Mathematics Education and Life at Times of Crisis

Proceedings of the Ninth International Mathematics Education and Society Conference

Volume 1

Edited by Anna Chronaki

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INTRODUCTION TO MES 9

Anna Chronaki
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The 9th International Conference on Mathematics Education and Society is one of a series aiming to create a collective for discussing ongoing research and praxis around the social, cultural, ethical and political dimensions of mathematics education. The first MES conference was organized at the University of Nottingham in September 1998, after frustration at the failure of international disciplinary associations in mathematics education, at the time, to acknowledge broader social issues as research domains. MEAS1 was convened by Peter Gates and Tony Cotton and embraced by the plenaries of Sal Restivo, Ole Skovsmose, Stephen Lerman, Anna Tsatsaroni, Marilyn Frankestein, Ubiratan d' Ambrosio, Jill Adler, Alan Bishop, Paul Dowling and Leone Burton. That first conference emerged as a recognizable need in the field to coordinate a forum for researchers, teacher educators and teachers who were deeply concerned with exploring, debating, reflecting, but also, interrogating explicitly the multiple interrelations amongst mathematics education and society. It has provided since then a space for people who are concerned with the failures of existing institutions and structures to address the socio-political aspects of mathematics and mathematics education.

However, the first MES conference did not happen in a vacuum. It was based on important precursors such as a small sequence of conferences under the title of Political Dimensions of Mathematics Education initiated by a network of people at the 6th International Conference of Mathematics Education in Budapest in 1988. Stieg Mellin-Olsen strongly contributed to its establishment. Consequently, three PDME conferences were held, the first in London in 1990, the next in Johannesburg in 1992 and the last in Bergen in 1995 where Mellin-Olsen led the preparations to host of conference, but his sudden loss took place only six months before the conference. Amongst members of that international network were Cyril Julie and Paulus Gerdes from the Southern Africa, Munir Fasheh from Palestine, Alan Bishop and Leone Burton from UK. It is due to the efforts, energies and dedicated work of all those people that we are here today.

During the last two decades, the series of MES conferences has produced an archive of research papers that is searchable and navigable in the site http://www.mescommunity.info. The succession of conferences held in the past years is as follows:

1998: Nottingham, UK
2000: Montechoro, Portugal
2002: Helsingor, Denmark
2005: Queensland, Australia
2008: Albufeira, Portugal
2010: Berlin, Germany
2013: Cape Town, South Africa
2015: Portland, USA
2017: Volos, Greece

It is evident that during these last twenty years a vivid group of researchers has been grounded around shared concerns for the everlasting hegemony of certain essentialist agendas in mathematics education researches, policies and practices. This collective has also been arranged around common interests for advancing alternative discourses of change through, sometimes, reformist agendas addressing issues of social justice and equity in relation to an increased marginalisation of diverse groups and communities, to extreme racism and xenophobia, and an inclination towards conservative or anti-democratic political acts. By and large, colleagues have been committed towards enacting emancipatory politics as part of their mathematics education research, exploring the potentials of mathematics education as a route to democracy, or questioning and critiquing the contemporary project of mathematics education worldwide as a matter of advanced neoliberalism and globalisation interests. On all occasions, people from around the world have always had the opportunity to share perspectives and to engage in reflexive accounts in their attempts to articulate counter arguments and debates concerning the subject of mathematics itself, the multiplicity of mathematics education practices and the purposes of mathematics education research.

MES 9 at Volos, Greece

Today, two decades after the first MES conference in 1998 at Nottingham, taking place in the midlands of England, there is a greater insight amongst researchers of how mathematics education cannot be seen anymore as an isolated discipline of experts, as well as, a greater interest of major disciplinary associations to acknowledge its social, cultural and political dimensions as domains of mathematics education research. There is more and more awareness of mathematics education as forming a complex assemblage of practices, discourses, affects, technologies, policies and politics playing out in societal terrains of global and local investments. Much can be said about not only the quality but also the potential direction of our field in the course of MES conferences throughout the years. However, we need to recognise how the current advance of research that addresses directly the socio-political dimensions of mathematics education was, mainly, made possible because of this nexus of gatherings. As such, the MES collective needs to be acknowledged as a space for producing a supportive net for making visible ground breaking work in our field, where, so far, even the reconfiguring of the community's identity went hand in hand with the rethinking and reinventing of its politics.

At MEAS1, Peter Gates[1] pointed out, the social turn in mathematics education emerged around a growing realisation for the need to: '*…move to re-orientate the organisation because a focus on psychology failed to recognise the issues and questions facing many cultures presently grappling with social change*' (Gates, 1998, p.1). This perspective has been offered by many other researchers and is fostered by MES conferences. It was evident at that time, but is more critical now, how existing research fora and established disciplinary networks had mainly served to legitimate certain epistemological and methodological traditions under the labels of 'robust' or 'strong' paradigms for either mathematics education research, everyday school practices or global and local educational policies. In consequence, they have contributed towards forming certain 'regimes of truth' about what is mathematics, mathematical activity and mathematics education research, making it hard to think otherwise or to consider viable alternatives. An open question remains to explore how far we have moved forwards with our struggles and aporias. But also, how far our research cultures have been transformed; in what directions, how and why, as well as, what is it that has remained, until now, stubbornly unchanged, same or similar. MES 9, as previous MES conferences, brings together mathematics education researchers, teacher educators, teachers and research students around the world for expressing, debating and sharing work and ideas. It provides a time-space for working within and upon long term collegial relations and networks of collaborative activity. But, what is special about MES 9?

First and foremost, MES 9 evolves at a time of designated global crisis when even the slightest hint of hope that everyday life and our work might get better by means of some clever trick or creative manoeuvres have been deemed as false. As has been noted also in the call for MES 9

1. Gates, P. (1998). *MEAS 1 Conference Proceedings*. Nottingham: University of Nottingham.

conference under the theme 'Mathematics Education and Life at times of Crisis', the economic and political crisis worldwide as well as the shrinking of the welfare state has affected all aspects of life. This, necessarily, includes the ways people, and especially young children and adolescents may experience and imagine (mathematics) education. Mathematics, as entangled with life, is embedded and embodied within a variety of institutional spaces such as the family, the school or the workplace, but also within non-institutional settings such as the street, the playground, the screen or the leisure site. Social and cultural diversities, global migration, unequal distribution of wealth, persistence of poverty, but also depleted nature and devastated environment, along with increased pressures for technologically mediated societal infrastructures provide the complex territory of late globalised capitalism and advanced neoliberalism that cannot be ignored by mathematics educators working from the tertiary level, to secondary or primary and, even the early years.

At the same time, crisis has its most serious effects when it works at the intersections of gender, race, ethnicity, sexuality, ability, social class, economic disadvantage and sustainability risk. Within this context, it has been essential to consider mathematics education and life as intertwined and to explore, on the one hand, what are the perceived effects of socioeconomic crisis on mathematics and mathematics education, and, on the other hand, what might be the potentialities afforded by mathematics education and mathematics education research towards confronting crisis and pursuing a life, as a relational ontology of the present. Based on the above, we have welcomed in the present 9th MES conference theoretical and empirical contributions in the form of papers, project presentations, symposia, discussion groups and posters that address the social, political and ethical dimensions of mathematics education and mathematics education research and life at recent times of crisis.

Second, but equally important to the first, MES 9 takes place at a specific chronotope signified as the core heart of crisis –Greece in the late 2010s. Massey (2005)[2] argues how we exist, simultaneously, in time and place. And these two entities cannot be simply static fragments of our being as some conventional geographers might prefer to understand. It is particularly important that MES 9 participants have the chance to let themselves surrender into the landscape of a country that is being repeatedly set under scrutiny for many different reasons. The small scale of the Volos urban landscape where the University of Thessaly has been inaugurated in the early 80s as a project soon after the de-industrialisation

2. Massey, C. (2005). *For Space*. London: Sage.

period in the area, as well as, the vivid village of Agria where the conference is held are awaiting to be explored. You will have the chance for a direct experience with people that could make you feel and sense life in this place as you might try to configure for your selves the politicised discourses of 'Greek crisis' and of Greece's 'indebted' economy repeatedly played by mass media worldwide during the last few years. Despite the fact that Greece is not a scandalous exception of a modern periphery country in Europe, the country and its people have been seriously affected not only by certain discourses of 'crisis' in south European states but also by a continuous return to its virtuously mythologised 'ancient' past. Being able to be together here in Greece, each one of us has the opportunity to experience a close-up familiarity with local citizens' urgencies, agonistic struggles and hopes grounded in their present but also rooted in their complex histories. This altered scale of 'crisis' may encourage us to reactivate our thoughts also on the political of contemporary mathematics education research and practice.

MES 9 Conference Program

The conference has been planned bearing in mind the importance of creating ample space for discussing and sharing research outcomes but also processes and stories of research and researching, for engaging in debates and embracing alternative ideas, perspectives, ideologies and experiences, as well as, for opening up a dialogue around contemporary struggles in mathematics education in both global and local arenas. A range of activities has been organised to support such challenges.

Opening

The Opening of the MES 9 conference aims to welcome warmly MES participants to the venue and to create an entry to the spatiotemporal hurries of the host country and city. As such it has been planned around two talks: First, an entry will be provided to some significant historical facts concerning the social struggles in the early decades of the 20th century in the city of Volos, as well as the democratic efforts of early educationists around issues of language, culture and gender. The talk will be given by historian Annita Prassa who is the director of the General State Archives of Magnesia. S*econd,* the current state of affairs of the Greek crisis through youth resistances will be discussed by political scientist Alexandros Kioupkiolis, Associate Professor at the Aristotelian University of Thessaloniki.

During the opening phase there will be an opportunity by Peter Gates and Beth Herbel-Eisenman as chairs (outgoing and incoming) of the MES International Committee to introduce MES and discuss its aims and values.

Plenary Addresses and Reactions

Four colleagues have been invited to offer plenaries to address issues of undercurrent research in mathematics education. Heather Mendick, Elizabeth de Freitas, Erica Bullock and Dimitris Chasapis. Specifically, Heather Mendick and Dimitris Chasapis each address the issue of financial crisis through the lenses of numbers and of mathematical discourses albeit through different interpretative analysis and positionings. Liz de Freitas explores the biopolitics of mathematics education research by focusing on how the biological and the social become entangled in current neuroscientist discourses. Erica Bullock addresses issues of intersectional analysis and critical mathematics education for sustaining justice communities. The range of plenary topics, as well as the reactions to such talks safeguard the presence of a stimulating dialogue amongst plenary speakers and the audience on current debates for the subject of mathematics, mathematics education and mathematics education research.

Open Talks

In all, three open talks have been prepared of which two are part of the opening and the third takes place at the evening of the 9^{th} April. They come under the themes of:

'Volos: Social, Educational and Culrural Initiatives in the first decades of the 20th century' by historian Annita Prassa

'Post-political biopower and heteropolitical resistances in the years of the Greek crisis' by political scientist Alexandros Kioupkiolis

'Science and Orthodox Christianity: a conflictual relationship?' by historian Efthymios Nikolaidis

It is hoped that the topics of these open talks will, on the one hand, sustain access to local social, political and historical exigencies, and, on the other hand, add to broader discourses that expand our visions of what might constitute locality.

Papers, Symposia, Discussion Groups, Projects and Poster presentations

After open peer review of all research contributions submitted, 61 papers, 19 projects, 9 symposia, 3 discussion groups and 6 posters have been accepted for presentation during the conference. The number of participants registered until the moment of writing this introduction is around 130 and comes from 29 countries: Australia, Austria, Belgium, Brazil, Canada, Chile, Colombia, Cyprus, Denmark, England, France, Germany, Ghana, Greece, India, Indonesia, Luxembourg, Norway, Palestine, Uruguay, South Africa, Spain, Portugal, Sweden, United Kingdom, USA, Turkey, Ireland, Iran.

Mujaawarah

The concept of Mujaawarah as '*being together in wisdom*' has been the basis of working out a short space-time within the program for sharing stories around mathematics and mathematics education in direct relation to life. The idea has been inspired by Munir Fasheh's plenary in MES 8 at Portland and will be held at MES9 by Munir Fasheh, Yasmine Abtahi and Anna Chronaki. Munir has been amongst the first to work towards challenging essentialism in mathematics education and to expand our views in courageously humble ways.

Agoras

Inspired by devoted participation during all previous MES conferences for the practice of agora, conceived as the Greek tradition of employing deliberatively the public space as the place for debate, voice, democratic dialogue and the configuration of the subject as citizen, two Agoras have been scheduled in the program that focus on discussing issues of the MES community, its current organisation and its future dynamics.

Music Events

A few music events have been planned where our graduate students and student-teachers, as well as students from local schools are actively involved into collectives that sustain a continuous learning relation with music. Volos, as well as, the surrounding area and especially the village of Agios Lavrentios, have a long lasting tradition in music and music festivals.

Community Work at MES 9

The MES 9 program and proceedings depend on the daring labours of many people who have effortlessly worked to not only review all submitted contributions, but also to language edit a small number of papers or posters where this was required. We provide this in order to support those participants who might otherwise be oppressed by the need to embrace English as the dominant colonialist lingua franca. At this conference, we also worked towards the idea of creating a support fund for some colleagues who applied for partial funding.

Reviewers

Here, we want to acknowledge and thank the reviewers for their tremendous help to make MES 9 happen. The reviewers were:

Aldo Parra, Alex Montecino, Alexandre Pais, Ali Sikunder, Andreas Moutsios-Rentzos, Anita Rampal, Anna Chronaki, Anna Tsatsaroni, Annica Andersson, Annie Savard, Ayşe Yolcu, Beth Herbel-Eisenmann, Brian Greer, Brian Lawler, Candia Morgan, Charoula Stathopoulou, Daniel Clark Orey, Danny Martin, David Kollosche, David Stinson, David Wagner, Dimitris Chassapis, Donna Kotsopoulos, Eric (Rico) Gutstein, Eric Vandendriessche, Erika Bullock, Eva Jablonka, Eva Norén, Felix Lensing, Gregory Larnell, Hannah Bartholomew, Hauke Straehler-Pohl, Heather Mendick, Helena Grundén, Herine Otieno, Hilary Povey, Jayasree Subramanian, Jessica Hunt, Karen Francois, Kate le Roux, Kicki Skog, Kjellrun Hiis Hauge, Lisa Darragh, Lisa Lunney Borden, Lisa Österling, Luz Valoyes-Chávez, Mark Boylan, Melissa Andrade Molina, Melissa Gresalfi, Milton Rosa, Miriam Godoy, Monica Mesquita, Nadia Jaber, Natalia Ruiz López, Nirmala Naresh, Nuria Planas, Paola Valero, Penelope Kalogeropoulos, Peter Gates, Richard Barwell, Robyn Jorgensen (Zevenbergen), Rochelle Gutiérrez, Sonia Kafoussi, Swapna Maukhopadhyay, Tony Cotton, Tonya Bartell, Veronica Albanese, Victoria Hand, Wee Tiong Seah, Yannis Pechtelidis, Yasmine Abtahi

Language Support

A small group of people who could provide language editing for those papers that needed such help was formed and was co-ordinated by Kate le Roux and Beth Herbel-Eisenmann. Here, again, we must thank them for such support. The colleagues who actually did language editing for MES 9 are: Lisa Darragh, Robin Averill, Peter Gates, Kate le Roux, Anna Chronaki and Andreas Moutsios-Rentzos.

MES 9 Support Fund

As part of this conference we have worked towards the idea of generating a support fund for colleagues who face financial difficulties to meet the expenses of their enrolment in an international conference. The resources for this fund came from three different sources, first the kind donations of colleagues, second, the city of Volos and the University of Thessaly and third, the University of Potsdam, Germany. In total we were able to provide partial support to 14 research students and colleagues who needed this. The great help of a group of people who worked meticulously towards this direction needs to be acknowledged. The group consisted of members of the IC committee; Yasmine Abtahi, Annica Andersson, Anna Chronaki, Kate Le Roux, David Kollosche, David Wagner, Jayasree Subramanian. The group was assisted by Eleni Kontaxi, Anthi Tsirogianni and Olga Ntasioti at the University of Thessaly. The MES IC are very keen to sort up a more robust support fund within MES and will be asking for contributions during the conference.

MES 9 Proceedings Organisation

The 9th MES Conference Proceedings' organisation consists of two volumes. The first volume contains the introduction, the plenaries, the reactions, the symposia, the discussion groups, the open forum of mujarawah, the project and poster papers. The second volume consists all research papers. In both volumes, the papers are alphabetically ordered in each sub-category by the second name of the first author. In order to support navigation styles and search of papers and authors, the conference day-by-day program, which contains the session themes and paper clusters, is also included in each volume.

We welcome you all at MES 9 at Volos, Greece and we wish that the present conference will provide the intellectual stimulation and collective ethos we experience in every MES meeting.

Acknowledgements

I would like to acknowledge the help I have received in completing this complex work of organising this conference from the International Committee for MES, as well as, from all colleagues-members of the national and the local organising committees of MES 9 conference. They have all provided great support in discussing various issues as they were emerging in this long process of planning and preparations. I thank them by heart for all their prompt responses and eagerness, as well as, for their encouragement and care. Thousands of thanks must be given for the support I have received from Anthi Tsirogianni and Eleni Kontaxi from initial stages up till now, as well as, my colleagues Sonia Kafoussi, Andreas Moutsios-Rentzos and Yannis Pechtelidis who were available and ready to discuss specific details anytime. At the same time I would like to thank Giorgos Giannikis, Tasos Matos, Olga Ntasioti and Spyros Kourias. In addition, I would like to thank all our reviewers and volunteers for their enthusiasm to help out in all last-minute burdens at the conference venue. Least, but not last, many thanks go to my parents, my family, including Ira, for tolerating my absence and devoted labour in this project especially during these last many months. MES 9 is also dedicated to you.

MES9 CONFERENCE PROGRAM

7th April, Saturday

14:00 - 17:00 Registration

17:00 Opening

8th April, Saturday

8:45 Plenary

Mathematical Futures: Discourses of Mathematics in Fictions of the Post 2008 Financial Crisis **Heather Mendick**

The Effects of Mathematics Education Discourse: A Dialogue with Mendick's Work **Gelsa Knijnik**

Saying 'No' to Mathematics: A response to Heather Mendick's 'Mathematical Futures' **David Kollosche**

14:00 - 16:00 Parallel Presentations

Unpacking Dominant Discourses

Historicizing "Math For All" **Ayşe Yolcu**

Bildung, Mathematical Literacy and Civic Education: The (Strange?) Case of Contemporary Austria and Germany **Andreas Vohns**

Old and New Naturalized Truths in Mathematics Education
Panagiotis Spyrou, Andromachi Karagiannidou, Villy Michelakou

Gamification, Standards and Surveillance in Mathematics Education: An Illustrative Example **Eva Jablonka**

Race, Class, Caste

Researching "Race" without Researching White Supremacy in Mathematics Education Research: A Strategic Discursive Practice **David Stinson**

Working Class, Intelligentsia and the "Spirit of Generalization"
Bronislaw Czarnocha

Beyond Poverty and Development: Caste Dynamics and Access to Mathematics Education in India **Jayasree Subramanian**

Examining Relations Between Students' Perception of "Being Known" and their Mathematics and Racial Identities **Tanner Wallace, Charles Munter**

Mathematical Temporalities

Multimathemacy: Time to Reset? **Karen François, Rik Pinxten**

Thinking Forward: Using Stories From the Recent Past in Mathematics Education in England **Hilary Povey, Gill Adams**

When an Education Ideology Travels: The Experience of the New Math Reform in Luxembourg **Shaghayegh Nadimi (Chista)**

Assembling MathLife Chronotopes **Anna Chronaki**

Mathematics in Higher Education

College Instructors' Attitudes Toward Statistics **Hyung Won Kim, Xiaohui Wang, Bongju Lee, Angelica Castillo**

Moving Up or Down the Ladder: University Mathematics Students Talk About Progress **Kate le Roux**

An Empirical Study into Difficulties Faced by 'Hindi Medium Board Students' in India at Undergraduate Mathematics and its Social Implications **Kumar Gandharv Mishra, Jyoti Sharma**

Working with Peers as a Means for Enhancing Mathematical Learning at University Level: Preliminary Investigation of Student Perceptions **Marios Ioannou** (project)

Symposium

Ethnomathematics Meets Curriculum Theory through Crisis **Peter Appelbaum, Charoula Stathopoulou, Milton Rosa, Daniel Clark Orey, Samuel Edmundo Lopez Bello, Dalene Swanson, Franco Favilli, Fiorenza Toriano, Robert Klein, Miriam Amrit**

Symposium

Majority Counts: What Mathematics for Life, to deal with Crises? **Brian Greer, Rochelle Gutiırrez, Eric Gutstein, Swapna Mukhopadhyay, Anita Rampal**

16:30 - 18:30 Parallel Presentations

The Neoliberal Teacher

What is Desired and the Governing of the Mathematics Teacher **Alex Montecino**

Fears and Desires: Researching Teachers in Neoliberal Contexts **Lisa Darragh** (project)

Be the Best Version of your Self! OECD'S Promises of Welfare through School Mathematics **Melissa Andrade-Molina**

Competence-Based Teacher Education – Revisited **Johanna Ruge**

Equity Reconsidered

Equity in a College Readiness Math Modelling Program: Limitations and Opportunities **Susan Staats, Douglas Robertson**

Macroinclusion and Microexclusion in Mathematics Education **Ana Carolina Faustino, Amanda Queiroz Moura, Guilherme Henrique Gomes da Silva, João Luiz Muzinatti, Ole Skovsmose**

Resolving Challenges when Teaching Pre-Service Mathematics Teachers through a Lens of Equity **Laura McLeman, Eugenia Vomvoridi-Ivanović** (project)

Identity Urgencies

Identity Change Through Inner and Outer Driving Forces for Studying Mathematics in the Swedish Prison Education Program **Ola Helenius, Linda Ahl** (project)

Sociopolitical Mathematics Teacher Identity: Mathography as Window **Emma Carene Gargroetzi, Brian Lawler** (project)

The Relevance of Pre-Service Teachers' Funds of Knowledge in their Adaptations of Mathematics Lessons **Carlos LópezLeiva** (project)

Academic Agency: A Framework for Responsibility **Lisa Poling, Tracy Goodson-Espy**

Developing Activity, Tasks and Creativity

Development and Contextualization of Tasks from an Ethnomathematical Perspective **Veronica Albanese, Natividad Adamuz-Povedano, Rafael Bracho-López**

Creative Insubordination Aspects Found in Ethnomodelling **Milton Rosa, Daniel Clark Orey**

When Geometry Meets the Language of Arts: Questioning the Disciplinary Boundaries of a School Curriculum **Panagiota Kotarinou, Eleni Gana, Charoula Stathopoulou**

Symposium

Race, Racism, and Mathematics Education: Local and Global Perspectives **Luz Valoyes-Chávez, Danny Martin, Joi Spencer, Paola Valero, Anna Chronaki**

Symposium

"Crisis" and Interface with Mathematics Education Research and Practice: An Everyday Issue **Aldo Parra, Arindam Bose, Jehad Alshwaikh, Magda González, Renato Marcone, Rossi D'Souza**

21:30 Mujaawarah

Mujaawarah: Being Together in Wisdom or Reclaiming Life for Mathematics Proposal for an Open Forum **Munir Fasheh, Yasmine Abtahi, Anna Chronaki**

9th April, Sunday

8:45:Plenary

Biosocial Becomings: Rethinking the Biolopitics of Mathematics Education Research **Elisabeth de Freitas**

Neuronal Politics in Mathematics Education **Karen François**

Re-experiencing Emotions in the Biosocial Space of Mathematics Education **Andreas Moutsios-Rentzos, Panagiotis Spyrou**

14:00 - 16:00 Parallel Presentations

Ideology and the Subject

The Ideology of Relevance in School Mathematics **David Kollosche**

The Repression of the Subject? - Quilting Threads of Subjectivization **Felix Lensing**

The Subject of Mathematics Education Research **Alexandre Pais**

Children, Policies, Politics

Where are the Children? An Analysis of News Media Reporting on Mathematics Education **Yasmine Abtahi, Richard Barwell**

Fabrication of Newly Arrived Students as Mathematical Learners in Swedish Policy **Eva Norén, Petra Svensson Källberg**

The Construction of the Mathematical Child in Swedish Preschool **Laurence Delacour** (project)

Social Aspects of Undergraduate Mathematics Students' Learning: Preparing for The Coursework **Marios Ioannou**

Discourses of Dis/Ability

Ableism in Mathematics Education: Ideology, Resistance and Solidarity **Rossi D'souza**

From Policy to Practice: Discourses of Mastery and "Ability" in England **Candia Morgan**

'Sets 4 and 5 Were Stuffed Full of Pupil Premium Kids': Two Teachers Experiences of 'Ability' Grouping **Colin Jackson**

Social Justice Revisited

Coming to Understand the Big Issues: Remaking Meaning of Social Justice Through Mathematics Across the School Year **Frances Harper**

Teaching Mathematics for Social Justice: Transforming Classroom Practice **Pete Wright**

Challenges in Dealing with Social Justice Concerns in Mathematics Classrooms **Shikha Takker**

Symposium

Neoliberalism: A Crisis for Mathematics Education? **Lisa Darragh, Lisa Björklund Boistrup, Paola Valero, Lisa Darragh, Gill Adams, Hilary Povey**

Symposium

Ethnomathematics Meets Curriculum Theory through Crisis **Peter Appelbaum, Charoula Stathopoulou, Milton Rosa, Daniel Clark Orey, Samuel Edmundo Lopez Bello, Dalene Swanson, Franco Favilli, Fiorenza Toriano, Robert Klein, Miriam Amrit**

Poster Session

Why Do We Need Them to Be Different Low Achieving Children's Conceptions of Unit Fraction **Jessica Hunt, Arla Westenskow, Patricia Moyer-Packenham**

Math, Social Justice, and Prospective Teachers in U.S.A. and Uruguay: Learning Together **Paula Guerra, Woong Lim, Raisa Lopez**

Enhancing Students Quantitative Literacy Skills: Using Google Drive as a Collaboration Tool for Interactive Online Feedback **Michelle Henry, Jumani Clarke, Sheena Rughubar-Reddy, Ian Schroeder**

Doing Research with Teachers: Ethical Considerations that Shaped the Researcher Stance **Annie Savard**

Mathematical Fiction in Education: Text in Action **Eleni Kontaxi, Stella Dimitrakopoulou**

AnthropoGeometries in the UrbanScape: Interrogating the Echo of Geometry **Anna Chronaki, Chrysa Papasarantou, Irene Lazaridi, Efi Manioti, Magda Koumparelou, Giorgos Giannikis**

16:30 - 18:30 Parallel Presentations

Ethical Encounters in the Field

Diversity in Meanings as an Issue in Research Interviews **Helena Grundén**

Tensions and Dilemmas as Source of Coherence
Jehad Alshwaikh, Jill Adler

How Local are Local People? Beyond Exoticism **Eric Vandendriessche, José Ricardo e Souza Mafra, Maria Cecilia Fantinato, Karen François**

Learners in their Social Contexts

Investigating Parental Influences on Sixth Graders' Mathematical Identity: The Case of Attainment **Sonia Kafoussi, Andreas Moutsios-Rentzos, Petros Chaviaris**

What is the Role of Value Alignment in Engaging Mathematics Learners? **Penelope Kalogeropoulos, Alan Bishop**

Love and Bullying in Mathematical Conversations **Annica Andersson, David Wagner**

Social Inquiry with Mathematics in two High School Classrooms **Anastasia Brelias**

Teachers Professional Growth

Pedagogical and Mathematical Capital: Does Teacher Education Make a Difference? **Robyn Jorgensen (Zevenbergen), Tom Lowrie**

Mathematics Teacher Professional Development Toward Equitable Systems: Weaving Together Mathematics, Discourse, Community, Positionality, and Action Research **Ashley Scroggins, Beth Herbel-Eisenmann, Frances Harper, Tonya Bartell**

Mathematics Teachers' Professional Learning **Iben Christiansen, Kicki Skog, Sarah Bansilal** (project)

Gender, Power, Mathematics

Recrafting Manipulatives: Toward a Critical Analysis of Gender and Mathematical Practice **Melissa Gresalfi, Katherine Chapman**

Understanding Relations of Power in the Mathematics Classroom: Explorations in Positioning Theory **Jennifer Langer-Osuna, Maxine McKinney de Royston**

Performing Girl and Good at Mathematics: Scripts in Young Adult Fiction **Lisa Darragh** (project)

Symposium

Beyond the Box: Rethinking Gender in Mathematics Education Research **Margaret Walshaw, Anna Chronaki, Luis Leyva, David Stinson, Dalene Swanson, Kathy Nolan, Heather Mendick**

Symposium

Inside Critical/Radical Mathematics Education: A Video Exploration **Maisie Gholson, Patricia Buenrostro, Lindsey Mann, Eric Gutstein, Mark Hoover**

10th April, Monday

8:45: Plenary

From 'isms' Groups to Justice Communities: Intersectional Analysis and Critical Mathematics Education **Erica Bullock**

Mathematics Education and the Matrix of Domination **Paola Valero**

Reaching across to a parallel universe below:The promise of Justice communities for researching caste in mathematics education **Jayasree Subramanian**

11th April, Tuesday

8:45: Plenary

'Numbers Have the Power' Or the Key Role of Numerical Discourse in Establishing a Regime of Truth about Crisis in Greece **Dimitris Chassapis**

Mathematical language in the political discourse: epistemological and educational reflections emerged from Dimitris Chassapis' conference plenary **Fragkiskos Kalavasis**

Response to Dimitris Chassapis' paper "Numbers have the power" or the key role of numerical discourse in establishing a regime of truth about crisis in Greece. **Alexandre Pais**

14:00 - 16:00 Parallel Presentations

Crisis, Education, Mathematics

On the Entanglement of Mathematics Remediation, Gatekeeping, and the Cooling-Out Phenomenon in Education **Gregory Larnell**

No, we didn't Light it, But we Tried to Fight it: Acknowledging and Connecting an Acute Crisis **Jeffrey Craig, Lynette Guzmán** (project)

Mathematics and Human Flourishing **Samuel Luke Tunstall**

Critical Mathematics Education and Social Inquiry

Using CME to Empower Prospective Teachers (and Students) Emerge as Mathematical Modellers **Nirmala Naresh, Lisa Poling, Tracy Goodson-Espy**

Categories of Critical Mathematics Based Reflections on Climate Change **Peter Gøtze, Ragnhild Hansen, Kjellrun Hiis Hauge, Lisa Steffensen**

Extending the Landscapes of Mathematical Investigation through Philosophical Inquiry **Nadia Stoyanova Kennedy**

Empowering Students in Citizenship: Teaching Mathematics and Learning Financial Concepts **Annie Savard** (project)

Space(s) for Mathematical Experience

Reconfiguring Mathematical Settings and Representations Through Whole-Body Collaboration **Jasmine Ma, Molly Kelton**

Social Nature of Mathematical Reasoning: Problem Solving Strategies of Middle Graders' with Diverse Out-of-School Experience **Arindam Bose**

The Shape of Taping Shape: Visitor Experiences with an Immersive Mathematics Exhibition **Molly Kelton, Bohdan Rhodehamel, Cierra Rawlings, Patti Saraniero, Ricardo Nemirovsky** (project)

Discussion Group

Assessing and Accessing Learning Experiences of Refugee Students and Teachers **Anna Jober, Anna Chronaki, Christine Knipping, Lena Anderson, Peter Bengston, Efthalia Balla, Eirini Lazaridou, Olga Ntasioti, Eirini Avgoustaki, Ismini Sotiri, Dalene Swanson, Nuria Planas, Candia Morgan**

Symposium

Ethnomathematics and Reconciliation **Lisa Lunney Borden, David Wagner**

16:30 - 18:30 Parallel Presentations

First Nation, Indigenous People, Rural Communities

Reflections on Pedagogy in a Remote Indigenous Community **Dianne Siemon**

Mathematics Learning and Social Background: Studying the Context of Learning in a Secondary School in a Semi Rural Area of Maharashtra **Varsha Sadafule, Maxine Berntsen**

Prioritizing Visual Spatial Mathematical Approaches in First Nation Early Years Classrooms **Joan Moss, Bev Caswell, Zachary Hawes, Jason Jones**

Developing 'Quality' Teachers in Remote Indigenous Contexts: Numeracy Leaders **Robyn Jorgensen (Zevenbergen)**

Dialogue, Mathematising, Thinking

"How did you get to that Result?": The Process of Holding a Dialogue in Math Classes of the Early Years of Primary School **Ana Carolina Faustino** (project)

Strengthening the Ways of Mathematising of Mapuche People at the School **Huencho Anahí** (project)

The Process of Dialogue in Teaching and Learning Mathematics with Deaf and Hearing Students **Amanda Queiroz Moura, Miriam Godoy Penteado** (project)

Social Creativity in the Design of Digital Resources to Afford Creative Mathematical Thinking **Chronis Kynigos, Maria Daskolia, Ioannis Papadopoulos** (project)

Developing Mathematical Concepts

Statistics Education: An Alternative for Children in Literacy Cycle to Develop the Number Sense **Maria Lúcia Wodewotzki, Sandra Gonçalves Vilas Bôas Campos**

The Concept of the Tangent in the Transition from Euclidean Geometry to Analysis – A Visualization via Touch **Panagiotis Stavropoulos, Maria Toultsinaki**

Developing Concepts in a Study of Mathematics Learning Pathways **Jasmine Ma, Molly Kelton** (project)

Critical, Reflective, Affective

Developing Critical and Reflective Dimensions of Mathematical Modelling **Daniel Clark Orey, Milton Rosa**

How Confidence Relates to Mathematics Achievement: A New Framework **Lesa Covington Clarkson, Quintin Love, Forster Ntow**

Economic Crisis: The Educational Game Euro-Axio-Polis **Maria Chionidou-Moskofoglou, Aikaterini Vamvouli** (project)

Discussion Group

Trajectories of Mathematics Education Research in Greece **Sonia Kafousi, Anna Chronaki, Panagiotis Spyrou, Mariana Tzekaki, Babis Lemonidis, Despoina Potari, Babis Sakonidis**

Symposium

Dealing with our Own Shit: The Researcher Behind the [Mathematics Education] Research **Alexandre Pais, Alyse Schneider, Mônica Mesquita**

12th April, Wednesday

09:00 - 10:00 Final Discussion Session

10:00 - noon

PLENARY PAPERS

BEYOND "ISM" GROUPS AND FIGURE HIDING: INTERSECTIONAL ANALYSIS AND CRITICAL MATHEMATICS EDUCATION

Erika C. Bullock

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As global mathematics education has taken a critical turn particularly toward acknowledging class, and (less so) gender, and (even less so) race, there has not been an equal effort to interrogate how these concepts interact within the complex constructions of identities, institutions, and ideologies. This creates an analytical vacuum because when humans engage with mathematics, they do so in the totality of their identities. What does it mean for critical mathematics education to exist in such a vacuum? What are the costs? What are the affordances? In this paper, I argue that confronting the messiness of humanity through intersectional analysis facilitates the construction of new types of community within critical mathematics education for which the locus is justice.

