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EDUCATIONAL OUTCOMES OF 2016-2018 REUT PROGRAM IN CALIFORNIA STATE UNIVERSITY, CHICO

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Educational Outcomes of 2016-2018 REUT Program in California State University, Chico

Synopsis:

Our program targets secondary teachers with a strong interest in mathematics or math education (RET) and students who have completed their junior year with coursework appropriate to the research project (REU). Our program is designed to engage participants in research problems with a high potential for publication and to create a research experience that broadens participants' perspective both of mathematics as a discipline and of research as an exciting exploratory process.

Educational Outcomes of 2016-2018 REUT Program in California State University, Chico

Abstract

The REUT program at California State University, Chico targets secondary teachers with a strong interest in mathematics or math education (RET) and students who have completed their junior year with coursework appropriate to the research project (REU). Our program is designed to engage participants in research problems with a high potential for publication and to create a research experience that broadens participants' perspective both of mathematics as a discipline and of research (whether mathematical or not) as an exciting exploratory process. By doing so, we hope to achieve the following specific objectives:

• Encourage undergraduate students, especially those from underrepresented groups, to pursue careers in sciences and engineering, including teaching.

• Help to better prepare students to pursue advanced degrees and careers in the sciences.

• Provide in-service teachers with a research experience that will foster excitement about mathematics, increase content understanding, and inspire pedagogical innovation in their classrooms.

• Promote and enhance mathematical research involving undergraduates at CSUC.

During summer 2016 we had two teams (one in applied mathematics, another in statistics) supervised by two faculty. The main purpose of the Math Modeling project was to obtain analytical solutions for tsunami wave propagation in the presence of underwater barriers, and also to specify the approach that accounts for nonlinear effects. The statistics research team used simulation methods to optimize NFL fourth down strategies.

During summer 2017 we had two faculty members that worked on several projects within two general project areas (Stochastic Processes Projects and Number Theory Projects). Within the Stochastic Processes project the following problems were considered: Spatial point pattern analysis in demography; Stochastic differential equation models in epidemiology; Partial differential equation models of spatial dispersal in ecology. Within the Number Theory project the following problems were considered: On the number of primes for which a polynomial is Eisenstein; Explicit bounds on the least k-th prime non-residue; Explicit lower bounds on the greatest prime divisor; S-Euclidean imaginary quadratic fields; Norm-Euclidean ideal classes in Galois cubic fields.

In summer of 2018 we had three teams that worked on three projects: Modeling of the thermo-drilling in Antarctica, Defining of physical properties of the solids, and Predicting the area of contamination within the subsurface aquifer. The goal of the projects was to provide a valuable research experience for 36 students and high school teachers. Participants prepared weekly presentations, prepared rough draft manuscripts, and prepared posters that described the research that they were conducting. The participants also continue their work into the academic year by presenting the research at various conferences. The educational outcomes and research results of the listed above projects will be discussed in the proposed talk.

Introduction

Within the current REUT grant we have completed the REUT summer programs in 2016-2018. Prior to the current grant we had very successful grants that supported twelve participants for each of 2004 to 2015. Our program targets secondary teachers with a strong interest in mathematics or math education (RET) and students who have completed their junior year with coursework appropriate to the research project (REU). From both populations, we will recruit members of underrepresented groups. We include about three students from CSUC each year; the remainders are recruited externally. Our program is designed to engage participants in research problems with a high potential for publication and to create a research experience that broadens participants' perspective both of mathematics as a discipline and of research (whether mathematical or not) as an exciting exploratory process. By doing so, we achieve the following specific objectives:

- Encourage undergraduate students, especially those from underrepresented groups, to pursue careers in sciences and engineering, including teaching.
- Help to better prepare students to pursue advanced degrees and careers in the sciences.
- Provide in-service teachers with a research experience that will foster excitement about mathematics, increase content understanding, and inspire pedagogical innovation in their classrooms.
- Promote and enhance mathematical research involving undergraduates at CSUC.

Both teachers and undergraduates benefit from working together on a research team. Participants develop connections not only with faculty but also with participants who have very different backgrounds, experiences, and career paths. Students have the opportunity to develop a direct relationship with a math educator. Students also benefit from the experience teachers have in communicating mathematical ideas and may be inspired to consider the possibility of teaching as a career. Secondary teachers benefit from the experience of close contact with outstanding undergraduates and see firsthand what some of their current students will be doing in a few years. Both populations benefit from their complementary mathematical backgrounds which enables them to help one another in their research exploration.

