Working Groups (8:00am-12:00pm)

**Working Group 1: Equity in Undergraduate Mathematics Education**
- Aditya P. Adiredja - adiredja@math.arizona.edu
- Luis Leyva - luis.a.leyva@vanderbilt.edu
- Room: Pt. Loma 1

**Working Group 2: Research on College Mathematics Instructor Professional Growth**
- Shandy Hauk - shauck@wested.org
- Natasha Speer - speer@math.umaine.edu
- Jessica Deshler - deshler@math.wvu.edu
- Room: Pt. Loma 2 & 3

**Working Group 3: Research on Community College Mathematics**
- Claire Wladis - profwladis@gmail.com & cwladis@bmcc.cuny.edu
- Ann Sitomer - ann.sitomer@gmail.com
- Room: La Jolla

**Working Group 4: Education Research at the Interface of Mathematics and Physics: Mathematization of Introductory Physics**
- Suzanne Brahmia - brahmia@uw.edu
- Michael Oehrtman - michael.oehrtman@okstate.edu
- Room: Coronado

**Working Group 5: Research Opportunities for RUME Researchers in the Context of Mathematics Resource Centers**
- Melissa Mills - memills@math.okstate.edu
- Michael Tallman - michael.tallman@okstate.edu
- Brian Rickard - brickar@uark.edu
- Room: Private Dining Room

Registration/Help Desk Open (11:00 AM – 6:00PM)
- Room: Pt. Loma Ballroom 3 Foyer

Opening Session (1:00 -1:15)
- Room: Pt. Loma 2 & 3

**Session 1 Contributed Reports (1:25-1:55)**

- **Common Algebraic Errors in Calculus Courses**
  - Sepideh Stewart and Stacy Reeder
  - Room: La Jolla

- **Mentor Professional Development for Mathematics Graduate Student Instructors**
  - Sean Yee and Kimberly Rogers
  - Room: Pt. Loma 1

- **Order of Operations: A Case of Mathematical Knowledge-in-Use**
  - Rina Zazkis
  - Room: Pt. Loma 2 & 3

- **Undergraduate Students’ Quantitative Reasoning in an Economic Context**
  - Thembinkosi Mkhatshwa and Helen Doerr
  - Room: Del Mar

- **Supporting Instructional Change in Mathematics: The Role of Online and In-person Communities**
  - Charles Hayward and Sandra Laursen
  - Room: Coronado

**Session 2 Preliminary Reports (2:05-2:35)**

- **Supporting students’ understanding of calculus concepts: Insights from middle-grades mathematics education research**
  - Steven Boyce
  - Room: La Jolla

- **An Explicit Method for Teaching Generalization to Pre-Service Teachers Using Computer Programming**
  - Cynthia Stenger, James Jenkins, Jessica Stovall and Janet Jenkins
Room: Bay Room
Instruction in Precalculus and Single-Variable Calculus in the United States: A Bird’s Eye View
   Dana Kirin, Kristen Vroom, Sean Larsen and Naneh Apkarian
Room: Coronado
Textbook Formations of Independence
   Adam Molnar and Steven Edalgo
Room: Private Dining
Underrepresented Students Succeeding in Math: The Challenges and Coping Strategies of Mathematically Talented Post-secondary Students
   Martha Makowski
   Room: Del Mar
CxN: Investigating the Creative Proving Process Using Neuroscience Methods
   Milos Savic, David Plaxco, Michael Wenger, Emily Cilli-Turner, Gail Tang, Houssein El Turkey and Gulden Karakok
   Room: Pt. Loma 1

Session 3 Preliminary Reports (2:45 PM – 3:15 PM)
Mental Constructions Involved in Differentiating a Function to a Function Power
   Rachel Rupnow and Catherine Ulrich
   Room: Coronado
Identification Matters: Effects of Female Peer Role Models Differ By Gender Between High and Low Mathematically Identified Students
   Susan Nickerson, Adam Dilla, Katie Bjorkman, Sei Jin Ko and David Marx
   Room: Pt. Loma 2 & 3
Teachers’ Beliefs & Knowledge of the Everyday Value of High School Algebra & Geometry: Is One More Useful than the Other?
   Jennifer Dunham
   Room: Bay Room
Raising reasoning through revision: A case study of an inquiry-based college geometry course
   Janessa Beach and Rebecca Dibbs
   Room: La Jolla
Studying Pre-Service Teachers’ Selection of Representations in a Technologically Enhanced Environment
   Robert Sigley, Muteb Alqahtani and Victoria Krupnik
   Room: Del Mar
Students’ Social Adaptation to Mathematical Tasks
   Jeffrey King
   Room: Private Dining

Coffee Break (3:15 PM – 3:45 PM)
   Room: Cabo Courtyard (Weather Permitting)

Session 4 Contributed Reports (3:45 PM – 4:15 PM)
A Success Factor Model for Calculus: The Relative Impact of and Connections between Factors Affecting Student Success in College Calculus
   Megan Ryals and Karen Keene
   Room: Coronado
Variations in Precalculus Through Calculus 2 Courses
   Matthew Voigt, Chris Rasmussen and Naneh Apkarian
   Room: Pt. Loam 2 & 3
Leveraging Real Analysis to Foster Pedagogical Practices
   Nicholas Wasserman, Keith Weber and William McGuffey
   Room: La Jolla
The Role of Visual Reasoning in Evaluating Complex Mathematical Statements: A Comparison of Two Advanced Calculus Students
   Erika David, Kyeong Hah Roh, Morgan Sellers and Kody D’Amours
   Room: Del Mar
Session 5 Contributed Reports (4:20 PM – 4:50 PM)
Infinitesimals-based registers for reasoning with definite integrals
   Robert Ely
   Room: Del Mar

Interaction, activities, and feedback: A taxonomy of GTA Professional Development
   Jess Ellis, Daniel Bragdon and Jessica Gehrtz
   Room: Pt. Loma 2 & 3

Mathematicians’ Evaluations of the Language of Mathematical Proof Writing at the Undergraduate Level in Three Different Pedagogical Contexts
   Kristen Lew and Juan Pablo Mejia-Ramos
   Room: Coronado

Exploration of the Factors that Support Learning: Web-based Activity and Testing Systems in Community College Algebra
   Shandy Hauk, Bryan Matlen and Larry Thomas
   Room: La Jolla

Principles for Designing Tasks that Promote Covariational Reasoning
   Irma Stevens, Teo Paoletti, Kevin Moore, Biyao Liang and Hamilton Hardison
   Room: Private Dining

Session 6 Contributed Reports (5:00 PM – 5:30 PM)
Developing Students’ Reasoning about the Derivative of Complex-Valued Functions with the Aid of Geometer’s Sketchpad (GSP)
   Jonathan Troup
   Room: Del Mar

Preservice Secondary Teachers’ Abilities to Use Representations and Realistic Tasks
   Kyunghee Moon
   Room: Bay Room

Physics Students’ Use Of Symbolic Forms When Constructing Differential Elements In Multivariable Coordinate Systems
   Benjamin Schermerhorn and John Thompson
   Room: Private Dining

Difficult Dialogs About Degenerate Cases: A Proof Script Study
   Stacy Brown
   Room: Coronado

Can/Should Students Learn Mathematics Theory-Building?
   Hyman Bass
   Room: La Jolla

Session 7 Contributed Reports (5:40 PM – 6:10 PM)
Definite Integrals Versus Indefinite Integrals: How do Students See Them as the Same or as Different?
   Steven Jones and Cache Thompson
   Room: Coronado

Transitioning to Proof with Worked Examples
   Dimitri Papadopoulos
   Room: Private Dining

Using Oral Presentations to Facilitate Learning Statistics
   Abeer Hasan and Sayonita Ghosh Hajra
   Room: Bay Room

Using Video in Online Work Groups to Support Faculty Collaboration
   Nicholas Fortune, Karen Keene and William Hall
   Room: La Jolla

Expert vs. Novice Reading of a Calculus Textbook: A Case Study Comparison
   Emilie Wiesner, Aaron Weinberg, John Barr and Nikki Upham
   Room: Del Mar
Poster Session 1 & Reception (6:10 PM – 7:00 PM)
Room: Cabo Courtyard (Weather Permitting)
Data Cleaning in Mathematics Education Research: The Overlooked Methodological Step
Aleata Hubbard
JITAR online modules to improve math preparation of engineering students
Alina Duca
Supporting Math Emporium Students’ Learning Through Short Instructional Opportunities
Andrea Alt
Interpretive reading of mathematical propositions for proving: A case study of a mathematician modeling reading to students during joint proof production.
Anna Zarkh
A Comparison of Faculty Expectations and Student Perceptions of Active Engagement in a Calculus I Class
Belinda Edwards
An Active Learning Environment in Introductory Analysis
Brynja Kohler
Beyond the Exam Score: Gauging Conceptual Understanding from Final Exams in Calculus II
Ciera Street and Kristen Amman
Online STEM and mathematics course-taking: Retention and Access
Claire Wladis
Conceptual Understanding of Differential Calculus: A Comparative Study
Daria Gerasimova, Kathleen Matson, Robert Sachs and Margret Hjalmarson
Service-Learning and a Shift in Beliefs about Mathematical Problem Solving
Ekaterina Yurasovskaya
Characterizing Normative Metacognitive Activity During Problem Solving in Undergraduate Classroom Communities
Emilie Hancock
Situational Characteristics Supporting Instructional Change
Estrella Johnson and Rachel Keller
Mathematics Affirmations
Geillan Aly
All The Math You Need: An Investigation into the Curricular Boundaries of Mathematical Literacy
Gizem Karaali
Questioning assumptions about the measurability of subdomains of Mathematical Knowledge for Teaching (MKT)
Heather Howell, Yvonne Lai and Heejoo Suh
Designing and Developing Likert Items that Capture Mathematical Problem Solving
James Epperson, Kathryn Rhoads and R. Cavender Campbell
Empowered Women In RUME: What Have We Been Up To?
Jess Ellis, Stacy Musgrave, Kathleen Melhuish, Eva Thanheiser and Megan Wawro
Extreme Apprenticeship
Johanna Rämö, Jokke Häsa, and Juulia Lahdenperä
Research in Courses before Calculus Through the Lens of Social Justice
Shandy Hauk, Allison Toney, April Brown and Katie Salguero
Hypophora: Why Take the Derivative? (no pause) Because it is the Rate
Kitty Roach
Who is Teaching the Precalculus Through Single-Variable Calculus Sequence and How are they Teaching it?
Kristen Vroom and Dana Kirin
STEM major mindset changes during their first undergraduate mathematics course
Laura Beene and Rebecca Dibbs
Designing a Richer Flipped Classroom Calculus Experience
Matthew Voigt and Helge Fredriksen
Connecting Reading Comprehension Research and College Mathematics Instruction
Melanie Butler
The Mathematics Attitudes and Perceptions Survey: New Data and Alignment with Other Recent Findings  
Warren Code and Wes Maciejewski

Students’ Mistakes and Strategies When Matching a Function’s Graph with its Derivative  
Nathan Jewkes and Amy Dwiggins

Analyzing Focus Groups of an Experimental Real Analysis Course: ULTRA  
Ruby Quea and William McGuffey

Using Evidence to Understand and Support an Educational Reform Movement: The Case of Inquiry-Based Learning (IBL) in College Mathematics  
Sandra Laursen, Charles Hayward and Zachary Haberler

Exploring the content–specific mathematical proving behavior of students in context: Opportunities for extracting and giving mathematical meaning  
Sarah Hough, William Jacob, Monica Mendoza and Alex Sacharuk

Schema as a theoretical framework in advanced mathematical thinking  
Sepideh Stewart

The Influences of a Teacher’s Mathematical Meaning of Constant Rate of Change on His Classroom Practices  
Sinem Bas Ader and Marilyn Carlson

Bridging the Gaps between Teachers’ and Students’ Perspectives of a Culturally Inclusive Classroom  
Thomas Mgonja and Kuo-Liang Chang

Reasoning about Relative Motion with Frames of Reference  
Surani Joshua

Individual and Group Work with Nonstandard Problems in an Ordinary Differential Equations Course for Engineering Students  
Svitlana Rogovchenko, Yuriy Rogovchenko and Stephanie Treffert-Thomas

A Topological Approach to Formal Limits Supported by Technology: What Concept Images do Students Form?  
Tamara Lefcourt Ruby and Shulamit Solomon

Mathitude: Precalculus Concept Knowledge and Mathematical Attitudes in Precalculus and Calculus I  
Todd Cadwallader Olsker

Algebra instruction at community colleges: An exploration of its relationship with student success  
Vilma Mesa, Irene Duranczyk, Nidhi Kohli, April Strom, Laura Watkins and Angeliki Mali

Upper-division Physics Student Thinking Regarding Non-Cartesian Coordinate Systems  
Warren Christensen, Brian Farlow, Marlene Vega and Michael Loverude

The Effects of Graphing Calculator on Learning Introductory Statistics  
Wei Wei and Katherine Johnson

Calculus Students’ Meanings for Average Rate of Change  
Wyatt Ehlke, Sayonita Ghosh Hajra

Exploratory Activities with Dynamic Geometry Environment in Axiomatic Geometry  
Younggon Bae

Quantitative Learning Centers: What We Know Now and Where We Go from Here  
Melissa Haire

Dinner & Plenary Session (7:00 PM – 9:30 PM)  
Living, Learning, and Leading in Socially Networked Systems  
Alan Daly  
Room: Pt Loma 2 & 3

Registration/Help Desk Open (7:00 AM – 6:30PM)  
Room: Pt. Loma Ballroom 3 Foyer

Breakfast (7:00 AM-8:30 AM)  
Room: Cabo Courtyard (Weather Permitting)

Session 8 Contributed Reports (8:35 AM – 9:05 AM)  
Beyond the Product Structure for Definite Integrals  
Courtney Simmons and Michael Oehrtman  
Room: Pt. Loma 1
Exploring a Pre-Service Teacher’s Conceptions of Area and Area Units
Sayonita Ghosh Hajra and Betsy McNeal
Room: Del Mar

Features of Explanatory Proofs: An Exploratory Study
Eyob Demek
Room: La Jolla

Undergraduate abstract algebra: Is teaching different at 'teaching' colleges?
Rachel Keller, Estrella Johnson, Valerie Peterson and Tim Fukawa-Connelly
Room: Coronado

Session 9 Preliminary Reports (9:15 AM – 9:45 AM)
The role of mathematics faculty in the development of African American male mathematics majors
Christopher Jett
Room: Del Mar

The Use of NCTM Articles as Reading Assignments to Motivate Prospective Elementary Teacher Engagement in Mathematics Courses
Krista Strand and Eva Thanheiser
Room: Bay Room

What Constitutes a Proof? Complementary Voices of a Mathematician and a Mathematics Educator in a Co-Taught Undergraduate Course on Mathematical Proof and Proving
Orit Zaslavsky and Jason Cooper
Room: Pt. Loma 1

The Effect of Attending Peer Tutoring on Course Grades in Calculus I
Brian Rickard and Melissa Mills
Room: La Jolla

Factors influencing instructor use of student ideas in the multivariable calculus classroom
Aaron Wangberg, Tisha Hooks, Elizabeth Gire, Jason Samuels and Brian Fisher
Room: Coronado

Implementation of Pre and Post Class Readings in Calculus
Salam Turki and Houssein El Turkey
Room: Private Dining

Coffee Break (9:45 AM – 10:15 AM)
Room: Cabo Courtyard (Weather Permitting)

Session 10 Contributed Reports (10:15AM – 10:45 AM)
Characterizing the Nature of Introduction to Proof Courses: A Survey of R1 and R2 Institutions across the US
Erika David and Dov Zazkis
Room: Pt. Loma 1

Approaches to the derivative in Korean and the U.S. Calculus Classrooms
Jungeun Park
Room: Del Mar

McNuggets, Bunnies, and Remainders, Oh My!
Nina Rocha and Jennifer Zakotnik-Gutierrez
Room: La Jolla

Managing Tensions Within a Coordinated Inquiry-Based Learning Linear Algebra Course: The Role of Worksheets
Vilma Mesa, Mollee Shultz and Ashley Jackson
Room: Coronado

Preservice Elementary Teachers’ Understandings of Greatest Common Factor Versus Least Common Multiple
Kristin Noblet
Room: Private Dining

Session 11 Preliminary Reports (10:55 AM – 11:25 AM)
An exploration of students' discourse using Sim2Bil within group work: A commognitive perspective
Ninni Marie Hogstad and Olov Viirman
Room: Del Mar
Second semester calculus students and the contrapositive of the nth term test
David Earls
Room: La Jolla
Developing Student Understanding: The Case of Proof by Contradiction
Darryl Chamberlain Jr and Draga Vidakovic,
Room: Pt. Loma 1
Analysis of Teachers’ Conceptions of Variation
Gabriel Tarr and April Strom
Room: Private Dining Room
Outcomes Beyond Success in a Problem Centered Developmental Mathematics Class
Martha Makowski
Room: Coronado

Session 12 Contributed Reports (11:35 AM – 12:05 PM)
Students’ Understanding of Vectors and Cross Products: Results from a Series of Visualization Tasks
Monica VanDieren, Deborah Moore-Russo and Jill Wilsey
Room: Pt. Loma 1
Using Women of Color’s Intuitive Examples to Reveal Nuances about Basis
Aditya Adiredja and Michelle Zandieh
Room: Del Mar
Preserve Secondary Teachers’ Abilities to Transfer from Graphical to Algebraic Representations of Functions
Kyunghee Moon
Room: Private Dining Room
Undergraduate Students’ Holistic Comprehension of a Proof
Eyob Demeke
Room: La Jolla
Tinker Bell’s Pixie Dust: Exploring the Role of Differentiation in Emergent Shape Thinking
Kristin Frank
Room: Coronado

Lunch and Business Meeting (12:05 – 1:05 PM)
Room: Pt. Loma 2 & 3

Session 13 Contributed Reports (1:05 PM – 1:35 PM)
Computational thinking in and for undergraduate mathematics: Perspectives of a mathematician
Miroslav Lovric and Ami Mamolo
Room: Private Dining Room
How Students Interpret Line and Vector Integral Expressions: Domains, Integrands, Differentials, and Outputs
Steven Jones and Omar Naranjo
Room: Coronado
SCNI: A Robust Technique to Investigate Small-Group Learning at College
Fady El Chidiac
Room: La Jolla
Graduate Student Instructors learning from peer observations
Daniel Reinholz
Room: Del Mar
Comparing Expert and Learner Mathematical Language: A Corpus Linguistics Approach
Lara Alcock, Matthew Inglis, Kristen Lew, Juan Pablo Mejia-Ramos, Paolo Rago and Chris Sangwin
Room: Pt. Loma 1

Session 14 Contributed Reports (1:45 PM – 2:15 PM)
Learning to Notice and Use Student Thinking in Undergraduate Mathematics Courses
Anna Pascoe
Room: Del Mar
Virtual Manipulatives, Vertical Number Lines, and Taylor Series Convergence: The Case of Cody
Matthew Thomas and Jason Martin  
Room: La Jolla
Using learning trajectories to structure teacher preparation in statistics
Anna Bargagliotti and Celia Anderson Rosseau  
Room: Private Dining Room
Exploring Undergraduates’ Experience of the Transition to Proof
Jack Smith, Mariana Levin, Younggon Bae and V. Satyam  
Room: Coronado
Examining Lecturer’s Questioning in Advanced Proof-Oriented Mathematics Classes
Teo Paoletti, Victoria Krupnik, Dimitri Papadopoulos, Joseph Olsen and Tim Fukawa-Connelly and Keith Weber  
Room: Pt. Loma 1

Session 15 Preliminary Reports (2:25 PM – 2:55 PM)
Locating a Realistic Starting Point for the Guided Reinvention of Limit at Infinity With Community College Students Prior to Pre-Calculus
William McGuffey  
Room: La Jolla
Do Students Really Know What a Function is?: Applying APOS Analysis to Student Small Group Presentations
Tara Davis and Georgianna Martin  
Room: Del Mar
Connecting Secondary and Tertiary Mathematics: Abstract Algebra and Inverse
Eileen Murray, Matthew Wright and Debasmita Basu  
Room: Coronado
Perturbing practice: The effects of virtual manipulatives as novel didactic objects on instruction
Krysten Pampel  
Room: Private Dining Room
Considerations for Explicit and Reflective Teaching of the Roles of Proof
Jeffrey Pair and Sarah Bleiler-Baxter  
Room: Pt. Loma 1

Coffee Break (2:55 PM – 3:25 PM)
Room: Cabo Courtyard (Weather Permitting)

Session 16 Preliminary Reports (3:25 PM – 3:55 PM)
Let’s Talk About Teaching: Investigating Instructors’ Social Networks
Kathleen Quardokus Fisher and Naneh Apkarian  
Room: Del Mar
Experts’ Varied Concept Images of the Symbol dx in Integrals and Differential Equations
Tim McCarty and Vicki Sealey  
Room: Coronado
Professional Development Linking the Concept of Inverse in Abstract Algebra to Function Inverses in the High School Curriculum
Melissa Mills and Cara Brun  
Room: Private Dining Room
Pedagogical Practices for Fostering Mathematical Creativity in Proof-Based Courses: Three Case Studies
Milos Savic, Houssein El Turkey, Gail Tang, Gulden Karakok, Emily Cilli-Turner, David Plaxco and Mohamed Omar  
Room: Pt. Loma 2 & 3
A Preliminary Investigation of the Reification of “Choosing” in Counting Problems
Elise Lockwood  
Room: Pt. Loma 1
Opportunities to Learn from Teaching: A Case Study of Two Graduate Teaching Assistants
Nathan Wakefield, Erica Miller and Yvonne Lai  
Room: La Jolla
Session 17 Preliminary Reports (4:05 PM – 4:35 PM)
Mathematicians’ Interplay of the Three Worlds of the Derivative and Integral of Complex-valued Functions
Hortensia Soto and Michael Oehrtman
Room: Pt. Loma 1

Meta-Representational Competence with Linear Algebra in Quantum Mechanics
Megan Wawro, Kevin Watson and Warren Christensen
Room: Coronado

An Investigation of the Development of Partitive Meanings for Division with Fractions: What Does It Mean to Split Something into 9/4 Groups?
Matthew Weber, Amie Pierone and April Strom
Room: Private Dining Room

Session 18 – Preliminary Reports (4:45 PM – 5:15 PM)
Instrumental Genesis and Generalization in Multivariable Calculus
Brian Fisher and Jason Samuels
Room: Pt. Loma 2 & 3

Examining Students’ Procedural and Conceptual Understanding of Eigenvectors and Eigenvalues in the Context of Inquiry-Oriented Instruction
Khalid Bouhjar, Muhammad Haidar and Christine Andrews-Larson
Room: La Jolla

The Effects of the Epsilon-N Relationship on Convergence of Functions
Zackery Reed
Room: Coronado

DNR-Based Professional Development: Factors that Afford or Constrain Implementation
Guershon Harel and Osvaldo Soto
Room: Pt. Loma 1

Mathematical Modelling and Mathematical Competencies: The case of Biology students.
Yannis Liakos
Room: Del Mar

Characterizing Mathematical Digital Literacy: A Preliminary Investigation
Todd Abel and Jeremy Brazas
Room: Private Dining Room

Special Session (5:30 - 6:30 PM)
The Changing Landscape of Undergraduate Mathematics Education and its Implications for the RUME Community
Uri Treisman
Room: Pt. Loma 2&3

Registration/Help Desk Open (7:00 AM – 6:30PM)
Room: Pt. Loma Ballroom 3 Foyer

Breakfast (7:00 AM -8:30 AM)
Room: Cabo Courtyard (Weather Permitting)

Session 19 Contributed Reports (8:35 AM – 9:05 AM)
Decontextualizing word problems and contextualizing symbols
Sayonita Ghosh Hajra and Victoria Kofman
Room: La Jolla
Completeness and Convergence: Interdependent Development in the Context of Proving the Intermediate Value Theorem
Stephen Strand
Room: Del Mar
A Case Study in Constructing Set-based Meanings for Conditional Truth
Alec Hub and Paul Dawkins
Room: Pt. Loma 1
Angle Measure, Quantitative Reasoning, and Instructional Coherence: The Case of David
Michael Tallman
Room: Coronado

Session 20 Preliminary Reports (9:15 AM – 9:45 AM)
The saga of Alice continues: Her progress with proof frameworks evaporates when she encounters unfamiliar concepts, but eventually returns
Annie Selden, John Selden and Ahmed Benkhalti
Room: Pt. Loma 1
Knowledge About Student Understanding of Eigentheory: Information Gained from Multiple Choice Extended Assessment
Kevin Watson, Megan Wawro, Michelle Zandieh and Sarah Kerrigan
Room: La Jolla
Undergraduates’ Reasoning about Integration of Complex Functions within Three Worlds of Mathematics
Brent Hancock
Room: Coronado
A Continued Exploration of Self – Inquiry in the Context of Proof and Problem Solving
Todd Grundmeier and Dylan Retsek
Room: Del Mar
Preservice Teachers Fractional Knowledge: Understanding the District Roles of Fractions
Eun Jung
Room: Private Dining Room

Coffee Break (9:45 AM – 10:15 AM)
Room: Cabo Courtyard (Weather Permitting)