It is a rare occasion when Hollywood and the world of mathematics converge. Such a convergence occurred in late 2016 as the Hollywood publicity machine prepared for *Hidden Figures* (Gigliotti, Chernin, Topping, Williams, Melfi, & Melfi, 2016), a film adaptation of Margot Lee Shetterley's 2016 book *Hidden Figures: The American Dream and the Untold Story of the Black Women Who Helped Win the Space Race.* Shetterley is a non-fiction writer, daughter of a National Aeronautics and Space Administration (NASA) father and Hampton University English professor mother, and founder of The Human Computer Project. Her book documents the stories of Christine Darden, Mary Jackson, Katherine Johnson, and Dorothy Vaughan, black women who played key roles in both the National Advisory Committee for Aeronautics [NACA; the agency that preceded NASA] and NASA through the Space Race. The eponymous film recounts Jackson, Johnson, and Vaughan's work at NASA in support to John Glenn's 1962 orbit of the Earth.[1] The release of the *Hidden Figures* film has prompted a surge in public discourse about girls and women in science, technology, engineering, and mathematics (STEM). Pepsico joined 20th Century Fox to launch "The Search for Hidden Figures,"[2] an initiative that includes a

1. Although Christine Darden's story is included in the book, she is not a central subject of the film because she did not join NASA until 1967.

2. http://www.searchforhiddenfigures.com

scholarship contest, a website containing STEM-related games and challenges, and two Twitter hashtags *#Search4HiddenFigures* and *#Search4STEM* used to bring visibility to “everyday people” who participate in STEM. Additionally, blogs, podcasts, and other media have emerged using the movie as a launching point to discuss broadening participation in STEM.

Shetterley’s (2016) book and the film (Gigliotti et al., 2016) are part of a recent surge of efforts to amend the dominant historical record to include “hidden figures” –the unlikely and unsung contributors to developments in mathematics and science. The Human Computer Project, the organization that Shetterley founded, is dedicated to telling stories of women in mathematics and science in hopes that “these role models will inspire a new generation of women and minorities to pursue careers in STEM fields, and that everyone will gain a broader sense of what mathematicians, engineers and scientists look like.”[3] Scientist Nathalia Holt’s (2016) book *Rise of the Rocket Girls: The Women Who Propelled Us, from Missiles to the Moon to Mars* and journalist Denise Kiernan’s (2013) *The Girls of Atomic City: The Untold Story of the Women Who Helped Win World War II* detail women’s scientific contributions. Mathematics education researcher Erica Walker (2014) wrote *Beyond Banneker: Black Mathematicians and the Paths to Excellence* to document the stories of black mathematicians in the United States. In *The Immortal Life of Henrietta Lacks* (Skloot, 2010) and *Medical Apartheid: The Dark History of Medial Experimentation on Black Americans from Colonial Times to the Present* (Washington, 2008) the authors report on science’s long history of using poor black people’s bodies for experimentation without consent. These biographical works add names and biographies to the roster of scientific contributors, thus troubling the narrative that scientific innovation is a white man’s story. In the case of Henrietta Lacks and those cases in *Medical Apartheid*, these authors use history to call the ethics of scientific discovery to question and to establish science’s debt to those who have been victimized in the name of innovation. In addition to these biographical works, mathematics education researchers have used their work to amplify narratives of unlikely success (see e.g., Baber, 2012; Berry, 2008; Jett, 2013b; Warren & Miller, 2013).

For those of us interested in critical mathematics education and the social and political dimensions of mathematics education, the idea of hidden figures in mathematics is central to much of our work. Often our hidden figures are everyday people who are marginalized or excluded from mathematics education. Some of us are concerned with how identities are hidden in mathematics education; some of us examine cultural forms of mathematics as hidden figures within academic mathematics; some of us

3. http://www.thehumancomputerproject.com

consider how the politics of mathematics education privilege certain modes of thought and exclude others. There are some of who examine specific curriculum, policies, and pedagogies while others use different theories to urge the community toward a full rethinking of the enterprise of mathematics education. While we all take on different domains of analysis, much of our work can be connected –more or less explicitly– to the social *isms*[4] that plague our world (e.g., sexism, racism, heterosexism, colonialism, capitalism, ableism, militarism, nationalism, religious sectarianism or extremism).

Although we all are concerned with social *isms*, it is unfortunate that we operate most often in silos; those of us concerned with racism huddle together in one corner while those focused on heterosexism gather elsewhere, and so on. We acknowledge and appreciate work across groups but there is little crosstalk. A survey of prior MES programs shows that this community has addressed nearly all the *isms* listed above. However, there often remains a sense that our own *ism* of interest is more important or more grave than others simply because it is nearest our hearts. This sensibility is dangerous because it limits our ability to engage in collective action. Furthermore, this sensibility does not align with the way that most people experience these oppressive social and political forces. Therefore, our response to oppression cannot be any less complex than oppression itself.

As depicted in the film, figures in mathematics education are hidden for reasons related to isms. Hence, deep exploration of each of these isms is necessary and collaborative efforts, or *ism groups*, offer great capacity for inquiry and change. However, it is rare that any person experiences only one of these *isms*. In other words, oppression rarely has a single pressure point; it bears down on us in multiple ways at once, producing varied, and often conflicting, effects. We can consider, therefore, the *isms* as existing within a matrix of domination (Collins, 1990/2009) that accounts for both the *isms* and their intersections. However, absent a framework for considering this matrix, critical mathematics education is vulnerable at their intersections which also happen to be the places where the most vulnerable figures are hidden. In this paper, I propose intersectional analysis as such a framework and use it to explore both how critical mathematics education is complicit in figure hiding and how intersectional analysis provides a methodology for moving beyond figure hiding.

INTERSECTIONALITY AND INTERSECTIONAL ANALYSIS

Legal scholar Kimberlé Crenshaw (1989, 1991, 2013) brought the term *intersectionality* into academe and black feminist scholars in the United States such as Zandria F. Robinson (2016), Brittney Cooper (2015), and Patricia Hill Collins (1990/2009, 2015; Collins & Bilge, 2016) and abroad

4. Special thanks to Dr. Gregory Larnell for the idea of *ism* groups generated in our conversations about this paper.

such as Nira Yuval-Davis (2006) have advanced this work to the point where it has become a significant concept in broader feminist scholarship (Davis, 2008). Crenshaw (1989) saw that the justice concerns of black women were often subsumed in anti-racist and feminist politics for black people or women, broadly considered. However, a black woman's experience is neither a *black* experience nor a *woman's* experience, so "this single-axis framework erases Black women in the conceptualization, identification and remediation of race and sex discrimination by limiting inquiry to the experiences of otherwise-privileged members of the group" (Crenshaw, 1989, p. 140). Crenshaw (1989) proposes intersectionality as a means to acknowledge "those who are multiply-burdened" (p. 140) by different modes of oppression –or different isms. The idea of multiple burden speaks to intersectionality's key concern that racism, sexism, and other forms of oppression, when considered in parallel, appear additive, but those who experience these oppressions in combination endure multiplicative effects (Choo & Ferree, 2010; Robinson, 2016; Yuval-Davis, 2006).

In recent years, intersectionality has garnered increased attention in academic and public circles as those who have been oppressed seek to articulate the multiple layers of oppression that correspond to different identity politics. Intersectionality embraces a more postmodern approach to identity politics that particularizes the intersections of identity categories (Crenshaw, 1991). For example, a person who identifies as a queer black woman experiences oppression in the name of racism, sexism, and heterosexism based on her racial, gender, and sexual identity, respectively. Intersectionality acknowledges that there is energy required to address each of these identities and that a person must sometimes make difficult decisions when those identity politics conflict.

Intersectionality's presence and proliferation in academic spaces represents a form of grassroots theorizing in which a woman of color used her scholarly position as a vehicle to represent the practices and embodied knowledges that, historically, have characterized the lived experiences of her women of color foremothers who have to simultaneously navigate the complexities of gender, race, language, and other identity politics (Collins & Bilge, 2016). Although the terminology is recent, there is a long history of intersectional analysis by both women of color scholars and lay scholars. Crenshaw's work rests upon the shoulders of women like Sojourner Truth, Anna Julia Cooper, Gloria Anzaldúa, Ida B. Wells-Barnett, Paula Gunn Allen, and countless other known and unknown women who have shaped the consciousness of women of color through the verbal and written articulation of their lived experiences. Like Crenshaw, Cooper (2015) identifies her mother's and grandmother's teachings as more than just simple life lessons:

> Because of Black feminism, I understand the *theorizing* that my mother and grandmother taught me to do as being critical and crucial to my survival as a Black woman of Southern [United States], semi-rural, working-class origins now navigating a middle class, urban, academic life. (p. 10, emphasis original)

Naming these articulations as Crenshaw did is a form of scholarly legitimization that makes them “more compatible with academic norms of discovery, authorship, and ownership” (Collins & Bilge, 2016, p. 80).

One significant characteristic of intersectionality is its commitment to praxis (Cho, Crenshaw, & McCall, 2013; Collins & Bilge, 2016). The women of color who have embraced intersectionality as both an intellectual and practical approach to the world throughout history have not had the luxury of separating their intellectual work from their efforts to survive the matrix of domination (Cooper, 2015). Therefore, the women who have advanced intersectionality within academe have retained praxis as a significant part of that conceptualization. Given this legacy, it is not enough to think through the multiple ways in which oppression weighs upon various identities, but it is the scholar’s responsibility to use her or his power to do something in response. This focus on praxis also validates the knowledges that lay scholars –scholars who do not share our academic credentials– bring to this work and promotes collaboration within and outside of academe.

It is also important to note that, although intersectionality is best known and most often articulated as a means of considering domination, oppression is not necessarily its focus. Rather, intersectionality considers the operations and intersections of social structures (which often are oppressive).

> It is worth emphasizing that intersectionality is *not* the opposite of privilege or advantage: it is possible to be intersectionally advantaged or privileged as well as intersectionally marginalized, dominated or oppressed....The idea of intersectionality also points out that social structures not only disadvantage particular groups (as the language of burdens [or oppression] suggests); they also privilege certain groups, again, in ways unique to particular gender-race-class groupings. Every person is marked by multiple social structures. So the idea of intersectionality criticizes, improves on, and moves beyond the language of double or triple burdens as well as the concept of “dual systems.” (Weldon, 2008, pp. 196, 197, emphasis original)

Thus, intersectionality has great analytical potential beyond those with which we are most familiar.

Collins and Bilge (2016) propose a distinction between *intersectionality* and *intersectional analysis* to capitalize on the theory’s great potential beyond considerations of identity. By bringing intersectionality into academe, Crenshaw (1989, 1991) opened up new possibilities for its use beyond her focus on black women's lived experiences in the United States. Once understood only as a theory of identity, over time intersectionality has taken on broader meaning and intersectional analysis has become a way to engage intersectionality in critical inquiry. Intersectional analysis represents a move in critical ism-focused scholarship "from parallelism to simultaneity and multiplicity" (Robinson, 2016, p. 491). As "oppressions must work together to produce injustice" (Collins, 1990/2009, p. 21), intersectional analyses interrogate both the individual modes of oppression and the entanglements that the matrix of domination (Collins, 1990/2009) produces. Weldon (2008) articulates intersectional analysis' potential beyond intersectionality's identity focus: "It refers to a form of relationship between social structures, specifically one in which social structure combine to create social categories to which certain experiences and forms of oppression are unique" (pp. 195–196).

McCall (2005) asserts that there are three forms of complexity that intersectional analysis can address: anticategorical complexity, intercategorical complexity, and intracategorical complexity. These three types of complexity exist on a continuum, with anticategorial and intercategorical complexity on either end and intracategorical complexity in between. Anticategorical complexity represents an approach similar to that of poststructural feminism (see e.g., St. Pierre, 2000) that considers all social categories as fictions that simultaneously produce difference and inequalities by denying the heterogeneity of experience. According to an anticategorical complexity, social life is too complex to create fixed categories. Intercategorical complexity, in contrast, means accepting social categories –at least temporarily– in order to document inequalities across social groups. We can locate the work of many feminists of color here. Finally, intracategorical complexity borrows the anticategorical process of interrogating the boundaries of social categories while acknowledging that there are stable and semi-stable relationships among categories in line with the intercategorical approach. The focal points of intercategorical complexity are "the neglected points of intersection" (McCall, 2005, p. 1774) among social categories. Although intersectional analysis emerged from this in-between space of intercategorical complexity, its proliferation in social science scholarship reveals its relevance across the continuum. This continuum of complexities mirrors that spectrum of critical postmodern theory that, as I have argued previously (Stinson & Bullock, 2012, 2015), holds great productive possibilities for mathematics education research and critical mathematics education research, particularly.

In his MES3 plenary paper, Thomas Popkewitz (2002) asks: "What are the concrete practices in the [mathematics] curriculum that produce the distinctions and divisions that qualify some and disqualify others?" (p. 2). Popkewitz places his question at the site of curriculum, but I see a form of this question as relevant to the enterprise of critical mathematics education. Therefore, I ask: "What are the practices in critical mathematics education that re-inscribe the distinctions and divisions that qualify some and disqualify others?" Said differently, while the project of critical mathematics education purports, at least in part, to be about inclusion and justice, in what ways so we intentionally or unintentionally undermine those goals? I pose these questions as central to our collective work as a community of critical mathematics educators and I offer intersectional analysis as a framework for our response.

INTERSECTIONAL ANALYSIS AS METHODOLOGY IN MATHEMATICS EDUCATION

Choo and Ferree (2010) propose three different categories of intersectionality that prove useful in responding to the questions I have raised: a group-centered approach focused on inclusion, a process-centered approach focused on analytical interactions, and an institution-centered approach focused on institutional primacy. "The first emphasizes including multiply-marginalized groups in the content of the research; the latter two focus on explaining intersectional dynamics through the way that the analysis of the data is done" (p. 130). Therefore, the first category –the group-centered approach– focuses on intersectionality while the other two –the process- and institution-centered approaches– are forms of intersectional analysis. In this section, I describe these categories, consider how each addresses figure hiding, and discuss the potential for each in our work related to the social and political dimensions of mathematics education.

Group-centered approach (Inclusion)

The group-centered approach to intersectional analysis is likely most familiar in that its focus is on including "multiply-marginalized" groups in research by "giving voice to the oppressed" (Choo & Ferree, 2010, p. 130). The factor that distinguishes intersectionality's approach to voice from that of other critical social theories is the explicit emphasis on the complexity of identity. This approach to intersectional analysis relies on the idea that figures are hidden when the analytical focus in on only one dimension of experience. In these situations, multiply-marginalized groups can be excluded. Consider a hypothetical study of first-generation students taking mathematics courses in a U.S. university. The hypothetical researcher is interested in racialized experience so they select black students as participants. This study takes on racism as its ism focus. If immigrant students are not included in the sample of participants, black immigrant students –a multiply-marginalized group– have been excluded and are hidden figures.

Intersectionality's presence in extant mathematics education research literature most often aligns most with this group-centered approach. Damarin and Erchick (2010) assert: "If mathematics education research is to promote equity for girls and women within multiple racial and ethnic groups, similar attention to the intersection of clearly defined constructs, including gender, is required" (p. 312). Gholson and Martin (2014) and Gholson (2016) use intersectionality as a central component of their analytical framework related to black girls' and women's experiences of mathematics. Lambert (2015) argues that intersectionality is useful for considering how disability intersects with race. Scholars such as Berry (2008), Jett (2013a), and McGee (2015) position intersectionality as a way of thinking about how mathematics identity operates with racial identity. These studies are excellent examples of how intersectionality can be used to engage identities in mathematics.

Process-centered approach (Analytical interactions)

The process-centered approach represents as turn toward intersectional analysis by taking up intersectionality as "a nonadditive process, a transformative interactivity of effects" (Choo & Ferree, 2010, p. 131). If the group-oriented approach is an "intersection-only" model, then the process-centered approach is "intersection-plus" (Choo & Ferree, 2010, p. 133; also Weldon, 2008). Hence, while the group-centered approach attends to the space of intersection of identities, in the process-centered approach, the intersectional analyst looks beyond those intersection points to consider the relations among the ism systems. Figure hiding in the process-centered category is the myopic focus on one ism at the exclusion of others in a way that limits the scope of analysis. Here, figure hiding moves from an issue of hidden identities to one of hidden systems.

In her study of successful women in mathematics, Solomon, Radovic, and Black (2015; also see Solomon, 2012) investigated how women negotiate their participation and gender performances in the masculinized world of mathematics. The authors argue that Roz, the subject of this study, experiences a "contradiction between doing mathematics and enacting femininity."

> Here, we can see that Roz views the other women as having resolved the contradiction between being female and being a mathematician by taking on masculine characteristics in order to fit into the world of mathematics, she has chosen to be different –to enact a different kind of mathematical identity, which retains simultaneously a strong and visible femininity (signalled by the use of the cultural tools of skirt and heels) alongside the mathematics. (p. 63)

Solomon and colleagues consider Roz as a woman succeeding in the masculinized discipline of mathematics. Considering this study through the lens of intersectionality leads me to wonder how Roz's other identities inform her choices regarding feminine performance. For example, what would it mean for this analysis to consider mathematics as both a masculine space and as white institutional space (Martin, 2011, 2013)? While the authors report that Roz is 52 years old, they do not address her race, so I cannot speculate about how her identity would be positioned within white institutional space. However, it is fair to say that, if Roz is a white woman, her experience of white institutional space would be different from that of a hypothetical non-white woman. Therefore, the conclusions drawn from an analysis of Roz's mathematical life could be racialized as well as gendered and her efforts to negotiate her identity as woman in mathematics could also be informed by an interaction between gender and race.

Adding an intersectional analysis of mathematics education as white institutional space to Solomon and colleagues' solid gender-focused approach would speak to how gender operates along with race in mathematics education. However, increasing the scope of analysis has significant methodological implications.

> The methodological demands of a process model are greater than those of an inclusion model, since explicit comparison, attention to dynamic processes, and variation by context are all understood as inherent in intersectionality. Insofar as the research embraces some notion of social construction, it also calls for data that are multilevel, capturing both the agency of individuals in making the world they inhabit and the enabling and constraining forces of the world as it has been produced. (Choo & Ferree, 2010, p. 134)

Surely this increase in analytical has implications for research design and data collection, analysis and representation (Stinson & Bullock, 2015), but the research should not be deterred. Process-centered intersectional analysis means, above all, intentionally zooming in and out (Stinson & Bullock, 2012) on the ism at the center of analysis "asking how that dimension of inequality is itself subdivided and crisscrossed with other axes of power and exclusion that are less well articulated" (Choo & Ferree, 2010, p. 135; also Yuval-Davis, 2006)

Institution-centered approach (Institutional primacy)

Like the process-centered approach, the institution-centered approach is one of intersectional analysis. In this case the "intersection-plus" idea (Choo & Ferree, 2010) extends to institutions. Often we connect certain isms with certain institutions (Choo & Ferree, 2010; Weldon, 2008). For example, class or capitalism are often central to discussions of economic institutions. Another ready example is the institution of the family; when discussing family, the analysis is most commonly related to gender or sexism (Choo & Ferree, 2010). It is difficult, if not impossible, to imagine these institutions existing in a way that does not prioritize one ism over another. The idea of the economy relies on economic theory, therefore economic theory –whether capitalism or otherwise– will likely always be central. The example of family presents a more reasonable possibility that the primary focus on gender could eventually shift from its place of primacy as the socio-historical constructs of family and marriage face political challenge. Given these histories, it is not prudent to take an “intersection-only” approach to analyzing institutions because it may not be possible to equalize isms. In other words, it is not possible to consider class equal with gender within the economic institution because of the foundation of the economic institution itself. However, “intersection-plus” does not allow for a class-*only* analysis of the economy –or a gender-only analysis of family, et cetera. Discussions of family, therefore, would take gender as a core construct of family. The institution-centered approach to intersectional analysis permits isms to have *primacy* within institutions but not *exclusivity*, so figure hiding occurs in this case when the central concern eclipses any other systems that may be in operation.

In an early paper, my colleagues and I (Larnell, Bullock, & Jett, 2016) consider the role of race in teaching and learning mathematics for social justice (TLMSJ) as a pedagogical system in mathematics education. We also use principles of critical race theory (CRT) to identify spaces within TLMSJ scholarship where CRT allows for a more nuanced analysis and to illuminate the potential within TLMSJ to address racialized inequities. Although we did not explicitly mention intersectionality in the article, my reflection upon that thinking in concert with Choo and Ferree’s (2010) categories of intersectionality reveals a connection specifically to the institution-centered approach. Given that intersectionality is a valued principle within CRT (Hobbel & Chapman, 2009), this connection aligns with the theoretical underpinnings of the original argument.

I argue that the analysis of TLMSJ presented in this prior article (Larnell et al., 2016) represents an institution-centered intersectional analysis. As a system, TLMSJ necessarily centers on mathematics. More precisely, TLMSJ relies on school mathematics in that its mathematics goals are dictated –perhaps in various degrees based on context– by the standards and norms of school mathematics. In examining TLMSJ, we noticed that tasks addressed justice issues rooted in isms such as racial profiling in traffic stops (racism) and wealth distribution (capitalism), but they did not address those issues as intersectional. We propose such an intersectional analysis of TLMSJ as a type of institution. In our analysis, we maintain mathematics as the core of TLMSJ but our concern is that the desire to fit justice issues into school mathematics may force an oversimplifation of these issues that can undermine justice aims. In one of the examples presented, Esmonde (2014) discusses a wealth distribution task conducted with affluent middle and secondary students that were nearly all white (12 of the 13 students). "Whiteness and racism," we argue "operate in tandem with socioeconomic wealth to generate societal privilege" (Larnell et al., 2016, p. 26). Therefore, the absence of discussion of the relationship between race and wealth distribution in the task and documented classroom interactions represent a missed intersectional opportunity that results in an incomplete presentation of the issue of wealth disparity.

CONCLUSION

The three categories of intersectional analysis that I have presented represent opportunities to address figure hiding in critical mathematics education by complexifying and enriching research into the social and political aspects of mathematics education. Communities like MES provide opportunities for collaboration in doing the work of intersectional analysis that moves beyond ism groups toward the justice work that, I believe, is the core work of critical mathematics education. According to Rawls (1971), justice is the first virtue of any social institution and "laws and institutions, no matter how efficient and well-arranged, must be reformed or abolished if they are unjust" (p. 3). I envision critical mathematics education's role within mathematics education writ large as pushing justice to the center of conversations about all parts of the "network of mathematics education practices" (Valero, 2010, p. 374).

Turning an intersectional analytic eye upon (critical) mathematics education cannot be done in isolation. It is not possible for any one of us or any one ism group to fully interrogate the matrix of domination (Collins 1990/2009); there are always things that we cannot see or commitments under which we cannot not operate. Therefore, the pursuit of justice through inquiry is a necessarily collaborative effort. MES offers an excellent platform for this kind of intentional collaboration among critical mathematics educators through what I call *justice communities*. The justice community is a strategic partnership in which scholars come together across *ism* groups to investigate one element or dimension of the matrix of oppression with the intention of pooling their intellectual resources in the service of justice. Justice communities can gather around identities (e.g., the mathematics education of trans youth), issues (e.g., islamophobia and mathematics education), places (e.g., mathematics education in rural China), or spaces (e.g., urban mathematics education). A justice community has one aim: to move toward justice by directly confronting the multiplicative effects of injustice and oppression.

In this paper, I have proposed intersectionality as a theory and intersectional analysis as a methodology for the critical mathematics educators to address the complexities of social and political realities and to identify ways that our current approaches to research unintentionally participate in figure hiding. Scholars within justice communities commit to justice above all. If we, as critical mathematics educators, take on Rawls' (1971) charge to place justice as our first virtue and to dismantle or reform any social institution that is unjust, we also agree to assume all risk associated with this commitment. Given that critical mathematics education has consistently operated on the fringes of the mathematics education landscape, we are accustomed to a measure of risk. However, we are not as comfortable with being vulnerable with each other.

Intersectional justice communities encourage a different form of accountability. As scholars, we are most often accountable to the theories we use, the participants and institutions we study, to our colleagues via blind review, and the discipline to which we belong. When different scholarly interests come together holding a common value, there is a different form of accountability. Each ism group becomes accountable to the others and, more importantly, to justice itself. While this situation makes us each vulnerable, that vulnerability creates the opportunity for less figure hiding, more critical self-reflection, stronger interpersonal relationships, and more effective coalitions. It is in this space that, I believe, we can do the real justice work required of us as critical mathematics educators.

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“NUMBERS HAVE THE POWER” OR THE KEY ROLE OF NUMERICAL DISCOURSE IN ESTABLISHING A REGIME OF TRUTH ABOUT CRISIS IN GREECE

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The relationships between mathematics, politics and public media are commented on in this address with references to the use and misuse of numbers and numerical expressions which appeared on the headlines of leading Greek newspapers from 2009 until 2012. During this period of time an initially announced by the government as fiscal crisis of the state emerged as a financial crisis of the country and the policies which were developed and implemented by the leading political forces for overcoming it encountered strong social reactions and labor strikes. The choice of particular numerical genres and their projections on the front pages of newspapers contributed to the construction of a regime of truth about crisis in Greece aiming to present the policies adopted as inevitable and to mitigate the social and political oppositions to them, goals which it seems that eventually accomplished.

TRUTH AND POWER

Foucault commenting on the relationship between power and truth he claimed that the distinction of these two notions is actually impossible. Truth is not existed either as an obvious ascertainment or as an independent statement about reality but it is constituted and renegotiated every moment inside a power plexus. In his words,

> “*Truth is to be understood as a system of ordered procedures for the production, regulation, distribution, circulation and operation of statements. ‘Truth‘ is linked in a circular relation with systems of power which produce and sustain it, and to effects of power which it induces and which extend it*” (Foucault, 1980, 133). Thus “*Each society has its regime of truth, its “general politics” of truth: that is, the type of discourse which it accepts and makes function as true; the mechanisms and instances which enable one to distinguish true and false statements, the means by which each is sanctioned; the techniques and procedures accorded value in the acquisition of truth; the status of those who are charged with saying what counts as true*” (Foucault, 1980, p. 131).

The term “regime” is used by Foucault in order to reflect comprehensively the relationship of truth to power; not only the power exerted by the political apparatuses (government, parliament, legal services, courts) but also that exerted on society by an informal system of relations in which many actors are involved (state, parties, church, guilds, associations, organizations, media, businesses, individuals) and a regime of truth it was a precondition of the formation, and it is a condition for the development, of capitalism (op. cit.133).

As put by Foucault,

> “*In societies like ours, the ‘political economy’ of truth is characterised by five important traits. ‘Truth’ is centred on the for m of scientific discourse and the institutions which produce it; it is subject to constant economic and political incitement (the demand for truth, as much for economic production as for political power); it is the object, under diverse forms, of immense diffusion and consumption (circulating through apparatuses of education and information whose extent is relatively broad in the social body, not withstanding certain strict limitations); it is produced and transmitted under the control, dominant if not exclusive, of a few great political and economic apparatuses (university, army, writing, media); lastly , it is the issue of a whole political debate and social confrontation (‘ideological’ struggles)* (op. cit.131-132)

In short, in every society, each historical period, a plexus of mechanisms, procedures and practices is developed, which is applied for the formulation, circulation and maintenance of those statements that the regime of truth seeks to present as truth. The regime of truth in a society is modified whenever major economic, political and social changes occur and these changes induce changes in the established power relations and therefore in the conditions of formulation, circulation and maintenance of truth.

This exactly happened in recent years, from 2009 onwards, in Greece due to an initially announced by the government as fiscal crisis of the state which emerged as a financial crisis of the country and finally turned into a social crisis which resulted to the collapse of credibility of the political system of the country. As a result, the implementation of any political program to tackle the crisis while preserving the interests of capital became extremely difficult without a formation of the necessary in case “regime of truth” which would ensure and finally ensured the consensus or at least the tolerance of the social strata which were demanded to pay the costs for overcoming the crisis.

THE TECHNO-MATHEMATICAL DISCOURSE AND ITS CONTRIBUTION TO THE FORMATION OF A REGIME OF TRUTH ABOUT CRISIS

A techno-mathematical discourse, an amalgam of technocratic and mathematical discourse, became all those years the crucial vehicle for the formulation, circulation and maintenance of a regime of truth. The term "discourse" is used for our purpose as

> "*an instance of situated language use which involves a set of meanings, metaphors, representations, images, stories, statements and so on that in some way together produce a particular version of events and practices which form the objects of which they speak*" (Foucault, 1972, p. 49). Thus, "*if we accept the view that a multitude of alternative versions of events are potentially available through language, then surrounding any one object, event, person etc. there may be a variety of different discourses, each with a different story to tell about the object in question, a different way of representing it to the world*" (Burr, 2003, p. 64).

A techno-mathematical discourse combining the rationality of the scientific discourse with terms, concepts and referents of mathematics transforms to, and presents the economic and social problems as technical problems promoting the view that their solutions is first and foremost an issue of technical regulations and proper managerial arrangements. Such a type of discourse over-using numerical expressions embedded in sentences orienting to their particular interpretations has transformed and transforms any discussion about crisis and its overcoming to a technical discussion; and this "technicization of politics" (a term due to Miller & Rose, 2008, p. 77) imposed through an artificially constructed by numbers image of reality as the reality, which in turn allowed only a certain type of choices and actions. In this regime of truth only those aspects of life which could be quantified and expressed numerically are comprehensible.

In fact, techno-mathematical discourse premises an action it covertly wants to recommend as policy, and then cites "evidence" and "reasoned arguments" which show that this action is the only feasible option. In such a context, any political approaches to the economic and social problems under consideration are "incomprehensible".

NUMBERS IN THE NEWS HEADLINES

The period of time under consideration, a particular version of techno-mathematical discourse structured around numbers and numerical indices, which were annotated and commented upon towards very specific interpretations flooded most newspapers front pages as well as radio and TV news bulletins whenever announced or commented on governmental plans and decisions on the crisis and the policies proper to tackle it. Thus, the press and broadcasting media set in a numerical language the framework and demarcated the content of related political debates. In this way, they played a crucial role in the formulation and enforcement of a regime of truth against which, as mentioned, the austerity policies, the elimination of labor rights and the reduction of the welfare services for the people legitimized and imposed as inevitable, while the objections and reactions of the affected social strata mitigated to a large extent.

This situation may be considered as a characteristic example of the use of numbers in political manipulations, keeping in mind that, as Alonso and Starr (1987, p.3) point out, acts of social quantification are "politicized" not in the sense that the numbers they use are somehow corrupt -although they may be– but because "political judgments are implicit in the choice of what to measure, how to measure it, how often to measure it and how to present and interpret the results". In the following, characteristic dimensions of this aspect of news headlines are presented in order to be highlighted the contribution of a techno-mathematical discourse in the formation of a regime of truth about crisis.

The data are drawn from a study aimed to analyze the numerical discourse which appeared on the front pages of the widely circulated daily Greek newspapers, issued from late October 2009, when the fiscal crisis of the country was first announced by the government, until June 2012 when, after a general election, the implementation of the aforementioned policies seems to have been finally stabilized. The method adopted for analyzing the numerical discourse is based on a version of critical discourse analysis as introduced by Fairclough (1995, 2003).