Nature of Participant Activities

Team Activities: We help the participants progress from dependent learners to independent investigators by modeling and explicitly discussing Polya's four stages of problem-solving: understanding the problem, devising a plan of attack, carrying out the plan, and reflecting on the work. Our activities are structured to facilitate the smooth progression from one stage to the next at a pace appropriate to the competence of each participant.

Following that model, in the initial stage, each research team leader offers a mini-course related to the team's mathematical focus area. This allows the team leader to give participants relevant background material, introduce computer software, evaluate the competence of each participant, foster a supportive team environment, and in general ensure the group has the necessary tools to carry out the research project. The team leader concurrently introduces open research problems and students are encouraged to begin their own exploration right away. As a first step towards independence, the team selects their research problem. At this point they are given research/expository articles to read in order to better understand their problem. The articles are then discussed in a group setting. These informal discussions help the faculty member ensure that the whole team "understands the problem" and is thus ready for the next stage.

In the second stage, the faculty member takes a step back and gradually moves from group director to group member. The team is responsible for "devising a plan of attack," which includes developing research directions and allocating responsibilities. The faculty member contributes to discussions and helps guide the group in fruitful directions without imposing his or her own ideas. He also ensures that each individual is contributing to the development of the team's plan and has a reasonable share of the responsibilities in carrying out the attack. This stage culminates in a presentation of the team's research problem and plan of attack.

In the third stage, the faculty member steps back even further. Having helped guide the group in the development of a plan, the faculty member now allows the group to carry out that plan with minimal assistance and acts primarily as an advisor as the team becomes self-sufficient and takes ownership of all aspects of their particular problem. Here, both teachers and undergraduates are confronted with their lack of experience in doing mathematical research. They can help each other to overcome this hurdle and learn to be independent mathematical explorers.

In the fourth and final stage the group "reflects" by jointly authoring a written report and preparing a presentation on their research including: a clear statement of their problem, their plan of attack, any obstacles which were encountered, results they obtained, and perhaps directions for further investigation. In this stage the faculty member's role is primarily to give advice and answer questions that may arise. The reflective stage often continues after the term of the REUT as students work with their team leader to revise a manuscript for publication and prepare to present their research at professional conferences.

The major activities and results of the REU 2016-2017

During summer 2016 we had 2 teams-Math modeling and Statistics, supervised by Sergei Fomin and Kathy Gray, respectively.

Major goals of the projects

The main purpose of the Math Modeling project was to obtain, within the framework of shallow water theory, analytical solutions for solitary wave propagation in the presence of underwater barriers, and also to specify the approach that accounts for nonlinear effects. Within the bounds of the linear approximation, find the exact analytical solutions for wave runup on a shelf, hollow, underwater bump, or series of bumps.

The goal of the Statistics project was to provide a valuable research experience for 5 statistics students and a high school teacher. The statistics research team spent 40 hours a week for seven weeks researching simulation methods to optimize NFL fourth down strategies. They prepared weekly presentations, prepared a rough draft manuscript, and prepared a poster that described the research that they were conducting. They also continued their work into the academic year by presenting the research at various conferences.

Major outcomes:

The statistics and math modeling research teams spent 40 hours a week for seven weeks of researching. They prepared weekly presentations, prepared draft manuscript for journal publications, and prepared posters that described the research that they were conducting. They also continued their work into the academic year by presenting their research at various conferences.

Statistics team:

1. Paper in preparation for submission to Journal of Quantitative Analysis in Sports. Planned submission in Aug, 2017.

2. Student presentation (Demond Handley) at StatFest Conference, Washington DC, Septermber 24, 2016. StatFest is a one day conference aimed at encouraging undergraduate students from historically underrepresented groups to consider careers and graduate studies in Statistics.

3. Planned student presentation (Nick Eisemann) at JSM conference from July 29August 3, 2017. JSM is the largest statistical conference in the world.