Session 21 Contributed Reports (10:15AM – 10:45 AM)
Students’ Conceptions of Mappings in Abstract Algebra
Rachel Rupnow
Room: La Jolla
Student Conceptions of Three-Dimensional Solids
Stepan Paul and Monica Mendoza
Room: Coronado
Inquiry as an Access Point to Equity in the Classroom
Gail Tang, Houssein El Turkey, Emily Cilli-Turner, Milos Savic, David Plaxco, and Gulden Karakok
Room: Del Mar
A Comparison of Calculus, Transition-to-Proof, and Advanced Calculus Student Quantifications in Complex Mathematical Statements
Morgan Sellers, Kyeong Hah Roh, Erika David and Kody D’Amours
Room: Pt. Loma 1

Session 22 Contributed Reports (10:55 AM – 11:25 AM)
Stages of Development for the Concept of Inverse in Abstract Algebra
John Paul Cook and Rosaura Uscanga
Room: La Jolla
How Limit can be Embodied and Arithmetized: A Critique of Lakoff and Núñez
Timothy Boester
Room: Del Mar
Those Who Teach the Teachers: Knowledge Growth in Teaching for Mathematics Teacher Educators
  Shandy Hauk, Billy Jackson and Jenq-Jong Tsay
  Room: Coronado

Student Mathematical Connections in an Introductory Linear Algebra Course
  Spencer Payton
  Room: Private Dining Room

“Explanatory” Talk in Mathematics Research Papers
  Juan Pablo Mejia-Ramos and Matthew Inglis
  Room: Pt. Loma 1

Session 23 Contributed Reports (11:35 AM – 12:05 PM)
Emerging Insights from the Evolving Framework of Structural Abstraction in Knowing and Learning Advanced Mathematics
  Thorsten Scheiner
  Room: Del Mar
Exploring Experts’ Covariational Reasoning
  Natalie Hobson and Kevin Moore
  Room: Pt. Loma 1

What Should Undergraduate Mathematics Majors Understand About the Nature of Mathematical Knowledge?
  Jeffrey Pair
  Room: La Jolla

Gender and Discipline Specific Differences in Mathematical Self-Efficacy of Incoming Students at a Large Public University
  Ulrike Genschel and Xuan Hien Nguyen
  Room: Private Dining Room

Student Proficiency with Transformational Geometry After a College Proof-Based Geometry Class
  Meredith Hegg and Tim Fukawa-Connelly
  Room: Coronado

Lunch and Mentoring Session (12:05 PM – 1:10 PM)
  Room: Boxed Lunches Provided

Session 24 Preliminary Reports (1:10 PM – 1:40 PM)
Exploring Student Conceptions of Binary Operation
  Kathleen Melhuish
  Room: La Jolla

Spatial Training and Calculus Ability: Investigating Impacts on Student Performance and Cognitive Learning Style
  Emily Cilli-Turner and Lindsay McCunn
  Room: Pt. Loma 1

Theoretical Framework of Algebraic Concepts for Elementary Algebra
  Claire Wladis
  Room: Del Mar

Evaluation of Graduate Student Professional Development and Instruction by Mathematics Departments: Results from a National Survey
  Natasha Speer, Jess Ellis and Jessica Deshler
  Room: Coronado

Blended Processing: Mathematics in Chemical Kinetics
  Kinsey Bain, Adam Zabih, Alena Moon and Marcy Towns
  Room: Private Dining Room

Session 25 Contributed Reports (1:50 PM – 2:20 PM)
Mathematical Actions, Mathematical Objects, and Mathematical Induction
  Rachel Arnold and Anderson Norton
  Room: Coronado
An Unexpected Outcome: Students’ Focus on Order in the Multiplication Principle  
_Elise Lockwood and Branwen Schaub_  
Room: La Jolla

Function Sameness to ‘Function’ Meaning  
_Alison Mirin_  
Room: Private Dining Room

Mathematicians’ Collaborative Silences  
_Matthew Petersen_  
Room: Bay Room

Making RUME for Institutional Change  
_Daniel Reinholz_  
Room: Del Mar

**Session 26 Preliminary Reports (2:30 PM – 3:00 PM)**

Corequisite Remediation and Math Pathways in Oklahoma  
_Matthew Wilson and Michael Oehrtman_  
Room: Pt. Loma 2 & 3

Career Decision Making Strategies of Calculus and Developmental Mathematics Students  
_Xiangming Wu, Jessica Deshler, Edgar Fuller and Marcela Mera Trujillo_  
Room: Bay Room

Student Gesture Use When Explaining the Second-Derivative Test and Optimization  
_Tim McCarty and Nicole Infante_  
Room: Coronado

The Lead TA Influence: Teaching Practices Focused on for an Active Learning Classroom  
_Hayley Milbourne and Susan Nickerson_  
Room: La Jolla

Signed Quantities: Mathematics Based Majors Struggle to Make Meaning  
_Suzanne Brahmia and Andrew Boudreaux_  
Room: Private Dining Room

Comparing graph use in STEM textbooks and practitioner journals  
_Teo Paoletti, Madhavi Vishnubhotla, Zareen Rahman, Justin Seventko and Debasmita Basu_  
Room: Del Mar

**Coffee Break (3:00 PM – 3:30 PM)**  
Room: Cabo Courtyard (Weather Permitting)

**Session 27 Contributed Reports (3:30 PM – 4:00 PM)**

Attention to Detail: Norms for Proof Evaluation in a Summer Mathematics Program  
_Cody Patterson and Xiaowen Cui_  
Room: Private Dining Room

Mathematics instruction leadership in undergraduate departments  
_Naneh Apkarian and Chris Rasmussen_  
Room: Coronado

Students’ Attitudes Toward Listing and Subsequent Behavior Solving Counting Problems  
_Sarah Erickson_  
Room: La Jolla

Generalising Univalence from Single to Multivariable Settings: The Case of Kyle  
_Allison Dorko_  
Room: Del Mar

Using Expectancy Value Theory To Account For Students’ Mathematical Justifications  
_Keith Weber, Kristen Lew and Juan Pablo Mejia-Ramos_  
Room: Pt. Loma 2 & 3

**Session 28 – Preliminary Reports (4:10 PM – 4:40 PM)**

Self-assessment Behaviors of Undergraduate Mathematics Students: A Preliminary Report  
_Kedar Nepal, Kailash Ghimire, Ramjee Sharma and Manoj Thapa_
Students’ Inclination to Use Visual Images During Problem Solving
Milé Krajcevski and Karen Keene
Room: Pt. Loma 2 & 3

Defining Functions: Choices That Affect Student Learning
Joshua Chesler
Room: Coronado

Students’ Understanding of Test Statistics in Hypothesis Testing
Annie Childers, Darryl Chamberlain Jr., Leslie Meadows, Harrison Stalvey, Draga Vidakovic and Aubrey Kemp
Room: Private Dining Room

Exploring Mathematics Graduate Teaching Assistants’ Developmental Stages for Teaching
Mary Beisiegel
Room: La Jolla

Poster Session 2 & Reception (4:50 PM – 5:50 PM)
Room: Cabo Courtyard (Weather Permitting)

Coping with the derivative of an atypical representation of a common function
Alison Mirin

Improving Undergraduate STEM Education Through Adjunct Mathematics Instructor Resources and Support (IUSE-AMIRS)
Amir Golnabi, Eileen Murray and Zareen Rahman

Building a Cognitive Model for Symmetry: How Well Does an Existing Framework Fit?
Anna Marie Bergman and Ben Wallek

A Framework for Characterizing a Teacher’s Decentering Tendencies
Ashley Duncan

Exploring Conceptions of Mathematics: A Comparison of Drawings and Attitudinal Scales
Ben Wescoot

Calculus Instructor Beliefs Regarding Student Engagement
Carolyn James

Variations of College Algebra Instructors’ Presentations of the Mathematics: The Case of Solving Quadratic Inequalities
Claire Gibbons

Examining Prospective Teachers’ Justifications of Children’s Temperature Stories
Dana Olanoff, Nicole Wessman-Enzinger and Jennifer Tobias

Online Course Component and Student Performance
Elizabeth DiScala

Mathematical Knowledge for Teaching & Cognitive Demand: A Case Study of Precalculus Examples that Involve Procedures
Erica Miller

Categorizing Teachers’ Beliefs about Statistics Through Cluster Analysis
Gabriel Tarr

Student Ways of Framing Differential Equations Tasks
George Kuster

Leveraging Research to Support Students’ Quantitative and Co-variational Reasoning in an Online Environment
Grant Sander and Marilyn Carlson

Speaking with Meaning about Angle Measure and the Sine Function
Stacy Musgrave and Marilyn Carlson

Classroom Participation as an Agent of Socialization for Identity Shaping of Preservice Mathematics Teachers
Janet Omitoyin

Equity Issues That (May) Arise in Active Learning Classrooms
Jessica Gehrtz, Richard Sampera and Jess Ellis

Student Understanding of Elements of Multivariable Calculus
John Thompson, Benjamin Schermerhorn and J. Caleb Speirs

Bringing Evidenced-Based Practices to a Large-Scale Precalculus Class: Preliminary Results
Karen Keene, Leslaw Skrzypek, Brooke Kott and Gregory Downing,
Student Understanding of the Product Layer of the Integral in Volume Problems
Krista Bresock and Vicki Sealey
Diagrams for the Reasoning and Proof of Amortization Formula
Kuo-Liang Chang, Hazel McKenna and Thomas Mgonja
A Reformed College Algebra Course: Understanding Instructors’ and Students’ Beliefs About Teaching and Learning Mathematics
Mary Williams
Putting on the Uniform: Coordination within the Calculus Curriculum
Matthew Voigt and Shawn Firouzian
Students’ Ways of Thinking About Transformational Geometry
Natasha Speer, Jennifer Dunham, Eric Pandiscio, Shandy Hauk and Eric Hsu
Engaging in Abstract Algebra through Game Play: Group Theory Card Game Groups
Patrick Galarza
Investigating Prospective Teachers’ Meanings of Covariation Before and After Calculus Coursework
Roser Gine
Student Attitudes, Beliefs, and Experiences Related to Counting Problems
Samantha McGee, Sarah Erickson and Elise Lockwood
Students’ Thinking In An Inquiry-Based Linear Algebra Course
Sarah Hough, Santa Barbara, William Jacob, Monica Mendoza, and Elizabeth Thoren
Linear algebra laboratory: Transitioning between three worlds of mathematical thinking
Sepideh Stewart
To Factorize or Not To Factorize: Novice Teachers’ Struggles
Hyungmi Cho, Miyeong Na, Oh Nam Kwon
Student Beliefs About Mathematics in an Inquiry-Based Introduction to Proof Course
Shiv Karunakaran, Abigail Higgins and James Whitbread, Jr
Mathematics Education as a Research Field: Reflections from ICME-13
Stacy Brown, Hortensia Soto and Spencer Bagley
Problem Posing and Developmental Mathematics Students
Steven Silber
Graphs Display Lengths, Not Locations
Surani Joshua
Reducing Abstraction in the Group Concept Inventory
Joshua Fagan and Kathleen Melhuish
Student reasoning with differentials and derivatives in upper-division physics
Michael Loverude
Investigating Student Learning Through Team-Based Learning Calculus Instruction
Travis Peters, Elgin Johnston, Heather Bolles, Craig Ogilvie and Alexis Knaub
Pre-service Teachers’ Use of Informal Language While Solving a Probabilistic Problem
Victoria Krupnik, Robert Sigley and Muteb Alqahtani
Some Logical issues in RUME
Viviane Durand-Guerrier
Post-class reflections and calibration in introductory calculus
Taylor Kline and Rebecca Dibbs
An alternate characterisation of Developmental Mathematics students
Wes Maciejewski and Cristina Tortora
Technology Use in the Teaching and Learning of an Introductory Statistics Course: The case of Excel and the ‘Knitr’ R-package
Sher Chhetri

Awards and Plenary Session (6:00 PM – 7:15 PM)
Student reasoning as the center of our research, curriculum development and teaching
Michelle Zandieh
Room: Pt. Loma 2 & 3
Thursday, February 23, 2017

Working Groups (8:00am-12:00pm)

Working Group 1: Equity in Undergraduate Mathematics Education
Aditya P. Adiredja - adiredja@math.arizona.edu
Luis Leyva - luis.a.leyva@vanderbilt.edu

Abstract: There remains a need to explore equity issues in undergraduate mathematics education, and consider ways that such perspectives complement existing research in the RUME community. To address this need, this working group serves as a collective of scholars and practitioners aimed at advancing the equity agenda in undergraduate mathematics education by exchanging constructive feedback on related scholarly work, instructional and curricular resources, and other artifacts from their professional practice. Particularly, the group aims to address the following questions: 1) In what ways can equity considerations conceptually and methodologically enhance the quality of research in RUME?; 2) Alongside the broader policy changes in higher education at large, how do we see issues of equity in the day-to-day teaching and learning experiences across undergraduate mathematics classrooms and other related learning contexts? 3) How can we leverage insights from K-12 mathematics education research to further advance the equity research agenda and inform more equitable teaching and learning opportunities in undergraduate mathematics? Informal and sustained mentorship will be encouraged within the working group considering the variation across members’ stages of academic and professional development.

Room: Pt. Loma 1

Working Group 2: Research on College Mathematics Instructor Professional Growth
Shandy Hauk - shauk@wested.org
Natasha Speer - speer@math.umaine.edu
Jessica Deshler - deshler@math.wvu.edu

Abstract: The group focus includes research on the professional development of all college mathematics instructors regardless of their level of experience or expertise. Many current members have a particular interest in the professional growth of novice college teachers (e.g., graduate student teaching assistants). The group meets online monthly throughout the year and once face-to-face at the RUME conference annually. We solicit proposals from researchers in all areas of the professional development of college mathematics instructors across institutional types (e.g., community college, university). This includes, but is not limited to, research on factors that shape instructional practices and the experiences of instructors as they attend to student thinking in their instruction. The group’s goals, historically and as they have evolved, continue to drive the focus of annual meetings. They include interaction that offers (1) informed individual support and feedback for researchers, (2) opportunities for networking and collaboration among mathematics educators interested in research and development of materials, processes, and theories to support the professional development of collegiate mathematics instructors, (3) continuing discussion of issues central to the field and ways to address them. The intended participants of this group include researchers in all of these areas, whether new to the field, to research in general (early career researchers) or experienced in both. Researchers need not present their work to participate in the group or provide feedback to others. Group meeting time is structured to allow feedback on research projects that are in progress. The working group is not meant to be a forum for presenting completed studies, but rather an opportunity to get feedback from peers on projects in any stage: from the refinement of research questions to study design, data collection and analysis to discussion of venues for future presentation and proposals for funding of projects. We also discuss strategies for sharing our work with the practice-oriented college mathematics instructor professional development community, the needs of the working group, and ways of sustaining collaborations and communication among group participants during the year.
Room: Pt. Loma 2 & 3

Working Group 3: Research on Community College Mathematics
Claire Wladis - profwladis@gmail.com & cwladis@bmcc.cuny.edu
Ann Sitomer - ann.sitomer@gmail.com

Abstract: Currently, national attention on community colleges, especially in mathematics, has provided a necessary spotlight for investigating mathematics education. President Obama's 2010 White House Summit on Community Colleges was preceded by a flurry of papers related to community college mathematics (e.g., Bailey, 2009; Rosenbaum, Stephan, & Rosenbaum, 2010; Stigler, Givven, & Thompson, 2010). Most of these authors are outside the field of mathematics education research and most have little, if any, experience teaching mathematics at community colleges. In addition, this scholarship refers to aspects of community colleges that, even though important (e.g., finances, access, retention) leave unexplored the one aspect that may have the greatest impact upon students' success: their experiences in the classroom. Supported through past working group sessions at RUME and committee work within AMATYC, a cadre of researchers has been collaborating to advance a national agenda and create a web of community college mathematics education research. We propose to leverage the RUME working group session to continue mapping the territory for research that focuses exclusively on community colleges. We will further the research agenda created in past working group sessions, with the aim of generating research products that will foster an understanding of community colleges as fundamental players in post-secondary education. In order to advance teaching and learning of mathematics at the community college level, we need a more coherent body of researchers and research across demographic, socioeconomic, racial/ethnic, and other institutional and individual identities that capture evidence-based instructional practices.

Room: La Jolla

Working Group 4: Education Research at the Interface of Mathematics and Physics: Mathematization of Introductory Physics
Suzanne Brahmia - brahmia@uw.edu
Michael Oehrtman - michael.oehrtman@okstate.edu

Abstract: The working group focus this year will be quantitative reasoning, modeling, and approximation with algebra and single variable calculus in the context of physics. The aim of this group is to educate and enrich research on the learning and teaching of mathematics and physics at the introductory college level of calculus and physics through cross-disciplinary discussions between researchers in both undergraduate mathematics and physics education. Activities will include a short interactive workshop to familiarize participants with the nature of the conceptual issues students encounter as they cognitively blend math and physics at the introductory level in calculus and in physics courses. Discussions will focus on relevant research literature and ongoing studies on learning and teaching of the content, as well as implications for theoretical studies, empirical studies, and instruction. While the focus of the working group will be limited to specific topics, the methods and ideas discussed will be broadly applicable to research within either field (RUME or PER) as well as extensions to other quantitative disciplines. Participants who wish to present briefly on their own relevant research during the working group should contact the organizers at least two weeks prior to the session.

Room: Coronado

Working Group 5: Research Opportunities for RUME Researchers in the Context of Mathematics Resource Centers
Melissa Mills - memills@math.okstate.edu
Michael Tallman - michael.tallman@okstate.edu
Brian Rickard - brickar@uark.edu

Abstract: Much of the research in the RUME community addresses student cognition in a classroom setting. While classroom instruction is important, it is not the only context in which learning can occur. The CSPCC study found that 89.5 percent of the universities surveyed offered mathematics tutoring services to undergraduates. Supplemental instruction and co-requisite instruction are other resources that are commonly offered to students in undergraduate mathematics courses. We propose that research about
student cognition can inform the teaching practices that take place in mathematics resource centers and SI sessions, and that these out-of-classroom resources provide an additional context in which research about student cognition can take place. There are several benefits to conducting research in the context of resource centers. First of all, resource centers have much fewer constraints than classroom instruction. The sizes of groups of students, length of sessions, and technology available can vary. Secondly, resource centers may offer more of an opportunity to affect change in instructional practices. It is not uncommon for university level instructors to lack the time, resources, or expertise to improve their instructional practices in the classroom. Since resource centers exist primarily for the purpose of addressing students’ instructional needs, tutors and SI leaders may be more capable of implementing the recommendations of research. This working group exists to bring together the collective expertise of RUME researchers to create a research agenda that investigates how current RUME research can inform the practices of resource centers and to explore how resource centers may provide a lucrative context for conducting future research about student cognition in mathematics.

Room: Private Dining Room

Registration/Help Desk Open (11:00 AM – 6:00PM)
Room: Pt. Loma Ballroom 3 Foyer

Opening Session (1:00 -1:15)
Room: Pt. Loma 2 & 3

Session 1 Contributed Reports (1:25-1:55)

Common Algebraic Errors in Calculus Courses
Sepideh Stewart and Stacy Reeder
College mathematics instructors often view the final problem solving steps in their respective disciplines as “just Algebra”, but in reality, a weak foundation in Algebra may be the cause of failure for many college students. The purpose of this paper is to identify common algebraic errors students make in college level mathematics courses that plague their ability to succeed in higher level courses. The identification of these common errors will aid in the creation of a model for intervention.
Submission: 164
Room: La Jolla

Mentor Professional Development for Mathematics Graduate Student Instructors
Sean Yee and Kimberly Rogers
To develop graduate student instructors’ (GSIs) skills and abilities as collegiate mathematics instructors, researchers at two universities implemented a peer-mentorship model where experienced GSIs completed a 15-week professional development (PD) to learn how to mentor novice GSIs in teaching undergraduate mathematics. Using pre-survey, post-survey, and semi-structured reflective interviews, we studied changes in 11 mentor GSIs’ perspectives on teaching and learning practices and what aspects of the mentor PD were deemed valuable by the mentors. Results suggest that this mentor PD, as a peer-mentorship model, helped GSIs deconstruct the dichotic mathematical paradigm of statements being true or false when discussing teaching. Moreover, mentor GSIs valued how the mentor PD helped guide them to facilitate novice GSI post-observation discussions.
Submission: 63
Room: Pt. Loma 1

Order of Operations: A Case of Mathematical Knowledge-in-Use
Rina Zazkis
I describe reactions of secondary school mathematics teachers to the following assertion: “According to the established order of operations, division should be performed before multiplication”. I use the notions of local and nonlocal mathematical landscape (Wasserman, 2016) to analyze teachers’ responses to the convention of order of operations in general and the presented assertion in particular.
Undergraduate Students’ Quantitative Reasoning in an Economic Context

Thembinkosi Mkhatshwa and Helen Doerr

The purpose of this study was to investigate students’ quantitative reasoning when solving a multivariable problem in a revenue maximization context. We conducted task-based interviews with 12 pairs of business calculus students. Analysis of verbal responses and work written by the students revealed that in reasoning about the relationships among the quantities (sales, discount, and total revenue) in the problem, nearly all the pairs of students created new quantities. The creation of these quantities helped the students to reason about the effect of the discount on sales and total revenue. An important finding of this study is that the students took different approaches to the meaning of the discount and only five pairs of the students interpreted the discount as intended in the design of the problem. The findings of this study have implications for business calculus instructors and business calculus textbook authors.

Supporting Instructional Change in Mathematics: The Role of Online and In-person Communities

Charles Hayward and Sandra Laursen

While studies continually show benefits of active learning strategies like inquiry-based learning (IBL), it is difficult to get faculty to adopt these methods. Particularly challenging is the third and final stage in Paulsen and Feldman’s (1995) model, ‘refreezing,’ when instructors use feedback and support to decide whether to continue with the instructional changes they have made or return to their previous methods. In this paper, we show how a workshop to teach college mathematics instructors to implement IBL used both online and in-person communities to help provide the ongoing feedback and support necessary for ‘refreezing.’ We offer lessons for how to increase the relevance of and participation in online support communities. We also use an innovative analytical approach, Social Network Analysis, to understand the ongoing processes of how e-mail exchanges provide feedback and both intellectual and emotional support to workshop participants.

Supporting students’ understanding of calculus concepts: Insights from middle-grades mathematics education research

Steven Boyce

In this preliminary proposal, we report on results from a paired-student teaching experiment focused on college calculus students’ developing notions of reversibility and reciprocity through compositions and transformations of linear relations. We anticipate fruitful discussions about relationships between numerical and quantitative reasoning and students’ thinking about graphs.

An Explicit Method for Teaching Generalization to Pre-Service Teachers Using Computer Programming

Cynthia Stenger, James Jerkins, Jessica Stovall and Janet Jenkins

As colleagues in a Mathematics/Computer Science department, we found that many of our undergraduates were not able to participate successfully in the full range of STEM course offerings. In response to this need, we developed a strategy for explicit instruction in mathematical generalization. Our instructional design is grounded in a theory of mathematical learning that uses computer programming to induce students to build the mental frameworks needed for understanding a math concept. The design includes writing mini programs to explore a mathematical concept, finding general expressions in the code, making conjectures about the relationships among general expressions, and writing logical arguments for the conjectures. We
share results from a study of 18 undergraduate math/secondary education majors. Our results indicate most pre-service teachers showed improvement in their level of abstraction over the concept of direct variation.
Submission: 28
Room: Bay Room

**Instruction in Precalculus and Single-Variable Calculus in the United States: A Bird’s Eye View**

Dana Kirin, Kristen Vroom, Sean Larsen and Naneh Apkarian

Improvement of mathematics courses in the first two years of college has recently become a priority in the United States. This is evidenced by multiple calls to enhance undergraduate education in the mathematical sciences and by funding allocated to related research and instructional improvement projects. As stakeholders make decisions to invest in the improvement of these courses, it is critical that these decisions be informed by reliable information regarding how these courses are currently being taught. The work described here is an effort to lay this groundwork by painting a comprehensive portrait of instruction in precalculus and single variable calculus (P2C2) in the United States. In this report we address two research questions; 1) What instructional formats are currently in place in the P2C2 sequence? and 2) How common are these instructional formats nationally?
Submission: 168
Room: Coronado

**Textbook Formations of Independence**

Adam Molnar and Steven Edalgo

The noun independence and adjective independent are applied in multiple mathematical contexts. In probability, independent events do not affect each other, but in algebra and regression, an independent variable has a non-symmetric effect on a dependent variable. Further complicating matters, independence in everyday language represents something in between. Prior research has shown that students and professors struggle to apply concepts of independence. As part of an investigation into curriculum about independence, textbook definitions about independence were examined. Across nine books, a mix of algebra and statistics texts, substantial variation existed in definitions of independent events and independent variables. Variations included the register of representation, verbal against algebraic, and the strength of the dependent effect. Little written guidance was provided to help learners navigate across the multiple formations.
Submission: 116
Room: Private Dining

**Underrepresented Students Succeeding in Math: The Challenges and Coping Strategies of Mathematically Talented Post-secondary Students**

Martha Makowski

Retaining mathematically talented underrepresented students in mathematics programs requires understanding the challenges the face during their post-secondary mathematics education. Using Swail’s framework (2003), this study investigates the self-identified challenges undergraduate and graduate mathematics students face and the coping mechanisms that helped them navigate and overcome those challenges. The vast majority of the challenges both groups of students encountered were cognitive in nature, suggesting that programs wishing to retain students should focus on providing social and institutional supports to provide balance.
Submission: 76
Room: Del Mar

**CxN: Investigating the Creative Proving Process Using Neuroscience Methods**

Milos Savic, David Plaxco, Michael Wenger, Emily Cilli-Turner, Gail Tang, Houssein El Turkey and Gulden Karakok

With this research, we seek to find theoretical constructs that correlate with participants’ neural activity that occurs as they are presented slides of mathematical proofs. We first asked three graduate student participants to complete two graduate level proofs (one each of abstract algebra and real analysis) using a LiveScribe pen. We then generated slides of their written work and researcher-generated proofs that we
used during electroencephalography (EEG) trials. Having coded the slides along 22 theoretical categories, we used step-wise model selection to determine suitable models for variance in neural activity. Preliminary results indicate that the best code-based models at a given instant can account for between 25 and 50 percent of the variance in electrical activity near the EEG electrode for that model when participants observe their own proofs and between 33 and 75 percent during researchers’ proofs.

