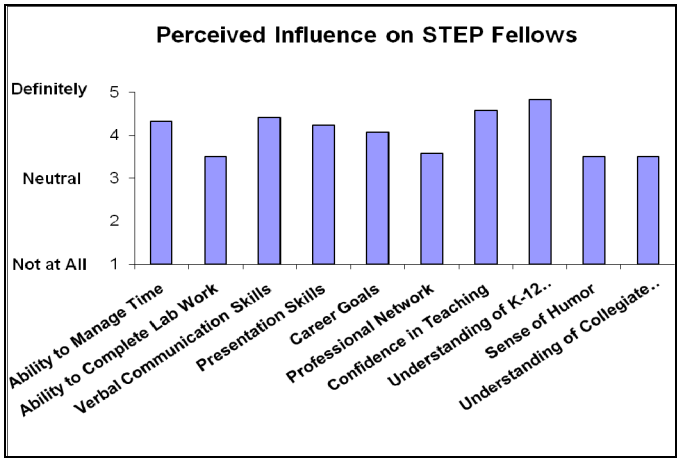

FIGURE 2
PROJECT STEP INFLUENCE ON STEP FELLOWS

FELLOWS AND SUSTANABILITY

Fellows are at the heart of Project STEP's sustainability. A review of the survey reflections submitted by 12 of the 15 past STEP Fellows from 2006 to present elucidates the role of the university graduate student in the STEP program. Each Fellow stands in a unique position as a kind of pivot point among high school and university educators, high school students, and the university research environment. Effects of the experience, voiced through the mouths of the participants, range from purposeful enthusiasm to the need for resolution. For most of the Fellows, STEP is an "eye-opener" into teaching, and most (67%) Fellows state that they want to teach at some level in the future. One Fellow states that STEP "*help[s] me see and understand realities of teaching*." STEP has an overall positive effect on the majority (70%) of Fellows based on the online survey as shown in Figure 2. The STEP Fellows show a better understanding for GK-12 everyday teacher challenges and student interactions. The overwhelming majority of Fellows found the STEP experience directly influenced their ability to manage time, their verbal communication and presentation skills, and their career goals. This 80% felt that the STEP program highly influenced their understanding of the K-12 environment in tandem with their confidence in teaching in general. Interestingly, two inquiries into STEP program influence turned up very different results: ability to complete lab work and understanding of collegiate teaching. In two cases, Fellows report no affect on their ability to complete lab work and in another the Fellow states that her understanding of collegiate teaching was unaffected. Despite some of these differences, positive comments regarding STEP abound. For example, a Fellow states, "*Being with the students has been great*!" The Fellows also participate in the following three main events during the academic year to promote STEP community awareness and effective communication skills: UC STEP Fellow Showcase, UC Technology Workshop, and the UC STEP Open House. It is no secret that, for the Fellow, the STEP program comprises an exciting, extreme immersion into a different environment, an opportunity to connect the distinct worlds of secondary school and the university at many levels. At the same time, it is quite clear that most Fellows (75%) exit this experience more sensitive to the needs of GK-12 teachers and learners, more likely to assume both roles in the future. Since Fellows, or future university faculty, recount empathy for teachers, compassion for learners, and interest in the learning process, this program has affected the outlook of future STEM professors on teaching and learning and thus ensures sustainability of Project STEP.

CHALLENGES

One aspect of the program that needs further attention is the influence that STEP has on the Fellows' research. There is a broad agreement among seven of the twelve responding Fellows (58%) that the STEP program requires more time and effort than initially anticipated. Specifically, time management is one of the biggest obstacles that the Fellows face. Four Fellows (33%) agree that STEP does not leave them enough time to focus on their research and related lab work. One Fellow stated that, *"STEP broke my time available for my own studies and research into little… chunks."* According to the survey, the STEP Fellowship takes priority in time management and further focus on graduate research can come only when STEP work is finished. Although time is an important topic in the survey, it is also shown that STEP helps the Fellows manage time more efficiently, based on the 87% rating (Figure 2).

Additionally, it has been a challenge to link the Fellows' research with specific content in the course curriculum maps provided by the secondary teachers before the academic year begins. A real key to sustainability of the program may be the ease of integrating lessons and mini-activities into the school district-required course content.

Lastly, wording in the student activity feedback form may lead to multiple interpretations. This is a concern. For example, "this lesson increased my interest in studying engineering," may be answered as 'neutral' or 'not at all' by a student who was already very interested in engineering.

CONCLUSION

STEP meets the definition of sustainability on all three levels including: lasting beyond funding, creating new programs, and acquiring new funding. This paper focuses on Project STEP and its impact to last beyond funding through the STEP Fellow lessons, student learning, teacher engagement (including the website), and STEP Fellow transition. In this formative process we embrace the socio-cultural framework where the journey is valued over any final product. These factors move from the largest arena of sustainability to the most intimate differences in teaching outlooks and habits. Evaluative research gathered since 2006, showcases the story of Project STEP's sustainability. Moreover, in addition to sustainability beyond funding, Project STEP has been the impetus for the creation of the

Research Experience for Teachers (Project RET) at UC as well as other programs (for example, the NSF's Science, Technology, Engineering, and Mathematics Talent Expansion Program grant and the Ohio Board of Regent's Choice Ohio First Scholarship Program which will support undergraduate students to work hand-in-hand with the Graduate Fellows in developing and teaching lessons in secondary school math and science classrooms). Finally, Project STEP has acquired new funding through the university itself and through other partnerships such as the Southwest Ohio Center for Excellence in Mathematics and Science. There is also a discussion at the university level to integrate the STEP educational training and outreach practicum program as part of the *Preparing Future Faculty* program offered in the College of Engineering and College of Arts and Sciences for doctoral students.

Our program works with excellent school sites that are interested in true partnerships and uses high-quality participants at all levels. The data that has been collected is rich with the participants own descriptions. This study examines data recently collected from participants over the last three years, and the opinions of the STEP program expressed have been formed from one to three years of participation. The data is triangulated between different participant groups' (student, teacher, Fellow, and university faculty) survey answers, observations of outside evaluators over the years, STEP lesson development and lesson plans, and website use. We used the member check system of allowing STEP teachers and PI's to comment on this paper and their responses were incorporated to reflect a truer vision the program. As well, this work has been thoroughly reviewed by the eight STEP participant authors.

SUMMARY AND IMPLICATIONS

The interdisciplinary nature of most STEP lessons may be because engineering graduate students are aware from their own studies and research that mathematics and science are inextricably linked in their applications. This working understanding of the interrelationships allows Fellows to make contributions in the classroom beyond the formal lessons. The goal in researching the trends of the created STEM lessons and their usage is to provide a baseline for approaching STEM lesson development in K-12 settings as well as to promote more efficient communication of STEM content by future engineering faculty (graduate students). Student responses reflect an increase in content knowledge as well as an increase in STEM career interest. Teacher responses showcase a welcoming environment for enriching STEM content with the promise of continued use of STEP lessons in the future. Lastly, STEP Fellow interactions show increased skills of communicating STEM content to the GK-12 audience during and after the STEP experience. All of these trends point to the sustainability of Project STEP and the hope for creating a model for others to follow.

Implications include that the STEP program and similar initiatives are the vehicles to provide training to the next cohort of scientists who will be charged with educating the next generation, as the Fellows become future faculty members. Another important impact of STEP on future engineers is encouraging secondary school students to pursue STEM careers. Future modifications of the program should include identifying and quantifying the participants' opinions about several aspects of the program multiple times throughout the school year in order to have more data to make summative generalizations.

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