4. Planned student presentation (Dylan Gouthro)at Northern California Undergraduate Mathematics Conference at Sonoma State University on March 11, 2017

5. Planned student Presentation (Dylan Gouthro and Nick Eisemann) at the College of Natural Sciences poster session. California State University, Chico, CA May, 2017

Math Modeling team:

Presentations:

1. Marcus Battraw, Seth Selken, Monica Swartz, Sergei Fomin, Tsunami WavePropagation Over Underwater Obstacles, 2016 International Mechanical Engineering Congress & Exposition (2017 IMECE), Phoenix, November 39, 2016

2. W. Noland, D., D. Smith, S. Fomin. Modeling Tsunami Run-Up and Draw-Down on a Beach, American Geophysical Union annual meeting, December 1116, 2016, San Francisco, CA.

3. William Noland, "Modeling Tsunami Run-Up and Draw-Down on the Beach," 2017 Emerging Researchers National (ERN) Conference in STEM, March 24, 2017, in Washington, D.C. (was awarded the second place prize for an oral presentation in mathematics)

4. William Noland, Dylan Smith, Seth Selken, Monica Swartz, Marcus Battraw, Sergei Fomin, Modeling Tsunami RunUp and DrawDown on the Beach, 2017 Joint AMS and MAA, Joint Mathematics Meetings, Atlanta, GA , January 47, 2017.

5. Dylan Smith , William Noland, College Advisor: Sergei Fomin, Modeling Tsunami RunUp and DrawDown on the Beach, 2017 Joint AMS and MAA, Joint Mathematics Meetings, Atlanta, GA , January 47, 2017.

6. William Noland,"Modeling Tsunami RunUp and DrawDown on the Beach," 31st Annual National Conference on Undergraduate Research (NCUR 31), University of Memphis April 68, 2017

7. Seth Selken, “Tsunami wave propagation over underwater obstacles” 2017 Symposium on Undergraduate Research & Creative Expression, Iowa State University, April 11, 2017 Ames, IA

Journal Papers:

1. William Noland, Dylan Smith, (faculty adviser Sergei Fomin) Modeling Tsunami RunUp and DrawDown on a Beach, 2017, published in SIAM Undergraduate Research Journal)

2. Marcus Battraw, Monica Swartz, Seth Selken, William Noland, Dylan Smith, Peter Gerrodette, and Sergei Fomin, Tsunami wave propagation over underwater obstacles, 2018 (prepared for the journal :Applied Mathematics and Computation).

Key outcomes:

Math modeling team, using the nonlinear shallow water equations, the propagation of small amplitude long waves is described by a linear approximation. This model is represented by the leading term in an asymptotic expansion of the solution in the small wave amplitude/water depth ratio characteristic of tsunamis. Within the bounds of the linear approximation, the exact analytical solutions for wave runup on a shelf, hollow, underwater bump, or series of bumps are found. Areas of practical application of these models include coastal defense against tsunami inundation, harbor protection and erosion prevention with submerged breakwaters. For wave runup on a shelf/hollow, the asymptotic expansion is applied for solving the nonlinear problem. Using the method of renormalization, a uniformly valid solution is obtained accounting for nonlinear effects in the vicinity of the sharp depth change. Numerical experiments were used to estimate the accuracy of the linear and nonlinear models in predicting the distributions of tsunami waves.

The major activities and results of the REU 2017-2018

During summer 2017 we had 2 teams- Stochastic Processes and Number theory supervised by Ben Nolting and Kevin McGown, respectively.

Description of Stochastic Processes Proect

(Faculty mentor Ben Nolting, students:Rajita Chandak, Lauren Hassett, Llasmin Lopez, Fransisco Martinez, Aria Radick)

Within the Stochastic Processes project the following problems were considered:

1. General Topic: Spatial point pattern analysis in demography

Student: Rajita Chandak

Project Title: Spatial point analysis of segregated communities and greenhouse gas sources

Overview: In this research project, we hypothesized that sources of pollution are more likely to be in highly segregated communities because segregated communities lack the social power to resist the establishment of these sources and disadvantaged racial minorities could be forced to live near existing sources.

2. General Topic: Stochastic differential equation models in epidemiology

Students: Yaneth Reyes, Francisco Martinez, and Llasmin Lopez

Project Title: Stochastic Differential Equation models of Ascaris (roundworm) infection

Overview: Ascaris lumbricoidesis is a parasite infects 0.8-1.2 billion people globally. Its greatest impact is on children in developing countries. We developed mathematical models of how Ascaris is transmitted through populations, with the goal of improving the ability of epidemiologists to predict the spread of this neglected tropical disease. First, we developed a differential equation model that describes how Ascaris is transmitted between people. We extended this model to include pigs, which are an important reservoir species for Ascaris. We further extended our models to structure the infected human population by worm burden, because this determines the severity of symptoms and the probability of transmitting worms to others.

