

ABSTRACT

Abstract your proposed project (500-word limit) below using non-technical language easily understandable to persons outside your field. Remember that a diverse group of faculty will be reviewing your proposal.

The Encyclopedic Database of Topological Spaces, also known as the π -Base and currently hosted at <http://topology.jdabbs.com>, is an open-source web application with the ability to cross-reference topological spaces, their properties, and the theorems which connect them. As an example, once a user has logged that the closed interval of real numbers between 0 and 1 is “compact” and “Hausdorff”, and EDTS automatically deduces that the space is also “normal”, and includes this space in search results for normal topological spaces. Historically, researchers memorized hundreds of various spaces, properties, and theorems from papers spread across numerous journal articles, but with our body of knowledge expanding exponentially as time progresses, a robust EDTS would facilitate efficient research by eliminating the difficulty of memorizing or finding such results in the ever-growing and ever-fragmenting literature. For comparison, the similar and more mature On-Line Encyclopedia of Integer Sequences, launched in its current form in late 2010, has been cited in over 5002 works. The applicant will use support from this award to collaborate with fellow researcher Ziqin Feng (Auburn University) and EDTS’s main programmer James Dabbs to polish the EDTS prototype for use in production by active researchers in topology, with the assistance of several active researchers who will beta test the EDTS platform throughout the project. Ultimately, the investigator aims to establish EDTS as a leading tool in researching and cataloging topological spaces and objects in other mathematical categories; by developing this prototype to a minimally viable product for active use by researchers, the investigators competitiveness for external funding to support the project will be increased.

DETAILED BUDGET

	USAFDC	Other Sources	Total Anticipated Budget
Books			
Copying, Printing			
Equipment			
Postage			
Professional Fees**			
Software	\$100		\$100
Student Wages* at \$17.50 per Hr	\$2100		\$2100
Supplies, Consumables			
Telephone			
Travel	\$2090		\$2090
Other			
TOTAL	\$4290		\$4290

* In the budget justification respond to Item 10 of general guidelines.

** Consulting or other professional services that are not available through the University.

BUDGET JUSTIFICATION (Required)

Provide a line-by-line justification for each item in the budget, including details of calculated totals as well as how each is necessary for execution of the project. Itemize equipment and detail travel. For proposals that will take longer than one year to accomplish, the budget and all project plans should fully reflect the timeline required. Use additional pages as necessary.

Software: **\$120** is requested to cover hosting costs for the EDTS website on a Digital Ocean cloud server for two years. **\$80** is requested to obtain the domain name edts.io (or similar) for two years.

Student Wages: One graduate student will be hired for Summer 2018 to assist the investigator with the auditing and expansion of the EDTS database. This student will be compensated at \$17.50 per hour (as limited by the proposal preparation guidelines), 15 hours per week, for 8 weeks, totaling **\$2100**. The work done by this student supports faculty research by filtering through the trivial (but time-consuming) data entry tasks, freeing the investigator to answer the non-trivial questions associated with this data entry (see the Methodology section for more details).

Travel: The investigator will travel to Auburn, AL for three days during May 2017 to meet with collaborator Prof. Ziqin Feng of Auburn University to develop a plan for auditing the EDTS database for use in cutting-edge research and marketing the tool to the community of researchers, including a selection of appropriate candidates for using the EDTS beta platform to assist their research. Compensation for mileage is estimated at **\$250**, and six days of meals is estimated at **\$165**. (Accommodations will be provided by Dr. Feng.)

The investigator will host the EDTS developer James Dabbs for one week during Summer 2017 to collaborate on the EDTS source code, making the necessary backend and user interface changes to ready it for production on a new domain and server for active use by researchers in topology. Airfare from Washington D.C. to Mobile is estimated at **\$700**, and five days of meals is estimated at **\$275**. Hotel accommodations for six nights are estimated at **\$700**.

Proposed Work Plan

Complete the following sections. Adjust the space provided as necessary but the work plan may not exceed five pages, excluding works cited. Supporting material may be attached as appendices but this is not necessarily encouraged. Please be reminded that the work plan should be easily understood by a broad academic audience.

A. Introduction

1. State objective(s) of proposed work.

The main objective of this project is to mature the π -Base web application for cataloging topological spaces, theorems, and properities from a casual side-project into a robust research tool for mathematicians in the fields of general and set-theoretic topology, an Encyclopedic Database of Topological Spaces (EDTS). The current application, hosted at <http://topology.jdabbs.com/>, is generally recieved well as a novelty by researchers, but has several flaws preventing it from being used as a reference in serious research.