Submission: 159
Room: Pt. Loma 1

Session 3 Preliminary Reports (2:45 PM – 3:15 PM)

Mental Constructions Involved in Differentiating a Function to a Function Power
Rachel Rupnow and Catherine Ulrich

Functions of the form $f(x) = (g(x))^h(x)$, including constant functions, power functions, and exponential functions, are fundamental examples of functions that differential calculus students should be able to differentiate. Yet students often struggle to distinguish between these forms. Drawing on APOS (Action-Process-Object-Schema) theory as well as Piaget and Garcia’s triad of schema development, this paper offers a genetic decomposition of the schemas students build for determining the derivative of a function to a function power. In particular, we analyze how students determine which differentiation rules to use with different function structures of a function to a function power and how students construct a conception of logarithmic differentiation. An initial genetic decomposition informed by existing literature was refined using the results of a series of three clinical interviews with each of two calculus students. Findings include the necessity of a strong background in functions, logarithms, and other differentiation rules.

Submission: 81
Room: Coronado

Identification Matters: Effects of Female Peer Role Models Differ By Gender Between High and Low Mathematically Identified Students
Susan Nickerson, Adam Dilla, Katie Bjorkman, Sei Jin Ko and David Marx

The study investigated an intervention whose aim was to address STEM retention disparities between men and women. We theorize that such disparities showing that women are up to twice as likely to leave the STEM fields during the Calculus sequence are due in part to stereotype threat. Stereotype threat’s effects are mitigated in the intervention by presentation by peer role models. Half of the Calculus break-out sections at a large university were visited by a peer role model and half served as controls. Our results show that peer role models have the intended effect on women highly identified with mathematics increasing both mathematical belonging and mathematical self-efficacy, but have no statistically significant effect on men or women with low mathematical identification.

Submission: 146
Room: Pt. Loma 2 & 3

Teachers’ Beliefs & Knowledge of the Everyday Value of High School Algebra & Geometry: Is One More Useful than the Other?
Jennifer Dunham

Despite recent emphases on teaching that mathematics is useful, little is known about teachers’ beliefs about the value of the topics they teach. While teachers have been found to believe mathematics overall is worthwhile, it may be that this belief varies among subjects. This study examines the beliefs and knowledge of students enrolled in teacher preparatory courses by employing a survey and algebra and geometry tasks related to each subject’s usefulness and connection to real-world applications. Preliminary results show they value algebra above geometry in terms of future use by their students. However, while their confidence was equal in their abilities to produce real-world applications, they were more successful producing those related to geometry than algebra. Further survey and clinical interview data collection is planned with additional pre-service and in-service teachers to examine beliefs and knowledge expert (in-service) teachers bring to teaching to inform the preparation of secondary school teachers.
Raising reasoning through revision: A case study of an inquiry-based college geometry course

Janessa Beach and Rebecca Dibbs

Geometry is the subject where U.S. students are weakest on international assessments, but college geometry is an area of proof that is understudied. Since geometry is secondary students' only exposure to proof, it is vital our secondary teachers can prove effectively in this content area. The purpose of this case study, drawn from a larger project, was to understand how, if at all, pre-service teachers' proof schemes became more axiomatic throughout a one semester inquiry based college geometry course. Although participants in this study had varying prior proof experience, both participants were using a perceptual proof scheme at the beginning of the semester. However, by the end of the semester, the chance to revise their proofs and discuss problems with their peers helped both students advance to more axiomatic geometric thinking.

Studying Pre-Service Teachers’ Selection of Representations in a Technologically Enhanced Environment

Robert Sigley, Muteb Alqahtani and Victoria Krupnik

This paper reports the results of four groups of three pre-service teachers working on a task that had them investigate the fairness of dice. The teachers used an online collaborative environment to sample from six different dice and the environment provided them with various representations, which they used to support their arguments. All four groups preferred the frequency table over bar and pie charts representations. After working on the task, they evaluated the work of students on the same problem. They viewed students' work that used other representations as not convincing regardless of the correctness of their solution and showed preference to the students only using one representation. Implications for pre-service teacher training in statistics and how to promote the use of multiple representations are discussed at the end.

Students' Social Adaptation to Mathematical Tasks

Jeffrey King

In this study, an advanced undergraduate geometry class taught in an inquiry-based learning setting was observed for social and socio-mathematical norms. Three pairs of students engaged in three task-based, semi-structured interviews: paired, individually, then paired again, solving the Seven Bridges of Königsberg and related tasks. A fourth stimulated-recall interview was performed using episodes from the last paired interview. Classroom observations and interview discourses were open coded for themes, structure, and function to analyze the norms developed within the classroom and by each pair as shaped by their social interactions. Tentative findings include: 1) norms of consensus, autonomy, and argumentation produced within the classroom, 2) varying metaphors across interview contexts, and 3) reliance on empirical strategies rather than structural reasoning. In this preliminary report, evidence from collected data is shared and a brief discussion how these results could help inform IBL teaching methods is included.
Coffee Break (3:15 PM – 3:45 PM)
Room: Cabo Courtyard (Weather Permitting)

Session 4 Contributed Reports (3:45 PM – 4:15 PM)

A Success Factor Model for Calculus: The Relative Impact of and Connections between Factors Affecting Student Success in College Calculus
Megan Ryals and Karen Keene
What factors (in terms of the student) contribute to success in college calculus, and what are the relationships between and relative importance of these factors? This study addresses these questions by building on the Academic Performance Determinants Model (Credé and Kuncel, 2008). A new model called the Success Factor Model for Calculus was developed using semi-structured and task-based interviews with fourteen first-semester college calculus students. The data suggests that creative mathematical reasoning and knowing-why are not required for success on college calculus tests. Alternatively, motivation is a determining factor in success in that students can perform well on exams by being motivated to know how to solve specific types of problems. Motivation is decreased by some course-specific factors, such as lack of structure and accountability, and its effect on success is sometimes decreased by a lack of study skills and habits.
Submission: 89
Room: Coronado

Variations in Precalculus Through Calculus 2 Courses
Matthew Voigt, Chris Rasmussen and Naneh Apkarian
In this paper we analyze variations in the structure of courses designed for the Precalculus through Calculus 2 (P2C2) sequence. We examine the nature of such variations, frequency nationally, and how DFW rates and instructional approach compare to the standard courses. While most identified variations in course structures have on average lower DFW rates when compared to the national average, a comparison within institutions indicates that these alternative course structures have higher DFW rates when compared to the standard P2C2 sequence offered at the respective institution. In addition, we observed that course variations which allow for increased instructional time have greater amounts of active learning techniques as part of the instructional format. Results from these findings along with their implications for the next phase of the Progress through Calculus project are discussed.
Submission: 92
Room: Pt. Loam 2 & 3

Leveraging Real Analysis to Foster Pedagogical Practices
Nicholas Wasserman, Keith Weber and William McGuffey
Although it is frequently a required course, many secondary teachers view real analysis as unnecessary and unrelated to teaching secondary mathematics. In accord with a proposed model for improving the teaching of advanced mathematics courses for teachers, we implemented a course that framed real analysis content by ‘building up from’ and ‘stepping down to’ teaching practice. In this paper, we describe how this model was implemented in a single module and analyze secondary mathematics teachers’ engagement in and reflections on the desired pedagogical aims, which provide evidence that they saw what they learned in the real analysis module as being useful for informing their pedagogical practice.
Submission: 79
Room: La Jolla

The Role of Visual Reasoning in Evaluating Complex Mathematical Statements: A Comparison of Two Advanced Calculus Students
Erika David, Kyeong Hah Roh, Morgan Sellers and Kody D’Amours
The purpose of this study is to examine the role of visual reasoning while students evaluate complex mathematical statements about real-valued functions. We conducted clinical interviews with nine undergraduate mathematics students. In the interviews, we asked these students to evaluate several
mathematical statements alone, and then using various graphs. In this paper, we focus on the cases of two students who had completed Advanced Calculus to highlight the contribution of their visual reasoning about several graphs. In particular, we focus on their meaning for “between,” and its affect on their statement evaluations. We found that even at this advanced level, the students’ visual cues dominated their reasoning about a statement. Our findings indicate that students’ visual reasoning contributes to their evaluation of mathematical statements and helps to account for differences between intended meaning and students’ meanings of statements.

**Submission:** 156
**Room:** Del Mar

**Session 5 Contributed Reports (4:20 PM – 4:50 PM)**

**Infinitesimals-based registers for reasoning with definite integrals**

**Robert Ely**

Two representation registers are described that support student reasoning with definite integral notation: adding up pieces (AUP) and multiplicatively-based summation (MBS). These registers were developed in a Calculus I class that used an informal infinitesimals approach, through which differentials such as dx directly represent infinitesimal quantities rather than serving as shorthand for a result of a limit process. Student reasoning reveals how the AUP register supports modeling with integral notation and how the MBS register supports sense-making with and evaluation of integrals.

**Submission:** 174
**Room:** Del Mar

**Interaction, activities, and feedback: A taxonomy of GTA Professional Development**

**Jess Ellis, Daniel Bragdon and Jessica Gehrtz**

In this report we present a taxonomy of mathematics graduate student teaching assistant (GTA) professional development (PD) programs. This taxonomy is based off of the characterization of GTA PD programs from 120 mathematics departments, and is informed by the framework developed by Ellis (2015) based on case studies of four GTA PD programs. A cluster analysis revealed nine distinct models of GTA PD within the 120 programs. These nine models vary with respect to the amount of interaction the GTAs have through the PD, the amount of activities involved in the PD, and the level of feedback given to GTAs involved with the PD. We present a characterization of one of the nine models using Ellis’s framework.

**Submission:** 155
**Room:** Pt. Loma 2 & 3

**Mathematicians’ Evaluations of the Language of Mathematical Proof Writing at the Undergraduate Level in Three Different Pedagogical Contexts**

**Kristen Lew and Juan Pablo Mejía-Ramos**

This proposal discusses the extent to which mathematicians agree amongst themselves with regard to what are some of the linguistic conventions of mathematical proof writing. Data from a survey of 128 mathematicians are used to address this question. Participants were asked whether various excerpts highlighted in four partial proofs were unconventional in each of three different contexts: how proofs appear in undergraduate mathematics textbooks, what instructors write on the blackboard in undergraduate mathematics courses, and how students write proofs in these courses. These data point to a lack of agreement among mathematicians on the linguistic expectations of the proofs written by their students.

**Submission:** 158
Exploration of the Factors that Support Learning: Web-based Activity and Testing Systems in Community College Algebra

Shandy Hauk, Bryan Matlen and Larry Thomas

A variety of computerized interactive learning platforms exist. Most include instructional supports in the form of problem sets. Feedback to users ranges from a single word like “Correct!” to offers of hints and partially- to fully-worked examples. Behind-the-scenes design of such systems varies as well – from static dictionaries of problems to “intelligent” and responsive programming that adapts assignments to users’ demonstrated skills within the computerized environment. This report presents background on digital learning contexts and early results of a cluster-randomized controlled trial study in community college elementary algebra classes where the intervention was a particular type of web-based activity and testing system.

Submission: 135

Room: La Jolla

Principles for Designing Tasks that Promote Covariational Reasoning

Irma Stevens, Teo Paoletti, Kevin Moore, Biyao Liang and Hamilton Hardison

Researchers have demonstrated the importance of covariational reasoning for students’ development of various mathematical ideas. Several researchers have also argued that creating and sustaining multiplicative objects is a necessary mental action to reason covariationally. In this report, we describe task-design principles we have found to be productive for investigating and supporting students’ construction of multiplicative objects and their covariational reasoning. Drawing on our research investigating students’ covariational reasoning, we include data that highlights how these principles have been productive in our research and teaching.

Submission: 88

Room: Private Dining

Session 6 Contributed Reports (5:00 PM – 5:30 PM)

Developing Students’ Reasoning about the Derivative of Complex-Valued Functions with the Aid of Geometer’s Sketchpad (GSP)

Jonathan Troup

In this paper, I share results of a case study describing the development of two undergraduate students’ geometric reasoning about the derivative of a complex-valued function with the aid of Geometer’s Sketchpad (GSP). My participants initially had difficulty reasoning about the derivative as a rotation and dilation. Without the aid of GSP, they could describe the rotation and dilation aspect of the derivative for linear complex-valued functions, but were unable to generalize this to non-linear complex-valued functions. Participants’ use of GSP, speech, and gesture assisted with discovering function behavior, generalizing how the derivative describes the rotation and dilation of an image with respect to its pre-image for non-linear complex-valued functions, and recognizing that the derivative is a local property.

Submission: 80

Room: Del Mar

Preservice Secondary Teachers’ Abilities to Use Representations and Realistic Tasks

Kyunghee Moon

This study reports three preservice secondary teachers’ abilities and tendencies to use representations in problem solving as well as their abilities to use realistic tasks after taking mathematics content and methods courses that emphasized the roles of representations and realistic tasks. Qualitative analyses showed that the preservice teachers developed beliefs that representations and realistic tasks are important components of secondary education and used motivational tasks in their instruction. However, they used the tasks mainly as the application of learned facts rather than as the departure of students’ construction of mathematical ideas. They also showed tendencies to use algebraic approaches in problem solving for grade 5-12 level tasks and had difficulties connecting algebraic and geometric representations when solving high school level algebra problems.
Physics Students’ Use Of Symbolic Forms When Constructing Differential Elements In Multivariable Coordinate Systems

Benjamin Schermerhorn and John Thompson

Analysis of properties of physical quantities represented by vector fields often involves symmetries and spatial relationships that are best expressed in non-Cartesian coordinate systems. Many important quantities, both scalar and vector in nature, are determined by paths, areas, or volume integrals of multivariable functions. The differential quantities in these systems are not trivial for students to understand and implement correctly. As part of an effort to investigate physics students’ understanding of the structure of non-Cartesian coordinate systems and the associated differential elements when using vector calculus in Electricity and Magnetism (E&M), we interviewed four pairs of students in the junior-level E&M course. In one particular task, students were asked to construct differential length elements for an unconventional spherical coordinate system. A symbolic forms analysis (Sherin, 2001) of student reasoning revealed both known and novel forms, and found that student difficulties with vector differential quantities were primarily conceptual rather than symbolic.

Difficult Dialogs About Degenerate Cases: A Proof Script Study

Stacy Brown

The purpose of the reported study is to explore students’ reasoning about the “within argument contradictions” that arise from degenerate cases by analyzing the problematics noticed in students’ proof scripts. The work proposes a framework for students’ noticed proof problematics and explores the viability of the proof script methodology as a mechanism for identifying difficulties experienced by students but unseen by experts. In the case of degenerate cases, findings indicate student held conceptions of proofs by cases that may inhibit students’ reasoning about the contradictions that arise from degenerate cases and students’ difficulties correctly reasoning with logical conjunctions.

Can/Should Students Learn Mathematics Theory-Building?

Hyman Bass

Mathematicians commonly distinguish two modes of work in the discipline: Problem solving, and theory building (Gowers, 2000). Mathematics education offers many opportunities to learn problem solving. This paper explores the possibility, and value, of designing instructional activities that provide opportunities to learn mathematics theory-building practices. It begins by providing a definition of these theory-building practices on the basis of which to formulate principles for instructional designs. The paper argues that theory-building practices serve not only the synthesizing role that they play in disciplinary mathematics, but they also have the potential to enrich learners’ reasoning powers and to enhance their problem solving skills. These instructional designs offer a new approach to supporting student work on generalization and abstraction. They have been piloted with preservice and practicing secondary teachers.

Session 7 Contributed Reports (5:40 PM – 6:10 PM)

Definite Integrals Versus Indefinite Integrals: How do Students See Them as the Same or as Different?

Steven Jones and Cache Thompson

Much of the calculus education research on student understanding of integrals has been separated into definite-integral-focused studies and indefinite-integral-focused studies. This means that research may not be capturing how students might see these two types of integrals in relation to one another, as opposed to
in isolation of each other. This study examines whether students see these two types of integrals as representing the same basic concept, distinct concepts, or as sharing some concepts while diverging in others. The results show that a large majority of students ascribe the exact same underlying conceptions to both types of integrals, even describing the indefinite integral as representing the area under a curve also. We relate what aspects of each type of conception students saw as common to both types of integrals, and what features of the conception the students saw as different between them.

Submission: 18
Room: Coronado

Transitioning to Proof with Worked Examples
Dimitri Papadopoulos
In this study, I explored the use of a worked-examples-based proof-writing framework as a pedagogical tool to improve undergraduate students’ ability to construct proofs. Over the course of three months, I ran a series of three workshops with five undergraduate students who had no prior experience with formal mathematical proof. In each workshop, participants worked through worksheets containing completed worked examples of mathematical proofs, followed by partially completed worked examples of proofs (to be completed by the participants), and, lastly, exercises. I collected and coded participants’ written work and reflections and explored changes in student proof-writing across workshop sessions. In this paper, I describe themes across student work and provide qualitative data supporting the benefits of incorporating the use of such a worked-examples-based proof-writing framework when introducing students to mathematical proof.

Submission: 172
Room: Private Dining

Using Oral Presentations to Facilitate Learning Statistics
Abeer Hasan and Sayonita Ghosh Hajra
In this paper we report on a study of assessment-based oral presentation tasks in a statistics course at a public university in the United States. We used statistical inference to test for the significance of the observed improvement in students’ attitudes towards using oral presentation tasks in learning statistics. Our results also suggest that use of oral presentation improves students’ mastery of statistical concepts. Moreover, responses to the anonymous course evaluation questionnaire provide insights on the benefits of using oral presentation tasks in statistics courses for students.

Submission: 55
Room: Bay Room

Using Video in Online Work Groups to Support Faculty Collaboration
Nicholas Fortune, Karen Keene and William Hall
Faculty in undergraduate mathematics departments are currently involved in making changes to their instruction, particularly by introducing different modes of student-centered type instruction. In this paper, we analyze a situation where faculty are involved in online collaboration using video of their own classrooms. We found that showing the video during the online work groups promotes more discussion of pedagogy rooted in instructional components than instructors watching the videos alone before. Pedagogy and students’ mathematics also become important discussion points that encouraged and supported the instructors. Providing instructional components as a frame proved to be successful in supporting the video discussions as they stay centered on instruction.

Submission: 69
Room: La Jolla

Expert vs. Novice Reading of a Calculus Textbook: A Case Study Comparison
Emilie Wiesner, Aaron Weinberg, John Barr and Nikki Upham
We present case studies of a student and a non-mathematics professor reading an excerpt from a calculus textbook. We use the ideas of sense-making frames and gaps and the implied reader to compare their reading experiences. In particular, we attempt to distinguish the role of calculus background knowledge from reading expertise in making sense of the text.

Submission: 52
Data Cleaning in Mathematics Education Research: The Overlooked Methodological Step
Aleata Hubbard

The results of educational research studies are only as accurate as the data used to produce them. Drawing on experiences conducting large-scale efficacy studies of classroom-based algebra interventions for community college and middle school students, I am developing practice-based data cleaning procedures to support scholars in conducting rigorous research. The poster identifies common sources of data errors in mathematics education research and offers a framework and related data cleaning process designed to address these errors. I seek feedback on the framework and discussion around data cleaning techniques used by other RUME scholars in their research and in the preparation of future researchers.
Submission: 177

JITAR online modules to improve math preparation of engineering students
Alina Duca

Engineering educators are challenged with students at greatly varying mathematical skill levels while needing to quickly bring all students up to the same mathematical mastery level at appropriate points during a semester. To address this problem our team designed a teaching e-tool in WeBWorK called Just-In-Time Assessment and Review (JITAR) to be delivered as an on-line system consisting of a series of individualized mathematics modules inserted within engineering courses at strategic points in the semester, prior to students needing those math skills. JITAR assesses the mathematical competency level of the individual student and provides formative individualized learning opportunities in time for the students to be successful in applying the necessary mathematics to the new engineering course material. The new type of WeBWorK assignment was designed to support the desired presentation and flow of the module integrating assessment and e-learning assistance by offering a customized learning path to students. This project is currently funded by National Science Foundation.
Submission: 221

Supporting Math Emporium Students' Learning Through Short Instructional Opportunities
Andrea Alt

This study focuses on the concept of including traditional math classroom experiences in a math emporium course. The aim of the study is to gain an insight into the opinions of students about which emporium structure they prefer as well as which they believe they can be more successful in. Also, this study will analyze emporium students’ academic success in both scenarios. To accomplish these goals, two sections of Algebra II in the math emporium were offered the option to attend short instructional opportunities led by the instructor.
Submission: 202

Interpretive reading of mathematical propositions for proving: A case study of a mathematician modeling reading to students during joint proof production.
Anna Zarkh

Successful proof production in advanced mathematics relies on meaningful apprehension of the to-be-proved proposition, yet we know that this is a challenge for many students. This study examines the ways in which a mathematician-instructor, addressing this issue, models the practice of interpretive reading of mathematical propositions to a pair of students in the context of joint proof-production in a Real Analysis course. Taking a social practice perspective on reading and adopting Sfard’s commognitive framework as a theoretical lens, I identify three aspects of the discursive work the expert engages with to demonstrate processes of active meaning-making to students: (1) re-reading of text with grammatical shifts, (2) posing comprehension monitoring questions, and (3) narrative enactment of text.
Submission: 211
A Comparison of Faculty Expectations and Student Perceptions of Active Engagement in a Calculus I Class

Belinda Edwards

This poster describes and includes a discussion of the learning benefits and gains that students, enrolled in a Calculus I course, and their instructor reported as a result of participating in an active learning environment. The alignment between what the instructor valued and what 67 students experienced as they engaged in Calculus I activities was assessed using a survey. The results indicate a positive relationship between perceived importance and reported frequency of engagement. Opportunities for improvement outcomes were found and can serve to support strategies that improve teaching and learning in Calculus I.

Submission: 252

An Active Learning Environment in Introductory Analysis

Brynja Kohler

At Utah State University, the course known as 'Math 4200: Foundations of Analysis' is a requirement for all department majors, and, in addition to introducing real analysis, serves as an introduction to rigorous proof. All too frequently, courses such as these are taught with the typical lecture format: the instructor enters the classroom to deliver polished explanations of definitions, theorems, and their proofs, while leaving students to struggle to follow lectures and then struggle further on their own to make sense of incomprehensible homework problems. This poster includes descriptions of easy-to-implement strategies that change the classroom to an active learning environment, with ample opportunities for formative assessment and feedback without overloading the professor with busywork. The strategies include: name tents, group exercises and quizzes, peer-reviewing of homework, concept quizzes, individual presentations, and growth mindset reflections. We surveyed students to find their reactions to these class activities and found positive and helpful implementation hints.

Submission: 267

Beyond the Exam Score: Gauging Conceptual Understanding from Final Exams in Calculus II

Ciera Street and Kristen Amman

Instructors often want to evaluate their students’ degrees of conceptual understanding in their mathematics courses, but are typically limited to course assignments and exams. In this research we ask: To what extent can mathematics instructors recognize conceptual understanding of their students based on final exam responses? During a summer REU program we examined pre-existing exams along with other course materials to address this question. We developed codes for student responses that were guided by Anderson and Krathwohl (2001), Mejia-Ramos et al. (2011), Thurston (1994), and the APOS framework. Student responses more clearly and often demonstrated lower level understanding than deeper, conceptual knowledge because few problems called for explanations or justifications. The goal of this research was to improve the effectiveness of assessments in evaluating conceptual understanding. In future exams, we suggest that prompting students to display behaviors typical of varying levels of understanding with justification would make evaluations more accurate.

Submission: 5

Online STEM and mathematics course-taking: Retention and Access

Claire Wladis

Using survey data and interviews from a large urban university system, this study explores factors that impact student decisions to take math classes online. The results suggest that access to online math courses likely impacts student course taking patterns, with significantly more students taking a different course if their desired math course is not offered online, compared to non-math courses.