3. General Topic: Partial differential equation models of spatial dispersal in ecology

Students: Branden Newberg-Cuellar and Lauren Hassett

Project Title: Quantifying the Spatiotemporal Effects of Bark Beetle Dispersal Across Different Forest Models

Overview: Bark beetles have become a growing concern for North American ecologists and regional foresters in the last decade. A small aggressive beetle that requires host trees to reproduce, bark beetles have caused unprecedented tree mortality from the southern Sierra Nevada to northern Canada. As a natural regulatory mechanism in forest ecology that helps maintain forest densities, the bark beetle is both ecologically important and economically significant. However, warmer global temperatures and extended droughts have created conditions favorable to bark beetle epidemics. Efforts to reduce the scale of impact include pheromone trappings as well as treating and thinning infected tree stands. Because many of these preventative measures rely on sophisticated knowledge of bark beetle dispersal behaviors, understanding how those behaviors change according to different landscapes will help to maximize the effectiveness of efforts to prevent wide-scale tree mortality.

4. General Topic: Stochastic search strategies and animal foraging behavior

Student: Qinyi Zeng

Project Title: Directional and non-directional sensory cues in stochastic search strategies Overview: This project examined the searching strategies used by animals to locate resources. The animals do not know the location of resources a priori, and hence employ random walks to encounter resources. The exact type of random walk, and the way that external information is incorporated into the random walk, constitute a stochastic search strategy. We investigated the relative efficiencies of two major classes of stochastic search strategies: those based on directional sensory cues and those based on non-directional sensory cues. In recent years, scientists have hypothesized that Lévy walks are utilized by organisms ranging from bacteria to sharks, and represent an evolutionarily optimal behavior. Composite searches are a generalization of Lévy walks that allow organisms to integrate external information into their strategies. These searches involve switching between different random walks based on information such as resource encounters, giving up time, or nondirectional sensory cues. A non-directional cue allows an organism to change its search mode, but does not allow an organism to directly orient itself to a resource. For example, a diffuse chemical signal is a non-directional cue if it gives an organism a general sense of when resources are nearby, but is not precise enough to allow for gradient following.

5. General Topic: Deterministic vs. stochastic models in astrophysics

Student: Aria Radick

Project Title: One-Zone Model for Stellar Pulsation

Overview: The stellar structure of variable stars is a widespread topic of interest among many researchers. Several researchers have tried to use deterministic models of internal stellar structure to capture the complicated observed dynamics of variable stars. The key question is whether these deterministic models can adequately produce the observed qualitative dynamics, which range from variable starts with fixed periods to stars with seemingly chaotic dynamics. We initially sought to study sought how closely these basic deterministic models matched non-periodic variable stars, and compare these models with stochastic ones. The previous, deterministic models were based on one-dimensional radial representations, with the stellar structure split into a core and a convective layer. Stellingwerf (1986) was the first to create a model of this type, which avoids the full three-dimensional hydrodynamic equations. Munteanu (2005) included turbulent pressure into this model and looked at its effect on the characteristics of limit cycle dynamics. Tanaka (2011) studied the chaotic nature of the model and later (2012) showed how these models can yield a broader range of qualitative dynamics.

Description of the Number Theory project

(Faculty mentor: Kevin McGown, students: Kelly Emmrich, Clark Lyons, Emma Mavis, Kyle Hammer, Hans Oberschelp, Mathias Wanner, teacher : James Fleisher)

Within the Number Theory project the following problems were considered:

1. Project Title: On the number of primes for which a polynomial is Eisenstein
Students: Shilin Ma, Devon Rhodes, Mathias Wanner
2. Project Title: Explicit bounds on the least kth prime non-residue
Students: Shilin Ma, Devon Rhodes, Mathias Wanner
3. Project Title: Explicit lower bounds on the greatest prime divisor of n^2+c
Students: Hans Oberschelp, Emma Mavis, James Fleisher
4. Project Title: S-Euclidean imaginary quadratic fields
Students: Kyle Hammer, Skip Moses
5. Project Title: Norm-Euclidean ideal classes in Galois cubic fields
Students: Kelly Emmrich and Clark Lyons

Accomplished under these goals

The Stochastic Processes and Number Theory research teams spent 40 hours a week for seven weeks of researching. They prepared weekly presentations, prepared draft manuscript for journal publications, and prepared posters that described the research that they were conducting. They also continued their work into the academic year by presenting the research at various conferences.