The most glaring of these is a lack of peer-review; the π -Base database is currently populated by a mix of results from the literature and unverified data from unvetted users. This will be corrected by auditing the contents of the database to reference peer-reviewed sources where possible, and flagging other entries as unverified. In addition, several important data points from the literature are not represented in the database, leaving too many holes for it to serve as an efficient resource resource for most researchers. To that end, the database will be expanded to a critical mass that meets the needs of several specific researchers in several niches of set-theoretic topology, who will be recruited by the investigator and his colleague Prof. Ziqin Feng of Auburn University. To support these necessary enhancements, the investigator will collaborate with π -Base developer James Dabbs to write the code required for these new features and user interface improvements.

In addition to revolutionizing the way research in set-theoretic and general topology is done, an additional objective of the project is to develop a mechanism for finding suitable undergraduate research projects in those fields. Research in mathematics typically involves finding logical proofs or counter-examples to mathematical conjectures which have yet to be solved. Due to this, it is often difficult to find accessible problems for undergraduates which would constitute truly original research. Most problems on the mind of topological researchers that could be tackled by undergraduates are usually solved trivially or at least in short time by mathematicians with more experience. However, once the EDTS database reflects the cutting-edge of topological research, it will be able to automatically produce open questions that are truly unknown, yet have not been considered by PhD researchers. Of course, what makes a question in topology “interesting” to researchers is determined by humans working in the field, so the majority of these computer-generated open questions would not be attractive to more advanced researchers, even those that are easily seen to not be difficult to solve. Such questions would be perfect for creating undergraduate projects or theses that allow students to work on truly original research in a field traditionally inaccessible to students without graduate cowasursework in the area.

Another objective for this project is to pursue external funding for the continued development of the EDTS platform and database, as described below under Anticipated Outcomes.

2. Background: Review scholarly work in the area and its relationship to the proposed study.

In 1970, Steen and Seebach published a handbook covering 143 important examples of topological spaces, entitled *Counterexamples in Topology* [10]. Renowned researcher Mary Ellen Rudin wrote the following in her review [9] of the original text. “*Counterexamples in Topology* is a valuable addition to the small collection of books I keep on the shelf in my office.” “The book is completely unique; no other book now in print serves its purpose.” Recognizing the maze of counterexamples littered throughout the field of set-theoretic topology, Rudin suggested that not only students could benefit from the text as a guidebook, but “Even those of us who work exactly in the area will profit from its organization.”

Several other *Counterexamples* texts in the tradition of Stein and Seebach have been published in several fields, including (but not limited to) real analysis [12], differential equations [8], probability [11], and graph theory [1]. The utility of such books is evident to the working mathematician, as it is invaluable to have a convenient resource that efficiently answers questions of the following forms:

- “Does the object T have property X ?”
- “Do all objects with properties $\{A, B, C\}$ also have properties $\{X, Y, Z\}$?”
- “Do we already know of an object that satisfies properties $\{A, B, C\}$?”

The limitations of these publications are just as evident. When entered into the existing π -Base prototype and automatically checked by the computer, several non-obvious errors were unearthed in *Counterexamples in Topology*. This is to be expected in such an ambitious work, but certainly would be a frustrating discovery for a mathematician relying on the faulty data. A computer-verified resource such as EDTS would prevent such inconsistencies from ever appearing in the database.

Furthermore, over 45 years later, *Counterexamples in Topology* is no longer on the cutting edge of research. It was originally written with the assistance of an NSF-funded undergraduate research experience, and represented the most recent developments of the time. However, as a book, it is not a living document and cannot evolve with the active community of research to continually serve its needs. The EDTS will continually be updated and expanded, allowing it to serve researchers of topology for years to come. In addition, the software that will power EDTS will be written in a generic fashion, so that it may similarly be used to power databases for literally any category of mathematics, including those with existing books and databases of counterexamples, and those which as of yet do not.

The benefits of such a robust database are already known in another field of mathematics. The On-Line Encyclopedia of Integer Sequences, hosted at <https://oeis.org>, is a frequently used and cited resource in number theory and its related fields. Since the site launched in its current form in late 2010, the OEIS has been cited in over 5002 works [7]. The success of OEIS is due to its ease of access and use by both researchers and students of mathematics, its robust referencing system connecting the database to the literature, and the community that maintains it. It is the investigator’s expectation that an enhanced Encyclopedic Database of Topological Spaces can achieve a similar level of success and notability by following the example of OEIS.

3. Preliminary work: Describe any work you have begun that relates to the project and how the proposed work validates or extends that work.

The π -Base prototype currently hosted at <http://topology.jdabbs.org> represents the preliminary work done for this project by the investigator, its developer, and the small community that has contributed to it over the past few years of its existence (similar to Wikipedia, but without the sizable userbase of content experts). Specifically, the investigator has contributed to the project by entering data related to his own research in set theoretic topology, for example [2, 3, 5, 6]. Using this prototype has allowed the investigator to cleanly catalog the raw data associated with the results of his research and generate open questions that have yet to be solved by those results; for example, despite the theorem <http://topology.jdabbs.com/theorems/168> (discussed in [4]) which states that all 2-Markov-Winning Menger spaces are Winning Menger, there is no known counter-example to the converse: a Winning Menger space which isn’t also 2-Markov-Winning Menger.