THE CHOICE OF NUMBERS IN THE NEWS HEADLINES: CREATING A CONTEXT

The main purpose of the newspapers that supported actively the governmental policies and decisions during the period under consideration was to persuade the public that the various consequences of the crisis that broke out in the country have to be borne equally by all citizens regardless of their individual income and its sources, since they have all been involved through their various actions, behaviors and stances in the creation of national fiscal deficits and thus in the causation of crisis. The Greek prime minister and leading persons of the government as well as the parliamentary principal opposition declare this thesis in a variety of verbal expressions.

Creating a context for the formation and promotion of this "truth", various types of numbers and numerical expressions were incorporated in the headlines of the widely circulated newspapers. According to the case, whole numbers, decimal numbers, fractions, but mainly percentages, are selected to put forward a "fact", a decision or a plan. Whole numbers, mainly expressing monetary amounts are in many instances abbreviated, thus requiring for their comprehension mental conversion, fluency which many people, and in particular those having low educational status, may lack.

The dominant numerical expression in the headlines under consideration is, as mentioned, percentages. Percentages, a seemingly simple and easily understandable numerical concept, are the dominant components in the creation and re-creation of a "reality" fabricated by newspapers. However, a percent does not express a quantity but a relation between two quantities; therefore, it is dependent on the change of the one or the other quantity or both and, at the same time, when it is written and re-written as a single numeral these quantities are not referred to at all. Percentages as relations have neither number properties nor may be subjected to number operations. Since they are numerical expressions but not numbers they are suitable for numerical alchemies and appropriate for political manipulations projecting –among other ideas– a false sense of equality, hence equity.

For example, the following headline using percentages, emphasizes the equal treatment of employees regarding the reduction of their salaries but conceals the inequality of the amounts corresponding to each particular salary. Thus, ostensibly and at the level of impressions, presenting the reduction of salaries by means of "equal percentages"


Η βραδυνή

ΜΕΙΩΣΗ
μισθών κατά 4%

Vradyni 19/12/2009

REDUCTION
to salaries 4%

The announced by the Minister of Finance cutback of 10% to allowances and overtime pay of the public servants results in a loss of 4% in their earnings"

obscures the inequality of differences that derives from the number operation of "subtraction" of amounts.

Whole numbers, decimals, fractions and percentages are, depending on the case, used to express a situation of change, an increase or a decrease;


ΕΛΕΥΘΕΡΟΤΥΠΙΑ

ΜΕΙΩΣΗ 35%
ΣΕ ΜΙΣΘΟΥΣ ΔΕΚΟ

«Μην κόβετε το ρεύμα»

Eleftherotypia
25/11/2011

REDUCTION BY 35%
TO
ALL SALARIES
OF EMPLOYEES
IN PUBLIC
ENTERPRISES

a part-whole relation in many cases expressed as a proportion;


ΕΛΕΥΘΕΡΟΤΥΠΙΑ

Παραδοχή Βενιζέλου: Με το Μνημόνιο καταστρέφεται 1 στις 4 θέσεις εργασίας και...

ΣΕ ΚΑΘΕ 100 € ΧΑΝΟΥΜΕ ΤΑ 20

Eleftherotypia 21/12/2011

Acknowledgment of the Minister of Finance: The application of memorandum results to loosing 1 out of 4 jobs and,

IN EVERY 100€ THEY TAKE AWAY 30

or a comparison involving one or more quantities;


ΕΛΕΥΘΕΡΟΤΥΠΙΑ

Απλά παραδείγματα για το τι περιμένει τους συνταξιούχους

Ιδού το τσεκούρι στις συντάξεις

Eleftherotypia 20/04/2010

Simple examples of what to be expected by pensioners

Here is the ax to the pensions

According to cognitive analyses of mathematical problems, “change”, “part-whole”, “combination” and “comparison” are semantic structures that may be considered as describing many of the quantitative situations encountered in everyday life (e.g. Resnick, 1992) and newspapers editors capitalized on all these numerical structures. It is, however, interesting that in many cases the situations of change and comparison are expressed by positive or negative numbers and even positive or negative percentages, thus obscuring their comprehension.

THE CHOICE OF NUMERICAL GENRE: INTERACTING WITH THE READERS

In the front-pages of the newspapers studied, numbers are included in different linguistic genres, the most common being declaration (primarily conveying information) and argument (primarily seeking to persuade), each one used in order to serve a different purpose according to the political interests promoted.

Genre is a typified rhetorical way of recognizing, responding to, acting meaningfully and consequentially within, and thus participating in the reproduction of, recurring situations. Genres both organize and generate kinds of texts and social actions, in complex, dynamic relation to one another. Genre is understood in our study as an ideologically active and historically changing force in the production and reception of texts, meanings, and social actions or as put by Bazerman (1997, p. 19) as "*frames for social … locations within which meaning is constructed* … (which) … *shape the thoughts we form and the communications by which we interact*".

The editors organize their reports in headlines around numbers. Although the information provided may sound real to the reader, its textual structure is not clear because the numbers used are either not clearly comprehensible or may be misunderstood by most readers due to particular number properties and references which may be unfamiliar to them.

In any case, however, the use of numbers gives to their declarations and arguments a sense of objectivity, independent of the person who writes or reads them. As Porter (1995) has explained, the language of mathematics is well suited to embody objective judgments and it is adopted when claims to knowledge need to gain trust and credibility beyond the bounds of locality and society.

When readers engage in the reading of texts composed on the basis of numerical data, it appears to them that such texts are reporting factual "realities" or actual problems to be solved. However, they may feel overwhelmed and thus, although they may be possibly paying attention to the news, they become in fact inactive against the declared or argued situation. The editors strategically decrease the interaction between the two sides of participants, and in the last analysis, between politicians and readers. Numerical discourse seems to be an effective medium in defusing public resentment.

THE CHOICE OF SENTENCES: INFLUENCING THE READER'S INTERPRETATION

The sentences always serve the main purpose of the text. Sentences composed around numbers acquire meaning by the referents of the numbers, the quantitative expressions related to the numbers and the modifiers of numbers. The quantities expressed by the number on each instance are found to denote measures of collections or sequences of discrete instances, as, for instance, are money amounts or population groups. However, the referents of the numbers reported are in some cases individuals and in other cases population or employee groups. In the second case, the numbers reported in order to be made sense of must be traced back to individual cases, a calculation usually unfeasible due to lack of data. For example,


ΤΑ ΝΕΑ

1000 μέρες λιτότητα
και λίστες φοροφυγάδων

Ta Nea 15/01/2010

1000 days austerity and tax evaders lists

Taxes: elimination of tax exemptions 1,1 bn €, real estate tax 400 m €, taxes on cigarettes and spirits 710 m €, tax on corporate profits 870 m €. Cuts: allowances of public servants - 650 m €, new recruitment - 80 m €, personnel reduction – 120 m €, reduction of subsidies – 540 m €.

Furthermore, it is interesting that the target number and the quantitative expressions to which it was related denote in many cases different referents. For instance,


Κυριακάτικη

Στα 65 και -30% όλες οι συντάξεις

Kyriakatiki Eleftherotypia
06/06/2010

Pensions reform:
At 65 years and -30% all pensions

Thus, it is formed a sentence which is rather difficult to be grasped at a glance, in contrast to other cases with the same referent which is instantly comprehensible, e.g.


ΤΑ ΝΕΑ

www.tanea.gr

Δραματικές αποφάσεις για το νέο Ασφαλιστικό

Κλείδωσε η σύνταξη

40 χρόνια δουλειά

60 το όριο ηλικίας

Ta Nea
02/06/2010

Dramatic decisions on the pensions
The pension has been locked

40 years work
60 years of age

Apart from the text, a variety of visual displays adds an elaborate visual dimension to the numerical expressions which influence their interpretation by the readers. The visual displays that the newspapers under consideration utilize, coloring and/or highlighting the numbers, create a referential field for the numerical discourse in use which, as Potter et al (1991, p. 343) have put it function as "parallel commentaries" which reinforce textual numerical expressions. The following depictions are illustrative.


ΤΑ ΝΕΑ

www.tanea.gr

Οι νέοι φόροι του 2010

Ψάχνουν 4,5 δισ.€ σε πέντε... πορτοφόλια

1,5 1 1 700 500

Ta Nea 02/11/2009
The new taxes for 2010

They are looking for 4.5 bn € in five … wallets

MATHEMATICS AND POLITICS

There can be no doubt that

> *"there is a constitutive interrelationship between quantification and democratic government. Democratic power is calculated power, and numbers are intrinsic to the forms of justification that give legitimacy to political power in democracies. Democratic power is calculating power, and numbers are integral to the technologies that seek to give effect to democracy as a particular set of mechanisms of rule. Democratic power requires citizens who calculate about power, and numeracy and a numericized space of public discourse are essential for making up self-controlling democratic citizens" (Rose, 1991, p. 675).*

On the other hand, it has been claimed that the referential meanings assigned to mathematical constructs, being properly manipulated, do not merely inscribe a preexisting real world situation but they constitute it (Chassapis, 1977).

Techniques of inscription in numerical formats and accumulation of facts about aspects of the "national economy", "public debt", "tax incomes" or "labor salaries" render visible particular domains with a certain internal homogeneity and external boundaries. The collection, manipulation and presentation of numerical data participate in each case in the fabrication of a "locus" within which thought and action can occur. Numbers delineate "fictive spaces" for the operation of governments, and establish a "plane of reality", marked out by a grid of norms, on which governments can operate according to the case (Miller & O Leary, 1987; Rose,1988; Miller & Rose, 1990).

At the same time, every such fabrication of real world situations, ostensibly endorsed by the objectivity and neutrality of mathematics and enhanced by the publicity power of media, prevails or actually is imposed as the unique representation of reality and finally as the reality itself (Skovsmose, 2010).

On such a ground, we are faced with a numericization of politics and respectively with a politicization of numbers. Keeping in mind a well known objection made by mathematicians: numbers and numerical operations is not (the) mathematics. I agree that mathematics is not limited to arithmetic, but arithmetic is historically and conceptually the basis of mathematics and the most known and publicly widespread aspect of mathematics.

CONCLUDING COMMENTS

In situations of economic and social crises, in which a plurality of political forces, interest groups and societal views are contesting, numerical discourse used by the media may produce a public rhetoric of interest or disinterest. Such rhetoric may play a crucial role in the creation of a public sphere where technical expertise dominates political debate excluding people not only from political debates but also from acting towards or reacting against political decisions and policies. This “technicization of politics”, as called by Miller & Rose (2008, p. 77), emerges from the transformation of economic and social problems in problems demanding for their solutions technical manipulations of numerical data and thus the imperative of advanced technical expertise. In this account, numbers are not just “used” in politics, they help to configure the respective boundaries of the political and the technical and, furthermore, they are involved in establishing what it is for a decision to be “interested” or “disinterested”. In other words, they crucially contribute in the formation of a regime of truth.

In these processes of technicization of politics, newspapers and media in general function as an important means for the production and dissemination of “truth”, including, excluding or diverting, processing and representing contributing to a large extent to the formation of a society s “general politics of truth”: the appropriate political technologies of truth production and reproduction, the expressions of truth which are deemed acceptable or not, the acceptable mechanisms of judging true and false statements, the sanctioning of statements; and the valorization of claim-makers as truth-tellers (Foucault, 1980). The particular role played by newspapers in the politics of truth concerns the production of “apparatuses of truth” which are discursive practices that are marked by “rules of formation” that define “concepts, procedures and objects”, “limits and forms of the sayable” and “criteria of transformation” that condition discursive performance and change, and “criteria of correlation” that situate discourses among other discourses and non-discursive institutions (Foucault 1980, 1991).

In this context, the governing and dominant political forces and interests in a society organize the truth so that their versions of reality gain credibility over others and, as Rouse (1994, p. 112) remarks, “to make truth-claims is to try to strengthen some epistemic alignments, and to challenge, undermine, or evade others”. Of course, a complete and full account of the highly complex relationships between power, truth and news reports is outside the scope of an essay this size. Yet even the analysis undertaken here, of a limited sample of headlines, demonstrates the fact that numerical discourse, as utilized in the front-pages of newspapers published in Greece during the years when the economic and social crisis broke out, played a crucial role in manufacturing a certain “regime of truth”, which served specific political views and policies as well as specific interest groups.

On the basis of the above conclusion, there emerge difficult questions and new challenges for critical mathematics educators worldwide, who now have to face the following dilemma: they must teach the mathematical meanings of numerical concepts, e.g. percentage, and at the same time they have to select some of the referential meanings of these concepts and reject others, all of which are widely promoted and everywhere visible in public life, today.

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BIOSOCIAL BECOMINGS: RETHINKING THE BIOPOLITICS OF MATHEMATICS EDUCATION RESEARCH[1]

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Biosocial research is at the vanguard of a radical reconfiguring of education research, merging methodologies from the life sciences and the social sciences. Education research has always been enamored with medical and psycho-physical explanations of learning, but there are distinctive new developments in the "biosocial" that mark the current situation as different. Evidence of this new biosocial emphasis can be found in social policy and funding priorities in the US and the UK, where a proliferation of inexpensive digital devices for tracking bodily movement and activity (be it brain activity, eye movement, or electro-dermal skin fluctuations), and a rapid take-up of machine learning and new computational approaches to processing such data, have led corporations like Pearson International to partner with IBM to develop learning and assessment tools that use this technology. Indeed, many contemporary biosocial interventions are being harnessed to highly conventional and reductionist models of learning conceived, designed and implemented by software companies.

NEW BIOTECHNOLOGICAL METHODS

My aim in this paper is both critical and creative, critiquing some current biosocial research into mathematics education while also carving out possibilities for more creative work within this field. My interest is in the proliferation of micro-sensor technology, and the massive tracking of bodily activity that is occurring below the level of human perception –be it neuro-imaging, eye-tracking, electro-dermal pulse tracking, accelerometers or some other device for attending to the 'precognitive' activity of the body occurring outside the small bandwidth of human consciousness. Many of these biotechnologies are being used with children and adults to track and modify attention, engagement, decision-making, emotional states, motion, performance and creativity. These developments are exciting, in that they attend to capacities that are often overlooked or poorly documented in conventional educational and social research, but they also carry serious ethical implications as they permit new levels of intervention.

1. This paper builds on previous ideas published in de Freitas & Sinclair (2016).

In mathematics education research, one finds ample evidence of this turn to pre-cognitive data, attending to the micro-sensory activity of the body as it performs mathematical tasks. Whether it be eye-tracking studies of how students attend and dwell on particular parts of a mathematical diagram or text (Andrá et al, 2015) or fMRI data recorded while children calculate sums (Bugden & Ansari, 2015), this kind of research is changing the way we study mathematics education. My aim today is to think broadly about the ramifications of this kind of research, while focusing in particular on recent research into *number sense*. Dehaene (1997) defines number sense as the "sense of approximate numerical magnitudes", but it has come to be used as a catchall phrase for describing arithmetic skills, particularly in the pre-k to grade 2 curriculum (e.g., NCTM, 2000). With the advent of brain imaging technology, cognitive neuroscientists have shown that a particular group of neurons in the brain –in the intraparietal sulcus (IPS)– are always "activated" whenever humans, and many other animals, are given a calculation task (see Bugden & Ansari, 2015; Neider & Dehaene, 2009). These scientists are searching for the "number neuron" on which they believe number sense is based. The impact of this research on education is potentially profound, as many dis/ability theorists cite it as evidence that number sense is biologically determined (see Chinn, 2015)). On the other hand, the neuro-diversity movement celebrates brain imaging data as evidence that brains are distinct and differently abled.

These findings raise many urgent questions: How does this new research change what it means to know mathematics? Where is the agency of the student when we turn to 'precognitive activity'? How is value being extracted from the body through neurocognitive tests of number sense? And how are the affordances of digital technology driving this kind of research? I'm interested in how the *bodily labour* of mathematics is reconfigured through this research. These developments in education research show how our bodies are being tapped in new ways to shape our theories of learning and to change the very meaning of mathematical dis/ability.

ALTERNATIVE THEORETICAL FRAMEWORKS

Rather than just dismiss biosocial research as failing to capture the complexity of lived experience, my aim is to reclaim the data as part of an entirely different kind of theoretical framework. In other words, I also want to discuss how we might attend to this kind of data, and extract it from its usual theoretical framework, and reclaim it for different purposes. Most of the literature that currently draws on precognitive data –be it eye tracking, brain scanning, or electrodermal data collection– is situated within constructivist theories of learning, that to some extent build on the initial forays into embodied mathematics articulated in Lakoff and Núñez (2000), who argued that the semantic content of mathematical concepts can be understood in terms of the way human bodies function in the world. Such an approach, however, continued to support a mind/body split, even as it attended more carefully to the role of the body in teaching and learning. The issue with "embodied mathematics" research of this kind is that it frequently involves interpreting the material actions of students and teachers as external "simulations" of some prior or primary *internal* conceptualization.

There is, however, a changing theoretical landscape across the humanities, following a paradigm shift away from social constructivist theories of the past decades. This shift is sometimes called "the ontological turn" or "the speculative turn" and involves a radical break with the language-focused theories of poststructuralism that were married (not always happily) to constructivist theories of learning. One might also characterize this theoretical shift as a return to realism (Agential realism in Karen Barad or Speculative realism in Graham Harman). Importantly, this is not the reductive realism of past behaviorisms, which treated matter as inert, passive, and ruled by determinism. This new kind of realism is instead an affirmation of bodily forces and materiality more generally. New materialist philosophers pursue this more radical direction, stretching studies of the body into more inclusive studies of the environment and matter more generally (Coole & Frost, 2010). Working in this vein, I have with Nathalie Sinclair advocated for a more than human "inclusive materialism" in the study of mathematical activity, allowing researchers to address the way that diverse material agencies are at work in teaching and learning. We analyze mathematical activity –be it expert or novice, state-sanctioned or renegade, coerced or free, human or non-human- as a material practice that produces specific kinds of bodies (or transmaterial assemblages) that incorporate, as part of their ongoing modulation, particular kinds of mathematical concepts.

Thus, alongside the methodological shift of the biosocial, in which researchers are taking up new biotechnologies to tap the body for new kinds of data, we have a theoretical shift that considers matter as generative and agential. Rather than simply treat the body as the inert and passive object of political interests, this theoretical framework emphasizes the non-discursive material force of bodies. My interest is in how these two developments –the methodological and the theoretical– might come together in innovative ways, breaking with the reductive scientism that often fuels biosocial research in education. If the previous decades saw researchers focusing on transcript and interview analysis, tracking the grammatical moves of identity construction within mathematics classrooms, the next few decades may well be characterized by (1) the study of the body and other material factors in teaching and learning, (2) the use of digital biotechnologies in structuring and assessing student learning; (3) the tracking of behaviour across assemblages of human and non-human agencies.

In this vein, one can find various projects drawing from neuroscience, genetics, ecology, information theory, anthropology, animal studies, affect theory and other fields to study what Claire Colebrook (2014) calls the "biosocial subject". In related efforts, recent work in anthropology has turned to the study of "biosocial becomings" in order to better understand how the social and the biological operate at all scales, beneath and beyond the human (Ingold & Palsson, 2013). This aim resonates with other biosocial projects informed by new materialisms and new kinds of realisms that are emerging across the humanities (Fitzgerald & Callard, 2015). We see everywhere a renewed interest in how the social and physical sciences might come together in new ways. Rose (2013), for instance, pursues "an affirmative relationship" with an emerging "new and non-reductive biology of human beings and other organisms in their milieu,.. which can thus be brought into conversation with… the social and human sciences" (p. 24). On the other hand, ebullient affirmations of the force of the biological/ chemical without adequate critique, as sometimes found in current work on affect, need to be interrogated (Papoulias & Callard, 2010). And interdisciplinary projects across the social and biological sciences are often sites where "the biosocial nexus starts to look distinctly bio-centric" (Fitzgerald & Callard, 2015, p. 14).

This is an exciting but dangerous time to be working in education research!

NUMBER SENSE

In the last few decades, number sense has become an important touchstone for mathematics education research and policy. Neurocognitive approaches to number sense have become increasingly central in mathematics education research, as was evident in the recent ICME in Hamburg in July 2016 and in numerous other special issues and funding opportunities on this topic. Neurocognitive research into "number sense" began in earnest in the 1950s and 1960s exploring animal, infant and trauma victims' ability to perform tasks that entailed some sort of quantitative discernment (Dehaene, 2011). Dehaene (2011) traces early attempts to study human number sense to 1886 when the American psychologist James McKeen Cattel designed an experiment to test participant's response time during tasks of enumerating the number of black dots on a series of cards.

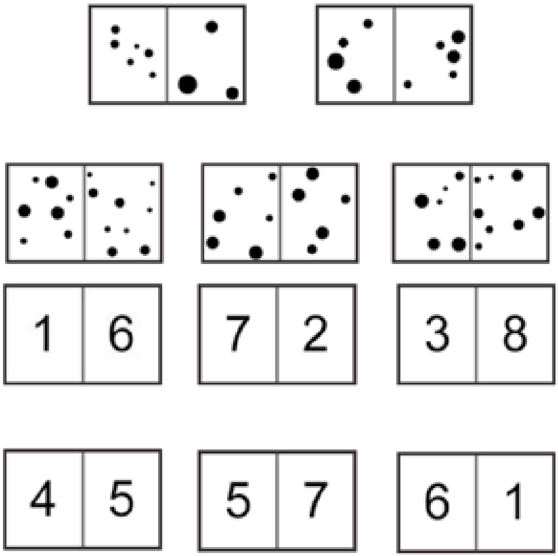

Figure 2: Which is bigger in each pair?

Participants were shown each slide - with two collections of dots or two numerals- and asked to identify the one that was larger. Performance is based on response time –the faster the better. This ‘skill’ is known as “subitization”, or the ability to enumerate without counting. The research with these tests has consistently showed that RT is longer when the numerals are more different (2 and 9, versus 2 and 4), and that this is true for both symbolic and non-symbolic settings (numerals or dots). In much the same way that it is easier to compare two very different weights or sound levels, people find it easier to identify which numeral is larger if they are extremely different. The nature of this cognitive labour depends on which theory is being used; some describe it as a mental construct of an internal number line while others refer to some arrangement and degree of neural activation. These theories, which posit an “approximate number system” (ANS), assume that people (even infants) and some non-human animals have an innate capacity to detect the ‘size’ of a number (see Dehaene, 1997).

The brain imaging evidence seems to suggest that one area in the brain -the intraparietal sulcus (IPS)- is a hot seat of brain activity correlating to such numerical tasks.

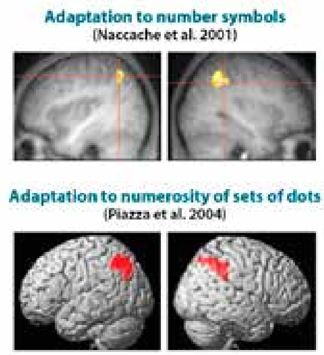

Figure 1: Source Bugden & Ansari (2015). IPS lights up when calculating

The IPS has been referred to as “the region that houses the representational system of quantity regardless of notation” (Budgen & Ansari, 2015, p. 23). It is here that these researchers claim to see the neuronal correlates of “numerical magnitude processing”(Butterworth, 2005).

Perhaps the IPS region is indeed the “ontogenetic neuronal origin” for processing numerosity, although there is evidence that children “recruit” other areas, such as the prefrontal neural regions as well. Indeed, the search for *number neurons* is thwarted by the fact that the IPS and other brain regions intermingle: “there does not seem to be a single, isolated piece of cortex that responds solely to number; parameters of object size and location also seem to be coded by intermingled neuronal circuits distributed within the same general area of IPS” (Nieder & Dehaene, 2009, p. 196). And there is considerable debate on how to identify the numerical tasks that might be adequate in designating a *performance* of number sense. Rips (2015) for instance, points out it is difficult to see how comparing two masses (a feather and a litre of milk), whose weight can be felt, or two spatial areas, whose size can be seen, is so different, especially from the dot task. This would call into question the existence of an isolated cognitive numerical ANS that is not simply part of a more cohesive sensual system. Further, as Rips points out, there are many ways in which we use numbers in everyday life that do not depend on assessment of magnitude, such as turning the dial to the radio station, finding the right seat in the theatre and turning to a specific page in a book. Yet despite all this confusion, the IPS remains the focus of neurocognitive brain imaging research on number sense.

DYSCALCULIA

Neurocognitive research and the IPS figure prominently in the diagnosis of dyscalculia. Studies have shown that children labeled developmentally dyscalculic recruited the IPS less than children without (Budgen & Ansari, 2015, p. 26). Thus the IPS becomes a biomarker of ability in mathematics, and is mobilized in various policies around dis/ability. Tests for dyscalculia include the same neurocognitive numerosity tests and brain imaging discussed above.

Emerson (2015) supplies three definitions of dyscalculia; the first comes from Ladislav Kosc, who formally introduced the term in the 1970s:

> A structural disorder of mathematical abilities which has its origins in a genetic or congenital disorder in those parts of the brain that are the anatomical-physiological substrate of the maturation of the mathematical abilities adequate to age, without a simultaneous disorder of general mental functions. (Kosc, 1974, p. 165)

Kosc's use of the term "maturation" is significant, as the distinction between maturation and learning will be enforced by Dehaene and others doing neurocognitive research, with the aim of identifying biological primitives for number sense that are independent of learning. The UK Department of Education, on the other hand, three decades later, defined dyscalculia with explicit reference to problems with *learning* number facts:

> Developmental dyscalculia is a condition that affects the ability to acquire arithmetical skills. Dyscalculic learners may have difficulty understanding number concepts, lack an intuitive grasp of numbers and have problems learning number facts and procedures. Even if they produce a correct answer or use a correct method, they may do so mechanically and without confidence. (DfES, 2001 cited in Emerson & Babtie, 2013, p.1)

In this definition, the notion of "intuitive grasp" of numbers suggests that there is some lack of sense-making, 'I can do it but it doesn't make sense'. The dyscalculic is thus alienated from the intellectual labour of computation because they lack this "intuitive grasp" of number operations, despite their material capacity to do it.

The World Health Organization (2010) has defined dyscalculia as a disorder attached to actual kinds of mathematical operations:

> Involves a specific impairment in arithmetical skills that is not solely explicable on the basis of general mental retardation or of inadequate schooling. The deficit concerns mastery of basic computational skills of addition, subtraction, multiplication and division rather than of the more abstract mathematical skills involved in algebra, trigonometry, geometry or calculus. (WHO, 2010, F81.2)

More recently, attempts are made to disentangle dyscalculia from other conditions in Kaufmann et al. (2013):

> Primary Developmental Dyscalculia is a heterogeneous disorder resulting from individual defects at behavioural, cognitive, neuro-pyschological and neuronal levels. The term Secondary Developmental Dyscalculia should be used if numeral/arithmetic dysfunctions are caused by non-numerical impairments such as attention disorders.

Finally, dyscalculia has been included in the 2013 *Diagnostic and statistical Manual of Mental Disorders* DSM 5, which is used across the world to diagnose and identify problems with "number sense", as "patterns of difficulties characterized by problems with processing numerical information, learning arithmetic facts, and performing accurate or fluid calculation" (APA 2013, p. 67). This DSM definition is pivotal in how it shifts the focus to the cognitive labour of "processing numerical information", using the language of computational informatics to describe number sense.

As Gifford and Rockliffe (2008) point out, the plethora of diverse definitions of dyscalculia makes the concept vague and open to misuse. Moreover, we can see how the definition shifts towards a more bio-informatic image of number sense, as education policy increasingly turns to brain research.

THE PROBLEM OF TEMPORALITY & ORDINALITY

One of the issues at the heart of neurocognitive research, troubling all of its scientific claims, is the question of time and temporality. This issue emerges in different ways. First there is the famous binding problem, which points to the lack of explanation of how a set of neurons associated with different tags –shape and number for instance– would fire simultaneously or be bound together when we think or observe two different kinds of polygons. This leads to the untenable claim that there is, for instance, a neuron for everything –even, say, your grandmother in her blue hat. On the other hand, the temporal approach suggests that there is a rhythmic spiking that unfolds for each neuron, and that resonant rhythms are generative of the kind of differences to which we attend. In other words, synaptic *events* assemble and resonate and are not instantaneous.

Another example of how time and temporality are an issue in this research involves the experimental equipment, which is fMRI, EEG or ERP, all said to measure neuronal correlate activity *with delay*. This delay makes it hard for researchers to claim correlation between stimulus and response.

In addition, the tasks themselves, as you've seen, are principally focused on near instantaneous judgements of the size of numbers or sets. Nieder and Dehaene (2009) identify two fundamental numerical concepts, associated with two different "empirical properties" of number sense: the first is *numerical quantity* (the cardinality of a set) and the second is *numerical* *rank* (the serial order of elements in a set). These correspond to set theoretic distinctions between cardinality and ordinality. As was the case with the early experimental investigations into number sense discussed above, the focus on subitizing emphasizes the cardinality concept. Regeiso-Crespo and Castro (2015), for instance, focus on *magnitude processing* of numbers in symbolic and non-symbolic formats and describe "numerical magnitude" exclusively as cardinality: "To grasp the magnitude concept we need to learn the distinction between the transformations that do or do not modify the cardinality of a set (e.g., adding or removing objects in a set modifies the cardinality; spreading or grouping objects does not). We also need to compare between the numerosity of different sets (e.g., set A could be smaller, larger or equal to set B)" (p. 60).

The experiments that are typically used in this research depend on automatic, near-instantaneous participant responses, which are more suitable for judgements of cardinality than of ordinality (Lyons & Beilock, 2011). Ordinality has a significant *temporal* dimension because counting unfolds in time, unlike semi-instantaneous judgements of the cardinality of sets. Indeed, number becomes a temporal event *through* ordinality, and this temporal dimension of number is crucial for reclaiming the labour involved in number sense. In other words, neurocognitive approaches effectively *deny* the ordinality of number, and thereby *deny* the time-value of cognitive labour. This bias towards the cardinality of number is a significant biopolitical issue because of the way it delimits the capacity of bodies and also the potentiality of mathematics.

My argument is meant to operate at two levels: on the one level, this kind of research produces dis/ability in human bodies through its image of what constitutes number sense, and on the other level, this research wrongly assumes that cardinality is the fundamental function or meaning of number.

We can see this bias in development models and "learning trajectory" models, which claim that subitizing and ANS (approximate number sense) enable the later development of comprehension of ordinal relations (Rubinstein & Sury, 2011). As a way of addressing the over-emphasis on cardinality, Lyons and Beilock (2011) devised an ordinal task in which sequences of three numbers (or three sets of dots) were shown to participants, who then had to decide whether they were correctly ordered (either ascending or descending) or not. For example, the sequences [2, 3, 4] and [4, 3, 2] are correctly ordered but the sequence [2, 4, 3] is not.[2] The researchers compared "close" sequences, in which the numerals were

2. Lyons and Beilock (2011) argue that this task differs from previous ones that aimed to study ordinality where two numerals were given and participants were asked whether one arrived earlier/later than the other or whether the numbers were in ascending or descending order, because these tasks actually required an initial judgment about cardinality.

consecutive, with “far” ones in which the difference between the numerals was two.

They argue that this experiment shows how the meaning of a numeral is relational, strongly tied to the unfolding of the *sequence* of numerals. This seems to suggest that the ordinal task calls upon the embodied memory of the rote and rhythmic experience of the “number song” (counting aloud 1,2,3,4,5,6 …). This hypothesis is interesting to consider in light of Seidenberg’s (1962) theory of the ritual origins of counting, in which the recitation of a ritual count precedes, historically speaking, the more cardinal counting of things (animals, people, money, etc.). Seidenberg argued that acts of ordinal counting are principally about calling forth the next or an(other), making the new or next appear, and not just about ordering that which is already visible. This emphasizes the power of ordinality, how it unfolds in time, how it indexes an *unfolding event* and future indefinite collective, and thus how it makes number temporal and generative. For Seidenberg (1962), number originates in human culture through a *ritual* ordinality, whereby participants in a ritual are called forth as one and then diffused in the ritual. This is an intensive transitive number –a number that is more than a predicate. Rather than timeless cardinal numbers that are either “processed” by brains or not, a more robust approach to the embodied experience of ordinality brings temporality back into number. Static images of sequences fail to capture the temporality of ordinality: 8 is bigger than 6 not only because it is further away along the presented number line, but because it takes longer to count to.

AN EXPANDED NOTION OF NUMBER SENSE

The fundamentally temporal nature of ordinality demands an ontological shift in the way we think of number. We need to recognize number as an event, as an interval of time, rather than an object. By reducing ordinality to the set theoretic notion of an ordered set, we produce an image of number that is static rather than dynamic. The temporal dimension of ordinality is essential for reclaiming the time-value of number sense. And this relates directly to political questions about the bodily labour of mathematics.