Publications of the Stochastic Processes project:

• Chico STEM Connection Collaborative Undergraduate Research Conference. Research talks on August 9th, 2017 in Chico, California. Two presentations were made: Stochastic Differential Equation models of Ascaris (roundworm) infection, presented by Yaneth Reyes and o Quantifying the Spatiotemporal Effects of Bark Beetle Dispersal Across Different Forest Models, presented by Branden Newberg-Cuellar.

• The Joint Mathematics Meeting of the American Mathematical Society and the Mathematical Society of America Two posters were presented at the poster session on January 19th, 2018 in San Diego, California: Spatial point analysis of segregated communities and greenhouse gas sources, presented by Rajita Chandak. and Stochastic Differential Equation models of Ascaris (roundworm) infection, presented by Yaneth Reyes and Llasmin Lopez.

• National Conference for Undergraduate Women in Mathematics
The poster was presented at the poster session on January 27th, 2018 in Lincoln, Nebraska: Stochastic Differential Equation models of Ascaris (roundworm) infection, presented by Llasmin Lopez.

<u>Number Theory project:</u>

• West Coast Number Theory Conference. Three research talks on December 17th, 18th, 19th, 2017 in Pacific Grove, California: (1) Norm-Euclidean ideal classes in Galois cubic fields, presented by Kelly Emmrich and Clark Lyons. (2) S-Euclidean imaginary quadratic fields, presented by Kyle Hammer, joint work with Skip Moses. (3) Lower bounds for the greatest prime divisor of n^2+c, presented by Hans Oberschelp, joint work with James Fleisher and Emma Mavis.

• The Joint Mathematics Meeting of the American Mathematical Society and the Mathematical Society of America The research talk was given during an AMS session on January 10th, 2018 in San Diego, California. (1) Norm-Euclidean ideal classes in Galois cubic fields, presented by Kelly Emmrich and Clark Lyons. The poster was presented at the poster session on January 12th, 2018 in San Diego, California.(2) The number of primes for which a polynomial is Eisenstein and the least k-th prime non-residue, presented by Shilin Ma, Devon Rhodes, and Mathias Wanner.

• National Conference for Undergraduate Women in Mathematics
The research talk was given on January 27th, 2018 in Lincoln, Nebraska.
Norm-Euclidean ideal classes in Galois cubic fields, presented Kelly Emmrich, joint work with Clark Lyons.

<u>Key outcomes.</u>

Stochastic Processes:

Within the project: "Spatial point analysis of segregated communities and greenhouse gas sources" , we designed a way to quantify segregation across a range of spatial scales using spatial pattern analysis tools: Ripley’s K function and the pair correlation function. We designed a coding framework to efficiently calculate these functions from 2010 census data. Previous studies typically only identify segregation at a single spatial scale, so our approach presents a novel way to understand this phenomenon. Using these results together with EPA data on Greenhouse Gas emissions, we examined the relationship between segregation and the location of pollution sources. Preliminary results show that areas with higher levels of racial segregation were more likely to contain major GHG emission sources. Our computational design also allows us to quantify the relationship between racial groups and pollution sources across a continuum of spatial scales, and preliminary results show that disadvantaged racial groups are more likely to be clustered near pollution sources. Within the Project "Stochastic Differential Equation models of Ascaris (roundworm) infection" , we developed stochastic differential equation versions of our models that included both demographic and environmental stochasticity. We numerically simulated many realizations of these equations to approximate the dynamics of the means, variances, and probability distributions associated with each disease class. Our results showed that including pig populations and worm burden structure had important impacts on model dynamics, particularly in terms of the duration and severity of outbreaks. Within the project "Quantifying the Spatiotemporal Effects of Bark Beetle Dispersal Across Different Forest Models", we set out to explore the spatiotemporal effects various tree patterns have on bark beetle diffusion. Utilizing a partial differential equation and spatial point processes, we constructed a spatially explicit reaction-diffusion model and used computer simulations to evaluate the variation in tree mortality rates among forest models constructed with different parameters that determine tree cluster densities and the total number of trees in the forest. The results show that smaller cluster radii produce more variation in terms of proportions of tree mortality. The same can be said of forests with smaller populations of trees. As the cluster radii and tree populations increase, the variation in tree mortality decreases as the diffusion process becomes more likely to infect the entire forest. Within the project "Directional and non-directional sensory cues in stochastic search strategies", using computer simulations, we evaluated how composite search strategies based on non-directional sensory cues compare to those based on directional sensory cues. These simulations were performed on a wide range of landscapes, allowing us to examine resource distributions with varying degrees of density and heterogeneity. We found that non-directional cues had similar efficiencies to directional sensory cues, a non-intuitive result that has implications for fields ranging from behavioral ecology to the design of autonomous search robots. Within the project "Deterministic vs. stochastic models in astrophysics", instead of doing a full deterministic vs. stochastic model comparison, we focused on expanding the qualitative classification scheme of the dynamics produced by one-zone deterministic models. We broadened the parameter space under exploration, developed an automated method of classification, and identified key parameters that cause shifts between types of variable stars. Number Theory:

Results obtained within the following projects "On the number of primes for which a polynomial is Eisenstein" , "Explicit bounds on the least k-th prime non-residue", "Explicit lower bounds on the greatest prime divisor of n^2+c" , "S-Euclidean imaginary quadratic fields", "Norm-Euclidean ideal classes in Galois cubic fields" are pure mathematical and in order to describe them we need to use equations and formulae. To this end, the key mathematical outcomes for these proects are presented below in the attached pdf file.

The major activities and results of the REU 2018-2019

During summer 2018 twelve participants divided into 3 teams worked on three projects in the area of Math Modeling. The teams were supervised by Sergei Fomin.

Description of the Projects

Project 1: Modeling the Spread of Radioactive Contaminant in Fractured Aquifers Surrounded by Porous Rock

This project examines the spread of radioactive contaminant by mass transfer through fractures and aquifers in subsurface porous rock. This is a topic of consideration for nuclear power plant and nuclear waste repository design, where radioactive waste must be isolated from the environment and especially groundwater sources. By solving a system of fractional differential equations that model the radioactive contaminant transport in the fractured aquifer and surrounding porous rocks for the steady-state case, the long-time equilibrium situation to determine the maximum possible zones of contamination is determined. The model accounts for the physical processes of diffusion, dispersion, and advection due to fluid flow, in addition to intrinsic properties of the system, such as rock porosity, radioactive half-life of the contaminant and anomalous fracture patterns in the rock. Due to prior experimental and theoretical results, which validates that fluid flow and mass transport in fracture patterns with fractal geometry are better modeled by fractional derivatives, this work utilizes these fractional-order terms to model the mass transport in the aquifer and porous rocks. The solutions can then be used to model contaminant spread and decay, and to examine contamination zones in various real-world conditions to help outline safety procedures and guidelines for disaster prevention.

Major outcomes: This work models the complete spread of radioactive contaminant by mass transfer in aquifers within porous rock under steady-state equilibrium. The analysis can be used for both Fickian and non-Fickian flow. Depending on the porosity, fracture patterns, and other specific conditions, either analytic or numerical solutions can be used to model the contaminant concentration in the physical system. Moreover, using this model, it is possible to show that the concentration of contaminant decays exponentially with respect to distance. By producing and solving a model for contaminant concentration in the subsurface repository, rocks, and aquifers, this work can be used to examine the risks and dangers of radioactive waste storage. The result is a general model which can be applied to analyze the situational outcome of hypothetical contamination hazards in numerous settings.

<u>Project 2: Obtaining the Thermophysical Properties of the Solids Using the Measured Distribution of Temperature Within the System of Contacting Solids at Uniform Heating</u>

By examining the concept of the device of the laboratory setup for defining thermo-physical properties of materials under uniform heating, it is possible derive a system of partial equation that will model said concept. Once this system is solved, it is then possible to implement two different algorithms that use experimental data and the analytic solution to find the thermo-physical properties of the material being studied.

The device of the laboratory set up for defining thermophysical properties of different materials is based on the following concept of the heat transfer process. The specimen of the material to be examined, which has the shape of cylindrical slab with radius r_o = 15mm and thickness L = 20mm, is placed between two semi-infinite solid media (such that the length of each medium must be much greater than the depth of penetration of temperature perturbations) with well documented thermophysical properties, and the periodic heating performed at one of the interfaces between the examined specimen and the confining solid medium. Fig.1 depicts the principal scheme of 3 contacting solids where the process of conductive heat transfer takes place. In this figure: 1, 3 – are solids with well-known thermophysical properties (sample solids), 2 – the solid specimen under examination, 4 – heating module, which secures the uniform heating along the interface between the solids 1 and 2.