Despite its promise, the utility of the existing prototype is limited by the current functionality of the site and the limited involvement by the broader community of researchers. The proposed work will allow the prototype to mature into a robust web application that immediately communicates its utility to active researchers. Combined with the proposed improvements to the π -Base software and user interface, the recruitment of leading researchers to contribute and maintain the database by the investigator and Dr. Feng will establish the new EDTS application as a primary resource for researchers to find and cite research results in topology. After its success is established, the EDTS software can then be expanded to serve other fields of mathematical research as well.

4. Significance: State the potential importance of the proposed work to the field of study. Also, please attach a letter of support from your department chair (or equivalent position) evaluating the merit of the proposal.

The EDTS will revolutionize the way research is done in general and set-theoretic topology. The density of modern literature in our field is a huge roadblock for efficient work in advancing research; without an efficient mechanism for sharing the results of our research (besides the consumption and memorization of thousands of pages of an ever-increasing body of literature), it is quite common for researchers to waste non-trivial amounts of time working on problems that have already been solved in a paper they had been unaware of. Other “problems” often can be solved with the right combination of results from two previously unconnected papers. Making these connections can be difficult, especially when the papers come from different niches of research. However, this difficulty is non-existent for a software package that automatically catalogs and connects entries to its database made by its users.

The benefits EDTS will have for undergraduate research (as described above in the stated objectives for this work) will also encourage more young researchers to enter the field of set-theoretic topology. Many mathematics graduate students have limited experience with these fields, but with an improved mechanism to develop appropriate undergraduate research projects, more students will view this field as more accessible and consider pursuing related research at the masters or doctoral level.

B. Methodology

1. Describe in detail your proposed work or approach to accomplishing the objective(s).

In May 2017 the investigator will travel to Auburn University for three days to collaborate with Ziqin Feng to identify the changes necessary to transform the existing π -Base prototype into an appropriate platform for active use by researchers. Several candidates who will be recruited to use and contribute to beta version of the EDTS platform will be identified. Other topology researchers at Auburn, including Michel Smith, Stuart Baldwin, and Gary Gruenhage, will be consulted to provide further guidance and advice on what other improvements should be made to the prototype.

Later that summer, π -Base developer James Dabbs will travel from Washington, D.C. to Mobile for one week to collaborate with the investigator on the development of the π -Base source code, transforming the prototype into a useable beta version of the future EDTS platform. A work plan will be made for the continued development of the EDTS codebase through the end of the following summer. Following this initial work of software development, the investigator and Dabbs will collaborate on this source code development remotely according to this plan.

Also during that summer, the chosen candidates for beta-testing will be recruited. Throughout the fall and spring semesters of the 2017-18 academic year, these testers will use the EDTS beta version to assist with their active research. Holes in the database will be identified, along with corresponding sources from the literature that can fill those holes: textbooks that provide basic facts, and journal articles that build up to the areas of active research studied by the participating beta-testers.

Finally in Summer 2018, a graduate student in mathematics will be hired to assist the investigator in entering the data from these identified sources into the EDTS database, with the consultation of the beta-testers to ensure the expanded database is sufficient to support their regular research. Much of this work is trivial, consisting of taking results from these papers and entering them into EDTS in an appropriate format. However, due to inconsistencies between authors or the use of non-standard terminology or methodologies, the student will not be able to complete this work alone. These issues will be filtered out by the student for consideration by the investigator, allowing him to handle the non-trivial issues that arise in serializing mathematical results that were not originally written with such serialization in mind.

At the conclusion of the project in August 2018, EDTS will be officially released to the research community

as version 1.0. The investigator and his collaborators will promote the new platform in appropriate venues, including professional conferences and scholarly articles.

2. If data are to be collected, outline the means by which they will be analyzed.

N/A

3. Timeline. Indicate the proposed timeline for project completion. For projects exceeding one year (12 calendar months), provide justification.

- May 2017. Investigator travels to Auburn University for preliminary consultations with colleagues, including Dr. Ziqin Feng.
- Summer 2017. π -Base developer James Dabbs travels to Mobile for one week to collaborate with the investigator on initial development of EDTS codebase from existing prototype. Testers are recruited for EDTS beta.
- September 2017: Beta-testing of EDTS begins. AMS Southeastern Meeting for Fall 2017 held in Orlando, FL.
- April 2018: AMS Southeastern Meeting for Spring 2018 held in Nashville, TN.
- Spring 2018: 52nd Spring Topology and Dynamics Conference held at TBD location.
- June-July 2018: Student hired to assist with data entry tasks based on beta-testing feedback and suggestions.
- August 2018: EDTS version 1.0 released.