Submission: 234
Conceptual Understanding of Differential Calculus: A Comparative Study
Daria Gerasimova, Kathleen Matson, Robert Sachs and Margret Hjalmarson

The research community shares a concern for students’ conceptual understanding of calculus and commonly advocates for student-centered approaches as a way to promote it. In this study, we investigated the effect of different instructional approaches on 151 undergraduate students’ conceptual understanding of differential calculus in context-specific, natural settings. We collected data on the pre and posttest of the Calculus Concept Inventory in three classes. In one class, most of the time was dedicated to conceptually oriented problem solving. Another class implemented practice problems for students. The third class was a traditional lecture class. The results showed that there was no difference in students’ conceptual understanding of differential calculus controlling for their initial understanding. Thus, our findings do not support the research that advocates for student-centered instruction suggesting that the approaches’ implementation and contextual differences may be sources of variation in their effectiveness.
Submission: 209

Service-Learning and a Shift in Beliefs about Mathematical Problem Solving
Ekaterina Yurasovskaya

During academic service-learning experiment, students in an experimental Precalculus class regularly tutored basic algebra to middle-schoolers. At the end of the quarter, student-tutors demonstrated academic improvement and a shift in beliefs about importance of conceptual understanding in problem solving. These manifested benefits can motivate mathematics departments to implement service-learning as part of academic curriculum.
Submission: 203

Characterizing Normative Metacognitive Activity During Problem Solving in Undergraduate Classroom Communities
Emilie Hancock

Mathematical problem-solving research studies abound, and a significant portion express the role of metacognition as an underlying component of the problem-solving process. Unfortunately, much of the research on metacognition in mathematics does not describe the explicit role metacognition plays during the problem-solving process. Moreover, metacognitive interventions are typically disconnected from natural mathematical activity and discourse within a classroom community. The purpose of this study is to characterize sociomathematical metacognitive norms within the context of an introductory number theory course intended for pre-service teachers. Utilizing Vygotsky’s conception of language-based, mediated action and activity theory as an analytic framework, this study aims to test the use of these methods to investigate “real-time” metacognition with explicit focus on the broader classroom community. Particular attention is paid to the dynamic relationship between the teacher and students.
Submission: 178

Situational Characteristics Supporting Instructional Change
Estrella Johnson and Rachel Keller

Instructional practice and decision-making are influenced by a myriad of factors, with both individual instructor characteristics (e.g., beliefs about teaching and learning and personal experience) and departmental/institutional characteristics (e.g., resources and supports) shaping day-to-day teaching practices. However, little is known about which factors are the most influential and how those factors influence pedagogy. In this project, in an effort to identify commonalities in situational contexts and better understand how these commonalities support non-lecture instructional approaches, we look at interviews from fourteen mathematicians who volunteered to implement inquiry-oriented instructional materials.
Submission: 208

Mathematics Affirmations
Geillan Aly

This poster reports on an action research project set in a developmental mathematics classroom in a community college. Students at the beginning of the semester expressed mathematics anxiety and did not believe they could succeed in the course. To help support students’ learning, the instructor and students co-
created a list of ten statements that became the prevailing philosophy in the class. These statements helped students alter their view of their own mathematics learning.
Submission: 210

All The Math You Need: An Investigation into the Curricular Boundaries of Mathematical Literacy
Gizem Karaali
This project attempts to seek out common threads and analyze discrepancies in the tertiary-level mathematical literacy / quantitative literacy curricula proposed by eight different textbooks and content-providers. Following the framework developed originally in (Harel 1987) we investigate sequencing of content, levels of generality, emphasized applications, introductory material, as well as explicitly stated learning outcomes.
Submission: 220

Questioning assumptions about the measurability of subdomains of Mathematical Knowledge for Teaching (MKT)
Heather Howell, Yvonne Lai and Heejoo Suh
The goals of undergraduate mathematics teacher education include developing teachers’ content knowledge and pedagogical content knowledge. As a strategy for conceptualizing and assessing these forms of knowledge, researchers have further divided these domains. However, it has proven difficult for research groups to create tasks to reliably capture a specific domain without involving other domains. Researchers have thus questioned the validity of these subdomains. We argue that tasks’ inability to measure subdomains separately is not evidence that tasks or theory are flawed. Instead, we propose that assessment tasks are effective in measuring MKT when they represent the work of teaching, rather than when they isolate subdomains. To make this argument, we use the case of 9 tasks previously validated to assess MKT through analysis of teachers’ thinking on these tasks. Though these tasks represent MKT, they cannot be meaningfully parsed into the subdomains of multiple established MKT frameworks.
Submission: 226

Designing and Developing Likert Items that Capture Mathematical Problem Solving
James Epperson, Kathryn Rhoads and R. Cavender Campbell
The Mathematical Problem Solving Item Development (MPSI) Project is designing and developing Likert items that capture students’ capacity in mathematical problem solving. The project, now in its second year, continues to refine Likert items that capture aspects of mathematical problem solving such as sense-making, justifying, representing and connecting, and looking-back. The refinement process has been informed by piloting items on over 1000 students in College Algebra and Calculus, hour-long think-aloud interviews with 26 students, and review and feedback by experts. The goal of this poster presentation is to provide information about the item development and design and gather feedback and suggestions on further design and development.
Submission: 262

Empowered Women In RUME: What Have We Been Up To?
Jess Ellis, Stacy Musgrave, Kathleen Melhuish, Eva Thanheiser and Megan Wawro
For the past three years we have run a seminar for 60 – 75 women in RUME the day before the annual conference called MPWR: Mentoring and Partnerships for Women in RUME. Participants included graduate students, post-doctoral fellows, faculty, and researchers outside of academic positions. In this poster, we provide a window into these seminars, specifically addressing the motivation for the seminar, the structure of the seminar, topics discussed in the seminar, research related to the efficacy and transferability of MPWR, and the future of MPWR. Our hope with this poster is to both share what we have been doing and get feedback from the community for what more can be done.
Submission: 238
Extreme Apprenticeship
Johanna Rämö, Jokke Häsa, and Juulia Lahdenperä
Extreme Apprenticeship is a novel, student-centred teaching method that is designed for teaching large courses with hundreds of students. It is based on Cognitive Apprenticeship. In this poster, we present the Extreme Apprenticeship method and data collected from courses taught with it.
Submission: 229

Research in Courses before Calculus Through the Lens of Social Justice
Shandy Hauk, Allison Toney, April Brown and Katie Salguero
The terms equity, diversity, inclusion, and social justice have entered the research lexicon. Yet, researchers face significant challenges in gaining a nuanced understanding of the various ideas associated with these words. This theoretically-focused poster presents some recent policy efforts to generate a shared meaning for “social justice” in mathematics education and presents a theoretical framework for making sense of (and making sense with) intercultural interactions as an essential component of rigorous research. The poster offers illustrations for how to use these tools for thinking and talking about research. To anchor discussion, we focus on research on teaching and learning in the courses before calculus (e.g., algebra, pre-calculus, liberal arts math, math for pre-service elementary school teachers, algebra-based statistics).
Submission: 201

Hypophora: Why Take the Derivative? (no pause) Because it is the Rate
Kitty Roach
Part of a larger study of the development of teaching among novice college mathematics instructors, this report focuses on one participant, Disha, and her use of a questioning technique called hypophora. At the beginning of the observations, 25% of her questions were hypophora. After video-case based activities during weekly coordination meetings her use of hypophora decreased to about 10% of questions. Although Disha rejected the idea that her teaching had changed in any way, she acknowledged that she began “breaking things into smaller pieces” to help students understand.
Submission: 191

Who is Teaching the Precalculus Through Single-Variable Calculus Sequence and How are they Teaching it?
Kristen Vroom and Dana Kirin
It is well documented that the precalculus through single-variable calculus sequence (P2C2) acts as a barrier for many STEM intending students. Students often cite poor instruction as a primary reason for switching out of STEM programs (PCAST, 2012; Seymour & Hewitt, 1997), which leads to questions about what instructors and instruction look like across the country. This poster presents findings from national census survey data collected as part of a larger study, Progress through Calculus (PtC). In particular, we answer: (1) What types of instructors are currently teaching courses in the P2C2 sequence and how prevalent are they nationally? (2) What relationship exists (if any) between instructor type and primary instructional format?
Submission: 200

STEM major mindset changes during their first undergraduate mathematics course
Laura Beene and Rebecca Dibbs
One of the reasons for the exodus in STEM majors is students’ experiences in their first undergraduate mathematics course, usually introductory calculus. However, students with a growth mindset are more likely to persist past these initial courses. Although there is evidence that curricula like CLEAR calculus promoted gains in students’ growth mindset, it is unclear how this curriculum compares to traditionally. The purpose of this quasi-experimental study was to investigate to what extent students enroll in CLEAR calculus become more growth mindset orientated than those that are enrolled in traditionally taught courses. The Patterns of Adaptive Learning Scale was used to measure the mindset of students in pre-calculus, calculus I, and calculus II. The analysis of the pilot data indicated CLEAR calculus students experience a small positive shift towards a growth mindset, while students in traditionally taught courses have a significantly more fixed mindset by the end of the semester.
Designing a Richer Flipped Classroom Calculus Experience

Matthew Voigt and Helge Fredriksen

The study presented here is an illustrative example of an action based research project, which was focused on broadening student partition in the flipped classroom experience in order to address issues of equity and social justice in the calculus curriculum. While flipped classrooms have gained recent notoriety within the literature, they rarely incorporate or addresses other critical perspectives. Our study highlights how using design principles such as realistic mathematics education (RME) and culturally responsive pedagogy can effectively target the hidden curriculum and shape the norms and classroom discourse features (Sfard, 2008).

Connecting Reading Comprehension Research and College Mathematics Instruction

Melanie Butler

The poster will have three parts. The first is a literature review of reading comprehension research. Connections will be drawn between different research studies that apply to college mathematics instruction. In addition, common themes from research will be used to motivate the need for reading comprehension instruction in college mathematics. The second part will give results of a new research study involving interviews about reading comprehension strategies and instruction with interdisciplinary faculty from several institutions. The third part will describe proposed methodology of future research on reading comprehension in college mathematics instruction. It is hoped that during the poster session, participants will have a chance to brainstorm about possible future directions and methodologies for research in this area.

The Mathematics Attitudes and Perceptions Survey: New Data and Alignment with Other Recent Findings

Warren Code and Wes Maciejewski

Student attitudes about and perceptions of mathematics influence their success and learning, and have been of interest for many years in mathematics education. The Mathematics Attitudes and Perceptions Survey is a short, validated Likert-scale instrument that measures confidence, interest, relation of mathematics to the real world, persistence in problem solving, growth mindset, use of sense-making behaviours, and the extent of other novice attitudes towards mathematics. In this poster, we share the complete instrument and its categories, a brief summary of the development process and resulting model statistics, as well as scores across different populations measured so far (3 institutions, variety of courses). The student responses include new data since the publication of the instrument as well as additional analysis of groups, in particular a comparison of attitudes between genders that matches with recent results relating STEM persistence to attitudes and beliefs (Ellis et al., 2016; Wang et al., 2016).

Students’ Mistakes and Strategies When Matching a Function’s Graph with its Derivative

Nathan Jewkes and Amy Dwiggins

This study explores a fundamental calculus connection between a function and its derivative by examining strategies students use when matching a function’s graph with the graph of its derivative. Through interviews with four students using multiple choice (MC) tasks, we wanted to explore whether common mistakes and students’ strategies when drawing the graph of the derivative of an original function are consistent with those found when using open-ended tasks. While tendency to find an equation of the graph in order to differentiate was observed, simple replication of the original function was not observed.

Analyzing Focus Groups of an Experimental Real Analysis Course: ULTRA

Ruby Quea and William McGuffey

As part of a larger study, we analyzed focus groups of students discussing their perceptions of an experimental real analysis course. The aim of this course was to teach real analysis to prospective and
practicing teachers in a way that improved their future teaching. This poster analyzes data from four focus group interviews from 20 students after they completed the experimental course. The majority of comments from the participants’ comments about the course, both in general and in regards to informing their future teaching of secondary mathematics, were favorable. We present commonalities in the participants' responses.
Submission: 204

Using Evidence to Understand and Support an Educational Reform Movement: The Case of Inquiry-Based Learning (IBL) in College Mathematics
Sandra Laursen, Charles Hayward and Zachary Haberler
We present a graphic review of a decade of research and evaluation work on inquiry-based learning in college mathematics. Featured studies examine student outcomes of IBL instruction, processes of change as instructors explore and adopt IBL approaches, and the workings of the faculty learning community that has formed to learn and promote IBL ideas. Collectively, these studies highlight the use of evidence to understand instructional practices and change in these practices, and to support evidence-based decision-making by instructors and change leaders.
Submission: 185

Exploring the content–specific mathematical proving behavior of students in context: Opportunities for extracting and giving mathematical meaning
Sarah Hough, William Jacob, Monica Mendoza and Alex Sacharuk
A series of studies were conducted to explore the efficacy of a non-traditional transition to upper division proof course using Freudenthal’s notion of mathematizing as a framework. Class video data and student work were collected and analyzed using grounded theory methodology. Results indicated that students in the non-traditional course had developed better understandings of the role of definition and counter example in proof through engagement in meaning making activities that fostered both the semantic and structural aspects of proof writing.
Submission: 199

Schema as a theoretical framework in advanced mathematical thinking
Sepideh Stewart
According to Skemp, concepts are embedded in a hierarchical structure of other concepts, these levels in the structure being classifications of concepts. As the concepts are paired together, relations between them as well as classifications are also possible. The complexity of this hierarchical structure comes from the fact that these classifications of concepts and relations are not unique, giving way to multiple hierarchical structures, which can be interrelated. When components of these conceptual structures come together to make a structure that would not be realized by only looking at the individual components, the resulting structure is called a schema. A schema integrates existing knowledge, serves as a tool for future learning, and allows for understanding to take place. Without a suitable schema in position, students will have difficulty in understanding or making sense of new concepts. The proposed framework will promote schematic learning and seek to identify whether the presence or absence of a certain schema will have an effect in understanding new knowledge.
Submission: 246

The Influences of a Teacher’s Mathematical Meaning of Constant Rate of Change on His Classroom Practices
Sinem Bas Ader and Marilyn Carlson
We investigated how a teacher’s meaning of the idea of constant rate of change influenced his teaching practices, including his explanations, questions and interactions with students. The results of our analysis revealed that a teacher with a strong mathematical meaning of constant rate of change was able to provide conceptually coherent explanations and pose questions that are based in his understanding of a mathematical idea and his models of students’ thinking.
Submission: 256
Bridging the Gaps between Teachers’ and Students’ Perspectives of a Culturally Inclusive Classroom
Thomas Mgonja and  Kuo-Liang Chang
Creating a culturally inclusive classroom has been suggested to help minority students improve their achievement in class. However, evidence shows gaps between teachers and students about what a culturally inclusive classroom should be. We propose a framework for investigating the differences between teachers’ and students’ beliefs on such a classroom.
Submission: 223

Reasoning about Relative Motion with Frames of Reference
Surani Joshua
In introductory physics classes, student frequently experience difficulties with relative motion problems. Previous studies have categorized student difficulties with reference frames, or used computer simulations or experiments to create seeming paradoxes that students would need frames of reference to resolve; however, these studies failed to define what they meant by a “frame of reference” in the mind of a student. In 2016 I carried out a pilot study that used our cognitive definition of a conceptualized and coordinate frame of reference (Joshua, Musgrave, Hatfield, & Thompson, 2015) as well as quantitative reasoning (Thompson, 1993) to guide an instructional intervention and analyze the difficulties the student had with relative motion tasks. Both constructs proved to have great explanatory power, as they revealed aspects of the student’s thinking that were not commonly explored in previous studies. Both the results of this study and their implications will be the topic of my poster.
Submission: 259

Individual and Group Work with Nonstandard Problems in an Ordinary Differential Equations Course for Engineering Students
Svitlana Rogovchenko, Yuriy Rogovchenko and Stephanie Treffert-Thomas
We explore understanding of the Existence and Uniqueness Theorems (EUTs) by a group of engineering students working on nonstandard problems. Students presented three sets of solutions: individual solutions produced in the first tutorial, solutions submitted as a homework, and solutions submitted after the discussion with peers in small groups during the second tutorial. The focus of the study is on the role of individual and group work with nonstandard problems. The results show that students gained a deeper understanding of EUTs and appreciated the experience.
Submission: 184

A Topological Approach to Formal Limits Supported by Technology: What Concept Images do Students Form?
Tamara Lefcourt Ruby and Shulamit Solomon
The formal definition of the limit of a function was taught in a first-year calculus course using open intervals and a topological approach. Student understanding was supported with computer-based visualization tools. The concept image framework was used to interpret results of a pilot study in which data was gathered through concept maps and analyzed using categorical content analysis. Results indicate some bridging between students understanding of formal limits presented via open sets and their informal limit conceptions; absolute values inequalities did not appear in the students’ concept images.
Submission: 213

Mathitude: Precalculus Concept Knowledge and Mathematical Attitudes in Precalculus and Calculus
Todd CadwalladerOlsker
There is a pattern of students citing calculus as a major factor in their decision to leave STEM majors (Rasmussen and Ellis, 2013). Industry and government leaders are calling for colleges and universities to understand and address this problem as it has implications in the hindrance of our nation’s economy and intellectual power. In this study we have explored students’ conceptual knowledge and mathematical attitudes in precalculus and calculus, using two instruments. First, the Precalculus Concept Assessment (PCA) instrument can assess student learning, effectiveness of curricular treatment, and determine student readiness (Carlson, Oehrtman & Engelke., 2010). Second, Mathematics Attitudes and Perceptions Survey
(MAPS) instrument can provide information about how well student beliefs of mathematics align with expert beliefs (Code, Merchant, Maciejewski, Thomas & Lo, 2016). Concept knowledge and expert-like attitudes and perceptions about mathematics are both critical components of mathematical expertise. By studying these components, we can help students to reach higher levels of expertise.

Submission: 266

Algebra instruction at community colleges: An exploration of its relationship with student success
Vilma Mesa, Irene Duranczyk, Nidhi Kohli, April Strom, Laura Watkins and Angeliki Mali
We present the research design and data collection strategies for a federally funded project (Watkins, Duranczyk, Mesa, Ström, & Kohli, 2016) that investigates the connection between instruction and student learning and performance in algebra courses at community colleges. The poster focuses on measurement issues we face in identifying the characteristics of mathematics instruction and students’ learning gain, specifically we address questions encountered from the pilot data collection (six community college faculty and nearly 150 students) that need to be resolved prior to data collection.

Submission: 193

Upper-division Physics Student Thinking Regarding Non-Cartesian Coordinate Systems
Warren Christensen, Brian Farlow, Marlene Vega and Michael Loverude
As part of a larger effort to develop a research-based math methods curriculum for undergraduate physics students, results from a case study probing student thinking on plane and spherical polar coordinates are presented. Using a resources framework, a think-aloud protocol was used to elicit student thinking regarding non-Cartesian coordinates. Findings are consistent with previously published literature regarding student thinking on coordinate systems. Mark, a senior physics major, despite initially clearly identifying and defining the radial and polar unit vectors on a diagnostic 2-dimensional problem, made inconsistent assertions when asked to apply those definitions in three-dimensions using spherical coordinates. Additionally, we will address content issues concerning the definition of displacement and position vectors in Cartesian and Non-Cartesian coordinate systems.

Submission: 255

The Effects of Graphing Calculator on Learning Introductory Statistics
Wei Wei and Katherine Johnson
Graphing calculators have been used for teaching introductory statistics for decades. They helped students to obtain accurate statistical analysis results. However, heavily relying on graphing calculators may hinder students’ understanding of certain statistical concepts such as the normal distribution and p-value. In this study, we focused on the effects of using graphing calculator on students’ conceptual understanding of normal transformation and p-value, and their performance of calculating normal probabilities and conducting a hypothesis test.

Submission: 179

Calculus Students’ Meanings for Average Rate of Change
Wyatt Ehlke, Sayonita Ghosh Hajra
This study considers calculus students’ conceptualization of average rate of change at a private liberal arts college in the Midwest. Researchers have indicated that undergraduate students do not develop productive meanings for average rate of change. In order to explore undergraduate students’ meanings for average rate of change further, we conducted clinical interviews with 10 undergraduate students on a four-item test. Participants were undergraduate students taking Calculus 1 at the time of the study. Interviews were conducted towards the end of the semester to ensure students have learned average rate of change. Qualitative techniques were used to analyze data. We will present and interpret data highlighting the techniques used by the students during the tasks. We will conclude with implications from our findings and questions for future research.

Submission: 196
Exploratory Activities with Dynamic Geometry Environment in Axiomatic Geometry
Younggon Bae
In this study, I designed and implemented an instructional sequence of exploratory activities using a Dynamic Geometry Environment (DGE) in an axiomatic geometry course. The tasks in the sequence aimed at providing students with opportunities to encounter cognitive conflicts between their prior knowledge on Euclidean geometry and new observations on non-Euclidean geometry. However, some did not appear, some did appear and students recognized them, but could not resolve or just passed by. The conflict between what I intended in designing tasks and what I found in student responses seems to result from several aspects of design and implementation of the tasks.
Submission: 254

Quantitative Learning Centers: What We Know Now and Where We Go from Here
Melissa Haire
Given the recent national and international events the need for developing students' quantitative literacy (QL) has taken center stage in the mathematics education community. We are interested in investigating the existing support structures and the impact they have on the development of QL. The purpose of this study is to investigate the literature on quantitative learning centers at institutions of higher education. This poster will discuss the themes that emerged from a qualitative analysis of these works, highlighting what we currently understand and identifying opportunities for growth.
Submission: 227

Dinner & Plenary Session (7:00 PM – 9:30 PM)
Living, Learning, and Leading in Socially Networked Systems
Alan Daly
Although efforts at change are documented and monitored through plans and reports, improvement does not necessarily result from these formal plans and blueprints, but rather occurs in the interaction of individuals. Change processes ultimately emerge and are maintained through interpersonal relationships, and it is the interdependence of relationships that may ultimately moderate, influence, and even determine the direction, speed, and depth of a change. Therefore, recognizing the importance of social ties is important in understanding how change and communication takes place or not. This perspective entails moving beyond the "human capital" of the individual (experience, training, education) to making better use of the more dynamic supports and constraints of the larger social "infrastructure" in which individuals resides. The idea driving this more relational approach is both a research based and intuitive one; relationships matter in very central ways to the work of change and growth.
Room: Pt Loma 2 & 3
Friday, February 24, 2017

Registration/Help Desk Open (7:00 AM – 6:30PM)
Room: Pt. Loma Ballroom 3 Foyer

Breakfast (7:00 AM-8:30 AM)
Room: Cabo Courtyard (Weather Permitting)

Session 8 Contributed Reports (8:35 AM – 9:05 AM)

Beyond the Product Structure for Definite Integrals
Courtney Simmons and Michael Oehrtman
Over the past decade research has shown that a Riemann sum based interpretation of the definite integral supports a robust understanding of the underlying structure of the integrand/differential relationship and facilitates students' ability to make sense of contextual integral models. However, current studies center this understanding on the multiplicative structure \( f(x) \cdot \Delta x \) which does not account for many practical uses of integration. In many situations, the \( \Delta x \) is most productively conceived as a component of another quantity which might then be incorporated in any of a variety of quantitative models, such as an inverse square law rather than a simple product. To fill this gap, this study utilized Dewey’s theory of inquiry to identify three interpretations of the definite integral which proved productive for students when modeling definite integrals that extend beyond the traditionally studied product structure.
Submission: 154
Room: Pt. Loma 1

Exploring a Pre-Service Teacher’s Conceptions of Area and Area Units
Sayonita Ghosh Hajra and Betsy McNeal
This is a case study of a pre-service teacher’s conception of area at a public university in the western United States. Her meanings of area and area units, both standard and non-standard, were explored throughout the semester. Analysis of our conversations with the pre-service teacher about her written work allowed us to unravel three critical features about area that we think should be the focus of our instruction, namely: 1) any 2-D shape can be an area unit, 2) area units can be decomposed, if needed, and 3) the comparison of a planar figure’s area with an appropriate unit can give a meaningful measurement without being exact.
Submission: 8
Room: Del Mar

Features of Explanatory Proofs: An Exploratory Study
Eyob Demeke
In mathematical research as well as pedagogy, mathematicians rely on proofs to convey mathematical knowledge. Both mathematicians and mathematics educators have argued that a proof is more valuable to students when it explains why a theorem is true. In this contributed report, I discuss attributes of explanatory proofs that eleven doctoral students in mathematics described. Doctoral students in this study interpreted the nature of mathematical explanation in the context of a proof in a wide range of ways. In particular, these participants expressed that they are more likely to consider a proof more explanatory when it succeeds in providing (a) insight into the derivation of certain formulas, (b) intuition as to why the theorem is true, or (c) insight into how the author might or the reader could have discovered the proof in practice.
Submission: 123
Room: La Jolla

Undergraduate abstract algebra: Is teaching different at 'teaching' colleges?
Rachel Keller, Estrella Johnson, Valerie Peterson and Tim Fukawa-Connelly
Reforming the way undergraduate mathematics is taught has been the target of significant research efforts for decades; however, lecture remains the predominant form of instruction. While interest has been primarily focused on entry-level courses in order to recruit and retain STEM-intending students, quality
instruction in upper division courses is also important. In a national survey of abstract algebra instructors, we investigated typical teaching practices, beliefs, and constraints that influence pedagogical decisions, and similarities/differences between those who do and do not lecture. Of particular interest was exploring whether instructors at Bachelor’s-granting institutions have markedly different circumstances than their counterparts at Master’s- and Doctoral-granting institutions and the effect (if any) this has on their pedagogical decisions.