Turning to the philosophy of mathematics opens up speculation about number, and turns away from the more dominant psychologizing of number sense. My argument is thus more philosophical than psychological, more speculative than what we often find in constructivist theories. I am interested in bringing more speculative philosophy into mathematics education research. Turning to Deleuze, I find inspiration, as he aims to rescue the concept of ordinality from being only the ordering of a set. The ordinal for Deleuze taps into the genetic differential and virtual depth of the “intensive spatium” that is the engine of his intensive ontology

(Deleuze, 1994, p323). For Deleuze, the concept of ordinality, rather than cardinality, is associated with the "intensity" of number: "even the simplest type of number displays this duality: natural numbers are first ordinal, in other words, originally intensive. Cardinal numbers result from these and are presented as the explication of the ordinal" (Deleuze, 1994, p. 322). He claims that counting is not only an act of determination of size (a naming of magnitude), but must actually entail a kind of dice-throw or affirmation of all of chance (Deleuze, 1983). When he says "all of chance" he means the *essential contingency* which is always rumbling beneath our clear and distinct concepts of number, destabilizing the concept of number itself. For instance, as I lean in to count the faces on a polyhedron, I move from face to face (one, two, three ...) and this activity entails my affirming not just the individuated number of faces, but *all of numeracy*. Counting might seem like a simple affair, but this obscures the indeterminacy at the heart of numeracy. Numeracy is continuously thread into the folding fabric of life, and each time we engage with number, we plug into the problematic of assembling the discrete with the continuous. Counting is both a blocking of that continuity (whereby I perform a particular count and number) and an affirmation of that continuity (whereby I feel the flow of an absolute infinite count - all of indeterminate number – and in some sense affirm all of chance) (Deleuze, 1983). Deleuze inserts chance and multiplicity into each and every individual count, but also, and perhaps more controversially, he claims that number is precisely how chance thrives.

Deleuze helps us reconsider the ontology of number. Again, my aim is dual –at one level, a political treatment of the research practice, and at the other level, a philosophical treatment of the mathematics itself. Together, I am hoping that this brings the material together with the mathematical in ways that allow us to think quite differently about the future of education research.

PRECOGNITION, DELAY AND FUTURAL MATTER

There is a larger concern that haunts this micro-sensory research- that being the fundamental delay of consciousness in relation to the body. Benjamin Libet's famous experiments in the 1970s showed that there was a microtemporal gap that separates neuronal events from consciousness –this was a missing half-second between brain activation and awareness. Neuroscientists like Antonio Damasio suggest that this delay undermines the agency of consciousness because it seems as though conscious discernment is simply that which performs or ratifies what has already been `decided' by the brain. Perhaps this shows how consciousness is an epiphenomenon, a belated effect of material conditions. Perhaps any process of becoming human entails this tragic aspect of coming too late to the party.

The accelerated speeds of new biometric devices seem to further bracket consciousness – plugging into number sense while circumventing the slow deliberative time of human consciousness. Hansen (2015) claims that data-gathering from computational microsensors "modulate[s] worldly sensibility directly" without the human subject necessarily recruiting any value from this activity. The humans are on the sidelines –they may indeed be effected, but indirectly because this new kind of digital technicity is simply better at plugging into a worldly vibrational sensibility. Humans –with their unwieldy organs– simply are not as good at plugging into that vibrational sensibility or "intensive spatium", to use Deleuze's term.

This proposal seems to echo Catherine Malabou's argument in her book *What should we do with our brains* (2008), regarding the profound plasicity of the brain. Brain plasticity allows for a new temporal dynamics characterized by a fundamental futural orientation. Consciousness in this new futural aspect doesn't simply lag behind the material efficacy of the brain, but plugs into the potentiality of the grey matter. According to this approach, neuronal events harbor an anticipatory orientation, a potentiality that is onto-generative. Because matter is vibrant and intensive, the experiments do more than record synaptic *actions*. The equipment plugs into the tendency, capacity, propensity or potentiality of the brain.

Now the proposal that the living present already includes the tickling agitation of the future was proposed by Edmund Husserl using the term "protention" and so it is indeed part of the phenomenological tradition. But this, argues Hansen (2015), was largely based on a 'ground' of finite possibilities, of memory and past as inert and recorded. And involved a mental mediation by which the human subject would access this potentiality in the present moment through ratiocination or consciousness. The future was then a sort of projection or a set of expectations based on mental or conscious reflection on this accumulated past. Instead, Hansen (2015), following Whitehead, argues that the future is felt in the present because the future is literally produced (rather than predicted) from out of the real potentiality of the present settled world. If we are looking for evidence of that potentiality in the present moment, we should attend to feelings of intensity. Hansen (2015) suggests that intensity –the vibratory character of actuality– is the future animating the present moment. The intensity of the present moment "simply is the index of the power of this potentiality" (Hansen, 2015, p. 210).

Thus it seems that these digital intrusions "enjoy a sensory domain all their own" (Hansen, 2015, p. 234) and are able to access "primordial sensibility" (Hansen, 2015, p. 234). This does seem to support the view that we can begin to consider sensibility outside the human-centric notions of perception, as there is no subjective unity capable of hosting perception.

What is at stake here, then, in our research on number sense, is a shift away from perception studies and constructivist theories of learning. This has huge ramifications for our research on mathematics education. How should mathematics education research proceed if we are to avoid the two dangerous poles of posturing scientisms and mystical obscurantisms? In other words, how avoid referencing this biodata as the singular cause of ability, while also avoiding the mystical assignment of occult forces at work in matter? If the human subject is a kind of after-image of subpersonal neurological and sensory-motor processes, what is the best way to research number sense as that which is imbricated across an environment? While one might consider neuroscience as that which seems to offer a 'disenchantment of nature' because it reduces matter to mere mechanism, my new materialist interpretation of this data affirms the indeterminate *generativity* of matter. And yet, I am still wondering, what should our research methods be as we take up neuro-data in non-reductive ways?

Of course, we are all too familiar with the threat of those who capitalize on this 'precognition' data. Today's data industries use predictive analytics to target the `operational present' of neuronal labour as a means of controlling the future. Surely all this granular sensing will lead to nothing else but more control. As Sally Satel and Scott Lilienfeld (2013) suggest, we may need to reject this kind of research because it cannot but undermine our commitment to civic, legal and ethical notions of freedom. Indeed, doesn't neurocognitive research simply deprive us of our ability to shape how are sensibility becomes our experience?

Tentatively, my answer is no. Hansen directs our attention to some key points (1) Data extracted from neuronal labour is not simply the recording and storing of human bodily experience, but is also a direct engagement or encounter with a posthuman `sensibility'. (2) The problem is not so much the technical accessing of causal efficacy but the fact that such data is stolen to serve the control state. We must not turn our backs on the technology permitting such data capture, but remain vigilant about how this technology plugs into a more expansive sensibility.

This suggests that the biosocial movement might move "from perception-centred accounts of experience to a broader understanding of sensibility as the concrete texture of experience across the board" (Hansen, 2015, p. 48). Indeed, the very notion of "lived experience" –as that fundamental focus of most if not all phenomenology– becomes unrecognizable in a world of microtemporal biometric data that circulates and is absorbed at rates well below and above the bandwidth of human consciousness. The crucial thing here is that this biotechnology is no longer a surrogate for a human faculty or capacity but instead operates directly on the sensibility of the "total" environment which precedes and underlies our own corporeal phenomenal experience. Thus the IPS data about number sense that feeds into current data gathering and predictive analytics can actually be seen as exposing the radical exteriority of experience. The challenge is to study neuronal participation in learning, without making it the biomarker of some essential interiority possessed by the individual. This approach has been taken up in the critical dis/ability literature in, for instance, Shakespeare and Watson (2001) who argue for an affirmative movement, where dis/ability is redefined as "[t]hat in the body which exceeds deterministic efforts to predict a life trajectory" (Snyder & Mitchell, 2001, p. 377).

The disability theorist James Overboe also takes on this task by arguing for an "impersonal life". Overboe (2009) borrows the term impersonal life from Deleuze so as to study 'a' body that does not belong to us in any definitive way –it is *not* personal. An impersonal life is a life that is networked and entangled in ways that trouble the conventional conception of person, and that allow for a radical potentiality. This impersonal life is a "pre-reflexive and impersonal consciousness, a qualitative duration of consciousness without a self ..." (Deleuze, 2001, p. 25). The disability theorist Goodley (2009) suggests that "the metaphor of the body as organism refers to an endemic societal view of the body as sovereign self: contained, knowable, measurable, and dis/abled" (p. 264). These developments in dis/ability theory are now studying sensation as that which is dispersed across an event, where a body is always becoming individuated with a provisional set of organs open to constant reorganisation.

CONCLUDING REMARKS: A NEW BIOPOLITICS

Foucault (1976) used the term *biopower* to describe the 18th century "explosion of numerous and diverse techniques for achieving the subjugations of bodies and the control of populations" (p.140). Biopolitics describes how capital saturates everyday life –health, hygiene, sexuality, learning– in order to control populations and to extract new value from new kinds of labour. Lazzarato (2002) emphasizes how biopower operates within a complex biopolitical terrain in which control and governance operate along with creative acts of becoming. If earlier versions of biopolitics tended to treat the body as a neutral container shaped entirely by political forces, there is now widespread interest in rethinking the power of the body in contemporary biopolitics (Negri, 2008; Protevi, 2013).

For instance, Malabou (2010) argues that Foucault's genealogical approach to the study of power needs to engage with the micropowers that operate at the cerebral level. It is time, she suggests, that we build a neuropolitics to address our current sociotechnical attachments to the body. Plasticity is, she continues, at work at all scales, be the neuronal or the expression of gender –in other words, plasticity captures our current metamorphic condition as we plug into the accelerated logics of the digital, and reconfigure the material relationality of our bodies.

> We have to stop thinking that politics is an expression of consciousness: it is something else. I think we are in a similar moment but with new forces, which are, yes, biological. For me, the political gesture is to try to figure out what this new non-awareness is. So political awareness is dependent on a new political unawareness and we have to understand what it is (Malabou, 2012).

Deleuze and Guattari (1987) offer similar suggestions, demanding we think the political at diverse scales, tracking traits and flows of capital across the molecular and the molar. In their claim that "every politics is simultaneously a *macropolitics* and a *micropolitics*" they shift focus to the molecular and imperceptible level (*italics in original*, p. 213). This molecularization of politics has the potential to radically open up our research to new ways of attending to the biopolitics of life. This approach underscores the way in which capitalism extracts value at all scales and speeds, whether it be from human qualities (race, gender, sexual orientation, etc.) or from the mathematical labour of eyes, hands, and neurons..

Neurocognitive research on mathematics dis/ability is redefining how mathematical competencies are performed and observed. Through this research, and related policy, the student's body is being reconfigured and reassembled. The conventional understanding of how a body "knows" mathematics is changing, and this change entails a simultaneous change in what constitutes number. As number neurons take on a more significant role in student achievement, the question as to what or who is doing mathematics is raised. Dystopic images of brains in vats come to mind, as they should, but this is not the time to deny the material force of neurons. Neurons do actually participate in learning, and create value, and we need to understand the way that value may or may *not* be recuperated by the human body. In other words, the neuron is currently being isolated as a worker 'whose' labour can be tapped and managed. This decidedly nightmare situation is also where we must turn, however, if we hope to generate an approach to dis/ability that is adequate to the accelerated flows of advanced capitalism. We need to find new ways of studying how the neuron participates in learning events, not simply as a biomarker of dis/ability.

This crucial shift in mathematics education research undermines the very notion of a learner as someone who identifies more or less with the norms of a human population. Previous notions of identity and subjectivity that posit a stable norm against which one reacts or conforms (the good student or the white student) are displaced by new molecular processes of differentiation. As researchers attend to the 'more than human', linking neurons directly to automated sources for modulating stimulus, our understanding of what constitutes the 'social' at MES needs to be reconsidered. We need to study how the digital sensors track the limit of human perception and turn it into the source for technical innovation and new configurations of control and governance. This paper has explored in particular the temporality of bodies –be they human, neuronal or conceptual– showing how new socio-technical plug-ins are changing the speeds of our collective material conditions, and demanding an entirely new bio-politics. A focus on temporality in this research practice (its technologies and experiments) and on the assumed atemporality of number (as "timeless truth") is crucial if we are to subvert the predictive analytics that claim *to know* the future based on present neuronal patterns.

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MATHEMATICAL FUTURES: DISCOURSES OF MATHEMATICS IN FICTIONS OF THE POST-2008 FINANCIAL CRISIS

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In this paper, I try to think against the view of mathematics as the most innocent and universal of disciplines, by exploring its implication in the ongoing 'crisis' following the 2008 financial crash. Mathematical instruments were at the heart of this crash. Yet, what are the stories we tell about the place, power and potential of mathematics through this crisis? To answer this question I analyse four financial-crisis fictions: the films Margin Call (Chandor, 2011) and The Big Short (McKay, 2015), and the novels Kapitoil (Wayne, 2010) and Capital (Lanchester, 2012). I argue that these fictions offer tentative critiques of the objectivity and elitism of mathematics that we can use to open up different mathematical possibilities.

INTRODUCTION

Jane Flax (1993, p. 32) wrote:

> I believe that four of the greatest tragedies of modern Europe –slavery, the oppression of women, Nazism and Stalinism– were potentiated by our collective wish that innocent and universal positions are possible and desirable.

Reading this and coming to MES during my doctorate helped me to think about how mathematics, positioned as the most innocent and universal of all disciplines, is implicated in terror and crisis. In this paper I try to develop this thinking by focusing on the ongoing crisis following the 2008 financial crash. The impact of the financial crash of 2008 has been global and devastating. In Greece, it has led to a public health crisis, with increases in the rates of suicide, mental health problems, tuberculosis, drug use and HIV infection (Chelala, 2015). Greece's education budget has been slashed by over 40% and youth unemployment remains above 50% (Education in Crisis, 2013). Mathematical instruments were at the heart of this crash. For example, mathematicians working in finance devised Collateralised Debt Obligations (CDOs) that bundle together thousands of debts and sell them off in slices with precisely calculated risks attached. Yet, what are the stories we tell about the place, power and potential of mathematics through this crisis? To answer this question I take a poststructural approach to analysing four financial-crisis fictions: the films *Margin Call* (Chandor, 2011) and *The Big Short* (McKay, 2015), and the novels *Kapitoil* (Wayne, 2010) and *Capital* (Lanchester, 2013). Stories matter. As Liakos and Kouki (2015), identify, they are central to how the crisis is playing out in Greece, as 'interpreting the past has been an arena of rival social visions, class divisions and interests over who is to blame, what is to be done and by whom'.

I first developed a poststructural approach when I investigated the intertwining of mathematics and gender for the study discussed in my book *Masculinities in Mathematics* (Mendick, 2006). For those unfamiliar with poststructuralism and with the time and inclination to learn more, the opening chapter is available here: https://www.academia.edu/165900/Masculinities_in_Mathematics. In brief, we can define poststructuralism through two orientations on knowing and being.

First, truth is re/positioned as the subject rather than the object of research. Within poststructural research, the goal is not to find truth outside the research but to explore the interweaving of power and knowledge that results in some things acquiring the status of truth. This of course implies seeing everything as socially constructed. But:

> it is not very enlightening to be told repeatedly that something claimed as 'objective' is in fact 'socially constructed'. Objects of thought are constructed in thought: what else could they be? So the interesting questions concern the ways in which they are constructed. (Rose, 1999, p. x)

To explore these 'interesting questions', poststructural analysis focuses on discourses, the collections of meanings through which objects come into being (Foucault, 1972). Studies track discourses, their rules and regulations, continuities and disjunctions, mapping the broader discursive formations we find 'whenever, between objects, types of statement, concepts, or thematic choices, one can define a regularity (an order, correlations, positions and functionings, transformation)' (Foucault, 1972, p. 38).

Second, human being is produced through discourses as people position themselves and are positioned within networks of power. Discourses discipline us into certain ways of being and acting, creating within us specific relationships to selfhood. The term subjectivity is used in place of identity to capture how we are simultaneously the subject of and subjected by discourse, with no essence or individuality that can be thought outside of that. As mainstream philosophy and sociology define human agency in terms of the capacity of individuals to act, the idea that we can never escape power seems to foreclose possibilities for agency. However, I would agree with Judith Butler that:

> the reconceptualization of identity as an *effect*, that is, as *produced* or *generated*, opens up possibilities of 'agency' that are insidiously foreclosed by positions that take identity categories as foundational and fixed. (Butler, 1999, p. 187, original emphasis)

These poststructural positions on knowing and being are ones that recur through MES. They are also central to the interventions I want to make in this conference.

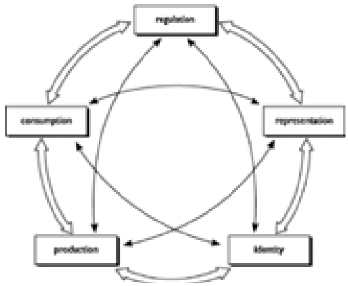
TWO INTERVENTIONS INTO MES

Like many others, MES is important to me. When I first encountered it while doing my PhD, I left feeling less isolated in my interests in the politics and sociology of mathematics. I have since moved away from the conferences as I have shifted from mathematics education research to studies of celebrity, youth aspirations and science education. More recently, I have moved away from academic conferences generally, as I have changed from being an institutional to a freelance academic. In returning to MES in 2017, I hope to intervene into two ongoing debates.

The theme of my last PME back in 2006 was 'mathematics in the centre'. This reflects an ongoing concern to locate the mathematics in mathematics education. While 'where's the math/s?' is not a question I expect to hear at any MES, I was asked it informally at MES7 in Cape Town. Via the ensuing conversation, I came to understand that my interlocutor and I were working with different ideas of mathematics, so that I could find it where she could not. Poststructuralism directs us to look not for what maths 'is' in an objective sense but for the discourses that bring it into being. If we view mathematics as a cultural text, we can find it by studying a circuit of culture (Figure 1), covering:

> its language or form of *representation*, its meanings; how it is used to mark *identity* and difference –what cultural identities it is helping to construct; its conditions of *production*; how it is transformed, and new meanings created, through circulation, *consumption*, appropriation and 'use'; how its uses and circulation are regulated, and what norms of *regulation* this reinforces. (The Open University of Hong Kong, no date, additional emphasis)

Figure 1: The circuit of culture (du Gay et al, 1997)



By focusing on how mathematics is represented in financial-crisis fictions, I hope to contribute to re-imagining mathematics as a cultural text rather than a body of knowledge and so to think differently about where the mathematics is in MES.

Also at MES7, Anna Chronaki (2013) offered a poststructural analysis of mathematics teacher identity politics around technology use. The responses to her paper largely ignored both her substantive arguments on teachers' social constructions of technology use for mathematics teaching and her original theorisation of the politics of 'identity work' based on Laclau and Mouffe (Lange, 2013; Pausigere, 2013). Her use of poststructuralism was subject to a level of critique not applied to the theories adopted by the other keynote speakers. In the subsequent discussion, the scepticism to poststructuralism seemed to be part of a commitment to activism that postmodern/poststructural approaches are often taken to preclude. Like Butler (2004, p. 48), I do not want to get tangled up in theoretical wrangling:

> We could have several engaged intellectual debates going on at the same time and find ourselves joined in the fight against violence, without having to agree on many epistemological issues. … If you saw me on such a protest line, would you wonder how a postmodernist was able to muster the necessary 'agency' to get there today? I doubt it. You would assume that I had walked or taken the subway! … We do not need to ground ourselves in a single model of communication, a single model of reason, a single notion of the subject before we are able to act.

However, also following Butler, in this paper, I am trying to make an implicit argument about the political potential of a poststructural move away from truth and essence, alongside my explicit argument about (representations of) mathematics.

SAMPLING FICTIONS OF THE POST-2008 FINANCIAL CRISIS

My focus on fictions about the post-2008 financial crisis is a response to the conference organisers' invitation 'to consider mathematics education, life and crisis as entangled and to explore ... what might be the potentialities afforded by mathematics education and mathematics education research towards confronting crisis' (MES9, 2016). I have long been interested in discourses of mathematics in the varied accounts of the global financial crisis. For this paper I began to collect examples of these into a makeshift archive. My archive is eclectic and structured through my encounters: 'my archive is also my world, my life-world, my past as well as present, where [ideas of mathematics have] echoed so powerfully' (Ahmed, 2010, p.19). I have chosen texts for diversity of form, focus and year of release, to explore how mathematics is imagined across the visual and the verbal. The diverse texts that I have 'read' include documentaries, such as Michael Moore's *Capitalism: a love story*, Charles Ferguson's *Inside Job* and Terry Gilliam's *Boom Bust Boom*. But for this paper I focus on popular fictions that challenge divisions 'between fact and fiction, history and story, truth and lies' (Popple and Macdonald, 2012, p. 4).

The films *The Big Short* and *Margin Call* centre on (mostly male, mostly white) workers in the US financial services sector. Their central characters notice problems in the derivatives markets before the rest of their sector and seek to profit from these. In *Margin Call*, we spend a night in the offices of an investment bank which has spotted an existential problem with their trading model. In a series of meetings between employees, they discuss how to respond, ultimately deciding to sell the assets that they now believe are toxic before a loss of market confidence renders them unsaleable. Being set mostly at night, inside the bank, it has a claustrophobic and eerie feeling. *The Big Short* is based on a true story of 'outsiders' who bet against the housing market, years before the bubble burst. We follow the financial crisis through their lives, as they take a risk and finally cash in their investments as the US economy and people's lives collapse around them. As I discuss more later, it is self-consciously postmodern with, for example, characters 'breaking the fourth wall', speaking direct to camera, to tell us whether the scenes depicted 'really' happened.

Kapitoil is a first person novel centred on Karim Issar, a young man from Qatar who is seconded to the Wall Street headquarters of his US employer, Schrub Equities, to tackle the Y2K bug. The book takes the form of his diary entries from 3 October to 31 December 1999 inclusive. Although set nearly a decade before the crash and two years before the 'war on terror' began, it can be read as a comment on both the financial crisis and post-9/11 US. We follow Karim as he creates a program (the eponymous Kapitoil) designed to use news reports on the Middle East to predict oil price fluctuations. We see how he deals with his company's attempts to control his program and with his developing sexual relationship with co-worker Rebecca.

Capital centres on a London street, Pepys Road, whose residents have benefited from the property boom. The novel's narration moves between 20 characters' points of view, including: Roger, a manager in an investment bank, Arabella, his shopaholic wife, and Mark, his ambitious deputy. Lanchester's sprawling 'state-of-the-nation' novel offers snapshots of its characters' lives in December 2007, and April, August and November 2008 as the financial crisis unfolds and Roger loses his job shortly before his bank goes under. Among the interlocking storylines is one focused on a campaign of harassment in Pepys Road, as residents begin to receive postcards bearing images of their homes and the words 'We Want What You Have'.

All four texts are broadly critical of the free market capitalist status quo that led to and sustains the ongoing financial crisis. The titles *Capital* and *Kapitoil* both reference Karl Marx's classic analysis of capitalism in *Das Capital*; *Margin Call* and *The Big Short* track that moment when it seems, in the words of the *Manifesto of the Communist Party*, 'all that is solid melts into air' (Marx, 1976; Marx & Engels, 1952). In this paper, I will argue that, because of this critical positioning, these fictions, while reproducing some dominant discourses of mathematics and mathematicians, also introduce new ways of viewing mathematics which trouble its objectivity and elitism.

In the past, I have written extensively about representations of mathematics and mathematicians (e.g. Mendick, 2015; Mendick, Moreau & Hollingworth, 2008). Perhaps because of this, I initially noticed the continuities between these four texts and the dominant discourses. But as I persisted in reading and rereading them, analysing them as part of wider discursive formations, I began to see discontinuities. I was drawn to 'optimistic readings that push the possibilities of both the dominant and the alternative as far as possible' towards mathematical ways of being that open up spaces for 'the pleasure of creative analytical media consumption … committed to social justice' (Projansky, 2014, p. 22). In the next two sections, I show how these texts both reproduce and trouble dominant discourses of mathematics as an objective and elite activity respectively, suggesting more subjective, open, democratic possibilities.

TROUBLING OBJECTIVITY: UN/FAMILIAR IMAGES OF MATHEMATICS

Typically films (and television programmes) use two visual techniques to represent mathematics (Mendick, 2015). First, there are specific images that stand in for the process of doing mathematics, usually, people writing feverishly on windows, mirrors and transparent whiteboards. Second, there are scenes that seek to explain mathematics. These extract you from the normal mise-en-scène, as images change to depict structure and pattern, and naturalistic speech is replaced by a pedagogic voice-over from a mathematical 'genius'. Such scenes naturalise what Ole Skovsmose (1994, p. 42) calls the formatting power of mathematics, the way that:

> mathematics produces new inventions in reality, not only in the sense that new insights may change interpretations, but also in the sense that mathematics colonises part of reality and reorders it.

These scenes convey the power of mathematics and the role of mathematicians in mediating that. Their specific mathematical content is irrelevant to the story.

There is no frantic writing in the *The Big Short* and *Margin Call*. The new visual shorthand for doing mathematics in these and other financial-crisis films is typing into computers, as small screens of numbers and graphs flicker across the big screen. This shift, from old-fashioned to contemporary images, arguably makes mathematics appear more accessible. This is supported by the four scenes explaining mathematics in *The Big Short*. Three exist outside of the main narrative, as in other mathematical fictions, using glamour, celebrity and metaphor to describe the financial mathematics of mortgage-backed securities, shorting a market, CDOs and synthetic CDOs. They feature: actor Margot Robbie sipping champagne in a bubble bath; celebrity-chef Anthony Bourdain preparing food in his restaurant; and 'Dr Richard Thaler, father of behavioural economics' and 'International Pop Star' Selena Gomez playing 21 in Vegas. In a change from previous representations of mathematics, the film invites its audience to understand the ideas and these are integrated into the subsequent narrative. The film's narrator, banker Jared Vennett, sets these scenes up in opposition to the confusing use of 'financial jargon' that he describes as a deliberate strategy to exclude by making 'you feel bored and stupid'. This financial jargon is implicitly mathematical.

Beyond this focus on the accessibility of mathematics we find a challenge to its objectivity. In a key scene, Jared tries to sell the idea of shorting the housing market. He is asked 'You're completely sure of the math'? In reply, he points to 'my quant', an East Asian man. Jared explains he speaks no English, is called Yang and came top in a China mathematics competition. The film instantly cuts to the 'quant'. Looking directly into the camera, he tells us that he speaks English, is called John, and came second in the competition. This draws attention to stereotypes of Chinese people as 'naturally able' at mathematics. It also exposes mathematical truth as reliant on social factors for authentication: who makes a claim is more critical than any 'objective' criteria.

In *Margin Call*, similarly, what is important is less the detail of the mathematics (glossed as an 'equation' or 'formula') than its meaning. The bank's CEO asks Peter, the young risk analyst who uncovers the problem, to 'speak as you might to a young child or a golden retriever'. Peter's immediate boss exclaims, 'Oh, Jesus. You know I can't fucking read these things. Just speak to me in English'. Thus, even those on 'the inside' are exposed as fallible. Uncertainty and questioning echo through the film. The 'formula' on which the bank has relied for so long is 'worthless. ... It's broken'. When someone objects, 'there are eight trillion dollars of paper around the world relying on that equation', the terse response is, 'well, we were wrong'. The equally terse response to that is: 'No, you mean *you* were wrong'. The film thus starts with a loss of mathematical certainty, that is never resolved. This is symbolised by the CEO's statement that, 'one and one no longer makes two'. Other characters ask 'Do we even know if he's right'? 'Is that figure right'? And 'You think he's right'? The responses, whether certain or uncertain ('looks pretty fucking right to me', 'I don't know, I can't be sure' and 'I know he's right'), are never final. There is also ambiguity around the film's use of 'right', which refers both to the 'rightness' of mathematics and to moral 'rightness'. Different characters take different views on whether the bank should liquidate their position. As one puts it, 'in acute situations such as this, often what is right can take on multiple interpretations'. While, this is a reference to disputes about what is morally right, given the continuing questioning of mathematical certainty in the film, it could also apply to mathematics. Thus, both films draw attention to the formatting power of mathematics, and so they *denaturalise* it.

In novels, the lack of visual signifiers seems to make it more difficult to represent mathematics. Sometimes mathematics is an absent presence (as in Dan Brown's *The Da Vinci Code*), or the story is patterned by mathematics (as in Michael Crichton's *Jurassic Park*), or a first person narrative gives access to mathematical ways of being (as in Yevgeny Zamyatin's *We*). *Kapitoil* uses the latter technique to question the objectivity of mathematics.

Karim's first person narration in *Kaptoil* gives insights into his mathematical way of being. For example, his account of visiting an art gallery includes this comment on the paintings of Piet Mondrian: 'His lines are perfectly straight like geometric Islamic designs and would extend infinitely if the frames did not restrict them' (p. 16). Mathematical references and analogies recur through Karim's diary, for example:

> Sometimes small details tell you more about someone than the big picture does, in the same way, e.g., that the infinity of real numbers between 0 and 1 is actually greater in cardinality than the infinity of all integers. (p. 114)

Karim's mathematical approach is also evident in his precise use of language: he lists new words beneath each diary entry and his Kapitoil computer program relies on nuanced distinctions, such as, between 'claiming' and 'taking' responsibility for terrorism. His distinct voice and approach are labelled Karim-esque and are linked to his mathematical and coding skills, but they are also related to the postmodern:

> musicians like Bob Dylan and Leonard Cohen are also appealing because they sing about subjects that reject binaries and are mysterious in the way math can be mysterious, e.g., sometimes you locate an answer and the universe becomes almost magical because in the middle of chaos there is still order, and sometimes there is no answer, and because of that the universe is even more magical since it has secrets that humans can never understand. I told Rebecca this, and she said, 'You're turning into a real postmodernist' (p. 272)

The connection of the mathematical to the postmodern, via the Karim-esque, suggests a mathematics beyond certainties and binaries, where 'sometimes there is no answer'.

Lanchester's *Capital* also presents a subjective uncertain mathematics. The novel mentions the mathematics within investment banking but does not seek to explain it. Yet it identifies a mathematics happening outside of banks (and other specialised spaces) through consumption. In a long passage, after Roger Yount has lost his highly-paid job in investment banking, he considers their outgoings, particularly Arabella's:

> *The worst of it was the maths.* The Younts' outgoings were still what they had been. Two houses to run and maintain, neither of them cheap, clothes and holidays, Arabella's completely out-of-control discretionary spending. … Talking to Arabella about money was like trying to talk to a child about nuclear physics. (p. 488, additional emphasis)

Their consumption and its costs is 'the maths' of the Younts' situation. It is analogous to 'nuclear physics'. If consumption is mathematics, then, within capitalism, everyone does mathematics. The novel reinforces this point through the 'We Want What You Have' harassment, that targets people's greed and delight in their soaring house prices. Similarly, in *Margin Call*, one banker justifies his role to another: '[If] people want to live like this, in their cars and the big fucking houses they can't even pay for, then you're necessary'. These can be read as ways of shifting responsibility for the financial crisis from the bankers to 'ordinary' people. However, they can also be read as an opening up of mathematics, towards democracy and away from elitism.

TROUBLING ELITISM: UN/FAMILIAR IMAGES OF MATHEMATICIANS

Typically, in mathematical fictions, people doing mathematics combine features of the socially-awkward geek/nerd and the heroic genius (Duchin, 2004, Mendick et al, 2008). The gender, race and class of central/peripheral figures align mathematics with masculinity, whiteness and middle-classness. All four texts reproduce these dominant discourses, but, as I indicated above, they also represent alternatives.

Margin Call's Peter is a former 'rocket scientist' who chooses to stay late at the office doing mathematics rather than going for a drink with his workmates. *The Big Short*'s Michael, who develops the idea of shorting the housing market, wears no shoes in the office and admits: 'I don't know how to be funny. I don't know how to work people. I just know how to read numbers'. He is one of the 'outsiders and weirdos' who saw the 'lie at the heart of the economy'. Although weird, they are presented as society's innovators: the man who invented Mortgage Backed Securities has 'changed your life more than Michael Jordan, the iPod and YouTube put together'. *Kapitoil*'s coding genius Karim's nerd status is evident in his Karim-esque voice, and when his girlfriend Rebecca refers to this as a trait they share. We see *Capital*'s Mark's social awkwardness through his boss Roger: 'His weirdo deputy was looking down at his feet and scowling, as if he'd suddenly realised that he was wearing the wrong shoes' (p. 340). Mark casts himself as both 'genius' and villain, against '[m]iddle-class mediocrity' (p. 448, 192).

These characters are simultaneously geeks and geniuses. But they are not the heroes of most mathematical fictions. As Jared chides us towards the end of *The Big Short*, after his $47M bonus for 2008, is announced, 'Hey I never said I was the hero of this story'. These characters provoke more alienation than empathy. Mark's arrogance lands him in jail. The 'long black cars and executive perks' in *Margin Call* are: 'paid for with what was inescapably fraud. One of the characters has a sick dog. The dog is the only creature in the entire film that anyone likes' (Ebert, 2011). Their nastiness and fallibility are a warning that we should not leave finance, and so mathematics, to an elite.

In the previous section, I argued that, by defining capitalist consumption as mathematics, *Capital* writes us all as participants in it. This implicates us in the crisis and asks us to intervene and not 'pretend [we] have no idea where it came from' (*Margin Call*). Similarly, breaking the fourth wall in *The Big Short* implicates us by placing us inside the action. This is most obvious at the end of the film, when Jared says:

> In the years that followed, hundreds of bankers and rating-agencies' executives went to jail. The SEC [Securities and Exchange Commission]

> was completely overhauled and Congress had no choice, but to break up the big banks and regulate the mortgage and derivative industries.