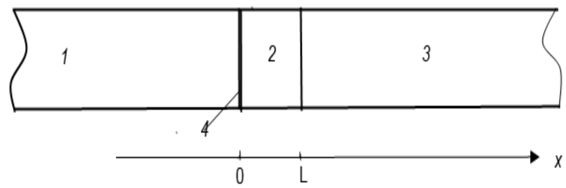

Fig 1: The schematic sketch of three contacting solids (the cross-section of the cylindrical solids by the plain that contains the axis of symmetry of solids).

Assuming that the side surface of this array of three contacting cylindrical solids is ideally insulated, then the heat transfer within these solids takes place in the x-direction. In addition, to obtain a simpler formulae, it is necessary to assume that solid 1 in Fig. 1 is an ideal insulator of heat, that is, the thermal conductivity of it is negligibly small. In this case, we have a system of two contacting solids, 2 and 3.
Major outcomes: Previous publications examine a situation when the heat flux from the heater 4 is periodic, that is, can be described by a periodic function. This periodic function can be presented by its Fourier series, which represents the infinite sum of the constant components of the heat flux and its different harmonics. Instead, we examine the situation when the heat flux is a real valued constant function. Lastly, once the analytic solution of the problem with constant heat flux and the corresponding measurements of the temperatures in the solid are known, the algorithms that determine the physical properties of the solid can be readily built. This algorithm was justified by numerous numerical experiments and comparison of computed values of heat conductivity with well documented data. Using this algorithm, the thermophysical properties of numerous materials can be readily determined.

Project 3: Effect of the Working Surface Shape of a Thermal Drill on Hot-Point Ice Boring Performance

Exploration drilling is one of the informative methods of geophysical research in glacier covered areas. Hot-point boring has become a widespread drilling technique in the past years. Application of thermal drilling and new technologies and equipment for the drilling of ice and snow deposits must be based on a comprehensive analysis of the processes of heat and mass transfer in the operation of a thermal drill. The temperature fields in the body of the drilling bit and in the surrounding ice sheet are connected by convection heat exchange with a layer of thaw water moving between the working surface of the bit and the melting ice surface. This complicates theoretical analysis and interferes with the choice of energy- efficient drilling operation conditions and the development of optimal designs of thermal drills. In our project we estimate how the shape of the boring bit of the thermal drill affects the speed of ice melting. Some important factors, such as convection heat transfer in the thaw water layer and the dissipation of heat in the ice sheet, however, were taken into account. The present project offers a mathematical description and a numeric analysis of these processes.

Major outcomes: The optimal shape of the thermal drill for different drilling conditions is determined. These results can be used for designing the thermo-drilling devices for drilling glaciers in Arctic and Antarctic regions.

Intellectual Merit of REUT

In addition to facilitating the solution of research problems in mathematics we provide a model for the integration of research experiences of teachers and undergraduates. The program assessment gauges the success of this model by measuring not only the impact on career decisions of undergraduate participants, but also the major changes in participants' perception of research in general and mathematics in particular. Methods for measuring this impact on participants' mathematical world-view are of interest not only to the NSF, but to science and mathematics educators. As such, this program fits into CSUC's strong tradition of externally funded and innovative programs for teacher preparation and continuing education in mathematics. Moreover, it builds on the department's history of involving undergraduates in research.

Broader Impacts of REUT

This project supports two significant NSF guiding strategies. First, the integration of research and education is carried out at several levels. Not only are students involved in research, but also high-school teachers and CSUC faculty are provided with an example of how to integrate research activities into the teaching and learning of math. By structuring our program after Polya's steps for problem solving we are disseminating an effective pedagogic approach to mathematics education. Second, the project also serves to broaden the participation of underrepresented groups through specific efforts to recruit women and underrepresented minorities. Further, the REU/T at Chico will promote faculty research programs and also open avenues for the inclusion of undergraduates in those programs, thus simultaneously serving two NSF-defined underrepresented populations, namely faculty and students at an undergraduate institute.

Acknowledgements

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