Submission: 109
Room: Coronado

**Session 9 Preliminary Reports (9:15 AM – 9:45 AM)**

The role of mathematics faculty in the development of African American male mathematics majors
Christopher Jett
HBCUs have a longstanding legacy of supporting African American students in mathematics. The undergraduate mathematics faculty members play a unique role in supporting and developing astute mathematics students, especially African American male students. This preliminary research report highlights the experiences of a cohort of 16 African American male mathematics majors at an all-male, private HBCU by investigating the role of the mathematics faculty members. Using qualitative research methods grounded in critical race theory, preliminary data show these African American male mathematics majors were affirmed mathematically and racially by their mathematics faculty members.
Submission: 101
Room: Del Mar

The Use of NCTM Articles as Reading Assignments to Motivate Prospective Elementary Teacher Engagement in Mathematics Courses
Krista Strand and Eva Thanheiser
In this study, we examine the use of assigning articles published in NCTM’s practitioner journals as readings in mathematics content courses for prospective elementary teachers (PTs). In particular, we study the articles’ roles in motivating PTs to engage in their content courses. As a conceptual foundation, we characterize NCTM articles as having potential to (1) increase PTs’ “buy-in” of pedagogical approaches used in content courses, (2) challenge PTs’ unproductive beliefs about mathematics, and (3) address mathematics content via children’s thinking. We plan to analyze an existing dataset of PTs’ online typed responses to assigned NCTM articles to identify whether and how their responses reflect increased motivation to engage in their content courses. We anticipate that our results will lead to an increased understanding of PTs’ actual experiences related to the assigned article readings.
Submission: 4
Room: Bay Room

What Constitutes a Proof? Complementary Voices of a Mathematician and a Mathematics Educator in a Co-Taught Undergraduate Course on Mathematical Proof and Proving
Orit Zaslavsky and Jason Cooper
The work reported in this paper is part of a study aimed at characterizing the processes and identifying the ways in which different kinds of expertise (mathematics vs. mathematics education) unfolded in the planning and teaching of an undergraduate course on Mathematical Proof and Proving (MPP), which was co-taught by a professor of mathematics and a professor of mathematics education. More specifically, the study aimed at unpacking the affordances and drawbacks of this collaboration. The collected data includes all 13 videotaped lessons in the 2012 semester, the second time the course was taught. The content of the course consisted of topics that were familiar/accessible to the students, e.g., high school level algebra, geometry, and basic number theory. In this paper we focus on how the views held by each instructor regarding what constitutes an acceptable proof and how it should be presented, are reflected in his/her teaching.
Submission: 105
The Effect of Attending Peer Tutoring on Course Grades in Calculus I
Brian Rickard and Melissa Mills

Tutoring centers are common in universities in the United States, but the effects of tutoring on student success are often not examined statistically. This study utilizes multiple regression analysis to model the effect of tutoring attendance on final course grades in Calculus I. Our model predicted that every three visits to the tutoring center would increase a students’ course grade by one percent, after controlling for prior academic ability. We also found that for lower achieving students attending tutoring had a greater impact on final grades.
Submission: 112

Factors influencing instructor use of student ideas in the multivariable calculus classroom
Aaron Wangberg, Tisha Hooks, Elizabeth Gire, Jason Samuels and Brian Fisher

Despite overwhelming evidence of the effectiveness of student engagement in instruction, practicing mathematics instructors often use instructor-centric practices even if they value student engagement. Answering a call by Henderson and Dancy (2007) to study the implementations of researched-based curriculum in the classroom, this paper looks at the change in practices and values of instructors utilizing active-engagement activities in multivariable calculus classes. This curriculum incorporates context and multiple representations, and we look for evidence that addresses whether these features facilitate instructor use of student ideas in instruction.
Submission: 170

Implementation of Pre and Post Class Readings in Calculus
Salam Turki and Houssein El Turkey

Active learning practices highly depend on students’ preparation for class in advance. However, reading Calculus can be a challenging task to students. We address this concern by assigning targeted pre-class readings and reading quizzes in two Calculus II classes. To study the effectiveness of these, we also provided them as post-class readings in two other classes. We report on our implementation and we discuss students’ feedback about the readings and quizzes.
Submission: 104

Coffee Break (9:45 AM – 10:15 AM)
Room: Cabo Courtyard (Weather Permitting)

Session 10 Contributed Reports (10:15AM – 10:45 AM)
CharacteMonizing the Nature of Introduction to Proof Courses: A Survey of R1 and R2 Institutions across the US
Erika David and Dov Zazkis

A number of institutions with mathematics programs offer introduction to proof courses in order to ease mathematics students’ transition from primarily calculation-based courses to proof-centered courses. However, unlike most tertiary mathematics courses, whose mathematical content is directly implied by their course titles, introduction to proof courses may vary in terms of the mathematics content discussed. In this study we document the variation in content of introduction to proof courses. This is achieved by examining recent syllabi and other relevant course documents from introduction to proof courses at 179 R1/R2 universities across the United States. The various types of content used in these courses are discussed. We describe the 15 categories of ITP courses that emerged from the course information we collected and offer our categories as a framework for classifying ITP courses or students in future studies.
Submission: 15
**Approaches to the derivative in Korean and the U.S. Calculus Classrooms**

**Jungeun Park**

This study explored how one Korean and one U.S. calculus class defined the word “derivative” as a point-specific object through the limit process on the difference quotient, and as a function on its domain. The analysis using Commognitive approach showed that both class used similar visual mediators for the limit process/object, but addressed different components of the definitions; Discussion of the derivative as a function before it was defined were frequently found in the U.S. class but rarely found in the Korean class; Words for the derivative at a point, and words for the derivative as a function explicitly differed in the Korean class compared to the U.S. class; and the derivative was first defined as a function through correspondence between x-value and the derivative value in Korean class, but through expansion of x values from a number to variable and corresponding changes in the U.S. class.

**Submission:** 62

**McNuggets, Bunnies, and Remainders, Oh My!**

**Nina Rocha and Jennifer Zakotnik-Gutierrez**

Given its applications in computing, coding, and cryptography, the Chinese Remainder Theorem is a worthwhile, accessible, and unexplored area of number theory. The purpose of this qualitative case study was to investigate strategies and reasoning that students exhibited while solving problems chosen to elicit thinking in elementary number theory topics related to the Chinese Remainder Theorem. We interviewed pairs of students from three different courses in order to investigate the similarities and differences that may occur as a result of varying mathematical backgrounds and partner dynamics. We identified a range of strategies including manipulating final digits, listing multiples while accounting for remainders, and implementing divisibility rules. This paper presents a portion of our findings comparing strategies for two of our three cases on several tasks from our interviews.

**Submission:** 94

**Managing Tensions Within a Coordinated Inquiry-Based Learning Linear Algebra Course: The Role of Worksheets**

**Vilma Mesa, Mollee Shultz and Ashley Jackson**

Student engagement in the classroom has been proposed as an essential component for meaningful learning (Kuh, 2008). A growing trend in mathematics departments encourages faculty to use inquiry-based learning methods (IBL), an approach that “invites students to work out ill-structured but meaningful problems… [and] construct, analyze, and critique arguments… present and discuss solutions alone at the board or via structured small-group work, while instructors guide and monitor this process” (Laursen, Hassi, Kogan, & Weston, 2014, p. 407). As part of an initiative to increase the number of students experiencing a different instructional approach, a group of nine instructors in a mathematics department at a research university engaged in a course-wide implementation of IBL in all eleven sections of linear algebra, a gateway course for mathematics majors. The department determined the book that would be used (Bretscher, 2013) and mandated common examinations, homework, and reading assignments. We followed the implementation with two goals in mind, first to understand how did the faculty operationalize teaching with inquiry-based learning methods and second, to document and understand how they managed the tension that arose because of the need to cover the prescribed content in sync with all the sections at the same time that instructors allowed students free exploration of the ideas to comply with the spirit of IBL. IBL has been described as an instructional approach that has the potential to help more students understand mathematical ideas and become more proficient in the practices required for doing mathematics: proving, communicating ideas, following arguments, etc. Having information about what happens when a department seeks to institute teaching changes in a key mathematics course such as linear algebra is informative for departments interested in pursuing similar moves. This study can thus contribute to the literature on teaching change in undergraduate settings.

**Submission:** 53
Preservice Elementary Teachers’ Understandings of Greatest Common Factor Versus Least Common Multiple
Kristin Noblet

Little is known about preservice elementary teachers’ understandings of greatest common factor (GCF) or how they relate to their understandings of least common multiple (LCM). As part of a larger case study in which an emergent perspective (Cobb & Yackel, 1996) was used to investigate preservice elementary teachers’ understandings of topics in number theory, task-based interviews elicited participants’ conceptions about modeling GCF and LCM using manipulatives, pictures, and story problems and the procedure for finding GCF and LCM using prime factorizations. Additional classroom data served to support findings. Participants held stronger understandings of modeling LCM than they did with modeling GCF. In contrast, participants’ understandings of the procedure for finding GCF were far more robust than their understandings of how to find LCM.
Submission: 130

Session 11 Preliminary Reports (10:55 AM – 11:25 AM)

An exploration of students’ discourse using Sim2Bil within group work: A commognitive perspective
Ninni Marie Hogstad and Olov Viirman

This paper reports on critical aspects of three engineering students’ discourse in group work using a digital tool called Sim2Bil while solving mathematical tasks. Applying a commognitive perspective, where mathematical discourse is characterized by words used, visual mediators applied, narratives developed and routines established, we investigate how these characteristics are influenced by the technological environment. It is found that all of the aspects of the students’ discourse are influenced by Sim2Bil. For instance, a “trial and error” routine directly connected to the use of the tool is present in the students’ discourse.
Submission: 85

Second semester calculus students and the contrapositive of the nth term test
David Earls

Little is known about the difficulties second semester calculus students have determining series convergence, and why students have such difficulty. This report seeks to add to the existing literature on series by analyzing second semester calculus student responses to a multiple choice item that involves the use of the contrapositive of the nth term test. We frame our discussion in terms of what these answers might say in terms of student concept images of series and sequences. We also analyze what prerequisite knowledge might help students be more successful in answering questions about series and sequences typically seen in a second semester calculus course.
Submission: 97

Developing Student Understanding: The Case of Proof by Contradiction
Darryl Chamberlain Jr and Draga Vidakovic,

Proof is central to the curriculum for undergraduate mathematics majors. Despite transition-to-proof courses designed to facilitate the transition from computation-based mathematics to proof-based mathematics, students continue to struggle with mathematical proof. In particular, proof by contradiction has been isolated as one of the most difficult proof methods for students to construct and comprehend. The purpose of this paper is to discuss preliminary results on student comprehension of proof by contradiction within a transition-to-proof course. Grounded in APOS Theory, this paper will illustrate that students’ ability to negate quantification plays an early role in student comprehension of proof by contradiction.
Submission: 7
Analysis of Teachers’ Conceptions of Variation
Gabriel Tarr and April Strom

The CCSSM emphasize statistical concepts for grades 6-12. A key factor in thinking statistically is to reason about variation and variability. This paper will present the analysis of survey questions and tasks given to in-service middle school teachers. The paper will attempt to answer the following question: “To what extent do middle school math teachers consider variation and variability when thinking about statistics and reasoning through statistical tasks?”
Submission: 151

Outcomes Beyond Success in a Problem Centered Developmental Mathematics Class
Martha Makowski

Low success rates in the pre-college level, or developmental, curriculum at many community colleges has resulted in the creation of classes that use problem solving and group work to help students become more mathematically empowered. This preliminary report describes one such class at a Midwestern community college and then outlines the results from a pre- and post-survey of students taking the class, focusing on whether students’ attitudes towards mathematics changed while enrolled in the class. Further analysis will examine how students evaluated the class and ranked the class structures. Generally, males, younger students, and Black students were less likely to complete the course. Students who came close to completing the class had an overall positive shift in their attitudes towards mathematics.
Submission: 75

Session 12 Contributed Reports (11:35 AM – 12:05 PM)

Students’ Understanding of Vectors and Cross Products: Results from a Series of Visualization Tasks
Monica VanDieren, Deborah Moore-Russo and Jill Wilsey

Previous studies have explored student understanding of vectors in physics, engineering, or linear algebra settings, but there has been scant research on student understanding of vectors in a multivariable calculus context. In this study, we begin to explore how students think about vectors and cross products by analyzing student responses to open-ended questions from an online, conceptually-oriented multivariable calculus cross product activity. We identify several themes consistent with previous research on physics students including confusion between the cross product and its magnitude as well as difficulty identifying or communicating the direction of the cross product vector. This preliminary research begins to develop categories that could outline a conceptual model of student understanding of vectors and cross product. The analysis also informs several recommendations for improving the cross product activity.
Submission: 117

Using Women of Color’s Intuitive Examples to Reveal Nuances about Basis
Aditya Adiredja and Michelle Zandieh

Research and surveys continue to document the underrepresentation of women of color (WOC) in mathematics. Historically, their achievement in mathematics has been framed in a deficit way. Following the broader call for more research concerning WOC’s learning experiences in STEM, we interviewed eight WOC about their understanding of basis in linear algebra. We documented diverse ways that these women creatively explained the concept of basis using intuitive ideas from their everyday lives. These examples revealed important nuances and aspects of understanding of basis that are rarely discussed in instruction. These students’ ideas can also serve as potentially productive avenues to access the topic. Our results also challenge the existing broader narrative about the underachievement of women of color in mathematics.
Submission: 169
Preservice Secondary Teachers’ Abilities to Transfer from Graphical to Algebraic Representations of Functions

Kyunhee Moon

In this study, I examined 14 preservice secondary teachers’ abilities to transfer graphical to algebraic representations of functions. The analysis showed that the vast majority of the participants had problems in noticing critical behaviors of function graphs and in using them to construct algebraic forms. About half or fewer of the participants noticed qualities such as x-intercepts, vertical asymptotes, slant asymptotes, and concavity/extrema, with only a few of them successfully using such qualities in constructing algebraic forms. Only a few noticed and used qualities such as horizontal asymptotes, point discontinuities, domain, and end behaviors in constructing algebraic forms. It is advisable that the teaching of the function concept incorporate transformational activities beyond algebraic to graphical transformations and focus more on the critical characteristics of functions.

Submission: 43

Undergraduate Students’ Holistic Comprehension of a Proof

Eyob Demeke

In this paper we explore eleven undergraduate students’ comprehension of a proof taken from an undergraduate abstract algebra course. Our understanding of what it means to understand a proof draws from a proof comprehension model developed by Mejia-Ramos, et al. (2012). This study in particular examines the extent to which undergraduate students are able to summarize a proof using the proof’s higher-level ideas. Additionally, eleven doctoral students in mathematics were asked to provide a summary of the same proof that undergraduates received. Undergraduates’ holistic comprehension of the proof was then analyzed in light of summaries that doctoral students provided. The main finding of the study is that undergraduates’ comprehension of the proof was overall inadequate—notably, they demonstrated limited skills in summarizing a proof via the proof’s main ideas. Moreover, undergraduates failed to recognize the scope of the method used in the proof.

Submission: 124

Tinker Bell’s Pixie Dust: Exploring the Role of Differentiation in Emergent Shape Thinking

Kristin Frank

Researchers have described the importance of seeing a graph as an emergent trace of how two quantities’ values vary simultaneously. Researchers have also identified the many difficulties students face when trying to construct this conceptualization of graphs. In this paper I explore the role of two didactic objects on a student’s conceptualization of graphs. In particular, I examined how a student’s interactions with these didactic objects supported her making key differentiations that enabled her to conceptualize a graph as emerging from simultaneously tracking two quantities’ varying values. My findings revealed that a student must differentiate a place on a function’s graph from the value of the function’s output. Also, the student must distinguish tracking a point in the plane from creating the point by simultaneously attending to the variation of two quantities.

Submission: 48
Computational thinking in and for undergraduate mathematics: Perspectives of a mathematician
Miroslav Lovric and Ami Mamolo
We report on a mathematician’s perceptions and awarenesses related to incorporating problem-based activities requiring computational thinking into an upper level undergraduate mathematics course. Computational thinking is understood as the thinking, strategies, and approaches for problem solving that parallel the design of computational algorithms which can be followed and executed by a computer. Data from this case study is qualitative in nature, and seeks to present an in-depth account of one professor’s experiences developing and teaching computational thinking in and for mathematics. Analyses highlight the similarities and differences amongst the values and opportunities perceived for computational thinking versus other more ubiquitous mathematical approaches, as well as the perceived tensions and challenges in trying to foster such values and opportunities.
Submission: 143

How Students Interpret Line and Vector Integral Expressions: Domains, Integrands, Differentials, and Outputs
Steven Jones and Omar Naranjo
This study expands on research happening in multivariate calculus education to an exploration of student understanding of line and vector integrals. We describe how students interpreted these types of integrals, including the various symbols in their expressions and their relationships to each other. We found that while the students struggled to give meaning to these types of integrals, they did invent many interesting interpretations for the various components of the integral expressions and for what the overall integral’s value might represent. We also found that students may need help conceptualizing the domain over which an integral happens, and we incorporate this into a general “domain-chop-evaluate-add” framework for integrals.
 Submission: 17

SCNI: A Robust Technique to Investigate Small-Group Learning at College
Fady El Chidiac
The Stimulated Construction of Narratives about Interactions (SCNI) technique for data collection, introduced in this paper, enables robust investigations of small-group learning at college. The SCNI technique consists of promptly soliciting participants’ perspectives on their recent joint activity using video records thereof. Thus the SCNI technique creates a space to network the narrative discourses, which shape how participants understand their world, and the pragmatic forces that govern participants’ interactions in a practice. Data reported in this paper are collected from a number theory class of ethnically diverse students. In this paper, I will report three cases to illustrate the advantages of SCNI data over data collected by video-records and unmediated interviews in elucidating, nuancing and expounding what matters for group work. Through these cases, I will use three different analyses appropriate for SCNI-data. Limitations and recommendations for efficient conduct of SCNI are discussed as well.
Submission: 73

Graduate Student Instructors learning from peer observations
Daniel Reinholz
Graduate Student Instructor (GSI) professional development addresses an urgent need to improve STEM retention. This paper focuses on a semester-long professional learning community in which six
mathematics GSIs engaged in regular cycles of peer observation, feedback, and reflection. In contrast to most GSI development work, this approach emphasized that GSIs give, not just receive, peer feedback. Analyses of post-semester interviews indicated that all GSIs enhanced their noticing of students. Moreover, insight into peer feedback was developed along three dimensions: (1) the importance of being an objective observer, (2) the impact of working with equal-status peers, and (3) the value of critical feedback.

Submission: 19
Room: Del Mar

Comparing Expert and Learner Mathematical Language: A Corpus Linguistics Approach
Lara Alcock, Matthew Inglis, Kristen Lew, Juan Pablo Mejia-Ramos, Paolo Rago and Chris Sangwin

Corpus linguists attempt to understand language by statistically analyzing large collections of text, known as corpora. We describe the creation of three corpora designed to enable the study of expert and learner mathematical language. Our corpora were formed by collecting and processing three different genres of mathematical texts: mathematical research papers, undergraduate-level textbooks, and undergraduate dissertations. We pay particular attention to the method by which our corpora were created, and present a mechanism by which LaTeX source files can be easily converted to a form suitable for use with corpus analysis software packages. We then compare these three different types of mathematical texts by analyzing their word frequency distributions. We find that undergraduate students write in remarkably similar ways to textbook authors, but that research papers are substantially different. These differences are discussed.

Submission: 56
Room: Pt. Loma 1

Session 14 Contributed Reports (1:45 PM – 2:15 PM)

Learning to Notice and Use Student Thinking in Undergraduate Mathematics Courses
Anna Pascoe

This study evaluated the outcomes of an intervention focused on developing mathematics graduate teaching assistants’ (GTAs’) skills of noticing and effectively responding to instances of student mathematical thinking that have significant potential to further students’ learning. Four GTAs participated in a semester-long intervention that included individual analysis and group discussion of video of undergraduate mathematics lessons. The MOST Analytic Framework (Stockero, Peterson, Leatham, & Van Zoest, 2014) was introduced to aid in these activities. The GTAs also completed a pre- and post-interview to document their real time noticing and an assessment of common content knowledge. Results indicate that the intervention was successful in improving the GTAs’ noticing skills in a variety of ways and in their ability to propose student-centered responses.

Submission: 107
Room: Del Mar

Virtual Manipulatives, Vertical Number Lines, and Taylor Series Convergence: The Case of Cody
Matthew Thomas and Jason Martin

Evidence from recent Taylor series studies suggests that well-designed virtual manipulatives can support calculus students in developing an understanding of Taylor series convergence consistent with the formal pointwise convergence definition. In particular, virtual manipulatives depicting convergence along vertical number lines (VNLs) provide graphical representations of quantities necessary for pointwise convergence. We detail one student’s reasoning about Taylor series convergence before and after a VNL was revealed in a Taylor series graph. Prior to the VNL the student had produced very accurate Taylor polynomial graphs based on visually perceptual clues but had omitted notions of pointwise convergence. After a VNL was revealed, the student’s reasoning now included quantities along the vertical as he responded to approximation tasks. We believe that such reasoning can later support the student in developing an understanding of pointwise convergence.

Submission: 161
Using learning trajectories to structure teacher preparation in statistics
Anna Bargagliotti and Celia Anderson Rosseau
As a result of the increased focus on data literacy and data science across the world, there has been a large demand for teacher preparation in statistics. However, exactly how this preparation should be structured remains an open question. The purpose of this paper is to report on the NSF-funded Project-XXX professional development program. Project-XXX provided professional development to enhance teachers’ statistical knowledge for teaching. The project constructed two hypothetical learning trajectories for teacher learning and subsequently used the hypothetical learning trajectories to structure the professional development curriculum. This main goal of this paper is to illustrate how the utilization of the learning trajectory structure to design professional development curriculum allowed participating teachers to develop several aspects of Statistics Knowledge for Teaching (Groth, 2013).
Submission: 49

Exploring Undergraduates’ Experience of the Transition to Proof
Jack Smith, Mariana Levin, Younggon Bae and V. Satyam
We report a qualitative analysis of 14 undergraduate students’ experience in a semester long introduction to proof course. Half were mathematics majors. Our research aims to characterize, conceptually and empirically, students’ transition from a focus on computation to proof in mathematics. Our analysis focused on how students saw the course as different from prior courses, how they described their work in it, and whether being successful in the course required new or different learning activity of them. This approach—targeting students’ overall experience of the course—differs from prior research that has tracked students’ challenges, focused on their work on specific proof problems, and explored how to support and improve their work (e.g., Selden & Selden, 2003). Our work has promise for informing the design of transition to proof courses and how those courses are organized and taught.
Submission: 20

Examining Lecturer’s Questioning in Advanced Proof-Oriented Mathematics Classes
Teo Paoletti, Victoria Krupnik, Dimitri Papadopoulos, Joseph Olsen and Tim Fukawa-Connelly and Keith Weber
There has been a substantial increase in mathematics education research in how proof-oriented university mathematics courses are traditionally taught. In this paper, we focus on the questions that lecturers pose to students. Specifically, we audio-recorded 11 proof-oriented mathematics lecturers and analyzed all of the questions they asked their students. We categorized each of the 1,031 questions according to a coding system we describe as well as identified wait time and subsequent speaker. We describe trends across all 11 lecturers, highlighting the limited opportunities students had to engage in important mathematical practices, and identify variances between how different lecturers used questions. We present qualitative data highlighting common and uncommon questioning techniques and conclude with a discussion of our results.
Submission: 102

Session 15 Preliminary Reports (2:25 PM – 2:55 PM)
Locating a Realistic Starting Point for the Guided Reinvention of Limit at Infinity With Community College Students Prior to Pre-Calculus
William McGuffey
In this paper I describe a teaching experiment conducted with a pair of undergraduate students at a two-year community college. My primary goal was to explore a realistic starting point for the guided reinvention of the concept of limit at infinity for students who had not yet studied limits. The teaching experiment included 5 weekly hour-long sessions in which the two students were presented with tasks
that involved describing the behavior of certain real-world phenomena. The initial analysis revealed that these students showed ways of thinking that anticipate the formal concept of limit at infinity. Further analysis will be used to develop an appropriate instructional sequence with a realistic starting point to be used in future teaching experiments in which students will be engaged in the guided reinvention of a formal definition of limit at infinity.

Submission: 96
Room: La Jolla

Do Students Really Know What a Function is?: Applying APOS Analysis to Student Small Group Presentations
Tara Davis and Georgianna Martin

One of the fundamental concepts in mathematics is that of a function. This concept also appears to be a difficult concept to grasp for a large percentage of students. In order to assess the overall understanding of the concept of a function, we conducted an experiment with math majors at our university. In an upper division math problem solving course, the students were asked specific questions about the nature of functions. Students presented their understandings of function in groups of 2-3, which were recorded and then transcribed. Based on the IBL teaching methodology and the small group and classroom discussion data collected we have applied a sociocultural framework. The innovation we add is applying APOS, an individually oriented theory, to the collective level. Analyzing the video transcripts, we will discuss the overall trends in understanding as well as some of the common misconceptions that we have identified.

Submission: 68
Room: Del Mar

Connecting Secondary and Tertiary Mathematics: Abstract Algebra and Inverse
Eileen Murray, Matthew Wright and Debasmita Basu

This study explores how practicing teachers make connections between secondary and tertiary mathematics. Using three frameworks for teacher knowledge of mathematics, along with the work on key developmental understandings (KDUs) (Simon, 2006) as related to teacher knowledge (Murray & Wasserman, 2016), we observe how a professional development workshop focused abstract algebra content impacts teachers understanding and teaching of secondary mathematics.

Submission: 138
Room: Coronado

Perturbing practice: The effects of virtual manipulatives as novel didactic objects on instruction
Krysten Pampel

The advancement of technology has significantly changed the practices of numerous professions, including teaching. When a school first adopts a new technology, established classroom practices are perturbed. These perturbations can have both positive and negative effects on teachers’ abilities to teach mathematical concepts with the new technology. Therefore, before new technology can be introduced into mathematics classrooms, we need to better understand how technology affects instruction. Using interviews and classroom observations, I explored perturbations in mathematical classroom practice as an instructor implemented novel didactic objects. In particular, the instructor was using didactic objects designed to lay the foundation for developing a conceptual understanding of rational functions through the coordination of relative magnitudes of the numerator and denominator. The results are organized according to a framework that captures leader actions, communication, expectations of technology, roles, timing, student engagement, and mathematical conceptions.