As Jared speaks we see images representing the events he describes. Then, after a pause, he announces 'just kidding', reminding us of the bank bail outs, bonuses and lack of reform. The brief fantasy 'moves us beyond what is merely actual and present into a realm of possibility, the not yet actualized or the not yet actualizable' (Butler, 2004, p. 28). It suggests we need democratic accountability in our financial systems, something which would also require a democratic mathematics. I look next at how such forms of mathematics are tentatively articulated through these texts' multiple masculinities.

With the exception of *Kapitoil*'s Karim and Rebecca and *Margin Call*'s Sarah, all the central financial characters are white middle-class men. The alignment of masculinity with mathematics is stronger in these than other mathematical fictions, reinforced by their financial settings. The gender identities of the isolated female bankers (Sarah and *Capital*'s Michelle) are subject to question. *Capital*'s Roger explains that: 'Female traders … either went super-girly and manipulative, or were more like alpha males than the alpha males. Michelle was the second type' (p. 282). The women in *The Big Short* are there to service the men's development. For example, the heterosexuality of the film's central male characters is secured by their two largely-silent wives; and a female actor in a bubble bath and an exotic dancer deliver exposition. The films' few black and Asian characters are also marginal and narratively subordinate to the white men. Aligning mathematics with masculinity is not only related to bodies but practices. A banker in *Margin Call* jokes to a man he manages: 'Have I ever told you how much I love your bag? … Do you have a little dress that matches it? … Because you could bounce around in it like a fucking girl'. Similar comments feature in all four texts.

Yet these excessive performances of masculinity evidence its fragility. Masculinity like mathematics in these texts is never secure: 'Masculinity is something that we have to be constantly trying to prove. It isn't anything that we can feel easy or relaxed with' (Seidler, 1997, p. 39). These men, their masculinity and their mathematics, are fallible. As I elaborate next, this fallibility demystifies them and opens up mathematics to different ways of being, as class and race function in intersection with gender.

Repeatedly within financial-crisis fictions we see two contrasting masculinities juxtaposed: a middle-class masculinity of mental labour within the financial services sector and a working-class masculinity of manual labour within construction. For example, *Capital* contrasts British banker Roger and Polish builder Zbigniew. Matya, the Younts' Hungarian nanny, has come to London to find a wealthy husband. She goes on dates with both Roger and Zbigniew. Yet it is Zbigniew to whom she is attracted despite his relative poverty and her commitment that 'a serious boyfriend should have serious money' (p. 529). She overcomes her distaste that he 'work[s] with his hands' because this work 'gave Zbigniew his body', and she is drawn towards his physicality: 'firm and taut … muscled and compact and clean' (p. 531). In *Margin Call*, a disillusioned quant reminisces: 'I built a bridge once … It spanned 912 feet above the Ohio River. And it cut out 35 miles of extra driving each way'. He focuses on the physical over the intellectual. Although, the speaker was an engineer who likely played no part in actually building the bridge, he appropriates this classed manual labour. Similarly, when sales manager, Sam (the owner of the likeable dog) reflects on his work, his boss dismisses his regrets telling him: 'You could have been digging ditches all these years'. Sam responds: 'That's true. And if I had, at least there'd be some holes in the ground to show for it'. The film's final image is of Sam digging a hole to bury his dog in his ex-wife's garden.

These texts set up an a series of oppositions: middle class vs working class; mental labour vs manual labour; abstract vs concrete; intellectual vs physical; doing finance/mathematics vs building and digging. Breaking with dominant discourses, they value the second over the first term in each opposition. Thus they implicitly critique the abstractness of mathematics when they critique middle-class financial masculinity. By valuing working-class physical masculinity, they assert the concrete over the abstract. But they stop short of dissolving the distinction between the two, so that we could understand the abstract as always already concrete and vice versa.

In Karim, *Kapitoil* offers a central character who, as a Qatari Muslim, is Other to whiteness and the West, and who is Other to dominant masculinity, preferring the company of women, and rejecting the laddish culture in his workplace. The use of Muslim characters to articulate resistance to US capitalism, is increasingly common in post-9/11 fictions such as Mohsin Hamid's *The Reluctant Fundamentalist*. It draws on Orientalist oppositions (Said, 1995), even while depicting the Muslim position as morally superior. In line with this, Karim refuses to reduce relationships to commodities. For example, he aims to network 'to build social capital. But whenever I meet someone, I have difficulty thinking primarily of that person as part of a future network' (p. 134). When Karim has 'nearly finished' programming his mathematical model in Kapitoil, he 'evaluate[s] the big picture of what I am creating':

> When violence occurs, especially in the Middle East, my program will attempt to leverage it for financial gain. But this violence will happen with or without my program. Therefore, by making money, the program produces at least some positives from a very negative situation. It turns the violence

> into a zero-sum game, because the money and violence cancel each other out, instead of producing exclusively a negative game. (p.42)

However, ultimately he rejects this zero-sum game, hoping for a positive game. He refuses to sell his program to Schrub Equities, sacrificing his right to live in the US (with Rebecca) and his family's financial security, to make his code freely available so that it can support global health and development. 'The code must be on the open market for the best people to utilize it. And there may be applications we have not thought of' (p. 281). Despite retaining a notion of 'the best people', this is largely a democratic vision of crowd-sourced mathematics, in opposition to the elitism of private ownership.

CONCLUSIONS

In this paper I have contributed to the work of understanding the relationship of mathematics to the post-2008 financial crisis by looking at the stories we tell about it.

> It is through such stories, or representations, that we develop understandings of the world and how to live in it. The contest between rival stories produces our notions of reality, and hence our beliefs about what we can and cannot do. (Sinfield, 1989, p. 23)

I have looked at how these fictions expose the fallibility and social construction of mathematics, displacing the dominant discourses of its objectivity and abstraction. Normally in mathematical fictions, from *Enigma* to *Numb3rs*, from *A Beautiful Mind* to *The Theory of Everything*, we see the subject's power – to solve crimes, win wars, analyse human behaviour and understand the universe. In mathematical fictions of the financial crisis, we encounter its failure and its intertwining with capitalist consumption.

Debate about the natural and physical sciences has long contained an idea of the abuse of scientific concepts. Research in the sociology of scientific knowledge has shown that scientists need to work to reconcile the idea of scientific proof with its political entanglement, in order to rescue the innocence of science (Gilbert & Mulkay, 1984). There is no comparable debate on mathematics, which is still largely seen as objective and apolitical. But these financial-crisis fictions represent mathematics as dangerous, something that has different political possibilities:

> My point is not that everything is bad, but that everything is dangerous, which is not exactly the same as bad. If everything is dangerous, then we always have something to do. (Foucault, 1983, p. 343)

Normally, mathematical fictions encourage us to view the subject as the province of an elite, who are special because of their 'ability' to do mathematics and whose specialness manifests in other ways from geekiness to mental health problems. But these texts suggest that this elite is not to be trusted with (financial) mathematics and implicates us all in the mathematical. If (financial) mathematics cannot be left to the experts, this opens up possibilities for discussing a democratisation of mathematical knowledge. This needs wider public engagement in mathematics alongside the accountability of professional mathematician. It is modelled by Karim, when he releases his own mathematics into the world, trusting other people's expertise over his own.

By sidestepping questions of what mathematics *is* and looking instead at what mathematics *does*, poststructuralism helps us to re-imagine 'the hard and masculine body [of mathematics] that penetrates [non-mathematics] but is not itself susceptible to penetration' to re-envision it as 'open and permeable' (Gibson-Graham, 1996, p. 544). This indicates the subversive political possibilities of focusing on discourse over essence. Although the truth claims in this paper are simply a few among many, competing for space in academic and public arenas, so too are those of mathematics.

Through such analyses, we see mathematics as a cultural object. Here I have focused on the *representation* element in the circuit of culture, arguing that new meanings are attaching to mathematics post-2008. However, these representations also have implications for the *identities* constructed through mathematics. Alongside the heroic mathematician figure they place a more equivocal, fallible and morally ambiguous financial operator, and so shift the power relations between 'them' and 'us'. How this does or does not change the identities people construct in relation to mathematics and the subject's *production*, *consumption* and *regulation*, are topics for further research.

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REACTION PAPERS

NEURONAL POLITICS IN MATHEMATICS EDUCATION

Reaction to Elizabeth de Freitas' Plenary

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In this article, I will comment on de Freitas' plenary entitled 'Biosocial becomings: rethinking the biopolitics of mathematics education'. My focus is placed on three points of critique. The first critique concerns the research design of cognitive sciences, the second one focusses on the use of data from cognitive science in education, and, the third one reframes the concept of embodiment in a new and positive context.

INTRODUCTION

Starting a debate from a common ground is the most fruitful way to continue a discussion that aims to deepen the subject under scrutiny. This is one of the things I learned from my professor in philosophy many years ago when I was doing my first Bachelor in Philosophy (at University Ghent, Belgium). We are on the same page now. Let's start a discussion about the value of neurocognitive research. The de Freitas' paper has a rich content that goes beyond critical thinking about the relevance, the challenges and the dangers of neurocognitive research in relation to mathematics education. The paper is both critical about current biosocial research and creative about possibilities within this new research field. De Freitas is also touching upon the philosophical foundations of mathematical concepts (e.g. number, ordinal number, cardinal number) and the implication on neurocognitive research design. In the frame of this short commentary we will focus on three points of critique. The first critique concerns the research design of cognitive sciences, the second one focusses on the use of data from cognitive science in education and the third one reframes the concept of embodiment in a new and positive context.

COGNITIVE RESEARCH DESIGN

In the section on 'Number sense' de Freitas focusses her critique on the research of cognitive science itself, the research design and the specific meanings of utilised concepts. She refers to the work of Dehaene (2011) and Bugden & Ansari (2015), who identify a specific locus at the brain, the 'intraparietalis sulcus' (IPS) as the biomarker of ability in mathematics. The phenomenon 'developmental dyscalculia' (DD) (identified with about

3.6-6.5% of the samples) has been defined as 'learning disorder' that affects the ability to acquire school level arithmetic skills. This reductionist view on the ontogenesis of number sense is criticised in the literature (Gifford & Rockliffe, 2008; Rips, 2015). They argue that the concept DD is vague and therefore open to misuse. They also point to the fact that IPS and other brain regions intermingle. Furthermore, there is a discussion on the research design and how numerical tasks are identified. The analysis of the research design in cognitive sciences and the use of a reduced meaning of numeracy (by denying ordinality and temporality) gives rise to a deep philosophical discussion on the ontological status of numeracy and thus even on the foundations of mathematics (we will elaborate on in the following section). De Freitas reacts on these shortcomings of the cognitive science research design by saying that 'Despite all this confusion, the IPS remains the focus of neurocognitive brain imaging research on number sense' (de Freitas, this volume). We do not question the relevance of having a deep and critical insight into the shortcomings of neurocognitive research design. We, rather, have to be aware that this kind of critique will give rise to the demand of new cognitive research and a deeper analysis of the phenomenon DD. It seems evident from the logic of the neurocognitive paradigm that researchers want to investigate more effort in researching vague concepts in order to have a clear answer on the causal effect or the causal network between the activation of IPS and mathematical activity. The question remains: is this what we want, more and deeper and reframed cognitive research?

THE USE OF BIOSOCIAL DATA

A more substantial critique –in my view– is the way how research findings are used to label the learners as dis/able, knowing from literature how the process of stereotyping works. Shifrer (2016) shows how learning disability designations may produce stigma by masking the –what she calls– real causes of learning differences. She shows the negative effect of learning disability designations on adolescents' math course attainment and how it can reproduce disadvantage through stigma and stratification. Thys & Van Houtte (2016) demonstrate the importance of teachers' expectation for the educational progress of students in an increasingly diverse Flemish school context. De Freitas refers to Chinns' (2015) volume of 'International Handbook of Dyscalculia and Mathematical Learning Difficulties' to argue that the impact that neurocognitive research has on education research and practices is indeed potentially profound. Many dis/ability theorists cite it as evidence of number sense being biological determined. Nature vs nurture is an age-old debate that shifted from focussing on the genes to the working of the brain or from the 'gene man' to the 'neuronal man' –with the universal nominator 'man'. We all know that some traits or behaviour is explained in terms of biomarkers and we also know from genetics research that even identical twins raised in a common family rarely show 100% trait correlation (Pinker, 2002). Nature vs nurture is a debate between scientists from the bio determinism paradigm (the essentialists) and the researchers/ philosophers from the constructivism paradigm (the constructivists). We know from history of sciences that researchers from different paradigms never convince each other (Kuhn, 1970). They can fight each other, they can even murder each other (we have some examples in the history of science, e.g. Giordano Bruno) or they can exist next to each other. We will never stop the bio determinism paradigm of the essentialists but indeed we have to keep a critical eye on it.

A central question in this context remains how to adapt these research findings to the learning context. I will introduce some findings on neurodiversity by showing the following cartoon in Figure 1. The cartoon speaks for itself. Although it is only referring to the assessment of individuals, it is also applicable to the teaching and learning process. The more broader question is how we, educators, teachers, education researchers and education philosophers, are adapting biodiversity, or, more specifically, in the context of this article, neurodiversity, within the learning context.

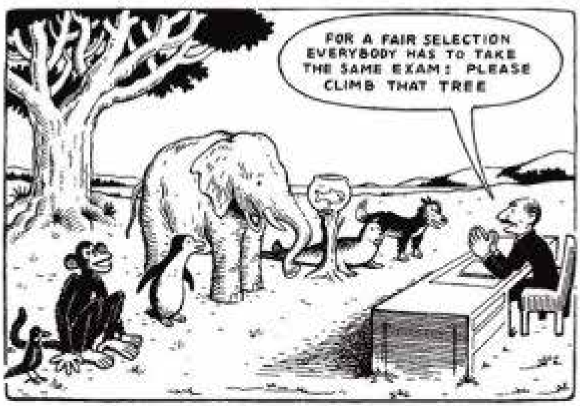

Figure 1: Learning diversity (LJA, 2013)

The idea of neurodiversity as developed by Blume in the late 1990 –although he did not use the term– suggests that what we call 'disability' ought to be described as 'diversity' or 'difference' (Armstrong, 2011, 2012). Armstrong (2011) argues that if all neurological differences are a part of the natural diversity of the human brain, we cannot simply use them as a biomarker for 'illnesses'. Many researchers from the constructivism paradigm explore the advantages, special skills, and other positive aspects of the different neuronal abilities. This is a main challenge for education. We can frame it as 'learning in diversity' where diversity can be biological, social, cultural or a hybrid in between. It is going beyond the background of the learner by focussing on the foreground (Skovsmose, 1994). This way of looking at education fits nicely with Malabou's (2008) and Hansen's (2015) alternative way of dealing with cognitive science. Hansen's (2015) points to an expansive posthuman, sensibility that goes beyond the lived experience and of which we are not aware. Malabou (2008) explains how these new biological forces as well as the new experience of non-awareness has to be investigated in order to figure out what this new non-awareness might be.

Based on this critical literature I agree with de Freitas that we have to support an alternative way of interpreting and using findings from cognitive science. Rather than looking backwards at the causal network of the brain activity, redistribute this causal mechanism into the future, Malabou (2008) analyses three different kinds of brain plasticity (developmental, modulational, reparative). This allows for new temporal dynamics with a fundamental futural orientation. We therefore need an expanded notion of number sense as explained by de Freitas (this volume) based on the work of Deleuze & Guattari (1987) who reconsider the ontology of number.

The work of Husserl (1970) provides a context for the discussion on the ontology of number and adds to this futural orientation a robust philosophical foundation. With the concept of retention and protention, Husserl emphasizes perception and memory and at the same time places the origin of geometry and number, in a temporal flow through which each moment of protention becomes the retention for the next one. The three temporal aspects (past, present, future) are intertwined in a complex temporal flow. The past is not just modifying the future; it serves future while it is guided by the present horizon of the human Lifeworld.

EMBODIMENT

De Freitas' paper is part of a larger project on the relation of the body and mathematics. Lakoff and *Núñez (2000) set the paradigm of the embodied mind holding that* mathematics results from the human cognitive apparatus. Therefore, it must be understood in cognitive terms. The embodiment of mathematics is a central discussion in the field of the ontology of mathematics and dates back to the ancient Greek period (Gillies, 2015). An interesting point of critique de Freitas is formulating (in the section 'Alternative theoretical frameworks') is the confusion on the terminology of 'embodied' and 'embodiment'. The concept can have different meanings and can be misunderstood easily. If 'embodied cognition' is interpreted as a higher act of cognition that is carried by its container or vessel, being the body, than we are reducing the body and the value and role it has in constructing knowledge. It also continues to support the Cartesian dualistic mind/body perception. This critique becomes even more relevant if we apply this reductionist meaning to the learning and teaching situation where the danger becomes real to interpret students' material actions as just a simulation of a deterministic trajectory in terms of a priory internal conceptualizations.

'Embodied' or 'embodiment' can have the opposite meaning where the body becomes highly relevant and meaningful in the construction of knowledge, even in the construction of objectivity. Donna Haraway (1991) refers to embodiment when it comes to the construction of objective knowledge. In her 'Situated Knowledges', Haraway (1991) aims to reconsider objectivity in exceeding the ancient opposition between objectivity and subjectivity. Knowledge is always situated and structured by privileged positions (e.g. gender, race, nation, class …) and it is the only possible way to 'negotiate' objective knowledge. She formulates an alternative to the epistemological scientific ideal of transcendental objectivity, a concept she describes as "the standpoint of the master, the Man, the God, whose Eye produces, appropriates, and orders all differences" (Haraway, 1991, p.193). She rewrites the objectivity criterion in terms of *situated knowledges* and argues in favour of an *embodied objectivity* as opposed to objectivism (François, 2011). In *objectivism* the so-called variables have been stripped as much as possible so as to acquire knowledge about an object that is stripped as much as possible of the living environmental factors (which is the case in the above criticised neurocognitive research by Dehaene (1997). In contrast to this view, *embodied objectivity* is a negotiated knowledge from different locations and different bodies. Here, the meaning of 'embodied' and 'embodiment' refers to the body and the (social, political and material) environment people are living in.

The idea of embodied objectivity and by extrapolation embodied mathematics relates to the work of the mathematics education scholars Davis & Simmt (2003) who define the body as an ecological system sustained through boundary negotiations. The emphasis on the situatedness of knowledge and of objectivity is also related to the material life of mathematical concepts (e.g. number, cardinals, ordinals, …) and the philosophical discussions on the origin of mathematics. Basic references are the work of Husserl (1970) and Serres (1989) who describe and explain the origin of geometry as developed in the midst of the Lifeworld. To my opinion, it fits nicely with the work of de Freitas who analyse mathematical activity "as a material practice that produces specific kinds of bodies (or transmaterial assemblages) that incorporate, as part of their ongoing modulation, particular kinds of mathematical concepts" (this volume).

AFTERTHOUGHT

If biosocial research findings claim that the future inheres in the actual present then the danger is that this can lead to a determinism, a teleology, a prescriptive destiny and a pre-given trajectory. We are all part of a big data environment and we are living in a global capitalist economy that is co-opting the present in smart environments. Buying a book at amazon.com predicts what we are willing to buy in the near future. This can be experienced as nice, interesting and helpful, although we hand over part of our freedom to the smart environment, on the other hand one can feel confined of his or her existential freedom. Being a critical citizen means at least that we are aware of the non-awareness and of the generative forces we are surrounded by. The danger engendered with the application of biosocial data in teaching and learning and, more specifically, of mathematics teaching and learning is even more critical since we, today, have empirical evidence that learning disability designations and teacher' expectation effects the learning process' outcomes in a negative way (Shifrer, 2016; Thys & Van Houtte, 2016).

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MATHEMATICAL LANGUAGE IN THE POLITICAL DISCOURSE: EPISTEMOLOGICAL AND EDUCATIONAL REFLECTIONS

Reaction to Dimitris Chassapis' Plenary

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The use of statistics is both “act of authority” and “authorized act”
Pierre Bourdieu

Mathematical language in political discourse (including numbers, ratios, geometrical figures, tables, function graphs or logical symbols) might help to understand the complexity of the situation or to describe aspects related to an interactive process of decision making. Unfortunately, the political and journalistic abuse of mathematical language transforms the modeling function of mathematics. In fact, it disarms reality from her mathematized connections and conduces to a superficial formulation of a deterministic political representation. Mathematisation for a better access to complex information seems to have been replaced by de-mathematisation and misinformation. This dangerously false instrumentalisation of mathematics results in reducing any democratic sense of politics, thus transforming mathematical language to a communication agent that manipulates public opinion. In the face of this crucial phenomenon, what is our responsibility as mathematicians, researchers, teachers, learners, and citizens? These are emerging epistemological and ethical questions that, in consequence, are closely related directly with processes of educational decisions concerning mathematics education and didactics. I will try to present some reflections upon the thoughtful lecture delivered by Dimitris Chassapis.

1.

Politicians and opinion makers often use and abuse scientific knowledge in the enunciation of their rhetoric to support and serve the argumentative dimension of their intentions. A kind of disjunction exists between designers and consumers of mathematics and statistics; a disjunction that characterises the forming of public discourse, in both local and global levels. The presumed inevitability of this phenomenon is not independent of the content of mathematics in the school curricula, neither of the pedagogic practices or the stereotypic beliefs concerning the relation among mathematics and reality. As Dimitris notes, the mathematical figures are implicitly and explicitly presumed to be neutral, accurate and objective and are thus characterised as 'distant' and 'cool'. These properties serve the purposes of rhetorical, argumentative and polemic political discourses. Mathematical symbols, already related to the image and status of mathematics in the epistemological, social and educational context, they now obtain political-value. Their use creates a new –unhuman, but unfortunately legally unhuman thanks to the scientific construction– narrative, inversing the meaning of fundamental political concepts, including national sovereignty, citizen responsibility, social justice and democratic awareness.

The aforementioned situation is highly complex and the danger for the mathematics education transcends the frontiers of mathematics education. How, could we then confront this situation? It seems that we need to turn towards cultivating very early in the schools an interdisciplinary approach of mathematics –an approach deeply related to the understanding and acceptance of complexity. We have to coordinate our teaching in close relation with other disciplines about a variety of concepts that surpasses the over-simplistic manipulative descriptions and manoeuvres enacted by both politicians and media-groups.

2.

Making use of numbers places the speaker on the side of the power, as numbers signify certainty in relation not only of knowledge, but also of ability and agency. The use of numbers in our local political context, is closely linked to managerial concepts, the epistemological context of which we must also consider. Three terms characterise this situation, because they bear clear links with their inner numerical structure, modelled with finite, measurable indicators: *effectiveness* (a method of reasoning that translates into actions), *efficiency* (the return of capacity, of performance), and *efficacity* (a quality that produces the expected effect). Thus, it is posited that we have to study *both* the transformation of the meaning of numbers through the bridges of specific interdisciplinary connections *and* the impact of our contemporary highly complex virtually expanded society to the public discourse, in order to gain deeper understanding of the effects of the (ab)use of mathematics in politics.

Dimitris Chassapis has the privilege to be not only a researcher, but also an acting person in the most difficult period of the crisis, by participating as the National Secretary of Education in the first Greek administration which, inspired by progressive and humanitarian ideas, tried to deconstruct the official image of the crisis. He had to re-orient education system from an elitist ideology and practice towards an inclusive and inquiry based perspective. I think that we can easily see mathematics education as the more fragile field in the contrast between the elitist point of view and the inclusive one. The school learning or teaching practices of both teachers and students must be measurable performances. To minimise the role of the social conditions, we choose the lesson of the mathematics. It is the perfect choice, if of course we decide to ignore all the didactical mathematical literacy and we assume that learning mathematics is a neutral game where we can measure general cognitive performances. They had added in the theory of the standards in mathematics education the practice of the so called *bank of topics*, a list of more sophisticated exercises.

But! Reality is much more complex than any of her descriptions! At the same time mathematics education is a 'resilient' field of education, considering the nature of mathematics as human construction and its development as a scientific philosophy that is not afraid of antinomies, paradoxes, infinities, irrationality or the in-expressible. Mathematical culture and science are nursed from the resilience. Their capacity to survive traversing through the paradoxes and to extend in a qualitative way the theories to include the antinomies of quantification and measurement is maybe one of the secret of their inexplicable power. The introduction of such characteristics in 'mathematical education for all', remains the main concern of the critic researchers-teachers. So, thank you for the opportunity to make some comments in the conference. I shall try to make some connections with the didactic of mathematics and in particular with the approach of complexity and interdisciplinary theories.

3.

The central topic of this plenary is the use and misuse of numbers and numerical expressions, which appear on the headlines, related to the construction of truth. I think that each individual and each community feels the necessity of truth and expresses this necessity by constructing a variety of relationships with the truth. Maybe truth is contained to its necessity, so each construction of truth is corresponding to the formulation of this necessity. It is exactly in this formulation of the necessity of truth that starts, from my point of view, the more difficult and interesting stage of the consequences of mathematics. It resembles the effort to construct the most accurate description of the complexity; for example, to construct the best map of a territory: the perfect identification is impossible, but the need of this (even impossible) identification conduces to the construction of a variety of models. To compare these constructions, we need indicators. Indicators have to be measurable, so we need numbers and then more sophisticated mathematical formulae, tables, figures and symbols to describe the models. The objective is the communication and the decision making, in order to persuade others about the representation of the reality, not the reality per se.

Thus, we measure dimensions and we calculate proportions in order to design a map upon which we can reflect and make action plans about the mapped territory. Mathematical objects are now in the first line of the construction. But the only perfect map of a territory is the territory itself an, even then, such a correspondence construction is impossible, because τὰ πάντα ῥεῖ (everything flows). Hence, the only possibility to understand and communicate the description of a complex phenomenon relies on the conventional agreement about the meaning and the use of language expressions and symbols.

What kind of number concepts and numerical expressions are used in the headlines? Do they correspond to cardinal numbers, ordinal numbers, ratios and analogies, limits of series, rhythms of variation, approximations? Not at all! We observe that the public opinion makers seem to avoid the use of high-school mathematics symbols and formulas. It is argued that such a decision prevents the citizens from trying to recall their mathematic knowledge in order to make sense of the model of the described situation. Instead, public opinion makers appear to prefer the employment of simple numerical formulations, usually number comparisons or easily representable percentages. A situation in which everybody could consider as easily conceivable and understandable and, consequently, a situation which nobody would try to read deeper into the presented information.

Let's try to distant ourselves for a moment from the 'newspapers' (in the broad sense, including both traditional and digital new media) and to ponder about the implications of mathematics in this kind of modelling. The necessity and expressing ability of mathematics can be discerned in the necessity to understand the phenomena corresponding to the formulation or the expression of a critical situation. But what mathematics do we need? And how this mathematics has been presented in school? Has it ever been related to concrete situations?

Dimitris notes that headlines particularly use numbers and numerical expressions and he becomes more concrete when he talks about "whole numbers, decimal numbers, fractions, but mainly percentages, … selected to put forward a "fact", a decision or a plan". Could we say now that we have in front of us a kind of mathematisation of the complexity? Or, maybe, the inverse? Isn't it a kind of reductionism to a simplistic mapping? Chassapis notes that "On such a ground, we are faced with a numericalization of politics and respectively with a politicalisation of numbers." I think that the situation is worse, in the sense that it is a distortion of reality that produces mathematical symbols empty of mathematical meanings. Such distortion produces disinformation.

4.

Truth, in the case of construction as described by Dimitris, is linked to fear. Such seems to be the purpose of this kind of journalism. Truth is obliged not to disturb the austerity project, otherwise we shall enter in the hell of uncertainty and unpredictable. Consequently, it may be obvious why the use of mathematical concepts that could help us to understand uncertainty and complexity is avoided, so that fear would not be replaced by alternative projects! The necessity of truth, linked to fear, decontextualizes the concept of its philosophical meaning, detaches it from its dialectical construction and its social and democratic dimension, thus imprisoning it in a strictly financial interpretation. A financial interpretation of and into a non financial modelling, because of the lack of financial mathematics. Such a line of thinking has already obtained the status of dogmatic truth and is no longer a political argument.

Thus, considering education, we must 'make a wink' to the financial mathematics and the concepts of the risk and loss functions, a research field that is developing more and more during the period of the crisis. Risk is the combination of four factors: a danger, a probability of occurrence, severity and acceptability. Hence, the "danger" being a dreaded event (by itself and its consequences) is not confused with the "risk", which results from the fact that this danger has a certain probability of manifesting itself and the gravity of its consequences. The criticality of a risk results from the combination of the impact (or effect or severity) and the probability of a risk. All these hidden concepts, might be studied in the context of mathematical modelling, quantifying and understanding the phenomena governing financial transactions and markets. Within this framework, it is crucial to understand the meaning of the time factor and estimation tools related with probability theory, stochastic calculus, statistics and differential calculus. 'Time' is unique, different from the other variables; it is irreversible! As states networks, banks and markets form a high complexity, a range of instruments for steering and monitoring is proposed for the governance systems; in particular, a system of indicators measuring the impact, effectiveness, efficiency and efficacy. These indicators are the main management tool for the pilot system.

The major difficulty rests on the choice of these indicators. The identification and choice of criteria that are "evaluable" (i.e. that can be the subject of a measurement) appear to be the only way to ensure, ultimately, that the objective of the policy concerned is reached. However, some of the services offered by the public sector lend themselves poorly to the establishment of statistical indicators, which appear to be too narrow in relation to the nature of the objectives sought. So how can we measure the effectiveness of an education system, a health system, or social assistance? In which ways is it possible to quantify effects of an essentially qualitative nature?

Another difficulty of the modelling and the interpretation of the use of mathematics in this framework is related to the expected impact of public activities: Should we try to measure the immediate outcome of each action, or the medium- and long-term global involvement in society? The evaluation of performance in the public or nonmarket sector concerns both the level of output (referring to the results obtained by the realization of services) and the level of impact (referring to the final results of a process of production of goods and services) in relation to the society or community concerned. Following these, taking for example the police action, the level of production could be the number of thieves arrested, while the level of result would be the impact on the feeling of security of the population.

Dimitris' plenary invites us to open perspective to include the great image of the insertion of mathematics in political language, which is linked to the organisation of the State. Today, the organisation of bureaucracy and of political discourse seems to be highly internationalised or globalized, whether it refers to the European Union or the OECD, to the IMF or the International Stock Market. The impact of communication technologies and of networks is on the linking of the aforementioned global structure with the construction of a multimodal language in which the numericalization and the organisational symbolization are the key poles. It is our responsibility to study this mathematics within its environment in the educational systems. What is the relationship of our difficulties to understand the role of the numerical expressions in the case of the headlines with the obstacles presented in the use of mathematics in other academic disciplines, as sciences (physics, chemistry, biology, geography), environmental studies or economics and management courses? Which kinds of epistemological obstacles and didactical difficulties emerge in each of these interdisciplinary contexts? Such really epistemological and educational questions are very pragmatic and of great methodological interest.

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THE EFFECTS OF MATHEMATICS EDUCATION DISCOURSE

Reaction to Heather Mendick's Plenary

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It is an honour and a privilege to comment on Heather's paper. I have known her work for a long time and therefore I was not surprised to read a text that is at the same time, inspiring, provocative and challenging. It is about fictions and mathematics education, about "the stories we tell about the place, power and potential of mathematics through [the 2008-financial] crises" (Heather, 2017:1). More precisely, it examines the effects of power produced by four post-2008 financial-crises fictions on mathematics education discourse.

Heather mentions how these crises reached countries like Greece, the venue of the MES9 conference. In my country, their consequences arrived later: last year they dramatically touched the Brazilian life in its financial, economic and political dimensions. This is how neoliberal globalization works: it embraces everything, every country, everyone. It is almost impossible to resist its microphysical claws. Following Heather's deep analysis and the Foucauldian notion of dispositive, I would say that mathematics and mathematics education discourses are some of the lines of forces of what I am calling, very provisionally, dispositive of *neoliberal globality*, an expression inspired by the Deleuzian notion of dispositive (Deleuze, 1991) and its uses in mathematics education research (Bocasanta & Knijnik, 2016). Heather not only puts mathematics education discourse in a broader perspective, not constraining it to itself. She assumes that mathematics education discourse is articulated to the cultural, the social, the political and the economic. Taking into account this assumption, the paper shows how this kind of articulation works in contemporaneity. This is one of the points that makes Heather's paper so valuable.

Heather summarizes the meanings she assigns to poststructuralism referring to its two orientations on knowing and being (p. 2). In her words: "First, truth is re/positioned as the subject rather than the object of research (...). Second, human being is produced through discourses as people position themselves and are positioned within networks of power". I consider that in the first orientation, what is at stake, at least in Foucault's work, is the process of veridiction, how a statement, which emerged in some epoch, was/is taken as a truth. The philosopher is interested in formulating a critique, which "consists in determining under what conditions and with what effects a veridiction is exercised". It is central to exercising a critique to determine the regime of veridiction established historically, "the determination of the regime of verdiction that enables [us] to say and assert a number of things as truths (...)" (Foucault, 2008: 36).

Heather definitely avoids some flat interpretations of the conception of truth in Foucault's work. She understands the role of cultural artefacts in framing our minds, our ways of thinking and feeling about ourselves and about the world. In particular, in affecting how we are positioned and position ourselves in teaching and learning mathematics (Valero, 2015; Valero & Knijnik, 2015; Valero & Knijnik, 2016).