The project timeline extends a total of sixteen months. Ideally, the student worker would be available to contribute to the project earlier; however, the appropriate coursework that enables a student to contribute to this project (MA 434 or MA 542) will not be offered until Fall 2017. Due to the usual workload of graduate assistants in the department, it would be infeasible to begin work on the project during the following spring, leaving Summer 2018 as the ideal time for the student's contributions. In addition, the start of the project is best scheduled for May 2017, allowing for more flexible travel by the investigator and collaborator James Dabbs during the May and Summer semesters. This additional time will also facilitate the careful feedback of testers and selection of appropriate literature to ensure that the EDTS platform meets the needs of active researchers. Support for the minimal costs to host the EDTS platform for two total years is requested so that the results of the project may continue to serve the research community while external funding is sought.

C. Anticipated outcomes:

1. Include names of probable journals, publishers, etc. A final written report and a presentation of project results at the Annual Research Forum are required; failure to comply may jeopardize future USAFDC funding opportunities.

Typical journals publishing in the area to be served by EDTS include *Topology and Its Applications*, *Topology Proceedings*, *Rocky Mountain Journal of Mathematics*, *Commentationes Mathematicae Universitatis Carolinae*, *Questions and Answers in General Topology*, *Fundamenta Mathematicae*, *Houston Journal of Mathematics*, and many others. A survey of the work associated with this project will be submitted to *Topology Proceedings*, due to its relationship with the Spring Topology and Dynamics Conference and Summer Conference on Topology and Its Applications, the two biggest professional conferences associated with this field of work. As with the similar OEIS platform, it is anticipated that a robust EDTS itself would be cited in several of the journals listed above, as well as others.

2. Describe plans for extending the project via external support, if any. (The USA Office of Research can provide help in identifying possible sources of external support relative to this proposal.)

As the completion of EDTS 1.0 approaches, external funding opportunities will be proposed by the investigator and his collaborators for the continued development of the EDTS platform. The National Science Foundation Division of Advanced Cyberinfrastructure has several opportunities for supporting such initiatives, including Computational and Data-Enabled Science and Engineering in Mathematical and Statistical Sciences, and Cyberinfrastructure for Emerging Science and Engineering Research. Potential partnerships with academic journals of mathematics will also be explored.

D. Facilities and Other Resources:

List the facilities available for this project, departmental contributions, and other support for the project not listed in the budget and budget justification pages.

The investigator has been provided a modern desktop Unix-based computer for his daily work as a professor. This computer is suitable for software development and will be the primary instrument used in contributing to this project.

E. List outcomes and dates of USAFDC grants received in past five years.

Provide titles and dates. List date and title of USAFDC Spring Forum poster presentation.

N/A

F. Describe how the proposed project differs from any previous USAFDC-funded project.

N/A

G. List of references cited in the grant application.

References

- [1] Michael Capobianco and John C. Molluzzo. *Examples and counterexamples in graph theory*. North-Holland, New York-Amsterdam-Oxford, 1978. Foreword by Gary Chartrand.
- [2] Steven Clontz. On k -tactics in Gruenhage's compact-point game. *Questions Answers Gen. Topology*, 34(1):1–10, 2016.
- [3] Steven Clontz. Tactic-proximal compact spaces are strong Eberlein compact. *Topology Appl.*, 204:306–317, 2016.
- [4] Steven Clontz. Applications of limited information strategies in Menger's game (to appear). *Comment. Math. Univ. Carolin.*, 2017.

- [5] Steven Clontz and Gary Gruenhage. Proximal compact spaces are Corson compact. *Topology Appl.*, 173:1–8, 2014.
- [6] Steven Clontz and Scott Varagona. Destruction of metrizability in generalized inverse limits. *Topology Proc.*, 48:289–297, 2016.
- [7] OEIS. Works citing OEIS. https://oeis.org/wiki/Works_Citing_OEIS. Accessed: 2017-01-20.
- [8] John M. Rassias. *Counterexamples in differential equations and related topics*. World Scientific Publishing Co., Inc., Teaneck, NJ, 1991.
- [9] Mary Ellen Rudin. Reviews: Counterexamples in Topology. *Amer. Math. Monthly*, 78(7):803–804, 1971.
- [10] Lynn Arthur Steen and J. Arthur Seebach, Jr. *Counterexamples in topology*. Dover Publications, Inc., Mineola, NY, 1995. Reprint of the second (1978) edition.
- [11] Jordan M. Stoyanov. *Counterexamples in probability*. Wiley Series in Probability and Mathematical Statistics: Probability and Mathematical Statistics. John Wiley & Sons, Ltd., Chichester, 1987.
- [12] Gary L. Wise and Eric B. Hall. *Counterexamples in probability and real analysis*. The Clarendon Press, Oxford University Press, New York, 1993.