Submission: 23
Room: Private Dining Room

Considerations for Explicit and Reflective Teaching of the Roles of Proof
Jeffrey Pair and Sarah Bleiler-Baxter

In a previous study we sought to understand the classroom activities that provided students the opportunity to engage in the five roles of proof described by Michael de Villiers (1990). In conducting the analysis for that study, we noticed that students’ views of proof were sometimes not aligned with de
Villiers’ views. This led us to the current investigation, where we explore alignment between undergraduate students’ views of the nature of proof and de Villiers’. We hypothesize that an explicit and reflective (ER) approach to instruction may be important if students are to learn about the nature of mathematics (in general) and the nature of proof (more specifically). We offer implications for both research and practice, with respect to the explicit and reflective instruction on roles of proof.

Submission: 121
Room: Pt. Loma 1

**Coffee Break (2:55 PM – 3:25 PM)**
Room: Cabo Courtyard (Weather Permitting)

**Session 16 Preliminary Reports (3:25 PM – 3:55 PM)**

**Let’s Talk About Teaching: Investigating Instructors’ Social Networks**
Kathleen Quardokus Fisher and Naneh Apkarian

Researchers who evaluate efforts to improve STEM undergraduate education have recently begun to explore the importance of instructors’ informal teaching discussion networks. These informal networks allow for the flow of knowledge between instructors that can include information about how to implement research-based instructional practices and creative perspectives that lead to innovative solutions to address localized classroom challenges. In this report, we reanalyze the network data from three pioneering studies in this area to explore the features of mathematics department networks as compared to other STEM department networks at multiple institutions. We plan to discuss implications of these features on the design and implementation of change efforts.

Submission: 106
Room: Del Mar

**Experts’ Varied Concept Images of the Symbol dx in Integrals and Differential Equations**
Tim McCarty and Vicki Sealey

The mathematical symbol “dx” is a symbol for which there can exist different views about its characteristics, purposes, and roles. We wished to see how experts viewed the dx in a variety of settings. We chose four mathematical contexts and interviewed four mathematics professors in order to understand their various concept images of the dx. While there was little agreement among the experts’ responses, most of them did have a strong concept image that remained consistent throughout their interviews, despite our attempts to create cognitive conflict between the different mathematical contexts. We conclude that the existence of a range in the experts’ opinions is noteworthy, and that further study should be conducted in order to more fully explore this range and any implications for instruction that may result from it.

Submission: 111
Room: Coronado

**Professional Development Linking the Concept of Inverse in Abstract Algebra to Function Inverses in the High School Curriculum**
Melissa Mills and Cara Brun

Pre-service and in-service high school teachers often do not leverage their experience with abstract algebra when interpreting the notation of inverse functions. For this study, we have designed a professional development activity in which teachers can explore inverses in different sets with different binary operations to elicit pseudo-empirical abstraction of the relationship “element * inverse = identity.” We used a scripting task found in previous literature to measure the impact of the activity on both the teacher’s understanding of inverses and how the teacher would explain the inverse function notation to students. We claim that emphasizing the role of the identity element when discussing inverses can help pre-service teachers overcome misconceptions about inverse functions.

Submission: 100
Pedagogical Practices for Fostering Mathematical Creativity in Proof-Based Courses: Three Case Studies
Milos Savic, Houssein El Turkey, Gail Tang, Gulden Karakok, Emily Cilli-Turner, David Plaxco and Mohamed Omar

Some mathematics education publications highlight the importance of fostering students' mathematical creativity in the undergraduate classroom. However, not many describe explicit instructional methodologies to accomplish this task. The authors attempted to address this gap using a formative assessment tool named the Creativity-in-Progress Rubric (CPR) on Proving. This tool was developed to encourage students to engage in practices that research studies, mathematicians, and students themselves suggest may promote creativity in processes of proving. Three instructors in different institutions used a variety of tasks, assignments, and in-class discussions in their proof-based courses centered around the CPR on Proving to explicitly discuss and foster mathematical creativity. These instructors’ actions are explored using Levenson’s four teacher roles of fostering mathematical creativity. In this report, preliminary results indicate that each of the three instructors assumed at least three of the four roles.
Submission: 127

A Preliminary Investigation of the Reification of “Choosing” in Counting Problems
Elise Lockwood

In a recent combinatorics-focused teaching experiment with two undergraduate students, the students developed a robust understanding of a three-stage counting process that provided a solution for problems involving combinations. So strong was the students’ three-stage process, they did not seem to naturally conceive of the singular process of “choosing,” which is an important aspect of understanding combinations. In this preliminary report, I question whether or not the students engaged in reification, which Sfard and Linchevski describe as “our mind’s eye’s ability to envision the result of processes as permanent entities in their own right” (1994, p. 194). I raise questions about what aspects of the student work might have fostered or hindered their ability to reify choosing, as well as what might be taken as evidence that reification has occurred in the context of combinatorics.
Submission: 60

Opportunities to Learn from Teaching: A Case Study of Two Graduate Teaching Assistants
Nathan Wakefield, Erica Miller and Yvonne Lai

Many mathematics departments with graduate programs rely on their graduate students to teach undergraduate courses. Since departments are responsible and accountable for the quality of instruction provided in their courses, many departments have begun to realize the importance of providing professional development for their graduate teaching assistants. In fact, there exist several exemplary models of professional development for graduate teaching assistants. To better understand these professional development programs, researchers have begun to study the process of how graduate students make sense of and enact the experiences graduate students are provided with during professional development. In this case study, we examine how two graduate students developed the ability to link observations of student work to hypotheses about student thinking and then connect these hypotheses about student thinking to future teaching actions.
Submission: 41
Session 17 Preliminary Reports (4:05 PM – 4:35 PM)

Mathematicians’ Interplay of the Three Worlds of the Derivative and Integral of Complex-valued Functions
Hortensia Soto and Michael Oehrtman

We engaged five research mathematicians in describing their images of differentiation and integration for functions of complex variables. Analyzing the data in terms of Tall’s three worlds, we explore the connections between the physical embodiments of the mathematicians’ reasoning, their descriptions for students, and their formalizations of these interpretations. For differentiation, the mathematicians relied heavily on direct application of concepts and analogies from differentiation of real-valued functions and employed rotation and stretching as a local linear description of the action of the function, corresponding to repeated mental imagery and physical gestures. For integrals, the mathematicians employed reasoning about line real-valued integrals, but acknowledged that they struggled to conceptually interpret what was being accumulated in the complex case. Instead, they all developed more personal meanings through a process of reconciling various aspects across their own conceptual-embodiment, operational-symbolic, and axiomatic-formal reasoning.
Submission: 70
Room: Pt. Loma 1

Meta-Representational Competence with Linear Algebra in Quantum Mechanics
Megan Wawro, Kevin Watson and Warren Christensen

In this report we share our preliminary analysis of one student’s meta-representational competence as he engages in solving a quantum mechanics problem involving linear algebra concepts, namely basis, eigenvectors, and eigenvalues. We provide detail on student A25, who serves as a paradigmatic example of a student’s power and flexibility in thinking in and using different notation systems. This preliminary work lends credence to and inspires our conjecture that strong meta-representational competence (MRC) is necessary not only to be fluent and proficient in the mathematics involved in solving quantum mechanics problems but also to develop a robust understanding of the quantum mechanics content.
Submission: 137
Room: Coronado

An Investigation of the Development of Partitive Meanings for Division with Fractions: What Does It Mean to Split Something into 9/4 Groups?
Matthew Weber, Amie Pierone and April Strom

In this paper we describe a study involving twelve pre-service elementary teachers who are attending a community college. The design and implementation of this study were guided by the research question: In what ways do students reason through a sequence of tasks which progressively become more abstract, and which challenge primitive intuitions regarding partitive division? We highlight students’ ways of thinking involved with division that are not easily generalizable, that favor numerical procedures over quantitative reasoning, and which are obstacles to the development of more robust meanings for division.
Submission: 139
Room: Private Dining Room

Students’ Epistemological Frames and Their Interpretation of Lectures in advanced mathematics
Victoria Krupnik, Keith Weber, Tim Fukawa-Connelly

In this paper, we present a comparative case study of two students with different epistemological frames watching the same real analysis lectures. We show the general point that students with different epistemological frames can interpret the same lecture in radically different ways. We also identify epistemological frames that are useful or counterproductive for understanding a lecture on how the rational numbers are constructed from the integers. These results illustrate how different students interpretations of a lecture are not inherently tied to the lecture, but rather depend on the student and that student’s perspective on mathematics. Thus, improving student learning may depend on more than
improving the quality of the lectures, but also changing student’s beliefs and orientations about mathematics and mathematics learning.
Submission: 141
Room: Pt. Loma 2 & 3

Flip vs. Fold: What is so important about the Rigidity of a Motion?
Anna Marie Bergman, Dana Kirin, Ben Wallek
This report will investigate the mathematical and pedagogical consequences of flipping versus folding in the identification of reflection symmetry. Preliminary results are presented from a teaching experiment aimed at exploring the development of one undergraduate student’s understanding of symmetry. The analysis indicated that throughout the teaching experiment, the student held two distinct versions of reflection symmetry. One version was what most would identify as reflection, while the other was an iterative process based on the participant’s ability to fold the figure. In this report, we share what this student identified as symmetries and how she justified her methods. In addition, we discuss why the definition of isometry necessitates a rigid motion and how the motion of folding is insufficient for identifying symmetries correctly. Lastly, we consider why understanding a rigid motion is advantageous for students who want to consider symmetries in more sophisticated mathematical contexts such as group theory.
Submission: 149
Room: Del Mar

Applying Variation Theory to Study Modeling Competencies
Jennifer Czocher
This paper presents preliminary results of using variation theory to design modeling tasks in order to explore ways of strengthening undergraduate engineering students’ modeling skills. The responses of two undergraduate engineering students enrolled in differential equations to a set of three versions of the same task is reported.
Submission: 120
Room: La Jolla

Session 18 – Preliminary Reports (4:45 PM – 5:15 PM)

Instrumental Genesis and Generalization in Multivariable Calculus
Brian Fisher and Jason Samuels
Raising Calculus to the Surface is a multi-year project designed to introduce important topics from multivariable calculus through the use of physical manipulatives. This report focuses on data collected through a series of task-based interviews with multivariable calculus students enrolled in a course featuring these manipulatives. To explain the students’ activity, a two-dimensional framework was designed based upon characterizations of their interaction with the instruments and the generality of their mathematical activity. The report concludes by discussing the contributions to the field and possible future uses of the framework.
Submission: 118
Room: Pt. Loma 2 & 3

Examining Students’ Procedural and Conceptual Understanding of Eigenvectors and Eigenvalues in the Context of Inquiry-Oriented Instruction
Khalid Bouhjar, Muhammad Haidar and Christine Andrews-Larson
This study examines students’ procedural and conceptual understanding as evidenced by their written responses to two questions designed to assess aspects of their understanding of eigenvalues and eigenvectors. This analysis draws on data taken from 126 students whose instructors taught using a particular inquiry-oriented instructional approach and 129 comparable students whose instructors did not use this instructional approach. In this proposal, we offer examples of student responses that provide insight into their reasoning and summarize broad trends observed in our quantitative analysis. In general, students in both groups performed better on the procedural item than on the conceptual item.
Additionally, the group of students who were taught with the inquiry-oriented approach outperformed the group of students who were taught using other approaches.

Submission: 157
Room: La Jolla

The Effects of the Epsilon-N Relationship on Convergence of Functions
Zackery Reed

Much work has been done in recent years to study students’ formulations of formal limiting processes within an introductory advanced calculus setting. One of the most common goals is to foster a productive understanding of the relationship between the error bound epsilon and the domain of the convergence; what is called a range-first perspective. My study examined an advanced calculus student’s understanding of the more complicated relationships involved in convergence of functions and how his prior experience with limits influenced his concept image. Through a case study of a task-based interview, I unpack his cognitive organization of the dependence relationships between epsilon, N and x in functional convergence. This case study demonstrates the effects of a persistent understanding that epsilon depend on N in the convergence of sequences.

Submission: 167
Room: Coronado

DNR-Based Professional Development: Factors that Afford or Constrain Implementation
Guershon Harel and Osvaldo Soto

DNR-based professional development (DBPD) is a long-running program spanning seven years with multiple cohorts of in-service secondary mathematics teacher participants. This report investigates teacher change among five key variables: facilitating public debate, using holistic problems, attending to students’ intellectual need, attending to meaning of quantities and use of students’ contributions. Is there evidence that DBPD contributed to higher implementation among participants over time? What factors afford/constrain DNR implementation over time? Classroom observation data indicate the largest impact was found in teachers’ attention to meaning of quantities and students’ intellectual necessity while interview data provide insights to what affords and constrains DNR implementation.

Submission: 173
Room: Pt. Loma 1

Mathematical Modelling and Mathematical Competencies: The case of Biology students.
Yannis Liakos

The research aims at introducing modelling tasks in order to engage students more actively into learning mathematics through tasks that are biologically ‘colored’. My focus is on the individual progression (if there is any) of students’ mathematical competencies during a sequence of modelling sessions that will be part of a regular course of their first year calculus. My ultimate goal is to construct a dynamic competence profile for every student that will participate in the project. Taking the above into consideration, my research suggests a number of interventions in a standard freshmen mathematics course for biology students, interventions that offer a fruitful didactical environment where students can sharpen their mathematical competencies.

Submission: 67
Room: Del Mar

Characterizing Mathematical Digital Literacy: A Preliminary Investigation
Todd Abel and Jeremy Brazas

This proposed preliminary report offers preliminary results from a study designed to begin identifying characteristics of digital literacy in mathematics. Undergraduate students in a three-course honors calculus sequence were provided with tablet computers as part of a digital literacy initiative and digital tasks were integrated into the courses. Student work was analyzed and coded for type of ICT tool use and possible components of mathematical digital literacy. The specific types of tasks developed for and integrated into the class will be discussed below with specific illustrative examples highlighted. The aspects of
mathematical digital literacy illuminated by student work will be outlined, with some initial conclusions about the nature of digital literacy in mathematics.

Submission: 134
Room: Private Dining Room

**Special Session (5:30 - 6:30 PM)**

**The Changing Landscape of Undergraduate Mathematics Education and its Implications for the RUME Community**

**Uri Treisman**

Talk about deep structural change in higher education should always be met with skepticism, if not cause the sane to run screaming from the room. Nonetheless, there have been times, e.g., the aftermath of WWII and Sputnik, when such change has taken place. I will argue and provide evidence for the claim that this is one such time. I will trace in broad outline the disciplinary, economic, and policy forces at play and the responses they have engendered in the mathematics community including a Common Vision for Undergraduate Mathematical Sciences Programs in 2025 and the creation of TPSEmath.org. The major part of the talk will focus on the implications of current reform initiatives for the RUME community. Finally, I will point to recent advances in social psychology, behavioral economics, organizational theory, and structural theories of causal inference that I believe can strengthen mathematics education’s methodological armamentarium.

Room: Pt. Loma 2&3
Saturday, February 25, 2017

Registration/Help Desk Open (7:00 AM – 6:30PM)
Room: Pt. Loma Ballroom 3 Foyer

Breakfast (7:00 AM -8:30 AM)
Room: Cabo Courtyard (Weather Permitting)

Session 19 Contributed Reports (8:35 AM – 9:05 AM)

Decontextualizing word problems and contextualizing symbols
Sayonita Ghosh Hajra and Victoria Kofman

The Common Core State Standards recommend students to decontextualize word problems using symbols and contextualize symbols by defining the meaning of values. We observed pre-service teachers’ difficulties with decontextualizing word problems, contextualizing symbols, and incorporating supplementary word problems’ modeling in instructions for an arithmetic course with pre-service teachers. After 6 weeks of instruction, on a midterm exam, our pre-service teachers started using symbols to present arithmetic word problems. However, many of them still could not clearly define the meaning of the symbols they used. After completing the program, students demonstrated significant improvement in their reasoning with symbols. We believe difficulties with defining symbols are connected to weaknesses with active scientific vocabulary in terms of measurable attributes. Therefore, we propose mathematics courses for prospective teachers to accentuate scientific vocabulary regarding measurable attributes.

Submission: 9
Room: La Jolla

Completeness and Convergence: Interdependent Development in the Context of Proving the Intermediate Value Theorem
Stephen Strand

As a part of a larger RME-based instructional design project for advanced calculus, this paper reports on two students’ reinventions of formal conceptions of sequence convergence and the completeness property of the real numbers in the context of developing a proof of the Intermediate Value Theorem (IVT). Over the course of ten, hour-long sessions I worked with two students in a clinical setting, as these students collaborated on a sequence of tasks designed to support them in producing a proof of the IVT. Along the way, these students conjectured and developed a proof of the Monotone Convergence Theorem. Through this development I found that student conceptions of completeness were based on the geometric representation of the real numbers as a number line, and that the development of formal conceptions of sequence convergence and completeness were inextricably intertwined.

Submission: 136
Room: Del Mar

A Case Study in Constructing Set-based Meanings for Conditional Truth
Alec Hub and Paul Dawkins

We present a case study of Hugo’s construction of Euler diagrams to develop set-based meanings for mathematical conditionals. This episode arose in a teaching experiment guiding students to reinvent mathematical logic from their reasoning about meaningful mathematical statements. We intended for Hugo and his interview partner to develop a subset meaning for conditional truth. Hugo successfully identified and used this condition, but he also introduced another formally equivalent meaning for conditional truth using his Euler diagram. We discuss the shifts in his thinking necessary for developing set-based reasoning and how this case influenced our goals for logic learning.

Submission: 38
Angle Measure, Quantitative Reasoning, and Instructional Coherence: The Case of David
Michael Tallman

This paper reports findings from a study that explored the effect of a secondary mathematics teacher's level of attention to quantitative reasoning on the quality and coherence of his instruction of angle measure. I analyzed 37 videos of an experienced teacher's instruction to characterize the extent to which he attended to supporting students in reasoning quantitatively, and to examine the consequences of this attention (or lack thereof) on the quality and coherence of the meanings the teacher's instruction supported. My analysis revealed that the incoherencies in the teacher's instruction were occasioned by his inattention to quantitative reasoning. This study therefore demonstrates that when teachers do not possess a disposition to attend to quantities and their relationships, the circumstances are ripe for instruction that emphasizes inconsistent, incoherent, and sometimes incompatible, mathematical meaning.

Session 20 Preliminary Reports (9:15 AM – 9:45 AM)

The saga of Alice continues: Her progress with proof frameworks evaporates when she encounters unfamiliar concepts, but eventually returns
Annie Selden, John Selden and Ahmed Benkhalti

This case study continues the story of the development of Alice’s proof-writing skills into the second semester. We analyzed the videotapes of her one-on-one sessions working through our inquiry-based transition-to-proof course notes. Our theoretical perspective informed our work and includes the view that proof construction is a sequence of mental, as well as physical, actions. It also includes the use of proof frameworks as a means of initiating a written proof. Previously, we documented Alice’s early reluctance to use proof frameworks, followed by her subsequent seeming acceptance of, and proficiency with, them by the end of the first semester (Authors, 2016). However, upon first encountering semigroups, with which she had no prior experience, during the second semester, her proof writing deteriorated, as she coped with understanding the new concepts. But later, she began using proof frameworks again and seemed to regain a sense of self-efficacy.

Knowledge About Student Understanding of Eigentheory: Information Gained from Multiple Choice Extended Assessment
Kevin Watson, Megan Wawro, Michelle Zandieh and Sarah Kerrigan

Eigentheory is a conceptually complex idea whose application is widespread in mathematics and beyond. Herein we describe the development and use of an extended multiple choice assessment that gives us further insight into the ways students think about and understand eigenvectors, eigenvalues, and their related concepts.

Undergraduates’ Reasoning about Integration of Complex Functions within Three Worlds of Mathematics
Brent Hancock

Recent research illustrates the importance of studying students’ nuanced mathematical argumentation, as well as students’ tendency to invoke attributes of real numbers that no longer apply to situations in complex analysis. This preliminary report explicates a study exploring undergraduate student pairs’ reasoning about integration of complex functions. I am particularly interested in students’ attention to the idiosyncratic hypotheses of powerful integration theorems as they evaluate integrals. Here reasoning is treated as contributing to collective argumentation within one or more of Tall’s (2013) three worlds of mathematics. Data were collected via task-based, semistructured interviews with pairs of undergraduates.
to elicit such reasoning, and classroom observations of the six class sessions devoted to integration prior to
the interviews. All interviews have been transcribed and current analysis consists of conducting a Toulmin
(2003) analysis, augmented by a three-world classification. Potential implications of this work and
connections to the associated literature are also discussed.
Submission: 27
Room: Coronado

A Continued Exploration of Self – Inquiry in the Context of Proof and Problem Solving
Todd Grundmeier and Dylan Retsek
Self-inquiry is the process of posing questions to oneself while solving a problem. The authors’ previous
work has explored the self-inquiry of undergraduate mathematics majors and a mathematics professor.
Student self-inquiry was explored via structured interviews requiring the solution of both mathematical
and non-mathematical problems. The professor’s self-inquiry was explored through self-reporting of
questions asked in an advanced problem-solving context. Using transcripts of the student interviews, a
coding scheme for questions posed was developed and extended after coding the professor’s self-inquiry.
Previous results will again be highlighted here but will be followed by a discussion of self-inquiry in the
context of an introduction to mathematical proof course. Data from the introduction to proof course is
being collected and will be analyzed using the already developed coding scheme. This analysis will be
compared and contrasted to previous self-inquiry results and we will present questions about possible
future directions for exploring self-inquiry.
Submission: 25
Room: Del Mar

Preservice Teachers Fractional Knowledge: Understanding the District Roles of Fractions
Eun Jung
Drawing from task-based interviews, classroom observation, and participants’ homework, the present
study examines ten middle grades preservice teachers’ understanding of the role of fractions as operators,
with an eye toward exploring how fractional reasoning is constructed. The results point to the construction
of the reversible distributive partitioning scheme as a requisite for understanding fractions as operators.
Further discussion will suggest that school curricula and teacher education programs may need to be
adjusted to reflect more current understandings of both early childhood cognitive development and future
teachers’ fractional knowledge.
Submission: 145
Room: Private Dining Room

Coffee Break (9:45 AM – 10:15 AM)
Room: Cabo Courtyard (Weather Permitting)

Session 21 Contributed Reports (10:15AM – 10:45 AM)

Students’ Conceptions of Mappings in Abstract Algebra
Rachel Rupnow
In an effort to understand ways students approach constructing homomorphisms and isomorphisms
between groups, six undergraduate math and engineering students in a lecture-based introductory abstract
algebra course were interviewed. These students experienced varied success in creating isomorphisms and
homomorphisms, which allowed both successful techniques for map creation and stumbling blocks to map
creation to emerge from the data. Some successful techniques for determining if groups were isomorphic
included checking the orders of the groups, looking for invertible maps between groups, and determining
the identity element and orders of elements of each group. Successful strategies for approaching the
creation of homomorphisms included checking if the groups were isomorphic, seeing if a proposed map
would preserve closure, and using strategic trial and error. Stumbling blocks included the inappropriate
use of definitions, an inability to interpret definitions, and misunderstanding the distinction between the
names and roles of elements in different groups.
Submission: 22
**Student Conceptions of Three-Dimensional Solids**

**Stepan Paul and Monica Mendoza**

In the study presented in this paper, the authors aim to construct a model for the processes by which students in a multivariable calculus class conceptualize solid regions in three dimensions. We designed and recorded student work from several tasks in which students must decode a description of a solid figure and answer questions assessing the strength of their conception of the figure. Presented here are findings from the analysis interviews and group work on one of these tasks in which students are asked to build a clay model of the solid region described by a set of a inequalities in three variables.

Submission: 165

---

**Inquiry as an Access Point to Equity in the Classroom**

**Gail Tang, Houssein El Turkey, Emily Cilli-Turner, Milos Savic, David Plaxco, and Gulden Karakok**

Although many policy documents include equity as part of mathematics education standards and principles, researchers continue to explore means by which equity might be supported. Teaching practices that include active learning have been proposed to address this issue (e.g., CBMS, 2016; NCTM, 2014). In this paper, we theoretically explore the ways in which active learning teaching practices that focus on teaching for inquiry (e.g., Inquiry-Based Learning (IBL) or Inquiry-Oriented Learning (IOL)) support equity in the classroom. Specifically, we claim that some characteristics of inquiry (Student Ownership, Knowledge Building, Peer-Involvement, Doing Mathematics, Student-Instructor Relationship, and Student Success) put forth by Cook, Murphy, and Fukawa-Connelly (2016) may align with the Four Dimensions of Equity (Access, Achievement, Identity, and Power) proposed by Gutiérrez (2009). Therefore, inquiry teaching may be a first step for a focus on equity without compromising the excellence (Gutiérrez, 2002) or material that is often prescribed in undergraduate mathematics courses.