Decades ago, mathematics education literature, and specifically MES conferences, looked at the role of mathematics education in the production and/or re-production of social inequalities. Mathematics education was scrutinized based on different theoretical perspectives, such as those inspired by Marxist approaches, or based on the work of Bernstein, Bourdieu and others. In recent decades, without looking down on social inequalities, we broadened our gaze to paying attention to cultural differences like gender, ethnic, 'racial' and sexuality markers. We enlarged our glance, not interested in only examining cultural diversity. Homi Bhabha (1994: 49-50) makes explicit this distinction:

> Cultural diversity is an epistemological object –culture as an object of empirical knowledge– whereas cultural difference is the process of the *enunciation* of culture as "knowledg*eable*," authoritative, adequate to the construction of systems of cultural identification. If cultural diversity is a category of comparative ethics, aesthetics, or ethnology, cultural difference is a process of signification through which statements *of* culture or *on* culture differentiate, discriminate, and authorize the production of fields of force, reference, applicability, and capacity.

Extending our focus to cultural differences, Hommi Bhabha and other postcolonial intellectuals as well as philosophers like Deleuze, Derrida, Foucault, Freud, Lacan and Laclau gave us significant help. Based on their work, were able to introduce new ways of examining our field, as shown by the work of de Freitas (2013), Brown (2011), Mendick (2006), Valero (2015) and Chronaki (2011), among others. These authors can be considered, in some way, pioneers in examining mathematics education with the use of different perspectives coming from poststructuralism.

In my own academic context, historically very much rooted in the work of Paulo Freire, we found it difficult to do that. Its "philosophical attack upon the scientific pretensions of social inquiry, including a critique of the very Enlightenment norms that educational research typical prides itself on: 'truth', 'objectivity' and 'progress'" its anti-essencialism and anti-representacional position are some elements that can explain why "poststructuralism has had making theoretical inroads" (Peters, 2004:4).

Currently, in Brazil, poststructuralism is one of the main theoretical references in educational research. In the mathematics education field it was gradually introduced (Giongo & Knijnik, 2016. Wanderer & Knijnik, 2016). Obviously, this does not imply rejecting or devaluing previous theories, in a position that can be identified with something like a "research Darwinistic perspective". It also does not imply setting aside our concern about what we learned from Nietzschen perspectivism. We are aware of the need to avoid the "will to totality", an expression I coined, inspired by Nietzsche's notion of "will to power". The will to totality can be described as the need to achieve a totality when constructing an object of research and doing the correspondent analytical exercise. In other words, the will to totality works as an imperative to analyze an object of research without losing any possible analytical perspective, any possible gaze.

The above discussion led us to question the political effects of the uses of poststructuralism perspectives in mathematics education research. How can they contribute to social change? How can they contribute to diminish discriminations against "the other"? Here is not the place to develop to develop their answers in depth. Nevertheless, some words must be said. Parkes, Gore & Amosa (2010) give possible answers to these questions:

> Through perpetual problematization, we can resist the tendency towards complacency. Through engaging in the pedagogical act as a process of knowledge problematization and concomitant self-creation, we can open up the possibility of refusing who we are. The analysis we have provided should refine and enhance social justice efforts through its recognition of the messy complexity that characterises pedagogical and social reality. Using poststructuralist approaches, it becomes possible to identify spaces of freedom for our own actions as educators that will allow us to work toward practices of freedom through which students can become other than who they are by refusing their inherited inscriptions. Engaging in pedagogy with all the insights that poststructuralism offers may make the project of social justice pedagogy less grand, but it also equips us with insights that may be marshalled to refuse and resist those discourses that erase difference and naturalise disadvantage (p.12)

Heather's paper can be seen from this perspective. As she explains: "By focusing on how mathematics is represented in financial-crisis fictions, I hope to contribute to re-imagining mathematics as a cultural text rather than a body of knowledge and so to think differently about where the mathematics is in MES". In fact, Heather's selection of the four fictions extends the empirical surface of the mainstream mathematics education research.

As a consequence, the question (mentioned critically by her): "where the mathematics is in MES?" loses its importance. Moreover, in the paper I found mathematics itself that is at stake, which I consider something particularly relevant for further in-depth discussions of current mathematics education, focusing on the political. I wonder how Heather conceives the interwoven connections between mathematics and mathematics education discourses.

I have thought about these connections using Wittgenstein's late work. It is well-known that the Austrian philosopher cannot be considered a poststructuralist. Nevertheless, the convergence of his late thinking with Foucault's theorizations (concerning their conceptions of language and the consequences of such convergence) has been establishing by important authors like Gros & Davidson (2011) and Gillot & Lorenzini (2016). Based on Wittgenstein's notions of forms of life, language games and family resemblances, I consider that the mathematical language games practiced by the mathematicians, in their forms of life (universities, centres of research etc), have family resemblances with those taught and learned by mathematics education in school forms of life. The forms of life are different. The language games practiced in each of them are not identical, just similar. They depend on a network of factors associated to the forms of life that produce (and are produced by) the language games. These similarities can be described by what I have called "a gradient of intensity" (Knijnik, 2016).

This means that some of the resemblances are stronger than others. As discussed elsewhere (Knijnik, 2012), concerning the rules of abstraction, the language games associated to school mathematics education present a gradient of resemblances with those practiced by the mathematicians. In the first years of compulsory schooling, the resemblances exist, but they are weaker than in the final years of secondary school. In brief, I moved from my previous explanation about the relation between mathematics and mathematics education discourses (based on the ideas of contextualization, de-contextualization and re-contextualization conceived by Bernstein) to the one presented above. Reading Heather's paper, I was led to think about the possible existing family resemblances between the language games practiced in the bank (or similar institutions) forms of life and those practiced in the financial education classes held in the school forms of life. I wonder about how power relations circulate between them and their effects of power.

My own experience with this thematic is limited to a PhD dissertation I advised some years ago (Vargas, 2012). At least in Brazil, financial education projects, which initially were only conducted by financial institutions, have been extended later on to school forms of life. Considering this, the research examined the program "National Strategy for Financial

Education" (organized by the Federal Government and supported by private and public institutions) and did a comparative study with the "Santander Bank Program on Financial Education", a booklet widely distributed in school forms of life.

Based on Foucault's theorizations and inspired by the work of Jørgensen (2007), the analytic exercise done on these documents showed that the inclusion of Financial Education in schools emerged in contemporaneity due to the development of financial markets and the current demographic, economic and political changes. Both programs acted on the students not only teaching them mathematical contents of financial education. The programs conducted the students' conduct in a specific direction: they subjected everyone to be bank investor who knows how to be their own entrepreneur.

In summary, the research showed that what was at stake in those programs was to create bank investors, who could accept as truth that the best way to ascend in the social sphere is to save money and perform bank investments (in other words, work as "institutional partners", allowing the growth of the banks' capital).

This research was one of my academic experiences that led me to argue for poststructuralist approaches to examine the mathematics education discourse. They can offer us specific tools to analyze its narrow cultural, social, economic and political injunctions. Similar to the arguments developed by Heather in her paper, this PhD dissertation showed how artefacts like the Santander booklet are fictions that act in the objectivation and subjectivation processes that constitute us as subjects of our time.

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SAYING ‘NO’ TO MATHEMATICS

Reaction to Heather Mendick's Plenary

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In my reaction to Heather Mendick’s inspiring plenary talk, I will shortly touch her discussion of the presentation of mathematics and mathematicians in cultural products on the financial crises. Although I acknowledge that these products offer a more fragile perception of mathematics, I argue that they still present mathematics as an elitist tool which allows a deeper understanding of the truth of human affairs and a thereby justified constitution of economic exploitation. To show this, I will allow myself to more generally discuss the role of mathematics in the perception and handling of this crises before returning to the role of mathematics education.

THE DOMINATION OF MATHEMATICS OVER MAN

In a 1984 paper, the Austrian mathematics educator Roland Fischer issued a warning:

> There is the risk that mathematics is conceived either as a monumental threat, as a Moloch who devours everything, which you have to escape from if you want to stay human, or as a safe refuge, which you can dedicate yourself to without compunction, which solves all solvable problems, which tells you what is right and what is wrong. Both attitudes result in the domination of mathematics over man. (p. 52; my translation)

According to Fischer, education in mathematics should therefore be conceptualised as the process of liberation from mathematics, enculturating not an ignorant but a critical attitude towards the discipline. His writings can be interpreted as an attempt to dismantle the objectivity of mathematics. Although he does not explicitly refer to post-modern or post-structuralist theories in his social analysis of mathematics, his early educational project resembles the Foucaultian understanding of critique as the art “how not to be governed *like that*, by that, in the name of those principles, with such and such an objective in mind and by means of such procedures” (Foucault, 1978/1997, p. 44). For example, Fischer (2006) argues that the use of mathematics in social decision making processes is to abstract from the chaotic reality of unique situations and to provide seemingly objective mechanisms for the processing of human affairs. In this ignorance of individual meaning, we see the return of the criticism of science in enlightened societies that the Frankfurt School offered when mathematics was yet at the edge of becoming ‘applied’:

> Science, in its neopositivist interpretation, becomes aestheticism, a system of isolated signs devoid of any intention transcending the system; it becomes the game which mathematicians have long since proudly declared their activity to be. (Horkheimer & Adorno, 1944/2002, p. 18)

Elsewhere, I have shown how a social function of mathematics education is to establish the mentalities to actively participate in or to at least passively accept the 'objective' (to make use of a positive connotation) or 'dehumanised' (to make use of a negative connotation) processing of human affairs, how "the domination of mathematics over man" is produced in education (Kollosche, 2014). Central to this domination is the often-contested belief that mathematics is indeed capable of providing 'objective' solutions to human problems (Skovsmose, 1994; Dowling, 1998). So, before returning to the role of mathematics education, I would like to direct some attention to the role that mathematics has played in the financial crises.

TWO STORIES OF FINANCIAL CRISIS

The first story I want to discuss is that of the crisis in the subprime mortgage market in the USA which started in 2007. In their search for profit, banks provided house buyers with high-risk loans which were then bundled into securities which eventually were attributed as low-risk by mathematical control mechanisms. After a race for issuing ever more loans, the market eventually collapsed, resulting in severe liquidity problems for banks and an extensive loss of private property, leaving many debt holder homeless and impoverished. The film *The big short* (Gardner, Kleiner, Milchan, Pitt, & McKay, 2015) focusses on the protagonists who spotted the instability of the mortgage market and successfully betted against it. However, it presents two different stories of spotting this instability. On the one hand, hedge fund manager Michael Burry is only working in his office, analysing numbers on this computer screen. He spots the instability of the market by his mathematical genius which allows him to see in the numbers what others cannot see. He might be regarded as the character who 'gets the maths right' while his colleagues appear as mere amateurs. On the other hand, the young investors Charlie Geller and Jamie Shipley are shown travelling to the countryside and talking to debt holders and bank clerks. There, they do not only learn that their scepticism is justified, but eventually, unlike Burry, they express moral concerns in light of the anticipated crisis. In this scene, we see the return of individual meaning which the mathematical system has so successfully blocked out. Here, mathematics appears not as the solution if only applied correctly, but as itself problematic in its distance from the specific situations 'out there'. In this sense, *The big short* presents two conflicting experiences of the capability of mathematics.

The second story is that of the European debt crisis which followed the crisis in the subprime mortgage market and hit Greece, the host country of this MES conference, the hardest. In the face of collapsing national banks and an increased awareness for risky investments, Greece found it hard to refinance its debts. Its European and international partners provided financial help only under the condition of severe shortcuts in state expenses. The German conservative government of Angela Merkel, which has been claiming responsibility for the economic upswing following the shortcuts in state expenses by the preceding government, described this policy with the neologism *alternativlos* (literally translating as 'alternativeless'), thereby implicating the same necessity as that of the mechanically derived truths of mathematics. And indeed, the European treatment of Greece was presented to be based on serious calculations which justified shortcuts in state expenses as necessary preconditions of an economic recovery. Horkheimer and Adorno (1944/2002) consider the construction of such necessity, especially with the help of mathematics, as typical for enlightened societies:

> When in mathematics the unknown becomes the unknown quantity in an equation, it is made into something long familiar before any value has been assigned. Nature, before and after quantum theory, is what can be registered mathematically; even what cannot be assimilated, the insoluble and irrational, is fenced in by mathematical theorems. In the preemptive identification of the thoroughly mathematized world with truth, enlightenment believes itself safe from the return of the mythical. It equates thought with mathematics. The latter is thereby cut loose, as it were, turned into an absolute authority. (p. 18)

Thus, the "system of isolated signs devoid of any intention transcending the system" becomes reality itself. Admittedly, in the case of economics, the ambiguity of its mathematical theories is all too obvious. In 2013, Eugene F. Fama and Robert J. Shiller, two economists with incompatible theories about the backgrounds of the crisis in the subprime mortgage market in the USA, were collectively awarded the Nobel Memorial Prize in Economic Science. This appreciation of two theories, of which, from a strict logical perspective, at least one must be partially false, obviously contradicts the assumption that economic models necessarily describe the truth of economic developments. Nevertheless, economists and politicians base their decisions on theories which are presented as mere necessities. In this regard, Yanis Varoufakis (2013), economist and Greek minister of finance until he resigned in protest against his government's acceptance of the claims of Greek's credit grantors, revealed "that we economists, independently of our intelligence or personal ethics, are no experts but that we belong to a sinister priesthood purveying thinly disguised, heavily mathematised superstition as scientific economics."

It is noteworthy that, from a naïve materialist perspective, the financial crisis is located in a purely symbolic realm. Neither by the boom nor by the crash any brick was formed or destroyed, any building constructed or demolished, any house made a home or left forsaken. Sitting at the computer, bankers such as Michael Burry did not produce or consume any good, did not create or satisfy any material need. Money is but the hope that it can be exchanged to a valuable good, and monetary products belong to the very same symbolic realm. Why did this symbolic realm become so important that it decided whether houses are inhabited or deserted, competent workers employed or fired, adolescents educated or forgotten, children nourished or left hungry? The answer is plain and simple: Through economic science necessities are formulated which eventually serve the rich at the cost of the poor. The rescue of the property of private investors lies at the heart of both the bank bailouts at the tax payer's expense and the demand that Greece repays at much of its debts as possible, irrespective of the social consequences. The success with which these necessities have been constructed in spite of the widely visible mockery of sceptics such as Varoufakis shows the already-achieved efficiency of the "the domination of mathematics over man".

EDUCATION AS LIBERATION FROM MATHEMATICS

Returning to education, what might be the role of mathematics classes in regard to the financial crisis? On a superficial level, it might be argued that mathematics education should engage the student with more interest-calculation and teach not to take loans she cannot pay back –a lesson that locates the responsibility for the financial crisis unilaterally with the common consumer. On a critical level, answers are not that straightforward. Heather Mendick proposes "a democratisation of mathematical knowledge". But what might that involve? Obviously, we cannot expect to realise a form of mathematics education that allows every student to understand and criticise the use of mathematics in all its various aspects. A more realistic alternative might be Fischer's (2001; cf. Vohns, 2017, in these proceedings) proposal to provide students with an education that allows them to interact with experts: to understand mathematical basics, to dive into deeper mathematics where needed, but also to question mathematisations and evaluate the suitability of mathematical approaches towards a given problem.

However, it is questionable whether demands for ever 'more mathematics' could contribute to the prevention of the described crises in the first place. Do not the protagonists of *The big short*, who Mendick presents as anti-heroes, show that outstanding proficiency in mathematics usually does not result in political activism but in ever more exploitation? Burry, Geller and Shipley do not seek the alliance with the debt holder to fight against their exploitation. Instead, they take pride and find profit in exploiting those who exploit the masses, they constitute a new top position in the food chain of capitalism. Although the films and novels discussed by Mendick present more fragile images of mathematics and mathematicians, mathematics is still presented as the means of domination. Therefore, the answer might not lie in a demand for ever 'more mathematics', but in the empowerment to say 'no to mathematics', and with it no to financial products which, in their dehumanised objectivity, are disconnected from the lives of the people. But, as such a resistance against mathematics eventually questions the ideology on which the government of our enlightened society is built, it is not only a pedagogical but a political project – a project which is yet far away from finding majorities.

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RE-EXPERIENCING EMOTIONS IN THE BIOSOCIAL SPACE OF MATHEMATICS EDUCATION

Reaction to Elizabeth de Freitas' Plenary

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The technological advancements in mapping human bio activity have found their way in mathematics education research revealing a hidden world, thus rendering imperative the critical re-visiting of related research practices and meanings. Drawing upon de Freita's (2017) discussion about the biopolitics of mathematics education research within this new reality, in this paper we focus on the role of emotions in the teaching and learning mathematics as re-visited through the recent biosocial research.

THE CORPUS IN MATHEMATICS EDUCATION RESEARCH

The role of the body has a diverse presence in mathematics education research, but it was the work of Lakoff and Núñez (2000) that drew the broad attention (positive or negative) of educators, researchers and mathematicians (Gold, 2001; Sinclair & Schiralli, 2003). Nevertheless, various conceptualisation of the body in mathematical thinking and learning have been put forward transcending a mere linguistic approach, to include, amongst others phenomenological ideas (Masciotra, Roth & de Marnand, 2007; Moutsios-Rentzos, Spyrou & Peteinara, 2014), complexity and systems theory (Davis & Simmt, 2003), neurocognitive approaches (Dehaene & Brannon, 2011), cultural-historical approaches (Radford, 2015) and socio-political perspectives (Chronaki, 2016; de Freitas & Sinclair, 2016). In this paper, we draw upon de Freitas' (2017) discussion about the biopolitics of mathematics education research to briefly reflect upon the role of emotions in the teaching and learning mathematics.

EMOTIONS IN MATHEMATICS THINKING: THE CASE OF PROVING

Various researchers have discussed the affective aspects of neuroscience research including emotions, empathy and values (see, for example, Changeux, Damasio, Singer & Christen, 2005). In this paper, we focus on emotions referring to situated, almost spontaneous affective responses to a stimulus as indicated by bodily, pre-cognitive reactions (Oatley & Jenkins, 1996). In mathematics education, researchers have discussed, amongst others, the role of emotions as evidenced in the students' body and/or facial movements as they deal with a amthematical tasks (Moutsios-Rentzos & Kalozoumi-Paizi, 2014; Op't Eynde & Hannula, 2006). This pre-dominantly non-verbal and pre-cognitive approach seems to be in contrast with a more traditional way of studying the students' emotions through the verbal means of communication (Evans, Morgan & Tsatsaroni, 2006). Are the pre-cognitive emotions the same with the emotions consciously expressed through language? To answer this question, we should consider the emotions to which neuroscience refers. The role of amygdala is at the crux of this discussion (LeDoux, 1996; Oatley & Jenkins, 1996): facially-expressed emotions are considered to be an affective *reflex* to a specific stimulus, directed by the amygdala (an 'older' –faster, but relatively imprecise– part of the brain) that alerts the whole body to be ready to appropriately react, before the stimulus is processed by the more developed, yet slower parts of the brain. This mechanism is considered to have been evolutionally developed to assist survival along the lines of the 'quick or be dead', but its speed may result in 'false' (as indicated by the situation) alert types. Thus, through the recognition of emotions through facial expressions, we identify emotional reflexes that may or may not be in line with subsequent affective or cognitive states that the conscious, socio-culturally affected, processing may produce.

Following these, in a study investigating the students' emotions as they produce an answer in exam-type proving questions, Moutsios-Rentzos and Kalozoumi-Paizi (2014) employed Ekman's typology of basic emotions (Ekman & Friesen, 1978) as identified in specific combinations of micro-movements of the facial muscles that seem to transcend socio-cultural settings. Hence, we attempted to identify basic affective reflexes linked with aspects of the proving process to identify pre-cognitive emotional states linked with specific cognitive productions and affective experiences. That project complements studies investigating verbal evidence of emotions or the students' conscious proving productions. 'Complements' in the sense that the students' proving phenomena are re-positioned in a space that emerges at the interaction of rough, pre-cognitive, yet fast and universally bodily expressed, affective states with conscious cognitive and affective socio-culturally embedded experiences. In other words, through linking non-verbal, pre-conscious communications with the students' conscious communications, we attempted to provide meaning to the relationships between the pre-conscious emotions in proving and the conscious proving.

AN EMERGENT AFFECTIVE BIOSOCIAL SPACE IN MATHEMATICS THINKING AND LEARNING

Affect has been found to be crucially linked with cognitive processes (Edelman & Tononi, 2000; Gelepithis, 2014), notably with our persistence in concentrating our cognitive efforts in successfully dealing with a challenging task that requires creativity and divergent thinking (Changeux & Connes, 1998). Neuroscience describes the invariant bodily mechanisms related to specific behaviours and thoughts, while efforts are made to provide physiological explanations with respect to our concentrating our cognitive efforts in specific endeavours, highlighting the affective aspect of thinking (for example, endorphins linked with pleasure). On the other hand, research has shown that though different personalities are linked with diverse brain structure, there seems to be developmental changes in personality and the linked brain structures.

From a Husserlian perspective "the body is not only an object in the world (a *Korper)* but also a medium whereby the world comes into being, an experiencer (a *Leib)*" (Roy, Petitot, Pachoud & Varela, 1999, p. 61). Thus, the questions are addressed from a different point of view focussing on the intentional, emotional mind that thematises the bodily perceived and constituted world: "embodiment cannot be separated from the analysis of an expanded horizon where *Leib* finds itself [...] the life-world *(Lebenswelt),* where empathy, affect, and intersubjectivity are dominant" (Roy et al, 1999, p. 61). In contrast to the Cartesian divide "embodiment is where both subjectivity and objective givens appear side by side" (Roy et al, 1999, p. 61). From a phenomenological perspective, neuroscientific evidence may be re-viewed to gaining deeper understanding about the knowing-feeling-sensing subjects, by concentrating on their intentionalities and their sense-making of a world that is given to and constituted by their bodies (for example, "information about depth that space cannot be seen as some neutral locus decoupled from bodily placement", Roy et al, 1999, p. 62).

It is posited that by adopting an approach to *learning as linking links* (Moutsios-Rentzos & Kalavasis, 2016) within an emerging affective biosocial space, the mathematical thinking and learning phenomena are meaningfully re-approached. The knowing subject and the to-be-known object are intertwined in an intentional, affective, bodily-evidenced Borromean relationship. Instead of seeking causal, temporal interactions between noetically imposed divides (such as body and mind), we suggest that the new means of research may help in our re-minding of our sense-making about the topology of the learning phenomena. The mind as a black box, re-positioned as a complex mechanism with diverse, identifiable processes, re-positioned as a part of a complex socio-cultural whole, re-positioned as a system of neural networks and neurons, re-positioned as complex bio-social part-wholes. Such re-positionings model diverse realities and, inescapably, diverse questions. Researching emotions in a biosocial research allows our linking the social experience with the bodily functions, the subjective meanings with the objective mechanisms, in a dialectic relationship that radically transforms our sense-making about them. Though the neuron may seem to be at the crux of biosocial research, it is posited that meaning emerges through the links identified amongst socioculturally embedded neural interactions, including important questions about consciousness and knowledge; for example, consider physicalism and the notion of qualia as addressed in the knowledge argument and the discussions about Frank Jackson's question about Mary's room.

What are the implications of this discussion in everyday teaching practices? Does this imply a teaching that reinforces the bodily positive experiences? How is this measured? Does this imply that the educational outcomes of a teaching, a class, a school, an educational system maybe measured and assessed at the micro-level of pre-cognitive functions? To an extreme, is it maybe ethically acceptable to help the students facing difficulties with mathematics learning through appropriate medication that enhance the affective experience or learning mathematics? It is argued that through a phenomenological perspective the brain is differentiated, but not severed or dissociated from the computational mind or from the phenomenological mind. The humans who are engaged in mathematics learning and creating are engaged in ways that resemble metaphysical, religious or ideological, investigations. They choose a Wittgensteinian 'language game' outside of which the world seems to be indifferent, sense-less and irrational. For example, considering famous mathematicians, Athanassios Fokas stressed in an interview that "if I don't work for a few days, I start to shiver", Janusz Charatonik described himself as a "workaholic" referring to the pleasure he drew from his work, while Russell noted (in Hoffman, 1998, p. 85): "if he [Hardy] could find a proof that I [Russell] was going to die in five minutes he would of course be sorry to lose me, but this sorrow would be quite outweighed by pleasure in the proof. I entirely sympathised with him and was not at all offended".

This ardent, almost erotic, mood is contingent, rare and authentic, whilst knowing derives primarily from emotion and secondarily from execution. The knowing subjects obtain their knowing identity through their active, emotional, full of desires, relationships with the life-world. Such knowledge is hardly addressed in everyday mathematics pedagogy where the mind rarely obtains an intentional relationship with the taught knowledge. Bio-social research expands, rather than limits, our view of mathematics learning to include and to integrate at a micro-level multiple aspects of learning. This re-focussing on aspects that transcend learning and not just mathematics learning may help in our re-minding at the meso and macro level that our students are not as Valero notes "schizo-mathematics-learners". Consequently, mathematics education research and theory should be developed (maybe through appropriate networking of theories; Bikner-Ahsbahs & Prediger, 2014) to address the emergent affective bio-social space within the contemporary radically transformed neo-liberally driven realities.

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"NUMBERS HAVE THE POWER" OR THE KEY ROLE OF NUMERICAL DISCOURSE IN ESTABLISHING A REGIME OF TRUTH ABOUT CRISIS IN GREECE

Reaction to Dmitris Chassapis' Plenary

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Dimitris' paper revisits some of the core assumptions of critical mathematics education, against the background of the recent Greek economic crisis. The author analyses the headlines of some Greek newspapers from 2009 to 2012, to show how journalists use numbers and mathematical formulas to justify and induce financial measures within a climate of austerity. Foucault's concepts of *power* and *regime of truth* are used in order to understand how particular governing and interests groups use numbers to portray a reality where problems are no longer perceived as being of a social and political nature, but likely to be solved through technical expertise. The argument developed by the author follows the typical critical mathematics education approach to the uses of mathematics. It identifies a series of problems in the way numbers are used to construct a certain reality, that then is used to justify political measures, by-passing any broader political discussion about the certainty or meaning of such numbers. There is a separation between those who govern and are dominant, using mathematics to frame people's mapping of the crisis and to justify the politics of austerity, and those who are the "consumers" of this information, what the author calls the "readers". The article finishes with a plea for critical mathematics: to teach numerical concepts not in a vacuum, but as being entangled in the creation and perpetuation of regimes of truth.

The article does present an interesting contribution to critical mathematics education (CME), albeit not a new one. As a field of research within mathematics education, CME emerged out of the concern about the way in which mathematics *formats* reality (e.g. Skovsmose, 1994; Frankenstein, 1983). Already twenty years ago, people such as Marcelo Borba, Ole Skovsmose, Marilyn Frankenstein, Arthur Powell, Eva Jablonka, Uwe Gellert, to mention just a few, have been analysing situations where mathematics is entangled with power and contributes to the formation of regimes of truth. Borba and Skosvmose (1997) coined the term “the ideology of certainty” to signal how mathematics is above all a “language of power” (p. 17), used to frame the political debate. The ideology of certainty derives from the position that mathematics occupies in the public imaginary, as a perfect system, as pure, as an infallible and neutral tool. This view circulates in television programmes, newspapers, schools and universities. As putted by Borba and Skovsmose (1997), twenty years ago:

> [M]athematics is often portrayed as a stable and unquestionable instrument/structure in a very unstable world. Phrases such as ‘it was mathematically proven’, ‘the numbers express the truth’, ‘the numbers speak for themselves’, ‘the equations show/assure that…’ are frequently used in the media and in schools. These phrases seem to express a view of mathematics as an ‘above-all’ referee, as a ‘judge’, one that is above humans, as a non-human device that can control human imperfections. (p. 17)

The last twenty years have witnessed a health of research addressing critical issues of mathematics and its education, many of them in the vein of what Dimitris is doing in his paper[1]. Mathematical knowledge might be important to the economic wealth of societies; however, the recognition that economy is a contentious field, with inequality and social injustice always lurking in the background, has led to research that criticises the role mathematics has in establishing systems of knowledge and control that favour market oriented economies. Their arguments rest on the importance for citizens to be mathematically informed about the way in which mathematics formats reality, in particular, the economic reality of the current world. Since most of the mathematics modelling our world is hidden behind complex formulae or technological hardware, students need to critically deconstruct the way in which mathematics formats reality, so that they can socially participate as informed citizens. In this way, the relation between economy and mathematics education is one that posits mathematics as an important knowledge to both enhance current economic models and to raise (critical) awareness of the inherent workings of these same models. The latter has been one of the aims of critical mathematics education, which advocates an exploration of real life situations in school mathematics and highlights the importance of mathematical modelling for economy and policymaking (e.g. Ernest, Sriraman & Ernest, 2016).

These ideas have been materialised in school curricula worldwide, and they inform international measurement projects such as PISA. The latter can be seen as the ultimate examination designed to evaluate students’ use of mathematics in everyday activities, including critical

1. See for instance Alrø, Ravn, and Valero (2010), and Ernest, Sriraman and Ernest (2016) for a collection of recent work in critical mathematics education.

situations where numbers are used to dupe people. However, as the examples explored by Dimitris show, and notwithstanding the awareness that mathematics can be used in manipulative ways, media, and newspapers in particular, often play with the power of the number and the realities it veils, to frame readers' opinions. Mathematics education research is not without its responsibilities in the creation of this reality. When we see people relating with mathematics in a quasi-deific way, we should inquire about our own role, as researchers in love with mathematics and its education, in the constitution of a discourse of importance that is then used to justify the reducing of political and social problem to a matter of technical/numeric expertise. In what follows I will elaborate a couple of key issues aimed at discussion. My aim is to situate some of the problems raised by Dimitris against the background of broader structural arrangements, which might help us understand better our own role in the same realities we so often lament. I will use elements from some of my previous publications, most notably Pais and Valero (2012).

In the way Dimitris develops his argument, newspaper editors are seen as using mathematics to deliberatively frame people's understanding of the crisis and to justify the politics of austerity. It seems as if each newspaper's headline is designed as part of an (hidden) agenda to hoodwink people's mentalities, by creating a regime of truth that regulates what counts as an effective approach to the economic crisis. However, do newspaper editors operate in such a Machiavellian way –knowing very well that they are (ab)using mathematics to make their own truths about political economy– or they rather convey broader discourses that are already present in society, and for which we are all responsible?

Dimitris criticizes what he calls, following Miller and Rose (2008, p. 77), the "technicization of politics", where economic and social problems are transformed into problems that can be solved through technical manipulations of numerical data and technical expertise. This reduction is seen today in a myriad of social dimensions, from health care to criminality. Education is also not immune to it. According to Biesta (2005), the tendency towards the *learnification* of education, that is, the reduction of the study of educational phenomena to the study of administrable, instrumental learning processes, contributes to erase political considerations from educational research. This is part of a larger societal trend that addresses fundamental social problems as if they are the object of expert management and administration (Agamben, 1998; Foucault, 1991, 1997). Foucault (1991, 1997) shows us that the government of life is achieved through two fundamental technologies that act upon the individual and the population. On the one hand, the technologies of the self refer to the processes of subjectification that force individuals to bind themselves to their own identity, defined by the degree of adherence to social norms. On the other hand, the political techniques or bio-power refer to the way the state assumes and integrates the care of natural life of individuals into its very centre. The interplay between the two mechanisms of subjectification –techniques of subjective individualisation and procedures of objective totalisation– creates a twofold political strategy which Foucault (1997) calls *bio-politics*: the growing inclusion of human natural life (as opposed to political life) within the mechanisms and calculations of power. In this way, politics is made operational. Its purpose is no longer to be a place where alternative emancipatory ways of living together can be thinkable, but to engage in the global regulation for the sake of the species' biological reproduction. For Agamben (1998), who built upon the work of Foucault, the only real question to be decided is which form of organisation would be the most suitable for the task of securing the care, control and use of bare life: human life stripped from its entire political dimension and reduced to its biological entity. Human bare life is that type of existence that can be measured, calculated and predicted. In other words, it is the object and result of technical expertise. Recognising this condition, Žižek (2006) argues that, today, we live in a *post-political society*: Politics has surrendered to specialised social administration, targeting the bare life of the individual by controlling its fluctuations according to global standards of normality.

Just as politics is being replaced by administration, education has given up its place in favour of learning and specialised, subject-matter pedagogy and didactics (Biesta, 2005). In the case of mathematics education research, the privileging of learning theories functions as a mechanism of bio-politics in constructing certain subjectivities and governing them, stripping them from their political condition (Pais & Valero, 2011). As such, what Dimitris calls the "technicization of politics" is operating at the very core of mathematics education. Its modus operandi however is not based on a conscious decision by teachers, researchers and even politicians to reduce education to an accountable matter. If interrogated, most of them will argue that such measures are beyond their control. Yet, they will not be possible without the workings of all of us who contribute to mathematics education.

As such, when confronted with the "power of the number", and how numbers are used by media to support certain economic decisions, instead of showing disgust at the way in which numbers and formulas are used to dupe people, we should question where does this power comes from? Why do people give so many credibility to numeric information? Or, more generally, why is mathematics seen as so important by many people? Where does the importance of mathematics come from? These are obviously not straightforward questions. But we should be able to recognise in mathematics education's endeavours a source for such importance. You will hardly find anyone working in mathematics education (either as a politician, a teacher or a researcher) willing to question the importance given to mathematics. It is assumed that, although people struggle with mathematics, often find it boring and useless, more efforts should be developed to improve its teaching and learning, seen as a crucial knowledge and competence for our contemporary societies. But, research has been questioning these assumptions. Troels Lange, in the last ICME in Hamburg, remarked that perhaps we should admit that mathematics is not that important (at least, not in a way envisage by many researchers). Researchers within a critical vein often ask why is mathematics (and not other disciplines) posited by politicians as such a strategic instrument for the deployment of neoliberal approaches to education. This is at least partly a result of the entire endeavour of MER, which has over 100 years (making it one of the oldest and arguably the strongest subject-matter field of scientific enquiry) reifying the importance of school mathematics for virtually any facet of human activity –from everyday tasks, to professional and technological endeavours. It is thus not surprising that politicians, governmental agencies and media posit and use mathematics as a mechanism of governance. We, as researchers, provide the ideological material for the deployment of mathematics as a crucial element in the technicization of politics.

Foucault (1991) suggests that the production and maintenance of a truth, instead of deriving from some universal knowledge about the world, is rather the result of particular individual interests. In a way, for Foucault, we tend to adopt the truths that are more convenient for the achievement of our own goals. As researchers, we cannot be blind to the fact that there are obvious benefits from the belief that mathematics is precious knowledge, a keystone of modern society, and an inescapable tool for citizenship. On the other hand, by positing mathematics for all as a goal to be achieved, and by asserting the importance of research in this process (against the malaises of practice) we set the ideological frame wherein we can continue to work, receiving our salaries, progressing in our careers, participating in conferences, travelling, enjoying ourselves. Such are the relations of power in which we are all involved, and which produces the truths that we take for granted when thinking about mathematics education.

As noticed by Foucault (1997), power is only exercised between free subjects, who might not recognise themselves as actors of power. Moreover, power is not a substance that can be deposited in subjects (the non-Foucauldian notion of empower) or kept by some sovereign figure (the typical case here being the monarch). The main objective when analysing power relations is not so much to decipher how power is present in "such or such" institution of power, or group, or elite, or class but rather how all the individuals "freely" participate in a certain technique or form of power. An analysis of the power relations in mathematics education will thus refrain from framing the problem in terms of a struggle between those who have power (the usual suspects: governments, bureaucrats, regulatory agencies) and those who have not (researchers, teachers, students). Instead, Foucault invites us to posit ourselves as part of the problem, as free subjects that participate in power relations within a certain structural arrangement. We must be able to perceive as a result of our own workings the use that newspapers such as the ones examined by Dimitris do of mathematics. If they rely on the power of mathematics to make their regimes of truth is because mathematics in itself is given that power. And this is done first and foremost by all of those who work with mathematics.

Finally, when we, as teachers, grade students in order to quantify their learning, aren't we as well operating with the power of the number, by reducing a full human being to a letter or a number? When we grade a test and give a percentage to a student, what exactly does this number signify? We want to believe it represents the right and truthful measure of his or her learning. But what does a test measures if not only the capacity to solve a test? Why do we assume that a test (or any other conventional evaluation procedure) measures students' learning when evidence tends to show the contrary?[2] The power of the number lives at the core of our most mundane practice as mathematics educators. Before addressing the ways in which media and other social actors use and abuse of mathematics, perhaps we should address our own role in this system of power, by reflecting on how we systematically use the power of the number to exclude people.

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RREACHING ACROSS TO A PARALLEL UNIVERSE BELOW: THE PROMISE OF JUSTICE COMMUNITIES FOR RESEARCHING CASTE IN MATHEMATICS EDUCATION

Reaction to Erika Bullock's Plenary

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Foregrounding the way in which critical mathematics education has emerged as a force to reckon with in the global mathematics education community, Erika Bullock commences her talk with a call for a critical reflection on critical mathematics education in order to engage with the multiple and intersecting forms of hierarchies and subjugation that operate in a society. She refers to a range of 'isms' such as sexism, racism, heterosexism, colonialism, capitalism, ableism, militarism, nationalism, religious sectarianism or extremism that plague our world and argues that while critical mathematics education engages with each of them, the engagements tend to remain in silos. Her question "What are the practices in critical mathematics education that re-inscribe the distinctions and divisions that qualify some and disqualify others?" underscores the urgent need for collective reflection on the part of the community if it wants to realise the objective of addressing injustice in mathematics education. She argues that as a multiplicity of 'isms' operate simultaneously to shape the complex identities of most people, there is a need for the critical mathematical community to adopt intersectional analysis as a methodology if it wants to avoid the analytical vacuum that even a deep engagement with any one of the isms create.

Her call for a coming together of different groups engaged in addressing different kinds of '*isms*' to form what she calls 'justice communities' rings promising and is the need of the hour. She is unequivocal in what she seeks to realize from intersectional analysis and 'justice communities':

> Intersectional analysis is not another intellectual exercise and justice communities are not another opportunity for conversations about injustice that do not translate to action. This is hard work that looks different from social and historical context –or one justice community– to the next.

To achieve the goal of justice in mathematics education through the 'justice communities' she wants the academics and activists to break the barriers and join hands.

The issues that Erika Bullock raises resonate well with the situation that we face in India and so I will respond to her lecture by reflecting on its relevance to the emerging community of critical mathematics educators from India. To be sure I hope my response is not specific to the Indian scenario but has enough to interest the larger MES community. After all, even as we come from different nationalities, what brings us together is a deep commitment to social justice that goes beyond our national boundaries. And there is much that India shares with her neighbours that this response will I hope represent their situation just as it does ours.

Marked variously as a post colonial, developing or low income country, with an agrarian economy and poor literacy levels, the regional, religious and other differences that separate us perhaps become invisible in the face of relative poverty that over powers any other image of India in the eyes of the global community. However, seen from within what we have is a very complex picture, perhaps doubly as complex as what one can imagine from outside. To the list of ism that Erika Bullock listed we need to add a few more among which casteism is most significant. Caste refers to a form of social stratification that places every Hindu and in fact every Indian irrespective one's religious affiliation into one of the several endogamous castes. The history of caste extends back to several centuries. Another related term that is used to refer to the social segregation is varna system, that dates back to some time between 600 to 200 BCE. There are four varnas, hierarchically placed with brahmins (the priestly class, placed at the top of the heirarchy), kshatriyas (the warrior class), vyshyas (the trading clas) and shudras (the working class, placed at the bottom of the heirarchy). Outside the four varnas are the panchamas (the out castes). It is believed that castes may have arisen out of subdivisions among the varnas, but it is caste that determines the rules and regulations of life. And there are several hundred castes across the country with regional variations. Unlike other social categories such as gender or race, there are no bodily markers that makes one's caste visible immediately. It is a standard practice in large parts of the country to attach the caste name as one's second name[1]. For example one would guess that those with second names Satry, or Sharma, Joshi are brahmins. Sen, Reddy, Pillai, Menon refer to non brahmin castes that are in the upper echelons of the caste hierarchy. The panchamas have faced and continue to face extreme forms of discrimination and exclusion. Variously referred as depressed classes or Harijan, dalit, or scheduled caste, these castes have been pushed

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1. In some part of the country like Tamil Nadu, where I come from, this system has been abolished.

to extreme levels of poverty that forces them to take up jobs that nobody wants to do. The complex nature of caste and how it operates requires a more serious engagement than is possible here[2]. It suffices to say that the exclusion and abuse that the so called outcastes, now referred to as scheduled castes or dalits, face(d) have much in common with racism that blacks have suffered in the US and other parts of the world. The dalit struggles for justice also draw inspiration from the struggles against racism in te US and South Africa. Apart from caste, those belonging to what are referred to as scheduled tribes also face extreme situation as they are being forced out of their lands in the post independent India.

Intersectionality is a term that is increasingly in use in the social sciences research in India (see for example Menon, 2009; Mehrothra, 2013). A poor, illiterate, dalit, disabled, migrant transgender person from rural India is certainly at the intersection of several 'isms' that operate to marginalise the person. It is important to note that caste is not peculiar to only India. Neighbouring countries like Nepal, Pakistan and Bangladesh also face caste based exclusion, though there may be significant differences in how caste operates in these countries (see for example Nightingale, 2011; Gazdar, 2007).

Countries like India have invested very little on education research. Interventions in education have largely been brought about by NGOs working with marginalised groups. It is only recently that a small group of academics have started engaging in education research and in particular in mathematics education research. A near absence of dalits and tribals in mathematics education research also means caste and ethnicity do not figure in mathematics education research even though mathematics remains a gate keeper in India as elsewhere. The challenge of engaging with mathematics education from the intersections of caste, gender and other social categories is therefore formidable as it stands now.

This brings us to the question of justice communities Erika Bullock envisages and the possible implication they have for far away places such as India and invisible identities such as caste identities. I would like to use the metaphor of 'parallel universes below' to refer to places with the multitude of intersecting hierarchies that operate the details of which are invisible from the site of critical mathematical enquiry because they are placed below. What are the ways in which MES and critical mathematics education community contribute to recognising, foregrounding and engaging with complex categories that operate almost in parallel, in those part of the world that do not belong to the centre of critical mathematics

2. There is extensive literature on caste in India. See for example Aloysius (1997), Teltumbde (2010), Ambedkar (2014) Omved (1995), Rege (2013) to get a better understanding of caste. Also the film 'India Untouched: Stories of a people apart' (Stalin, 2007) documents how caste operates across the country and across religion.

education research? How would we vision justice communities to engage with regions and issues that have poor visibility in mathematics education research, given that such engagements will have far reaching consequences for the learners who are at the intersection of several 'isms' in a parallel world below? What promises do alliances across the parallel universes placed hierarchically have for solidarity and mutual enrichment? These are some of the questions I would like to place before us in response to Erika Bullock's compelling invitation for forming justice communities to take forward the agenda of critical mathematical education.

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MATHEMATICS EDUCATION AND THE MATRIX OF DOMINATION

Reaction to Erika Bullock's Plenary

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In commenting Erika Bullock's plenary talk, I highlight Erika's main argument and comment on some points that call my attention. In particular I pick on the potential of intersectionality and intersectional analysis to challenge the historical role of mathematics in the generation of orderings and measurements that have classified people and cultures.

People who experience multiple oppressions in combination endure the multiplicative effects of the added layers of each one of the "isms" that mark them, make them and sometimes confine them to remain "hidden figures". If one of the concerns of mathematics education adopting political approaches is a commitment with justice, intersectionality and intersectional analysis together offer a possible framework to unravel and act on the matrix of domination instantiated in the practices of mathematics education. Intersectionality, as a recognition of the frequent overlap of multiple identity positions that individuals experience, helps examining and remediating the operation of discrimination as part of the game of identity politics. Voicing and recognizing the points of intersection and how people become affected –as well as are effectors– in continuous, multiple and systematic discrimination is a way of starting to fight oppression. Intersectional analysis, as an analytic, critical move, interrogates the entanglement of identity positions in institutions and systems, and thus focuses on relationships and configurations of oppressions. In other words, it makes possible to see how identities become constituted in a grid of oppression in the simultaneity and multiplicity that operate discrimination. A methodological move that brings together intersectionality and intersectional analysis attempts to go beyond the silo-isms that characterize current research where typically one category of identity would be privileged in the analysis of in(ex) clusions in mathematics education.

With this statement, Erika calls MES for a collective effort to perform a scholarship and practice concerned with how the articulation of intersections of oppression advances the chances of generating more effective coalitions to do the real justice work required of critical mathematics educators. This could be a way of putting a critical eye on the ways in which current research in mathematics education adopting political analytical lenses itself contributes in re-inscribing the distinctions and divisions that qualify some and disqualify others.

I embrace Erika's text and in engaging in her suggestion, I comment on some issues that resonate with me, and also take a discussion of some points that could be further elaborated. Erika's text starts formulating implicitly an interest in troubling persistent narratives about mathematics, science, scientific innovation –and with them probably access to and success in mathematics (and science) education– as "a white man's story". The counterpart of such narrative are the very many possible "hidden figures" whose work and bodies have contributed to the technoscientific enterprise by being producers or victims of it. Erika uses the metaphor of "figure hiding" not only to allude to the Hollywood movie "Hidden figures" that recognizes the contributions of black female, intellectual work force in one of the greatest of white American enterprises of the Cold War. It is also an invitation to consider the many students whose good thinking and talent are being overshadowed or neglected in mathematics classrooms. I would say that "figure hiding" also points to the very same effects of power on the ones who definitely are deemed useless and superfluous. The ones who have learned that school (math) success –or, for the sake of the matter even any kind of success– is not possible and will never happen for them. Even more crudely, those for whom failure is a necessity associated with the success of others, particularly if such success could eventually connect with the attribution of some value.

What is the invitation that Erika proposes about? Is it to fight for making possible that hidden figures can shine to be part of the promises of the good life of those on the bright side of the technoscientific enterprise? Or is it to get confronted with the unpleasant discomfort that dismantling the promise of a bright future with and through success in (school) mathematics is built on a logic of disparity that the well-intentioned pedagogical theorizing and doings of mathematics educators can hardly move? I would like to interpret her invitation to sharpen our awareness as educators and researchers on the tensions generated when current salvation narratives on math in STEM education are part of an entangled grid of economic success of individuals, communities and nations. In the growing conflation between technoscientific supremacy with economic superiority, we cannot be naïve about our desire for better mathematics education. Various technologies come in operation to close the files and filters for who is meant to benefit and who is meant to loose.

In other words, alluding to the metaphor of "hidden figures" would become dangerous if we interpret it as the good desire of ending oppression to gain full success in mathematics, and, consequently contribute to a more just society. I would argue that such argument would not show more than the fact that one has been completely co-opted by and become part of the “white man’s story”. By this I do not mean that an attempt to make children better mathematics learners who could have success in school, in further education and eventually have a better life opportunity is not desirable. I would be dismissing my own personal story and that of many here who have gained social, cultural and economic well-being through acquiring value in education. I am more concerned with the fact that optimism should not blur an analytic sharpness to dissect and dismantle the pervasive narrative of superiority of white males, and with it its uninterrupted and largely unquestioned persistence in the narratives on the supremacy of mathematics.

The question emerges of how a sharpened focus on the intersections of multiple categorizations in a matrix of oppression can help challenging the way in which a particularly historically assembled mathematical rationality is part of the very many orderings and classifications of humans and their production of culture and materiality. The methodological framework of interesectionality and intersectional analysis does point to the procedures in which the practices of mathematics education re-insert in the terrain of educational practices the classifications, segregations and oppressions that operate in society. In other words, the cultural politics of identity with and through simultaneous “isms” is not particular to mathematics classrooms. It is part of how power is effected through education as an important institution in the governing of the population in Modern times.

The issue of what is particular to mathematics classrooms brings us to pay attention to *school mathematics* and its associations with *mathematics*. However, when I say mathematics in this context, I am not talking about the contents of teaching and learning processes and how they are organized in a curriculum or how they are being transposed, pedagogized and didacticized for the purpose of rendering them graspable by students. I rather have in mind school mathematics and mathematics as historically articulated rationalities in time and space, that have become a salient element in the constitution of Western culture, at least in Modernity. And it is here where I wonder whether intersectionality and intersectional analysis offer possibilities to unpack, dissect and point to this issue, because leaving the entanglement of mathematics and school mathematics as modern rationalities untouched would lead us to keep on assuming that they are neutral rather than constitutive in themselves of the larger cultural logic and its associated technologies of governing that order and classify human beings, with all the consequences that this entails. Can some kind of historization that questions the entanglement of (school) mathematics in the matrix of domination be articulated to intersectional analysis? More precisely, and to take an example, would it be possible to bring to the toolbox of intersectional analysis some nails and hammers from Foucault to nail down the cultural politics of (school) mathematics?

Some of Foucault's concepts and analytical strategies provide for me a point of entry in generating questions that help troubling the epistemological dominance of western mathematics reinserted in the school mathematics curriculum as a white male story. A nowadays commonly accepted narrative on the history and philosophy of mathematics builds on elements such as the special and prominent status of mathematical objects and forms of knowing, its development in a logic sequence of discoveries by (male, "white") geniuses, and its great contribution to progress through being the language of science and technology. An alternative cultural history of mathematics would first take mathematics as being no different than any other kind of human or cultural production. It would rather ask questions about the conditions of possibility of the production of mathematical concepts and techniques within a network of materialities, political struggles, economic arrangements, moral and philosophical debates, and decided forms of government of the time and space configuration in which they emerged. While such types of histories have been frequent for the natural sciences, they are rarer for mathematics. Such an invitation pushes the researcher outside of the comfortable boundaries of the internalistic understanding of mathematics and places such endeavor in the messiness of the making of human life and culture. Furthermore, in times, spaces and places that are not necessarily familiar with the present that we know. It forces into a form of operating as a researcher which is tentative, detective-like, following traces and enunciating documented, plausible enunciations about the relationships in the network of events that constitute power and its effected matrix of orders, classifications –segregations and oppressions. In the Order of Things (Foucault, 1994), Foucault leaves an interesting trace to investigate. *Mathesis*, "a universal science of measurement and order" (p. 56), a central element in the Classic episteme mainly dominant in the 17th and 18th centuries, link mechanism and the desire to mathematize. In this link,

> "relations between beings are indeed to be conceived in the form of order and measurement, but with this fundamental imbalance, that it is always possible to reduce problems of measurement to problems of order. So that the relation of all knowledge to the mathesis is posited as the possibility of establishing an ordered succession between things, even non-measurable ones. In this sense, analysis was very quickly to acquire the value of a universal method; and the Leibnizian project of establishing a mathematics of qualitative orders is situated at the very heart of Classical thought; its gravitational centre." (p. 57)

Markley (1999) explores the network of material and discursive practices within which Leibniz's writings articulated central elements of the early modern mathesis. In his analysis, the historization of the emergence of measurement and order is unfolded in the ecological, economic and political crisis of the forming European states during the 17th century. Leibniz' ideas of continuity expressed in his calculation and formalization of integration and differentiation in calculus related to his natural philosophy of "nature not making leaps". They articulated with conceptions of nature, conceived as continuous and eternal, and with strategies of intensification of production in and exploitation of nature as generators of wealth and, thus, value. In this sense, these notions are inseparable from the early forming of liberal Capitalist economics. In this sense, the narrative of purity of mathematics does not hold; and we are invited to unpack how mathematics as a knowledge and rationality is inseparably entangled with Capitalist economy, and when in educational settings may also bring these traces into the making of educational subjects.

Part of the network of materiality that is not touched in Markley's analysis is how mathesis permeated and got expression in the enterprise of colonization and the unfolding of techniques to govern and exploit the resources of the "new world". The 16th and 17th centuries were also a time of the building of colonial empires where European powers organized the ruling and economic exploitation of large territories and populations in all continents. Mathesis in this context makes part of the consolidation of the classification and ordering of species which was the project of naturalists such as Linnaeus and very many other men who documented the new worlds. The hierarchical, comparative logic imposed on nature became a way of thinking present in later justifications for the placing of the "Others" in a lower ranking of humans. Notions of race as part of strategies of governing through political and economic technologies made appear natural that beings whose bodies, language and culture were distinct from the white European master's characteristics were to be differentiated, ordered and deemed inferior. This means that mathematical forms of thinking are in no ways just abstractions built on the work of white men's geniality, rather they are epistemologically constituted in an ordering of species and culture that place one particular race and culture on top of the order of things and humans. If this is the case, then the issue for mathematics education is not simply a matter of inclusive pedagogies for those who are excluded and hidden; but a serious political question of challenging the very heart of what has constituted Western culture where different characteristics of the mathematical mindset have been fundamental in the very process of historical differentiation. Providing detailed study of the network of practices through which the entanglement of mathesis and power have been produced and reproduced, also in instances of education, is a project to engage in. Challenging the neutrality of mathematics and mathematics education by visibilizing their configuration, as suggested before, in Capitalist and racialized orders become an interesting path for a cultural politics of mathematics education.

If intersectionality and intersectional analysis open opportunities for unpacking such cultural, historical configurations ways that challenge what we take for granted as both the oppressions in mathematics education as well as the possibilities of striving for justice, then there is no doubt that it is a way worth pursuing. Erika's invitation to consider the matrix of domination in which mathematics education practices are performed is certainly a challenge for mathematics educators concerned with the state of the world.

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SYMPOSIA

ETHNOMATHEMATICS MEETS CURRICULUM THEORY THROUGH CRISIS

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AIMS OF THE SYMPOSIUM

To bring ethnomathematics and curriculum theory into productive dialogue via attention to global crises. Ethnomathematics has moved from exoticization and celebration of indigenous mathematics through use of local mathematics as resource for a globalized notion of universalized school mathematics, toward reconceptualization of programs in the context of equity, diversity, and social transformation, that is, curriculum. Likewise, curriculum approaches to mathematics education have moved from a narrow focus on content and hyper-reification of psychologized pedagogy through social and cultural issues of multiculturalism, toward a politicized need to address *diaspora* cultures, its roles in global imperialism and the perpetuation of colonialism, i.e., ethnomathematics. This symposium begins a proactive response to present and projected crises evolving from extreme climate and weather changes, mass migration, and political upheaval.

We have initially invited ten scholars from five continents to provoke this project. Our plan is to invite MES attendees to join us, using two sessions to form working subgroups for emerging themes, including: development of a monograph representing the range of ideas; trans-national program development, and social media projects as a hybrid praxis. Provocation-presenters have been sent a discussion document composed by the organizers of the symposium. They will use their own scholarship to either illustrate what they think are important ideas and questions in the discussion document, or to challenge and critique its assumptions.

RATIONALE

Mathematics educators can no longer isolate themselves in academic oases of intellectual conversation about post-colonial mathematics curricula. Current and impending global crises increasingly demand both theoretical and practical responses situating mathematics education within collaboration across boundaries of research that have been coexisting for several decades.

Curriculum studies pays particular attention to those dimensions absent from typical curriculum decision making, prioritizing issues of equity, access, and voice. Translating this priority into the various practices of mathematics education leads, for example, to several key questions: What (mathematical) knowledge is of most worth? Who gets to decide? How does the second question matter? Tinkering with curriculum as merely a matter of expanded or clarified objectives leaves the fundamental questions unaddressed. Rather than apparent "solutions" to the complexity of this cultural-historical moment of transition and, trends emphasize "deliberation" and "complicated conversations", suggesting frequent collaborative meetings of teachers, students, community members, and others to engage in important discussion, always ready to respond to the likely realization that some possible perspective has been and should no longer be excluded.

Ethnomathematics owes both its power and its limitations to its origins in the Western conceptual axioms of culture and mathematics. These potentially contradictory impulses often prevent richer applications, as well as some ways through which these contradictions sometimes preserve forms of indignity and injustice. We strive for alternative foundations for this project grounded in post-colonial notions of dignity, recognition and reconciliation, connecting these ideas to forgiveness as both critical awareness of dispossession, and as refusal to allow dispossession and indignity to influence the present and future.

Curriculum centers in interdisciplinary study of the *experience* of learning in the unfolding processes of always becoming mathematical and always being subjected to mathematical aspects of culture, power, and equity. "Until we are able to see that *mathematics needs people* as much as *people need mathematics* [...], we risk tinkering with education in a way that fails to address power issues or true transformations in society". A mathematics curriculum could in this way be organized around the exploration of how it became possible to think/be/feel/act the way people do with/because of/or in spite of mathematics. Mathematics education would become at the same time something to resist and something that can be coopted for social change.

Ethnomathematics and Curriculum Theorizing reveal in symbiotic and mutually critical ways ethical and political aspects of mathematics education especially visible in times of crisis: (1) Null and hidden curricula, when ignored or left unexplored, are powerfully implicated in maintaining the *status quo* and its associated forms of inequity and oppression. On the other hand, questioning assumptions for what has been routinely acting as a null or hidden curriculum is a tactic of social and political change. (2) Educational programs reflect relative power relations on a global geopolitical scale. Some regions of the world rely on models of ideal mathematics programs from abroad, whether out of desire to emulate dominant cultures, or forced to do so by development institutions and international funding sources. The adoption of non-indigenous programs that ignore different conditions and overlapping ideological targets has unforeseen consequences ripe for research and related political action. (3) Routine use of school programs as sources for inspiration and questions neglects potentially more important scholarship of curriculum as *experience* in all of its forms. Stepping away from school programs toward ongoing co-development of mathematical enculturation, acculturation, social practices, and forms of knowledge is the promise of this symposium.

SYMPOSIUM PLAN

Session 1: Weaving Ethnomathematics & Curriculum Through and With Paramount Crises

<u>Introduction</u>: Peter Appelbaum, Arcadia University, USA Explaining the broader project of these two sessions, and inviting participants to consider how their own work might be related (See rationale above for a sketch of some of the ideas).

<u>Responsible Subversion & Emic Perception</u>: Milton Rosa & Daniel Clark Orey, Universidade Federal de Ouro Preto, Brazil. Milton and Daniel will introduce *ethnomodelling, ethnocomputing*, examples of ethnomathematics and multiculturalism , in order to provoke discussion around how professionals attempt to make sense of and integrate underlying social, cultural, and political frameworks within which diverse mathematical ideas, procedures, and practices are embedded. An important dilemma in mathematics education in relation to the curriculum is an overwhelming bias against local orientations in the traditional research paradigm. Acknowledging local mathematical knowledge as well as its implications for social, cultural, and political transformation of a society triggers creative and responsible subversion, and encourages debate about the true nature of mathematics as it relates to culture and society.

<u>When Ethnomathematics runs from Multiculturalism</u>: Samuel Edmundo Lopez Bello, UFRGS/Brazil, and University of Lyon, France. Samuel will provoke conversation grounded in post-structuralist critiques of (mathematics) knowledge: the question of “knowledge” or Contents –

not only to select what we have to teach, but what is considered as true knowledge that has to be taught; the conception of "subject and processes of subjectivation", i.e. what kind of subjects and conduits are very much desirable and pertinent for our society, and fantasies of what students will or should become; relations of power -what are the forces that guide these selections. Consequently, curriculum organization is mostly about "values". Multiculturalism is simultaneously a "dispositive" of government where the same questions are mainly articulated in relation to the cultural identities, their ways of knowing, theirs values, their conduits, and that paradoxically has reinforced the proliferation of differences consequently providing different kinds of inequalities. The different relationships between mathematics (as a knowledge) and culture (as belonging to an ethnic group) have situated Ethnomathematics inside of this multicultural dispositive.

Theo-Philosophical and Institutional Curricula in Post-colonial, Diasporic Conditions: Dalene Swanson, University of Stirling, Scotland, and Adjunct Professor, University of Alberta. Dalene will ask us to consider how recent, broader conceptions of ethnomathematics take into account more critical historical, political, philosophical and institutional perspectives and landscapes of learning within the current global modernist world (dis)order (offering a greater role for postcolonial and postmodern enactments of complexity and relationality), yet nevertheless still tend to conceptualise these broader, more critical curriculum conversations within existing, *modernist* framings that assume situated 'locals' and the 'global' as somewhat static and fixed, or at least fixable. In a global condition of increasing polarization, contradiction and conflict, with systemic mass failure of ecological, economic and social systems, there is a burgeoning of displaced, migrant and diasporic people who are in a constant state of institutional statelessness, movement, fragility, transition, and in which the only constancy remains these exceptions as normalised. Within this moving frame, theological texts of mathematics education move beyond old inherited traditions of mathematics' moralising in ways that reference scriptural thinking. Instead, they act to 'immortalise' globalising capitalist modernity as inevitable and demanding devotion, even as diasporic and displaced peoples and the precariate are written out.

Open Conversation: we will open up discussion of the provocations, and ask symposium participants to identify emerging themes, to situate their own work and interests in relation to these themes, and to consider how this project might or should unfold. Suggested working group concepts will be further explored between sessions by participants during open free time at the conference.

Session 2: From Conception to Working Groups on Publication, Curriculum Development, and Social Media Action

Introduction: Charoula Stathopoulou, Greece, Explaining the broader project of these two sessions, and inviting participants to consider how their own work might berelated (See rationale above for a sketch of some of the ideas). Today will be shorter provocations combined with future planning.

Learning to know, Learning to do, Learning to be and live with others: Franco Favilli and Fiorenza Toriano, University of Pisa, Italy. Franco and Fiorenza will provoke us to consider the challenges of integrating indigenous and academic mathematical knowledge, as an entry into imagining mathematics curriculum: as a tool of tolerance and promotion of human rights, to go beyond linguistic, cultural, religious, and gender differences; to deconstruct stereotypes of difference such as gender, disaporic identity, and community affiliation; and to design educational and training modules adapted to the needs of pupils at risk of exclusion, but consistent with the formal education that a school system requires.

Communities of Problem Solvers: Robert Klein, Ohio University, USA. Bob will share how his work with Navajo Math Circles involves groups who can organize and sustain the circles locally, support that empowers them to do so; weaving with culture as well as political and social (and economic) constraints; and specifically attention to collaboration, questioning and interrogation. Circles directly challenge the idea that questions belong to the facilitator by encouraging all participants to share in the questioning and creating of mathematical ideas.

Nomadic Transitions and Ensuing Complexity: Miriam Amit, Ben Gurion University of the Negev, Israel, will use her work with Bedouin social and political changes as they relate to mathematics, equity, and culture. The specificity of this presentation will serve as a mini-case-study for discussion in the context of Middle East politics, tensions, cultural transition, and the implications for global issues of ethnomathematics and curriculum: can we apply the vocabulary of session 1 to this case and at the same time find connections to other global crises?

Open Critique: We will reserve time for 1-2 participants who not included in the original proposal to share some specific research and/or theoretical viewpoints that they suggest as important, and to join the symposium

Responder: Charalampos Sakonidis, Demokritio University, Greece

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NEOLIBERALISM: A CRISIS FOR MATHEMATICS EDUCATION?

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Paola Valero[2], **Gill Adams**[3], **Hilary Povey**[3]

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Neoliberal policies have become dominant in many parts of the world over the past few decades. In this symposium we will discuss some effects of neoliberalism on mathematics education in various contexts globally and locally. We will explore the question(s): Is neoliberalism a crisis for mathematics education and if so how might we combat the negative effects of these policies?

INTRODUCTION

> For neoliberals, the world in essence is a vast supermarket. 'Consumer choice' is the guarantor of democracy…education is seen as simply one more product…[and] just as in real life, there are individuals who indeed can go into supermarkets and choose among a vast array of similar or diverse products. And there are those who can only engage in what can best be called 'postmodern' consumption. They stand outside the supermarket and can only consume the image. (Apple, 2000, p60)

It is those who stand outside the supermarket that are of central concern to the MES community. Neoliberalism promotes policies and discourses of the free market, of competition, choice and privatisation (Hursh, 2007) as well as accountability, performativity and individual responsibility (Llewellyn & Mendick, 2011). This political and economic discourse manifests in a variety of ways worldwide and is apparent in policies such as charter schools, voucher systems and the allowance of for-profit schools (Apple, 2000; Hursh, 2007; Robertson, 2012). Whilst it is argued that this freedom of choice may provide opportunities for marginalised groups to find and 'purchase' education that may cater for their particular needs, research has shown that choice is not freely available to all and these policies lead to greater marginalisation (Apple, 2000; Sleeter, 2008).

AIMS OF THE SYMPOSIUM

In this symposium we plan to explore the impacts of neoliberal policy in mathematics education. We will present contrasting perspectives on the ways in which neoliberalism plays out in a variety of local and global contexts and explore the impact of policy on students, in particular marginalised groups, on teachers, and through testing regimes. We will examine the global impact of the OECD and its relation to mathematics education and also consider possible ways to push back against the neoliberal discourse. The overarching aims are to firstly respond to the titular question: Is neoliberalism a crisis for mathematics education? Secondly, we aim to discuss possible ways to work against (/within) neoliberal agendas through our research and involvement in mathematics education.

RATIONALE

How does mathematics education specifically relate to the neoliberal project? We suggest mathematics is deeply implicated in various ways. As a STEM field mathematics plays a key role in generating the discourse of students as human capital. Individual students are seen as the future producers (and consumers) in the economy. Mathematical expertise is regarded as essential for this economic growth and also for the potential of a nation to compete effectively on the global scale (Tatto, 2006; Valero, 2016). Mathematics is seen by some as “a language of the market” (Woodrow, 2003 in Llewellyn & Mendick, 2011). Mathematics is also implicated by virtue of being a key component in international testing regimes such as PISA and TIMMS. These tests form a major part of the neoliberal agenda of the OECD (Robertson, 2012) and contribute to international competition which in turn feeds the production of more neoliberal educational policies (Valero, 2016). This works to essentially change common sense, making policies appear inevitable (Apple, 2000) and forming the view that the neoliberal way is the only way.

Standardised testing in general has gained prominence during the last decades (Au, 2011; Hursh, 2007). These tests often lead to the blame for poor results being placed at the feet of teachers (Robertson, 2012; Zeichner, 2010). Teachers must therefore undergo evaluations often finding themselves measured in relation to their students’ results in high stakes testing regimes. Teachers who were *responsible* for the education of their students are now instead held *accountable*. Neoliberal discourses enter our language affecting the way we view teachers and how they view themselves (Ball, 2003; Robertson, 2012).