Submission: 119

---

**A Comparison of Calculus, Transition-to-Proof, and Advanced Calculus Student Quantifications in Complex Mathematical Statements**

**Morgan Sellers, Kyeong Hah Roh, Erika David and Kody D'Amours**

This study investigates Calculus, Transition-to-Proof, and Advanced Calculus students’ meanings for quantifiers in conditional statements involving multiple quantifiers. Three students from each course participated in clinical interviews. Students were presented with the Intermediate Value Theorem (IVT) and three other statements whose sentence structure was similar to the IVT except for reordered quantifiers and their attached variables. The results reveal that Advanced Calculus and Transition-to-Proof students made distinctions between the different statements more often than Calculus students. Several student meanings for quantification were found to be necessary for making distinctions between each of the four statements. We also address student quantifications that emerged for the phrase “Suppose f is a function.”

Submission: 148

---

**Session 22 Contributed Reports (10:55 AM – 11:25 AM)**

**Stages of Development for the Concept of Inverse in Abstract Algebra**

**John Paul Cook and Rosaura Uscanga**

In this study, we conducted a teaching experiment with two students to investigate the development of a generalized concept of inverse in abstract algebra. In particular, we document the stages through which the students’ reasoning progressed, initiating with an initial understanding of the additive inverse of an element as the result of a procedure (negative one times that element), and concluding with a generalized understanding of inverse as an element. Of critical importance to the development of a generalized...
understanding of inverse was the development of and coordination with a corresponding concept of identity.
Submission: 162
Room: La Jolla

How Limit can be Embodied and Arithmetized: A Critique of Lakoff and Núñez
Timothy Boester
In Where Mathematics Comes From, Lakoff and Núñez (2001) describe how the notions of infinity, continuity, and limit can be constructed through metaphorical extensions of embodied experiences. This paper will critique their historical and psychological analysis, revealing an unresolved tension between a simplified, geometric “approaching” conception and the arithmetization of calculus by Weierstrass. A proposal of how to rectify this conflict through acknowledging how novices can metaphorically tie these concepts together is discussed.
Submission: 163
Room: Del Mar

Those Who Teach the Teachers: Knowledge Growth in Teaching for Mathematics Teacher Educators
Shandy Hauk, Billy Jackson and Jenq-Jong Tsay
This theory-based report gives evidence and builds a conceptual framework for a construct called “mathematical knowledge for teaching future teachers” (MKT-FT). Mathematics teacher educators construct MKT-FT as they teach courses for pre-service teachers. Connections to mathematical knowledge for teaching (MKT) are discussed, with an emphasis on the complex relationships between MKT-FT and MKT.
Submission: 133
Room: Coronado

Student Mathematical Connections in an Introductory Linear Algebra Course
Spencer Payton
In an introductory linear algebra course, students are expected to learn a plethora of new concepts as well as how these concepts are connected to one another. Learning these connections can be quite challenging for students due to the vast number of connections and student inexperience with mathematical logic. The study reported here consisted of an investigation into how inquiry-oriented teaching methods could be employed in an attempt to create opportunities for students to develop mathematical connections in an introductory linear algebra course.
Submission: 65
Room: Private Dining Room

“Explanatory” Talk in Mathematics Research Papers
Juan Pablo Mejia-Ramos and Matthew Inglis
In this paper we explore the ways in which mathematicians talk about explanation in their research papers. We analyze the use of the words explain/explanation (and various related words) in a large corpus of text containing research papers in both mathematics and physical sciences. We found that mathematicians do not frequently use this family of words and that their use is considerably more prevalent in physics papers than in mathematics papers. In particular, we found that physicists talk about explaining why disproportionately more often than mathematicians. We discuss some possible accounts for these differences.
Submission: 171
Session 23 Contributed Reports (11:35 AM – 12:05 PM)

Emerging Insights from the Evolving Framework of Structural Abstraction in Knowing and Learning Advanced Mathematics
Thorsten Scheiner

Only recently ‘abstraction on objects’ has attracted attention in the literature as a form of abstraction that has the potential to take account of the complexity of students’ knowing and learning processes compatible with their strategy of giving meaning. This paper draws attention to several emerging insights from the evolving framework of structural abstraction in students’ knowing and learning of the limit concept of a sequence. Particular insights are accentuated that we need to understand from a theoretical point of view since they reveal a new way of understanding knowing and learning advanced mathematical concepts and have significant implications for educational practice.
Submission: 54

Exploring Experts’ Covariational Reasoning
Natalie Hobson and Kevin Moore

In this paper, we discuss two experts’ reasoning abilities when tasked with drawing a graph that relates two varying quantities. We present evidence that in some cases, these experts had constructed and coordinated the amounts of change of the quantities (while interpreting and constructing graphs). By comparing the activity of each expert, and corroborating previous researchers’ findings, we argue that constructing a multiplicative object is critical to conceiving a graph and situation as constituted by covarying quantities. We identify particular complexities involved in the development of covariational reasoning including the conceptualization, coordination, and referent accumulation of the amounts of change of two quantities.
Submission: 87

What Should Undergraduate Mathematics Majors Understand About the Nature of Mathematical Knowledge?
Jeffrey Pair

A primary function of mathematics education is that students understand the subject matter of mathematics. That is, students are supported in understanding mathematical concepts and attaining mathematical knowledge. But there is another function of mathematics education, often unaddressed in research, which deserves more attention. In addition to learning content, students must be supported in developing informed views about the human processes by which mathematical knowledge is produced and the unique characteristics of that knowledge. Through an exploration of humanistic philosophy of mathematics, the purpose of this paper is to identify characteristics of the nature of mathematical knowledge that may be important for undergraduate mathematics majors to know and understand. Four characteristics are discussed: mathematical knowledge is subject to revision; mathematical knowledge is socially validated; proofs are bearers of mathematical knowledge; and informal mathematical work is the foundation of formal knowledge.
Submission: 6

Gender and Discipline Specific Differences in Mathematical Self-Efficacy of Incoming Students at a Large Public University
Ulrike Genschel and Xuan Hien Nguyen

This study investigates differences in mathematical self-efficacy and outcome expectations of 3107 incoming students enrolled in introductory level mathematics or statistics courses at a land grant university in the Midwest. Students were grouped by discipline (STEM (Science, Technology, Engineering and Mathematics), Social Sciences and Arts & Humanities) and by gender within each discipline. All
students enrolled in an introductory mathematics or statistics course during their first semester at the institution were surveyed about their perceived mathematical self-efficacy and outcome expectations at the beginning of that semester. Our results suggest that discipline specific differences are dependent on the definition of STEM majors, namely distinguishing between math intensive and non-math intensive STEM majors. After accounting for this distinction gender differences in mathematical self-efficacy and outcome expectations disappear.

Submission: 113
Room: Private Dining Room

**Student Proficiency with Transformational Geometry After a College Proof-Based Geometry Class**
Meredith Hegg and Tim Fukawa-Connelly

This report explores pre-service teachers’ proficiency with concepts of transformational geometry at the end of a semester-long advanced geometry course. During the course, the instructor presented transformational geometry content, including congruence proofs, in an attempt to align with the Common Core State Standards for Mathematics. At the end of the course, the students, all pre-service teachers, appeared to mix ideas from the traditional approach involving triangle congruence criteria (SAS, ASA, SSS, AAS) and transformational approaches and also struggled with conceiving of transformation functions as objects. These difficulties appear to compound in their proof-writing attempts such that after citing appropriate transformational geometry ideas, such as the angle- or distance-preservation property, they would then supplement with congruence-based approaches in order to finish the proof. This has implications, especially for professional development, as this is the final mathematics class that these pre-service teachers will take concerning transformational geometry prior to beginning their classroom instruction.

Submission: 140
Room: Coronado

**Lunch and Mentoring Session (12:05 PM – 1:10 PM)**
Room: Boxed Lunches Provided

**Session 24 Preliminary Reports (1:10 PM – 1:40 PM)**

**Exploring Student Conceptions of Binary Operation**
Kathleen Melhuish

Binary Operations are essential to many undergraduate mathematics courses. However, little is known about student conceptions around binary operation. This report presents preliminary results from nine student surveys about the topic. The question set was developed in response to Group Concept Inventory (GCI) results. We look at three activities closely related to binary operation: identifying when an instantiation is a binary operation, identifying when two instantiation are the same binary operation, and generating an original binary operation instantiation. We use the lens of variation theory to make sense of student responses. We found that students’ concept image of binary operation may be missing key attributes (such as requiring two inputs) and contain unnecessary attributes (requiring a general rule.)

Submission: 147
Room: La Jolla

**Spatial Training and Calculus Ability: Investigating Impacts on Student Performance and Cognitive Learning Style**
Emily Cilli-Turner and Lindsay McCunn

Despite concerted efforts on the part of educational policy makers, women are still underrepresented in the STEM fields. Researchers have shown that calculus plays a major role in this gender disparity since it requires spatial skills to succeed: skills that women tend to lack compared to men. However, previous studies have shown that spatial ability is malleable and spatial skills can be improved with training. This pilot study employed spatial training in a third-term calculus course and measured the effects of this training on students’ calculus ability, spatial rotation ability, and cognitive learning style. Associations between cognitive learning style and task performance were also measured. Preliminary results indicate
that spatial training does not significantly impact student performance on a calculus skills assessment or a test of mental rotations, but effects on students' cognitive learning style are present.

Submission: 36
Room: Pt. Loma 1

Theoretical Framework of Algebraic Concepts for Elementary Algebra
Claire Wladis
The long-term aim of this study is to develop a conceptual framework outlining the concepts necessary for college students to be able to successfully complete fundamental tasks of elementary algebra. The first stage of this research, which is the focus of this paper, focuses on instructor perceptions of what concepts are fundamental to successful completion of elementary algebra tasks. The framework presented here is the result of an action research project that was a collaboration among five college instructors who teach elementary algebra. Future stages of the research will include an extensive exploration of the literature as it pertains to those concepts identified by the instructors in the first stage of the research (and to enumerate concepts that might have been overlooked by the instructors) as well as cognitive interviews with students using concept-inventory-type questions to pinpoint specific aspects of student thinking included in the framework.
Submission: 132
Room: Del Mar

Evaluation of Graduate Student Professional Development and Instruction by Mathematics Departments: Results from a National Survey
Natasha Speer, Jess Ellis and Jessica Deshler
Findings from a recent national survey indicate that two thirds of graduate-degree-granting mathematics departments provide some form of teaching-related professional development to their graduate students. Despite the prevalence of such programs, little is known about how departments evaluate the quality of the graduate students’ instruction or the efficacy of their professional development. We present a mixed-method analysis of data to shed light on both of these topics. We found that graduate students and their professional development are most often evaluated based on student evaluations. Other research indicates the ineffectiveness of student evaluations as measures of teaching, and so this finding indicates a need for research-guided evaluation tools for graduate student professional development.
Submission: 128
Room: Coronado

Blended Processing: Mathematics in Chemical Kinetics
Kinsey Bain, Adam Zabih, Alena Moon and Marcy Towns
This work investigates the following research question: How do non-major students understand and use mathematics to solve chemical kinetics problems involving integrated rate laws? Personal constructs, a blend of personal and social constructivism, serves as the theoretical framework for this study. Semi-structured interviews with 36 general chemistry students, 5 upper-level physical chemistry students, and 3 chemical engineering students were conducted using a think-aloud protocol. Audio and written data were collected using a Livescribe pen. The audio data were transcribed, and screenshots of students’ written data were inserted into the transcripts; these transcripts were refashioned into problem-solving maps. Open coding of the problem-solving maps reveals initial themes regarding students’ understanding and use of mathematics when solving chemical kinetics problems. Blended processing was used as a methodological framework to guide the coding process. Through this analysis, distinctive types of blended processing have emerged.
Submission: 37
Session 25 Contributed Reports (1:50 PM – 2:20 PM)

Mathematical Actions, Mathematical Objects, and Mathematical Induction
Rachel Arnold and Anderson Norton
Proof by mathematical induction is arguably the most difficult proof technique for students to master. We explain this difficulty within an action-object framework. Specifically, we report on results from clinical interviews with two mathematics majors in which the first author administered tasks designed to elucidate each students’ understanding of logical implications as mental objects. We found that the framework explains much of the difficulty inherent in proof by induction. Outside of the framework, we found that hidden quantifiers also play a key role.
Submission: 66
Room: Coronado

An Unexpected Outcome: Students’ Focus on Order in the Multiplication Principle
Elise Lockwood and Branwen Schaub
In an effort to better understand students’ understanding of the multiplication principle, which is a fundamental aspect of combinatorial enumeration, we had two undergraduate students engage in reinvention of a statement of the principle during an eight-session teaching experiment. In this presentation, we report on the students’ unexpected attention to the order in which they complete stages of counting process in a counting problem. We suggest that an early experience with a particular problem prompted them to think about order, and this way of thinking persisted throughout the experiment. The students’ reasoning about order sheds light on ways in which students may think about order and about the nature of multiplication in counting. We conclude with potential implications and directions for further research.
Submission: 50
Room: La Jolla

Function Sameness to ‘Function’ Meaning
Alison Mirin
Exploring students’ conceptions of sameness is an avenue for exploring their understanding of the objects being compared. More specifically, finding what students think it means for functions to be identical can help us figure out what students think it means for something to be a function, since identity is inextricably tied to what something is. This paper has three primary aims: to illustrate the importance of using students’ assessments of sameness as a means to discover their concept images, to describe a particular student’s concept image of function, and to suggest that the math education research community develop a more refined understanding of a “process” (cf., (Breidenbach, Dubinsky, Hawks, & Nichols, 1992) conception of function.
Submission: 166
Room: Private Dining Room

Mathematicians’ Collaborative Silences
Matthew Petersen
This paper re-analyzes the transcripts from Smith (2012) to investigate silence in mathematicians’ collaborative work. I provide an existence proof that silence, at times, forms a significant aspect of mathematicians’ embodied work. Based off a discussion of the nature of embodied interaction, the paper concludes that it is likely that silence forms a significant aspect of mathematicians’ collaborative work, more generally, both in discovering new mathematics, and in ordering the mathematicians together toward the task of discovering new mathematics. Because this use of silence is different from that of everyday conversation, this raises important pedagogical questions regarding students’ apprenticeship into the mathematics profession.
Submission: 39
Making RUME for Institutional Change
Daniel Reinholz

Overwhelming evidence favors the use of active learning in undergraduate STEM classrooms. Thus, the issue faced by educators is no longer what to do in classrooms, but how to enact what is known to be effective. This poses a challenge, because faculty teaching is embedded in the context of departments, universities, and the broader disciplinary culture. Thus, improving education requires knowledge of how systems work and how to enact systemic change. While organizational change has studied these issues for decades in nonprofit and business settings, the application of this knowledge to higher education is relatively new. Accordingly, this theoretical paper provides an introduction to the organizational change literature in the context of higher education and provides an example of its application through Departmental Action Teams (DATs). By highlighting five principles from organizational change, this paper serves as a reference for change agents wishing to improve undergraduate mathematics education.

Session 26 Preliminary Reports (2:30 PM – 3:00 PM)
Corequisite Remediation and Math Pathways in Oklahoma
Matthew Wilson and Michael Oehrtman

We examine the current progress of implementing both corequisite remediation and math pathways in the state of Oklahoma. In this paper, we discuss the details of these effort and the underlying needs while providing a national perspective about the reforms. We present preliminary data from pilot sections of a corequisite College Algebra course and a new math pathway for degrees that require significant quantitative literacy but do not require engineering calculus. We also present statewide data on student course-taking patterns, degree requirements, and existing institutional efforts that will inform state-level decisions.

Career Decision Making Strategies of Calculus and Developmental Mathematics Students
Xiangming Wu, Jessica Deshler, Edgar Fuller and Marcela Mera Trujillo

Students who have persisted in mathematics coursework long enough to be present in calculus or who enter mathematics at the level of calculus would be expected have more robust notions concerning their career choices than those who enter developmental mathematics. In the current work, we give a preliminary comparison of data generated by a career decision making survey administered to students in a developmental mathematics course and to students in a first semester calculus course at a large research university during the fall 2015 semester. We consider some initial results for students who switch majors after a semester of mathematics coursework.

Student Gesture Use When Explaining the Second-Derivative Test and Optimization
Tim McCarty and Nicole Infante

The Second-Derivative Test and optimization can naturally evoke gestures from an instructor while he or she is teaching. We wanted to establish how student learning might be affected by an instructor's use of gesture. Students viewed either a gesture-rich or gesture-free video of an instructor solving an optimization problem, and were interviewed a week later to assess both their understandings of optimization and how they used gesture to support their explanations. Very few gestures were used when the students explained how they solved the optimization problem. However, when describing the second derivative test separate from optimization, students used a number of gestures. We conclude that further study should be undertaken, but such study should be focused on the Second-Derivative Test without the context of optimization problems.
The Lead TA Influence: Teaching Practices Focused on for an Active Learning Classroom
Hayley Milbourne and Susan Nickerson
Across the nation, there is increased national interest in improving the way mathematics departments prepare their GTAs. In particular, this research focuses on how the mentor GTAs in the graduate teaching assistant program under consideration share effective teaching practices and how this affects changes in the teaching practice of GTAs. I report preliminary results on how the focus of particular teaching practices of mentor GTAs (known as lead TAs) change over the period of one term through their participating in professional development. With an understanding of the differences and the similarities between the focuses of the lead TAs, an analysis of the differences between the Calculus I and II GTAs will become more apparent. The research presented here represents the start of an increased understanding of how GTAs form their own teaching practices.
Submission: 160

Signed Quantities: Mathematics Based Majors Struggle to Make Meaning
Suzanne Brahnia and Andrew Boudreaux
Physics students struggle to make meaning of the negative sign in a variety of mathematical and physical contexts. This study is part of an ongoing concurrent mixed methods exploration of student understanding of negativity in physics. A set of multiple-choice items, modified from a prior study, was administered to over 500 calculus-based college students from diverse backgrounds. Results suggest that when the positive sign is an explicit part of a quantity, students struggle with positive quantity just as they do with negative quantities, and that the language that instructors use may inadvertently impute unintended meaning about signs.
Submission: 30

Comparing graph use in STEM textbooks and practitioner journals
Teo Paoletti, Madhavi Vishnubhotla, Zareen Rahman, Justin Seventko and Debasmita Basu
In this study we aim to explore how school mathematics is attentive to the demands of science, technology and engineering (STE) fields. We focus on the use of graphical representations to find similarities and differences regarding how graphs are used in mathematics textbooks and how they are used in the STE textbooks and journals. After highlighting the need for our study and summarizing the results of related studies, we present our methods. We then present key preliminary findings regarding how textbooks and journals in various STE fields use graphical representations. We conclude with preliminary implications and questions.
Submission: 110

Coffee Break (3:00 PM – 3:30 PM)
Room: Cabo Courtyard (Weather Permitting)

Session 27 Contributed Reports (3:30 PM – 4:00 PM)
Attention to Detail: Norms for Proof Evaluation in a Summer Mathematics Program
Cody Patterson and Xiaowen Cui
In this study, we explore the norms by which students and undergraduate mentors in a summer mathematics program evaluate proofs of theorems in number theory. By utilizing cognitive interviews during which students and mentors evaluate number theory proofs written by a hypothetical student, we find that for students as well as mentors, “rigor” is a dimension of mathematical acceptability of proofs distinct from, though related to, proof validity. Additionally, we find that both students and mentors frequently adhere to strict unwritten norms that govern how they believe proofs should be constructed and presented, and that these norms may be more rigid than the intended proof-writing norms of the mathematicians who teach in the summer program. This study suggests some potential challenges
associated with the growing practice of asking undergraduate student graders to evaluate proofs written by students in introduction-to-proof courses.

Submission: **153**

Room: Private Dining Room

**Mathematics instruction leadership in undergraduate departments**

*Naneh Apkarian and Chris Rasmussen*

Many universities have begun to coordinate their introductory mathematics courses to handle multiple sections of the same course, a situation necessitated by the large numbers of students taking precalculus and calculus. Robust coordination systems consist of two major elements: uniform course elements (e.g., common text; exams) and regular instructor meetings. These regular meetings may turn calculus instruction into a joint enterprise, potentially engendering a community of practice. Of particular importance are those who act as leaders (formally and/or informally) within these coordination systems – these people have the potential to influence and “nudge” instructors towards improving their practice (Author). This study combines case study findings with social network data to investigate instructional leaders at five diverse institutions, considering both formal and informal coordination phenomena, and hypothesize about their potential to influence practice in their departments.

Submission: **51**

Room: Coronado

**Students’ Attitudes Toward Listing and Subsequent Behavior Solving Counting Problems**

*Sarah Erickson*

Counting problems provide rich mathematical content and a variety of applications for students, motivating investigation into the difficulties students face while counting. In particular, an important result supported by previous quantitative and qualitative evidence is that listing may be an effective strategy for combating some student struggles in counting, particularly since it draws explicit attention to outcome structure. However, anecdotal experience has shown that students can resist listing and feel that it is tedious and not worth the effort. To investigate whether these negative mindsets exist outside these anecdotes, task-based interviews were conducted targeting student attitudes toward listing and their success in using listing to solve counting problems. Contrary to the anecdotal evidence, the students in the study expressed that they felt listing is a worthwhile activity, but their work on counting problems suggest that they would benefit from more explicit support relating to listing in their discrete mathematics classes.

Submission: **99**

Room: La Jolla

**Generalising Univalence from Single to Multivariable Settings: The Case of Kyle**

*Allison Dorko*

A function is defined as a mapping from one nonempty set (the domain) to another nonempty set (the codomain or range) such that each element of the domain maps to exactly one element of the range. Algebra curricula typically include classification tasks in which students determine if a relation violates the univalence criterion – the condition that each element in the domain corresponds to exactly one element of the range. This paper provides a longitudinal case study of how one student generalised the univalence criterion from single- to multivariable functions. For f(x), Kyle primarily thought of univalence in terms of the vertical line test and the variables x and y. He generalised univalence for the multivariable function f(x,y) by thinking about input, output, independence, and dependence. Kyle’s story provides an example of how a student might generalise facets of the function concept in normatively correct ways.

Submission: **59**

Room: Del Mar

**Using Expectancy Value Theory To Account For Students’ Mathematical Justifications**

*Keith Weber, Kristen Lew and Juan Pablo Mejia-Ramos*

There is a robust body of research demonstrating that when students are asked to justify a mathematical assertion, they will frequently generate empirical arguments to do so. They also sometimes claim a deductive argument does not supply them with certainty that the assertion is correct. Mathematics
educators frequently attribute this to students having deficient standards of conviction. In this paper, we illustrate another theoretical account. Students might believe that they lack the cognitive capacity to produce a superior argument to an empirical argument or to verify that a deductive argument is correct.

Submission: 150
Room: Pt. Loma 2 & 3

Session 28 – Preliminary Reports (4:10 PM – 4:40 PM)

Self-assessment Behaviors of Undergraduate Mathematics Students: A Preliminary Report
Kedar Nepal, Kailash Ghimire, Ramjee Sharma and Manoj Thapa
Research shows that low-achieving students are less able to accurately assess their own weaknesses. As a result, many might fail to see the need to explore the subject matter more deeply, in order to improve their conceptual understanding and procedural fluency. This study investigates undergraduate mathematics students’ self-assessment behaviors. Students from a broad range of courses at three universities were asked to predict their expected grades on assignments, and these predictions were compared with the grades assessed by their instructors. They were also asked to justify their self-assessments if they did not give themselves full points. Preliminary results showed that students overall overestimate their grades. There was a significant difference between expected and actual grades. As test scores increased, the difference increased from negative to positive. Students in the B-range (between 80-89%) were the most accurate predictors.
Submission: 33
Room: Del Mar

Students' Inclination to Use Visual Images During Problem Solving
Milé Krajcevski and Karen Keene
This is a preliminary report on a study to investigate the inclination of calculus III students to use visual reasoning in problem solving situations. One of our research hypotheses was that there is a correlation between students’ inclination towards visual representations when taking notes and their use of visual representations in problem solving situations. Surprisingly, preliminary analysis of the results suggests that there may not be a correlation, although work is ongoing.
Submission: 90
Room: Pt. Loma 2 & 3

Defining Functions: Choices That Affect Student Learning
Joshua Chesler
Textbook authors and instructors choose how to define the concept of function for students. This study examines the impact of definition choice on the mathematics work of graduate students, all of whom were mathematics majors and most of whom are in-service mathematics teachers. Data are student work on tasks requiring the application of different textbook definitions of functions. By drawing on ideas about action vs. object conceptions of function, it is hypothesized that certain linguistic features of definitions may affect students’ abilities to use the definition and to build a robust concept image of function.
Submission: 103
Room: Coronado

Students' Understanding of Test Statistics in Hypothesis Testing
Annie Childers, Darryl Chamberlain Jr., Leslie Meadows, Harrison Stalvey, Draga Vidakovic and Aubrey Kemp
Hypothesis testing is a key concept included in many introductory statistics courses. Due to common misunderstandings of both scientists and students, the use of hypothesis testing to interpret experimental data has received criticism. This paper describes preliminary results obtained from a larger study designed to investigate introductory statistics students’ understanding of one sample hypothesis testing. APOS theory is used as a guiding theoretical framework. Preliminary data analysis focused on two students’ distinctions between test statistics when performing hypothesis tests on real world data. The results
suggest a significant difference in these two students' understanding, one being identified having an action conception while the other had an object conception of hypothesis testing as situated in the study.

Submission: 26
Room: Private Dining Room

**Exploring Mathematics Graduate Teaching Assistants’ Developmental Stages for Teaching**

Mary Beisiegel

Traditional training programs that address mathematics graduate teaching assistants’ (MGTAs) teaching practices are offered when they first arrive to campus, when they have little, if any, teaching experience. However, not much research has investigated how MGTAs’ thinking about and facility with teaching change over the course of their graduate programs and, consequently, how their need for training changes over time. The goal of this study is to understand MGTAs developmental stages for teaching and how understanding these stages can inform the creation of a multi-year training program. Eleven MGTAs from a large, doctoral granting institution were surveyed and interviewed over the course of an academic year. Survey and interview responses were examined using a specific model of teacher development. Preliminary analyses, suggestions for multi-year MGTA training programs, and questions for future research are discussed.

Submission: 122
Room: La Jolla

**Poster Session 2 & Reception (4:50 PM – 5:50 PM)**

A reception and cash bar

Room: Cabo Courtyard (Weather Permitting)

**Coping with the derivative of an atypical representation of a common function**

Alison Mirin

250 calculus students were asked to evaluate \( f'(2) \) when \( f(x)=x^3 \) if \( x=2 \) and \( f(x)=8 \) if \( x=2 \). Responses were coded, and eight students were interviewed about their answers. The data provide insight into students’ understandings of function, derivative, and graph.

Submission: 257

**Improving Undergraduate STEM Education Through Adjunct Mathematics Instructor Resources and Support (IUSE-AMIRS)**

Amir Golnabi, Eileen Murray and Zareen Rahman

The Improving Undergraduate STEM Education Through Adjunct Mathematics Instructor Resources and Support (IUSE-AMIRS) project aims to measure the impact of course coordination and support on adjunct mathematics instructors’ knowledge, instructional practices, and job satisfaction. In this project, we use the organization and coordination of Precalculus with the goals of 1) implementing best practices for learning and instruction, 2) improving instructor knowledge, and 3) creating a professional learning community. As a part of this project we measure the impact of Precalculus course coordination and adjunct support on student achievement, leading to student retention in STEM majors. We believe our initiative can be implemented in other departments and institutions that have a similar need for adjunct instructors in math courses with multiple sections.

Submission: 187

**Building a Cognitive Model for Symmetry: How Well Does an Existing Framework Fit?**

Anna Marie Bergman and Ben Wallek

Symmetry has been found to be a rich and natural context for developing group theory (Larsen, 2009), yet the existing literature offers little insight on the complex cognitive processes in this domain. This poster will describe an attempt to use a pre-existing cognitive model of a student’s understanding of symmetry, to help analyze the data from a recent teaching experiment aimed at exploring the development of one undergraduate student’s understanding of symmetry. We share the ways in which the existing model accurately describes the student’s cognitive processes associated with symmetry and also the places in which the model fell short in capturing the complexity of the student’s thinking.
A Framework for Characterizing a Teacher’s Decentering Tendencies
Ashley Duncan
This poster presents a framework for characterizing teachers’ decentering during teacher-student interactions when teaching. Analysis of video data of a graduate teaching assistant’s (GTA’s) precalculus class generated six levels of teacher-student interactions. These levels will be described and illustrated with excerpts from this video analysis.
Submission: 243

Exploring Conceptions of Mathematics: A Comparison of Drawings and Attitudinal Scales
Ben Wescoatt
This study explores beliefs about doing math held by pre-service teachers. Pre-service teachers in a mathematics content course drew pictures of a person doing math. Additionally, modified Fennema-Sherman Mathematics Attitude Scales (FSMAS) (Ren, Green, & Smith, 2016) were administered to the students. The drawings were analyzed using a framework developed from the Farland-Smith (2012) rubric. In addition to exploring beliefs about doing math held by the students as evidenced by the drawings, the study considers the validity of the drawing methodology through a comparison to the FSMAS results.
Submission: 253

Calculus Instructor Beliefs Regarding Student Engagement
Carolyn James
Student engagement has been identified as a critical element in student learning of mathematics, yet most university math classrooms have very little active content (Olson & Riordan, 2012). Guided by Schoenfeld’s (2011) framework for instructional decision-making, this study examines calculus instructor beliefs about, purposes for, and barriers against student engagement. Results indicate instructors utilize active learning primarily for formative assessment and improving student dispositions, with development of understanding as a secondary goal.
Submission: 249

Variations of College Algebra Instructors’ Presentations of the Mathematics: The Case of Solving Quadratic Inequalities
Claire Gibbons
The mathematical content presented during instruction has been shown to have an effect on student achievement. To investigate the content presented by instructors during College Algebra instruction, the Mathematical Quality of Instruction observation protocol was applied to video recordings featuring instructors’ presentations of examples of solving quadratic inequalities. Wide variation was observed in the solution methods chosen by instructors and in the rationale provided for choosing a particular procedure. This poster summarizes the variation in the mathematics that was observed and describes the ability of the MQI protocol to capture this variation.
Submission: 180

Examining Prospective Teachers’ Justifications of Children’s Temperature Stories
Dana Olanoff, Nicole Wessman-Enzinger and Jennifer Tobias
Part of the work of mathematics teacher educators (MTEs) are to provide authentic experiences to prospective teachers. In this study, we showed four temperature story problems involving integers to prospective teachers (PTs), and asked them if the stories matched given number sentences. While each of the stories were similar to the number sentence, none of them matched exactly. In this poster, we examine the reasons PTs gave for saying that the stories matched the number sentences, and discuss implications of their thinking for mathematics content courses for prospective teachers.
Submission: 240

Online Course Component and Student Performance
Elizabeth DiScala
Abstract: A study was conducted in a small, private university in Northeastern United States in order to determine if introducing an online component to a first year Calculus course would influence student
learning. An online component was presented in two sections of the calculus courses while two sections were taught using the traditional format. Preliminary data suggest a positive correlation between the online component and improved student performance in the course.

Submission: 232

Mathematical Knowledge for Teaching & Cognitive Demand: A Case Study of Precalculus Examples that Involve Procedures
Erica Miller
In 2010, Charalambous published an article that examined the relationship between mathematical knowledge for teaching (MKT) and task unfolding. As a result of this study, Charalambous found evidence to support the claim that there is a positive relationship between a teacher's MKT and the cognitive level of task presentation and enactment. Drawing upon this finding, the purpose of this case study is to utilize unfolding and cognitive demand as a lens through which to examine mathematical knowledge for teaching at the undergraduate level. While MKT has been studied extensively at the K-12 level, there are relatively few studies that focus on MKT at the collegiate level. In order to help fill this gap, this case study first identifies how Precalculus instructors unfold examples that involve procedures and then examines the MKT that is involved in this unfolding.

Submission: 237

Categorizing Teachers’ Beliefs about Statistics Through Cluster Analysis
Gabriel Tarr
The CCSSM emphasize statistical concepts for grades 6-12. The paper will attempt to answer the following question: How do middle school mathematics teachers in a professional development program differ from each other with regard to how they view statistics?

Submission: 224

Student Ways of Framing Differential Equations Tasks
George Kuster
In this research presentation I utilize the theoretical perspective Knowledge In Pieces (diSessa, 1993) to identify the knowledge resources two students utilized while in the process of completing various differential equations tasks. The results provide a fine-grained description of the knowledge students consider to be productive with regard to completing various differential equations tasks. Further the analysis resulted in the identification of five ways students frame differential equations tasks and how these framings are related to the different knowledge resources students utilize while completing the various tasks. These framings did not only provide insight into the students’ general approaches to completing the task; differences in the individual students’ applications of knowledge across the tasks were accounted for by the different Framings. The results have direct implications with regard to the teaching of differential equations as they inform the ideas students view as productive when completing various tasks involving differential equations.

Submission: 248

Leveraging Research to Support Students’ Quantitative and Co-variational Reasoning in an Online Environment
Grant Sander and Marilyn Carlson
Quantitative and Co-variational reasoning have been shown to be important facets of a student’s mathematical learning. We are proposing an online workbook as a tool for supporting students in reasoning quantitatively and co-variationally. In this poster, we will briefly present a section on understanding graphs as representing the co-variation of two quantities’ values.

Submission: 265

Speaking with Meaning about Angle Measure and the Sine Function
Stacy Musgrave and Marilyn Carlson
Researchers have reported on the difficulties K-12 students, pre-service teachers and in-service teachers have in reasoning and communicating about angle, angle measure and trigonometric functions. This work extends the existing literature to highlight that even mathematically sophisticated individuals (e.g., PhD
students in mathematics) often struggle to speak with meaning about these ideas without targeted interventions to support them in doing so. We share tasks and associated data from semi-structured clinical interviews conducted with graduate teaching assistants (GTAs) to highlight the differences in communication about these ideas pre- versus post-intervention.

Submission: 239

Classroom Participation as an Agent of Socialization for Identity Shaping of Preservice Mathematics Teachers
Janet Omitoyin
This study explores classroom participation as an agent of socialization for preservice elementary mathematics teachers. Each character, the teacher, student and curriculum in the classroom plays various roles in the socialization process. But the teacher plays a major role because she is responsible for creating the environment where participation is possible. In this work, the analysis of data shows the teacher's teaching method(s), questioning and listening skills, as well her background understanding of the specialized mathematics knowledge needed for teaching and her students all help to create such environment. Also, as students explore mathematics by doing through group work, class discussions, and individual work, they experience growth in mathematics classroom practices that results in change in the mathematics identity of the students.

Submission: 245

Equity Issues That (May) Arise in Active Learning Classrooms
Jessica Gehrtz, Richard Sampera and Jess Ellis
There is an overwhelming amount of evidence that the incorporation of active learning in the classroom benefits all students and can be especially beneficial for women and underrepresented populations. However, our work is not finished when it becomes an integral part of teaching and learning across the nation. Classroom settings that foster group interaction and collaboration may result in an environment that is even more undermining to underrepresented populations. In this poster we illustrate these potential issues that arose in an abstract algebra course.

Submission: 225

Student Understanding of Elements of Multivariable Calculus
John Thompson, Benjamin Schermerhorn and J. Caleb Speirs
We present preliminary findings from written, post-instruction surveys to gauge student understanding of various elements of multivariable calculus. The content addressed includes contour plots, partial derivatives, representations of gradients and slopes, construction of volume difference integrals.

Submission: 235

Bringing Evidenced-Based Practices to a Large-Scale Precalculus Class: Preliminary Results
Karen Keene, Leslaw Skrzypek, Brooke Kott and Gregory Downing
Using evidenced-based practices in a large lecture-style undergraduate mathematics classroom can be very challenging but the results of recent research on the advantages of using active-learning strategies that are evidenced-based are clear and demand investigation. Preliminary results of a study conducted on a large scale precalculus class where the instructor introduced evidenced-based practices are presented. Early results show that students already have self-confidence upon entering the classes, but there is slight gain in perceptions of the value and appreciation of mathematics. Additionally, the team activities and clickers are considered meaningful, useful, and important by many, but not all of the students interviewed.

Submission: 230

Student Understanding of the Product Layer of the Integral in Volume Problems
Krista Bresock and Vicki Sealey
Research has shown that students have difficulties attending to the underlying product and summation structure of the integral when solving application problems. This study examines student conceptions of the product layer when solving volume problems. Participants were second-semester calculus students enrolled in a large, public university. Task-based interviews consisted of students working through and discussing volume problems. Preliminary results show that a majority of students’ volume integral setups
are highly formulaic and linked to memorized patterns and methods seen in class, as opposed to having a true understanding of the underlying structure of the problem. We plan to conduct more interviews of this type with additional volume problems and investigate other aspects such as visualization and gesture.
Submission: 205

Diagrams for the Reasoning and Proof of Amortization Formula
Kuo-Liang Chang, Hazel McKenna and Thomas Mgonja

Many liberal arts or humanities students who are required to take quantitative reasoning in college have mathematics anxiety. One cause is a lack of symbolic skills for reasoning. Learning style theories suggest that different people learn in different ways. This study constructs a diagrammatic reasoning model for the concept of amortization to help students learn quantitative reasoning. The model also connects the basic concepts to the proof of the mortgage payment formula.
Submission: 181

A Reformed College Algebra Course: Understanding Instructors’ and Students’ Beliefs About Teaching and Learning Mathematics
Mary Williams

Reforms of undergraduate mathematics are changing the practices of teaching and learning mathematics. Yet prior research has established strong connections between practices and beliefs; therefore, changing the practices within these courses may be affecting the beliefs of those tasked to enact the reformed practices. This qualitative case study analyzes the beliefs of two instructors and two students, all from one section of a semester-long, reformed College Algebra course, to gain a deeper understanding of what happens to instructors’ and students’ beliefs when involved in a reformed course. Data analyzed included pre and post surveys, interviews using the pre and post surveys, interviews using video clips of moments from their classroom, and observation notes of the class. Analyses suggest participants’ beliefs changed in different ways, ranging from a dramatic transformation to more subtle changes. Making teaching decisions public was one significant catalyst for why beliefs changed.
Submission: 219

Putting on the Uniform: Coordination within the Calculus Curriculum
Matthew Voigt and Shawn Firouzian

The study presented here examines the types and relative frequency of uniform course components (exams, textbooks, etc.) currently in place in the Precalculus through single variable calculus sequence at graduate universities and how those components are effected by the presence of department factors such as regular course meetings, instructor type, and the presence of a course coordinator. Our results indicate that while the total number of uniform course components decline throughout the Precalculus through single variable calculus sequence, its effect is mitigated by the presence of a course coordinator and regular course meetings. In addition, student success is significantly related to the presence of both a course coordinator and regular course meetings.
Submission: 241

Students’ Ways of Thinking About Transformational Geometry
Natasha Speer, Jennifer Dunham, Eric Pandiscio, Shandy Hauk and Eric Hsu

As part of an NSF-funded proof-of-concept development project, we created multi-media activities and instructor support materials for pre-service secondary mathematics teacher professional preparation. One focal topic is transformational geometry. To inform development of the materials, undergraduate and secondary school students solved transformational geometry tasks in surveys and in interviews. Despite its prominence in the Common Core State Standards for Mathematics (CCSSM), little is known about how students think about ideas in transformational geometry or about how they engage with items used on CCSSM assessments for this topic. Goals of this presentation are to report findings from our analysis of student thinking, to gather suggestions for other transformational geometry topics worthy of examination, and to solicit ideas for further disseminating findings to the education community.
Submission: 216
Engaging in Abstract Algebra through Game Play: Group Theory Card Game Groups
Patrick Galarza

In this presentation, I discuss the viability of a mathematical game as a learning tool for abstract algebra—specifically, the groups of order four. Throughout 2016, I designed and tested variants of my group theory card game, Groups, among individuals ranging from no post-secondary mathematics experience to current or prior graduate level mathematics study. Here, I review the design choices and challenges central to working in a game space drawing heavily on abstract algebra, and assess alterations to the game’s mechanics influenced by my interactions with players.
Submission: 189

Investigating Prospective Teachers’ Meanings of Covariation Before and After Calculus Coursework
Roser Gine

This study seeks to uncover prospective teachers’ construction of mathematical meanings before and after engaging in a two semester calculus sequence. In particular, we hope to place a lens on meanings that students develop of covariation and to explore any productive transfer of mathematical ideas from calculus to concepts that permeate the secondary school curriculum. Because the site of the study is a university with a focus on educating teachers, this work may have implications for course design, particularly around emphasis of concepts and pedagogy in calculus courses for teachers, and also for supporting meaning making within the mathematics methods courses that students subsequently take in the math education program at the school.
Submission: 186

Student Attitudes, Beliefs, and Experiences Related to Counting Problems
Samantha McGee, Sarah Erickson and Elise Lockwood

Mathematics textbooks and mathematics education research articles frame counting problems as requiring clever insight and being inherently challenging and especially accessible. In this study, we distributed a survey to mathematics students in order to examine student attitudes about counting problems and the extent to which these attitudes aligned with presentations of counting in the literature. In this poster, we present results from this survey that highlight some surprising ways in which the responses did and did not align with the literature.
Submission: 195

Students’ Thinking In An Inquiry-Based Linear Algebra Course
Sarah Hough, Santa Barbara, William Jacob, Monica Mendoza, and Elizabeth Thoren

This evaluation study compared the mathematical thinking of linear algebra students (as they responded to class work and interview prompts) who participated in an inquiry-based course linear algebra course to a comparison group of students who participated in a traditional course.
Submission: 228

Linear algebra laboratory: Transitioning between three worlds of mathematical thinking
Sepideh Stewart

The aim of this study is to investigate students’ transition between the three worlds of mathematical thinking and the challenges that they face in making these transitions. We anticipate that by creating more opportunities to move between the worlds we will encourage students to think in multiple modes of thinking and hence gain richer conceptual understanding.
Submission: 244

To Factorize or Not To Factorize: Novice Teachers’ Struggles
Hyungmi Cho, Miyeong Na, Oh Nam Kwon

What role does college mathematics knowledge play as teacher knowledge for teaching mathematics? To answer this question, much research has been devoted to mathematics teacher knowledge (see e.g. Ball, Hill & Bass, 2005; Evens & Ball 2009; Buchholtz et al., 2013). While these studies have been useful in providing us with the general features of mathematical knowledge for teaching, there is a lack of specific research on how college mathematical knowledge may (or may not) contribute to teaching school mathematics. With regard to the concepts that intersect between college mathematics and school
mathematics, we focus on the concept of unique factorization domains (UFD) in college mathematics and polynomial factorization in school mathematics. Polynomial factorization in school mathematics could be related with UFD at an advanced standpoint. The purpose of this study is to examine how teachers are utilizing their college mathematics knowledge in the context of school mathematics.

Submission: 214

Student Beliefs About Mathematics in an Inquiry-Based Introduction to Proof Course
Shiv Karunakaran, Abigail Higgins and James Whitbread, Jr
An "Introduction to Proof" or "Transition to Proof" course is widely offered as an essential part of the undergraduate mathematics curriculum at most post-secondary institutions. This poster reports on the iterative development of one such course that used an Inquiry-based approach to the teaching and learning of mathematical proving and proof. Moreover, the changing beliefs of students, about the nature of mathematics and about doing mathematics, in this course, are discussed.

Submission: 215

Mathematics Education as a Research Field: Reflections from ICME-13
Stacy Brown, Hortensia Soto and Spencer Bagley
In an effort to broaden knowledge within the United States, the National Council of Teachers of Mathematics, with support from the National Science Foundation, funded multiple scholars’ participation in the 13th International Congress of Mathematics Education. Working in NCTM theme groups these scholars met, discussed, and provided reports to various American educational organizations, so as to bring back findings related to a variety of ICME Topic Study Groups. The purpose of this poster is share findings from the “Mathematics Education as a Research Field” NCTM theme group.

Submission: 264

Problem Posing and Developmental Mathematics Students
Steven Silber
Engaging in mathematical problem posing activities can have positive effects on students’ mathematical thinking and can advance students’ understanding of mathematical concepts. Knowing how under-prepared undergraduate students pose problems informs the use of problem-posing activities for helping these students advance their understanding of mathematics as they transition to college-level mathematics courses. Forty-five undergraduate students enrolled in a developmental mathematics course participated in a written problem-posing assessment to describe what under-prepared undergraduate students’ problem posing looks like. Students’ written responses were assessed for whether the response was a mathematical question, whether the responses were solvable, and the connections between each response a student provided. Results of the assessment indicate students at all levels of course performance posed solvable mathematical problems and commonly posed problems by changing the objective for each problem created.

Submission: 183

Graphs Display Lengths, Not Locations
Surani Joshua
Students are frequently asked to reason about graphs that they see as geometric shapes, instead of representations that show the relationship between two quantities. This study shows an instructional intervention, using the theory of multiplicative objects (Saldanha and Thompson, 1998) that has great potential for orienting students to the quantities involved and their relationships, by focusing on how graphs display orthogonal lengths whose magnitudes are measures of quantities.

Submission: 258

Reducing Abstraction in the Group Concept Inventory
Joshua Fagan and Kathleen Melhuish
In this poster we report on results from the Group Concept Inventory (GCI), a conceptual assessment for introductory group theory students. Over 400 students from thirty institutions took the inventory. We use the framework of reducing abstraction (Hazzan, 1999) to situate student responses. We found that students frequently reduced abstraction (in a multitude of ways) when dealing with fundamental concepts in group theory.
Student reasoning with differentials and derivatives in upper-division physics
Michael Loverude
Students encounter multiple mathematical representations of change in physics courses. In addition to the complexity of the material, students must navigate mathematical notation that can seem arbitrary as well as potentially distinct from conventions used in mathematics coursework. In this poster we will examine student responses illustrating the challenges of mathematical representations of change, drawn from students in upper-division physics courses in math methods and thermal physics. There is considerable evidence to suggest that students have difficulty in distinguishing change quantities.

Investigating Student Learning Through Team-Based Learning Calculus Instruction
Travis Peters, Elgin Johnston, Heather Bolles, Craig Ogilvie and Alexis Knaub
We have a collection of ongoing studies designed to investigate the impact of Team-Based Learning in calculus instruction on student learning. The first study involves the implementation of Team-Based Learning in Calculus I and II. Initial findings suggest that students in Team-Based Learning have larger score gains on the Calculus Concept Inventory (CCI) than students receiving traditional instruction. However, there seems to be a gender gap as women tended to have smaller CCI gains than men. The second study investigates the transfer of calculus to major courses by asking students calculus content questions in subsequent major courses. The third study also investigates the transfer of calculus to major courses, but does so through the educational setting of first-year student Learning Communities.

Pre-service Teachers’ Use of Informal Language While Solving a Probabilistic Problem
Victoria Krupnik, Robert Sigley and Muteb Alqahtani
This exploratory study investigates pre-service teachers’ (PSTS) collaborative discussions to solve probabilistic problem. The PSTs synchronously collaborated online using Virtual Math Teams with GeoGebra to investigate the fairness of a series of die by using interactive simulation to randomly sample from the die with replacement. While discussing their solution in the chat panel, the PSTs used informal, non-standard language to describe the distribution of the data. In this poster, we present examples of how the PSTs, using informal language, co-constructed their knowledge of different probabilistic concepts while solving the problem. This study contributes one of a series of tasks that were designed to elicit how PSTs build understandings of mathematical concepts without formal introductions to these concepts.

Some Logical issues in RUME
Viviane Durand-Guerrier
In this communication, we will present various arguments supporting the claim that it is worthwhile taking in account logical issues in research in undergraduate mathematics education. We will provide arguments relying on research on student’s difficulties and their links with teachers’ practices on the one hand; on relevance for researchers on the other hand.

Post-class reflections and calibration in introductory calculus
Taylor Kline and Rebecca Dibbs
One of the reasons for the exodus in STEM majors is students’ experiences in their first undergraduate mathematics course, usually introductory calculus. However, students with high calibration are more likely to be aware of their deficiencies and seek assistance in time for it to be effective. Although there is evidence that students who regularly complete post class reflections are more successful than those that do not, it is not known if such assignment also improves students’ calibration. The purpose of this correlational study was to investigate to what extent students enroll in CLEAR calculus become more growth mindset orientated the relationship between post-class reflections, calibration, and achievement in introductory calculus.
An alternate characterisation of Developmental Mathematics students
Wes Maciejewski and Cristina Tortora

Developmental – or the antiquated “remedial” – mathematics is a large enterprise in American colleges. For the California State University (CSU) system roughly one-third of all students require developmental mathematics. Placement in these courses in the CSU is determined by a standardized test. Those who fail are required to take some campus-specific variant of developmental mathematics. This poster addresses the question, what more can be said about students enrolled in developmental mathematics programs other than they have failed an exam? An analysis of survey instrument data will be presented that shows San Jose State University developmental mathematics students are fundamentally different, undesirably so, than their non-developmental counterparts on a range of attitudinal, affective, and dispositional measures.
Submission: 263

Technology Use in the Teaching and Learning of an Introductory Statistics Course: The case of Excel and the ‘Knitr’ R-package
Sher Chhetri

We cannot imagine teaching statistics today without using some form of technology. Teaching statistics courses in the past was very challenging due to time consuming calculations. The computations are now done by time-efficient computers and other software packages. However, understanding and interpreting the results of these computations is the current challenge. In this work, we will discuss how we have been teaching introductory statistics courses with and without computer software and compare results from both scenarios. Additionally, due to the recent improvement of the power of computing, we present a dynamic documentation of computational outputs from a statistical programming language using R markdown (included in the package “knitr”) which is a simple formatting syntax for authoring HTML, PDF, and MS Word documents. Hence the main goal of this presentation is to give an outline of the method used in the past, its challenges as mentioned by Christine Duller (2008) and a demonstration of an R package which recently brought great attention to teachers of statistics and researchers. The usefulness of the package will be presented using some data analysis and graphs using R programming language. Since R Markdown supports dozens of static and dynamic output formats, including HTML, PDF, MS Word, Beamer, HTML slides, Tufté-style handouts, books, dashboards, shiny applications, scientific articles, websites, and more, it is more popular with researchers, teachers of statistics and collaborators.
Submission: 242

Awards and Plenary Session (6:00 PM – 7:15 PM)

Student reasoning as the center of our research, curriculum development and teaching
Michelle Zandieh

Much of our work as mathematics education researchers involves inquiry into students' mathematical reasoning. Inquiry into student reasoning is a key component not only of our research but also of curriculum design and inquiry-oriented teaching. This talk will highlight a variety of ways of analyzing student reasoning from my work with colleagues over the last 20 years. Important distinctions in the work include the notion that mathematical progress can be thought of both from an individual and a collective standpoint, as well as the importance of researching disciplinary practices such as defining, symbolizing and proving as well as student progress in conceptual understanding. Examples of the latter will emphasize cognitive linguistics as one key to interpreting student reasoning. It is through exploring student reasoning that I have learned more about the mathematics itself and ways in which it can be taught. In this way, student reasoning can be a driving force for curriculum design and teaching.

Room: Pt. Loma 2 & 3