Despite the language of freedom, in fact teachers have much less freedom over their own teaching, in some cases being forced to use a word for word scripted curriculum (Tatto, 2006; Zeichner, 2010), having to follow a narrowed curriculum in preparation for national tests (Au, 2011; Zeichner, 2010) or teach according to lesson plans of school administrators (Robertson, 2012; Tatto, 2006). Increasingly the responsibility for teaching decisions rests outside of the classroom (Zeichner, 2010) contributing to the de-professionalisation of teachers; teachers are reframed as technicians within neoliberalism (Sleeter, 2008). We may see other examples of this de-professionalism movement with the deregulation of teacher education institutions (Apple, 2001; Tatto, 2006; Zeichner, 2010), the lowering of a teacher qualification to less than a university degree (Sleeter, 2008), or minimalist ‘earn while you learn’ programmes, usually servicing already marginalised communities (Zeichner, 2010). These apply in particular to STEM fields, such as mathematics, where there are often claims of teacher shortages in these subjects that are seen as ‘crucial’ to the economy (Hagedorn & Purnamasari, 2012).

Given the prominent role of mathematics in the neoliberal project, we have the responsibility as researchers in this field to consider whether mathematics education and mathematics education research also helps to contribute to these neoliberal agendas by perpetuating the above relationships, for example in published articles and grant applications. This is one area for discussion during the symposium.

SESSION PLAN

Introduction to the purposes of the symposium and introduction of presenters: **Lisa Darragh** *(5 minutes)*

***Mathematics education and human capital: A look at the making of modern curricula since the 1950s*: Paola Valero** (15 minutes)

Mathematics education is not affected by neoliberalism. Mathematics education is at the very core of the expansion of neoliberal economic and political forms of government. Through a historization of the post Second World War and the rise of the OECD as an institution in charge of bringing economic and social development, I examine the entanglements of the New Math Curriculum, the push for scientific optimism after the Sputnik Shock, and the expansion of theories of human capital development. The New Math was not only a curricular proposal; it represented a whole new way of governing mathematics education to advance the making of modern, capitalist citizens.

***The de-professionalization of teachers: Chile, New Zealand and Global contexts:* Lisa Darragh** (15 minutes)

I discuss the ways neoliberal policies work to de-professionalise the mathematics teacher. This can be seen, for example, in the relocation of teaching decisions outside of the classroom, often dictated by international and national testing regimes; and by definitions of what it means to be a good teacher of mathematics being increasingly located outside of the teacher, defined by external evaluations and student test results.

***Using stories from mathematics education to do political work: difficulties and dilemmas*: Hilary Povey & Gill Adams** (15 minutes)

“Neoliberalism de-historicises our experience of the present and cuts us off from envisaging alternative possible futures. We have endeavoured to combat some of this absence of history through the creation of a website which features stories from the recent past in mathematics education in England. In this presentation we will be reporting on the difficulties and dilemmas we have encountered."

Discussant: Lisa Björklund Boistrup (10 minutes)

Whole group discussion (30 minutes) ***Chair: Lisa Björklund Boistrup***

- How do neoliberal educational policies compare and contrast in various local contexts? What are the effects of these?
- In what ways might mathematics education and/or mathematics education research contribute to the neoliberal agenda?
- In what ways can we and do we push back against neoliberalism? For example can we create space to benefit from positive opportunities whilst fighting against negative consequences of these policies?
- Does the rise of neoliberalism constitute a crisis for (mathematics) education and what are the alternative possibilities? How might we, as a community and as individual researchers, respond to this crisis?

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INSIDE CRITICAL/RADICAL MATHEMATICS EDUCATION: A VIDEO EXPLORATION

Maisie L. Gholson,[2] Patricia Buenrostro,[1] Lindsey Mann,[2] Eric "Rico" Gutstein,[1] & Mark Hoover[2]

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Symposium participants will observe and discuss video of two distinct enactments of the practice of two experienced critical/radical educators, Eric (Rico) Gutstein and Robert Moses. A major goal of the session is to further theorize and problematize practical applications of critical/radical mathematics education.

The goals of the proposed symposium are for participants to: (a) compare, contrast, problematize two paradigms of critical/radical mathematics education in practice and better understand how teachers may enact them; (b) analyse relationships between critical/radical mathematics educators' claims regarding their philosophical, political, and pedagogical perspectives and how they enact these in practice; (c) watch classroom video of experienced critical/radical mathematics educators attempting to enact their theoretical perspectives in practice, that is, to get a sense of what it "looks like" in classrooms; and (d) examine how critical/radical mathematics education teachers may position students in the classroom with respect to their participation as meaning makers and creators, both doing mathematics and awaking/engaging politically. To achieve these aims, we will engage the symposium participants in the central question: *Why might this be critical/radical mathematics education?*

AN EXAMPLE OF READING AND WRITING THE WORLD WITH MATHEMATICS

Gutstein (2006) has built on the scholarship of Freire (1970/1998) who coined and defined the term *reading the world* and *reading the word* as two dialectical processes that lead to critical consciousness and critical, reflexive action. Freire's pedagogical aims were to engage adults in learning how to read the word (literacy) while simultaneously learning to read the world (critically reading society). Through critical literacy (reading the word/world), Freire advanced the notion of writing the world (acting upon the world to transform it) as the interrelated complement to reading the world. Similarly, Gutstein's teaching of reading and writing the world with mathematics (RWWM), building on Frankenstein (1983), entails learning to read the mathematical word (school-sanctioned mathematical knowledge) while simultaneously learning to read the world with (and without) mathematics –both competencies necessary to effectively change or write the world with mathematics. To teach using a RWWM framework accordingly means that

> … students develop deeper sociopolitical awareness through learning and using mathematics to study reality, which prepares them to shape society by using mathematics, at the moment and in the future. They come to view mathematics as useful in this process (a dispositional shift), recognize some of its limitations, and also learn that mathematics is but one way to read and write the world. Through understanding and acting in the world–even if their actions are limited by being in school–they also transform themselves (Gutstein, 2016, p. 457).

Gutstein (2016) theorized that RWWM involves two sets of dialectical relationships –one, reading the world (in general) and reading the mathematical word, and two, reading and writing the world with mathematics. That is, learning to unpack one's sociopolitical reality with mathematics contributes to students being able to act upon reality to transform it both with, and without, mathematics.

One of the videos to be shown and analysed is an example of RWWM. In 2008-2009 Gutstein taught a twelfth grade mathematics class to 21 African-American and Latin@ students in which RWWM was the primary aim. Gutstein and students used mathematics as a lens to study four main thematic units: voter disenfranchisement, displacement forces (deportation and gentrification), AIDS, and criminalization of youth/people of colour. Students explored social issues plaguing their lives, their families, and their communities through the study of mathematics. Students culminated the year by presenting their learnings to their communities. This class took place in a small, non-selective-enrolment, public school born out of a community struggle whose thematic focus as a school was social justice.

AN EXAMPLE OF MATHEMATICS EDUCATION AS A CIVIL RIGHT

Robert Moses has drawn on his experience with the African-American Civil Rights Movement in addressing the constitutional status of children with respect to their public school education in the United States. As a member of the Student Nonviolent Coordinating Committee, he directed efforts to address Mississippi sharecroppers' exclusion from voting and to gain standing in the National Democratic Party (Moses, Kamii, Swap, & Howard, 1989). After opening up political access, Moses continued to address the issues he found around him, in particular, in the lives of his children, and to "transform them into broader political questions" (Moses, et al., 1989). Given high school algebra's role as a gatekeeper and its importance in an increasingly technological world, he identified success in algebra as an immediate issue for the children in his community (Moses & Cobb, 2001).

He then worked inside and outside the school to shift the conversation from asking who would get access to higher-level mathematics to asking what would need to be changed in order for all students to have that access. Continuing this shift, and expanding its scope, Moses identified mathematics literacy as strategic in demanding a quality education as a constitutional right (Perry, Moses, Wynne, Cortes, & Delpit, 2010). Founding the Algebra Project in 1982, Moses works nationally to create a grassroots demand for quality education among young people from the underserved lowest quartile of the U.S. population.

In all of these efforts, Moses continues to draw on the grassroots, nonviolent approach of Ella Baker (Moses et al., 1989), often describing it as earned insurgency (Moses, 2016). We identify three key features of this approach. First, racism is a form of violence. Violence can create trauma, erode capability, and undermine development (Herman, 2015). The Algebra Project attends to the conditions of learning and uses safety, empowerment, reconnection, and commonality to *address and manage the trauma of injustice*. Second, *addressing social injustice and developing capabilities are mutual activities*. Justice can open the door, but stepping through requires investing in and exercising capabilities; and developed capabilities are squandered if the door remains closed. In other words, learning mathematics is an essential component of the uprising. Third, *earned* insurgency is about a politics of peace, one that deemphasizes notions of sides and emphasizes inclusion, where all are responsible for addressing injustice. Instead of attacking an enemy, the approach is about earning trust for the work –of the people students, that the movement is serious about the work, of the national government, that the movement ought to be provided with a legal crawlspace, and of the country, that it ought to take a look at itself (Moses, 2016). For the movement, *insurgency is built on truth and trust*.

To teach in the spirit of the Algebra Project requires appreciating that public school education in the United States remains the clearest manifestation of the nation's caste system and that building success in mathematics education is an organizing tool for establishing the right to quality education for meaningful democratic citizenship. Indeed, this is the initial understanding with students –the Algebra Project will support your education as part of your participation in pursuing this common agenda. Students' initial understanding may be nascent, but this is the point of reference for the mathematical work students learn to do. When students detach, act out, or just loose focus, it is this agenda and its urgency that guide the response.

The Secondary Mathematics Laboratory (SML) was a two-week summertime math class for 18 underserved students taught by Moses, with an aim of making skilled, disruptive teaching "visible" to observers.

The curricular design and pedagogical approach are grounded in initial experiences that support students recording of observations in their own words, *people talk*, which they then learn to rewrite as *feature talk*, then represent iconically, and finally as formal symbolic mathematics (Moses & Cobb, 2001). The topical focus was on symbolic notation for, and interpretation of, binomials and trinomials. Students built objects out of materials designed to reflect the mathematical structure of polynomials, manipulated the objects, made observations, developed an understanding of features, and developed iconic and symbolic notations for their observations. Video recordings, lesson plans, and other instructional artifacts from the SML will provide a window into this second political-pedagogical perspective.

AN EMERGING ISSUE AND PLANS FOR THE SESSION

Larnell, Bullock, and Jett (2016) suggest a contrast between Gutstein's and Moses' approaches, as social-justice-as-critical-consciousness and social-justice-as-instrumental-access respectively. Martin and McGee (2009) criticize Moses' approach as focusing on preparation for the job market without promoting critical consciousness. Our initial examination of the two approaches and their classroom enactments suggests that both approaches are concerned with critical consciousness, but that where Gutstein's focuses on knowledge as power (its production and use), Moses' focuses on earned insurgency for a legal guarantee of rights. After presenters briefly frame the session, for each of the two enactments they will contextualize the video and provide significant time for small-group and then whole-group discussion, concluding with a final whole-group discussion and a few concluding remarks.

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MAJORITY COUNTS: WHAT MATHEMATICS FOR LIFE, TO DEAL WITH CRISES?

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A complex hegemonic relationship between mathematics-as-discipline and mathematics-as-school-subject shapes contemporary curricular conversations across the globe, while the transmission of a rigidly structured body of knowledge continues to oppress and marginalize the majority, not acknowledging its agency, aspirations, cultural rootedness and lived experiences. In this symposium, participants will interrogate the increasingly homogenising discourse around what constitutes school mathematics and its perceived role in education. Instead of a standardised product marketed to all –heavily encrusted with inertial tradition, circularly defined by globally benchmarked 'world-class' curricula, and calibrated by corporate testing regimes to manufacture 'national crises'– how could curricula honour the mathematical imaginations of all, embedded in historical, cultural, social, and political contexts? What curricula for teacher education would enable them to understand the politics of school mathematics and life, to reflect on substantive issues of equity and security, even as their students face existential questions of place, identity and 'voice' for survival? How do we forge a critical community of educators and activists who can invert (and subvert) the hegemonic pyramid to realize 'mathematics for the majority'?

An aggressive rhetoric of mathematics (and science) education to help counter threats to 'national security', or ensure economic survival in a globally competitive world, pushes for conventional advanced curricula, makes children more vulnerable, while targeting teachers for declining 'outcomes'. The consequent collateral damage is great –emotional, in the form of alienation; intellectual, in the form of devaluation of other forms of intelligence; practical, in terms of the erection of artificial barriers to educational and economic opportunities. Contrast this nationalistic stance with D'Ambrosio's (2010) passionate plea that mathematicians and mathematics educators should collectively be seeking solutions to the crises facing humanity.

Paulo Freire's observation that "education is politics" applies specifically to mathematics education, with far-reaching consequences. Modern life is increasingly governed by mathematical models that are often invisible to, and almost always beyond the control of, the majority

–what Skovsmose (2005) termed “mathematics in action”. Mathematics education predominantly fails to prepare students (or teachers) to become citizens with a critical disposition to understand, and agency to disrupt, misapplied mathematical models, for example in relation to the economics that makes them vulnerable to crises (Greer and Mukhopadhyay, 2012). We would argue that this failure in mathematics education serves to protect political systems from critique. By contrast, one of us (Eric Gutstein (known as "Rico"), 2012) has shown how mathematics can become a weapon in the struggle for social justice by teaching students how it can be a tool for analyzing and then acting upon, issues of importance in their lives, even at times of crisis. Working through generative themes emerging from the sociopolitical experiences of students in Chicago, an epicentre of neoliberal oppression in education, money and politics, police and other violence –but also of resistance– and combining classical, community, and critical mathematics, students were enabled to read (understand) and write (act to change) their world (Gutstein, 2006).

How are we challenging the elevated status accorded to mathematics, which also serves as a proxy for intelligence, in schools and society at large? Why can a mathematics curriculum not be creative, challenging, and related to lived experiences of the majority, while keeping open the possibility of some going on to become academic mathematicians? How is mathematics education to be framed, not in terms of economic competitiveness and nationalism, but for addressing the problems facing humanity (https://en.wikiversity.org/wiki/Ethics/Nonkilling/Mathematics)?

The blizzard of standardization of school mathematics, tied to aggressive formulations of measurement metrics, is undermining the small but critical space that UNESCO's World Declaration on Education for All, 1990, had allowed to be forged in highly diverse developing countries; it had called for an ‘expanded vision for education’, “recognizing that traditional knowledge and indigenous cultural heritage have value and validity in their own right and capacity to both define and promote development”. In India, for instance, this had aligned well with the participatory campaign for adult literacy (and numeracy) in the nineties, addressing local cultural knowledge. Subsequently, the national primary textbooks (‘Math-Magic’ published by the National Council for Educational Research and Training (NCERT), accessible online at http://epathshala.nic.in/e-pathshala-4/flipbook/) were based on a culturally responsive pedagogy, and chaired by one of us (Rampal, 2015). In a conscious effort to bridge the mathematical discourses –of the home, community, and school– this attempt questioned the valorisation of certain privileged knowledges within the hierarchies of school subjects. There are increasingly daunting challenges of developing curricula for schools as diverse and unequal as are in India, through pedagogies of empathy that enable democratic participation (Rampal, 2013). With more than half the children not able to complete secondary school, the State Board examinations (Class X and XII) serve to support the hegemony of mathematics as 'gate keeper', for future professional opportunities. In poor countries with high inequalities, the myth of math only for the 'academically talented' thus helps to reserve the coveted fields of higher education for the privileged, often those who buy their way in, through a burgeoning industry of private coaching, allied with the information and communication technologies. Mathematics can be doubly oppressive for those in vocational streams. For instance, the Indonesian class X textbook for tourism or business management, with hundreds of intimidating pages on logarithms, integral calculus, trigonometry and matrices, flaunts content unsuitable for any 16 year old, vocational or not. Why is there no attempt to develop creative curricula for post-compulsory mathematics that would interest and engage those in diverse 'real' work situations?

Concerted pressure from international agencies and corporate advocacy groups, pushing governments into 'standardised' testing, using 'outcomes' to shame public education, whips the discourse to abandon larger visions of education for democracy and equity, and notions of cultural rootedness of learning. Pushing poor countries into PISA, along with hysterical chest-beating by the media on poor performance, demoralises those that have striven for basic provisions to public education despite abysmally low resources. This serves the interests of the privatisation lobby and the billion dollar market share of 'low fee private schools', actively promoted in developing countries, with low-paid unqualified teachers and programmed tablets (ipads) to deliver 'outcomes'.

Mathematics teachers are generally ill-prepared to deal with children coming from disadvantaged and diverse cultural backgrounds, owing to their deeply entrenched beliefs about the subject and the 'slow learners' it constructs (George, 2014). Teacher education may at best focus on content knowledge, pedagogical knowledge, and knowledge of students, but we argue for a fourth –political knowledge. With political knowledge about mathematics education and the lives and crises faced by their students, they are able to deconstruct deficit narratives, are better prepared to question issues of equity and power, and to make professional decisions about the kinds of learning opportunities and 'outcomes' that are most enabling for their students (Gutiérrez, 2012; 2013). We must ask how far we have been able to shape our teacher education programmes to enable them to address mathematics for the majority, not simply comply with playing the game to get good 'scores'? Do teachers understand, for instance, the alarming implications of the monopoly wielded by for-profit corporations pressing for neo-liberal policies that ensure that students' scores also affect their own salaries, or even their ability to stay in teaching?

The varied perspectives we offer on humanistic approaches to framing mathematics education, in differing contexts, stand in stark contrast to the prevailing forces towards homogenization and corporatization of (mathematics) education globally, against a background of political crises, and indeed a crisis of rationality. We have no choice but to continue the struggle.

STRUCTURE

The Symposium will be participative and structured as follows: Each presentation will be for 20 minutes, to flag different dimensions of the theme. These will be followed by an hour of discussion and sharing of experiences, where observations from other participants coming from different country contexts will be invited and deliberated upon.

1. Anita Rampal: Introduction; Standardisation and resistance in a developing country context; 2. Rico Gutstein: Mathematics curriculum and pedagogy for social justice in times of crises; 3. Rochelle Gutiérrez: Teacher education to counter homegenisation and corporatisation; 4. Brian Greer and Swapna Mukhopadhyay: Inverting the pyramid to realise mathematics for the majority;

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ETHNOMATHEMATICS AND RECONCILIATION

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Symposium participants will discuss the possibilities and challenges of ethnomathematics in support of reconciliation efforts in historically marginalized or traumatized communities. Connecting with calls to action for reconciliation between non-Aboriginal and Aboriginal Canadians, we will share reflections on our experiences working in Indigenous communities in Atlantic Canada through the Show Me Your Math program. Participants will also be invited to share reflections on their own stories of ethnomathematics and reconciliation. Together, we will work toward a shared understanding of how we, as researchers working with the people in our communities, can do work that honours the values of the communities, acknowledges injustices in the communities, and takes steps toward reconciliation.

INTRODUCTION AND RATIONALE

This symposium will engage participants in a discussion about the possibilities and challenges of mathematics education, in particular ethnomathematics, to support reconciliation and healing in historically marginalized communities. We are inspired by movements within Canada to address reconciliation between non-Aboriginal and Aboriginal peoples within all areas of education. We are equally inspired by the Show Me Your Math program we began in conjunction with Mi'kmaw Kina'matnewey (MK) schools in Nova Scotia in 2007, that has since spread to other parts of the country. Show Me Your Math invites Aboriginal youth to explore the mathematics that is used within their own cultural communities through working with elders and knowledge keepers. We have seen many moments of healing emerging from this work but we have also struggled with how to share this work in a good way. In this symposium we will share some of the moments of healing we have seen and some of our struggles with dissemination. We will invite participants to reflect on and share their experiences working with ethnomathematics and ask how those interactions addressed needs for healing and reconciliation in those communities. From these conversations, we hope to identify practices (ethnomathematical and otherwise) that have the potential for supporting healing and reconciliation, and to understand better the ethics of dissemination in these contexts.

RECONCILIATION IN THE CANADIAN CONTEXT

Canada's residential school system perpetuated an act of cultural genocide on Indigenous peoples, the effects of which are still significantly impacting these communities today (Truth and Reconciliation Commission of Canada, 2015). In 2015, the Truth and Reconciliation Commission (TRC) released a final report that included calls to action in response to the horrors of residential schools for Aboriginal Canadians. These calls to action are focused on establishing a renewed relationships between non-Aboriginal and Aboriginal Canadians to "restore what must be restored, repair what must be repaired, and return what must be returned" (2015, p. 6). The ultimate goal of reconciliation is "to transform Canadian society so that our children and grandchildren can live together in dignity, peace, and prosperity on these lands we now share." (p. 8) The TRC names the education system as having an essential role in repairing the damages caused by residential schools. The experiences that have emerged in response to the Show Me Your Math program over the past ten years have shown promise in bringing about such acts of reconciliation.

SHOW ME YOUR MATH

Show Me Your Math (SMYM) is a program that emerged from our own ethnomathematical conversations with Mi'kmaw elders in Atlantic Canada, the richness of which prompted us to find ways to engage Mi'kmaw youth in similar types of investigations and interaction with their community knowledge holders (Wagner & Lunney Borden, 2015). Since 2007 thousands of Mi'kmaw and Wolastoqey youth have worked with teachers, classmates, elders and community knowledge holders to explore the mathematics that is inherent in their own cultural context. Some communities have held SMYM events that engage both First Nations and settler children, all investigating cultural practices from their own heritages. We have seen projects focused on exploring mathematics in basket making, birch bark biting, constructing wi'kwams and sweat lodges, baking, beading and more. In many of these projects, we have seen moments of cultural reclamation and what we believe to be healing.

One example occurred when children in an 8th grade class made canoe paddles and shared their completed projects with a number of elders who were both former champion canoe racers in Mi'kmaw summer games and grandfathers of many of the students in the class. The grandfathers' lunch provided moments of connection in which stories were exchanged between the youth and elders. One grandfather shared his belief in the importance of this work, given that when he was young he was not afforded the opportunity to engage in such learning as most traditional community practices were not permitted by government agents.

Birch bark biting projects (see Lunney Borden, 2015) have also provided moments of reconciliation with teachers from the community sharing memories of late community elders who were known to have been birch bark biters. The work with birch bark biting has also provided rich moments for mathematical inquiry, covering many aspects of the geometry curriculum covered in Atlantic Canadian middle schools. When we see such promise in these investigations we want to share this work with others, yet Lunney Borden has found that when sharing about birch bark biting in particular, teachers are often interested in doing birch bark biting with their students, yet they are less interested in making meaningful connections to members of the communities they serve that would help to connect these practices (or not) with their contexts. This creates a tension –while we want to share the stories so that others might appreciate the process that resulted in the healing work, we fear that in sharing, others may chose to appropriate the task without valuing the connection to the community, thus risking a trivializing approach. We have heard others, doing similar work, share the same concerns about dissemination.

CONNECTING WITH OTHER ETHNOMATHEMATICAL PROJECTS

The symposium will provide a space for participants to share their stories of ethnomathematics and reconciliation. We will invite participants to share about the contexts in which they have worked, the nature of the historical trauma that have been experienced in those community, and how ethnomathematics and other mathematical practices might be helping to heal or ignore the wounds of these traumas. We are also interested in how mathematics as a discourse/discipline is constructed through these practices. We hope others will share both the successes and the challenges within their own work so that we might begin to build a shared understanding of how we, as researchers working with the people in our communities, can do work that honours the values of the communities, acknowledges injustices in the communities, and takes steps toward reconciliation.

PLAN FOR SYMPOSIUM

Key Questions

The fundamental questions in our symposium are these: What role can mathematics education and specifically ethnomathematics play in reconciliation? How can ethnomathematics help to heal the wounds of colonization and cultural genocide? However, these questions are too general for reflection. Thus we will use the following questions to initiate reflection and discussion. First, we will apply them to our own ethnomathematical research experiences, and then we will ask symposium participants to apply them to their contexts. We find it helpful to think of particular interactions we have had in our research contexts, rather than trying to apply the questions to the whole set of experiences. We encourage prospective symposium participants to use these questions to reflect on their experiences in preparation for the symposium.

1. What were the most important cultural/community narratives in the context? Specifically, what injustices warranted attention?
2. What mathematical practices brought to attention cultural/ community narratives, and how were these narratives positioned in those practices? (Mathematical practices may include physical manipulation of objects, discourse moves, and more.)
3. What mathematical practices masked cultural/community narratives?
4. Were there ethnomathematical practices that foregrounded certain narratives and thus eclipsed others?
5. What evidence was there of healing? How could that healing be described for others to understand?
6. What ethical dilemmas and discourse traditions affected considerations of how to share/disseminate (or not) stories of pain and healing?
7. How was mathematics constructed for the people in the interaction? How is that different from common constructions of mathematics in school?
8. What aspects of the interaction felt important yet were not addressed in the above questions? What other questions could be added to this list to capture the most significant aspects of ethnomathematical interactions (especially with an orientation to reconciliation)?

Agenda

We will structure the symposium as like a discussion group to address the key questions we have identified above in reflection, and to generalize them as warranted. Specifically we will use the 90 minutes to do the following:

1. A brief introduction to the purpose of the symposium, the agenda for the session, and the goals. (10 minutes)
2. Setting the context through sharing our stories of Show Me Your Math in both the Nova Scotia and New Brunswick context as well as how this program is being taken up in other areas. (15 minutes)
3. Inviting session participants who have done ethnomathematics or seen it in action to describe the pains/violence in the community's history, and to describe how the ethnomathematical work has addressed that. (15 minutes)
4. Small group discussions focused on the key questions. (15 minutes)
5. Sharing from groups. (10 minutes)
6. Discussion and synthesis, to set some vision for how we as scholars

might move forward both in healing practices and in publishing about it. (25 minutes)

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DEALING WITH OUR OWN SHIT: THE RESEARCHER BEHIND THE [MATHEMATICS EDUCATION] RESEARCH

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AIM AND RATIONALE

It is commonplace for mathematics education researchers to complain about the limited impact that our research has in changing the current state of affairs of school mathematics. The reasons presented to justify this absence include teachers' resistance to changing their classroom practices, that politicians systematically overlook relevant research insights, or the political pressure to reduce education to a matter of accountability and governance. In any case, the problem is seen as being somewhere "out there", while we struggle "here": alone against the wicked forces that corrupt what would be a meaningful mathematical experience.

In this symposium, we turn our researcher's gaze unto ourselves as researchers. Instead of locating the problems of mathematics education in some external entity, we develop a (scrappy) rationale to understand our own role(s) in perpetuating the same situations we so often criticise. Our challenge is not only to criticise other researchers with whom we might not agree –studies on the "social turn" have been doing this quite emphatically– but also ourselves, critical researchers with an awareness and a concern with the political implications of mathematics education. This exercise in *positionality* has become more frequent in recent mathematics education research, in which authors have been calling our attention to the importance of teasing out the assumptions and discourses generated within the field (e.g. Bullock, 2013; Lundin, 2012; Martin, 2011; Pais & Valero, 2012; Straehler-Pohl, Bohlmann & Pais, 2016). This exercise allows us to "estrange" ourselves from mathematics education research, and thus to better locate ourselves within it. This symposium is thus an invitation for us to posit ourselves as part of the problem, without shame and without guilt, but also without a safety net. As Edward Norton so eloquently poses in *Fight Club*, if you want to change the world, start with your own shit. It is our contention that such an approach, although not directly aimed at providing some kind of insight for action, can help us redefine the coordinates we use to make sense of the problems of the field.

THE PLAN

The symposium will consist of three short paper presentations and lots of space for discussion. All three of us have been developing research about the role that academics, particularly but not exclusively in mathematics education, have in reproducing a reality through their concrete actions, while in the abstract presenting ourselves as critics of that same reality. Each of our papers highlights the value of taking a structural approach to considering researcher positionality –in this case, we consider mathematics education research in relation to capitalism. We will bring into play contemporary theory, including Antonio Gramsci, Jacques Lacan, Slavoj Žižek, Étienne Balibar and David Harvey. These will be used to analyse different research assumptions about the role of mathematics education in our current world, and to raise a set of questions about our role as critically engaged researchers. In what follows we briefly describe each of the paper presentations.

THE PAPERS/PRESENTATIONS

Alexandre Pais

It is difficult for us to acknowledge that our efforts to make mathematics more meaningful and relevant can actually contribute to the exclusionary role this subject plays in school. We need to know that the goal for which we all strive is equality (that the presupposition of the "system" is a "good" one), so that we can accept the unequal reality in which we live. However, as researchers, we cannot be blind to the fact that there are obvious benefits of the belief that mathematics is precious knowledge, a keystone of modern society, and an inescapable tool for citizenship. By positing mathematics for all as a goal to be achieved, and by asserting the importance of research in this process, we set the ideological frame so that we can continue to work, receive our salaries, progress in our careers, participate in conferences, travel, and enjoy ourselves. The true difficulty for us is not to criticise the current state of affairs in MER, something we have been doing very successfully, but rather to change what we enjoy. Capital exerts its power not by means of a conscious decision by the ones in power but through the distribution of simple pleasures that keep people captive. Are we willing to recognise our own enjoyment of the shitty reality we so often lament? In this presentation, I will explore a set of commonly shared assumptions –the importance given to the use-value of mathematics, the idea that mathematics should be enjoyable and for all, the assumption that research improves practice and should be about reporting successful experiences– that function as a fantasy screen, enabling us to continue our work, notwithstanding the crude reality that it would not bring about the so-desired change we want for mathematics education and for the world.

Alyse Schneider

While critical mathematics education researchers have drawn connections between the beliefs, ideologies, and stated intentions of mathematics education research and its political interests for decades (e.g. Secada, 1989; Valero, 2004), this topic has garnered increased attention in recent years (e.g. Martin, 2011; Bullock, 2013; Wolfmeyer, 2014). This theoretical paper seeks to contribute to our understanding of the connection between ideology and political interest in mathematics education research by considering our positionality as an *expert group*. In order to do this, I will explain relevant insights from Gramsci (1971) and Boltanski and Chiapello (2005), connecting them to the case of mathematics education research.

As an expert group, we take up specific roles in the maintenance of our own position as experts as well as in the over-arching struggle between capitalists and wage-earners. Gramsci as well as Boltanski and Chiapello theorize experts as taking a leading role in maintaining the consent of wage-earners to inequality and the capitalist system at large, which involves assimilating their critiques of capitalism. However, as wage-earner critiques are taken up by experts, they are often altered and channelled in preservation of a balance of forces in the favour of capitalists. As a first example, when critiques are assimilated in to the education system, they are typically altered so that they become a project of reforming the individual through education instead of a collective threat to the relations of production (Bowles & Gintis, 1976).

Additionally, and especially since the 70s, experts have taken up a critique of a lack of meaning and hierarchical relations at work (and in mathematics pedagogy) that, while associated with critiques of material inequality, serves to sublimate these concerns (Boltanski & Chiapello, 2005). The pursuit of meaning and the mitigation of hierarchy in the common good and the fight against "traditionalists" legitimates the class position of experts, particularly over managers (and teachers) who must be entrained into this new *esprit de corps* on behalf of workers and students. In mathematics education research, this takes the form of progressive pedagogy. The need for meaningful math and mitigated teacher authority *is* responsive to wage-earner interests and demands, as is the rhetorical commitment to mathematics for all. However, the expert response to these interests further legitimates mathematics examinations and credentials as a means of sorting students, by giving the appearance that they are in the process of becoming more equitable.

Mônica Mesquita

Let us be intolerant with ourselves! With this sentence, I finished a small contribution, in fact an outburst, submitted to *The Disorder of Mathematics*

Education, in early 2015, in Berlin (Mesquita, 2016). With a brief introduction of some points of view over our choices, questioning our freedom, going through the political flows of our survival, and enquiring about the role of our production, reproduction, and contradictions as researchers, my goal was to promote a search for our *situationality* (Freire, 1970) in the current capitalist process. For me, to *disorder* the field means to shake ourselves as researchers and to think about who we produce research for, as well as how this research is entangled with the lack of dignity in current human life. This entails thinking about the contradictions of our work, and centering the role of the researcher in our political discussions.

This position can be seen as anthropocentric (indeed, this was one of the comments given by a meeting participant). The recent trend towards (new)-materiality and post-humanist research seems to leave no space to analyse the researcher's desire, focusing instead in matters that exclude human subjectivity. It seems to me that this move, while important in dismantling philosophies that carry humanism as an alibi, has served as a *disavowal mechanism* (Žižek, 2006) inhibiting us from confronting the truth about why are we engaged in research; and for whom we are doing it. It also feeds the old separation between "doing" and "thinking" (Tragtenber, 2002), allowing researchers to pursue their agendas without any real concern about the ways in which it affects or is affected by broader politics.

Here, I highlight the importance of considering our situationality as researchers, including how we occupy the spaces that regulate current society. This implies a certain level of bravery in order to understand our economically rooted relationships, which are the source of many of the contradictions we experience in our daily work. This is not always an easy exercise to do, and we often take on a certain level of blindness in order to keep contradictions out of sight. As posed by Nietzsche (1996), courage is needed, not so much to follow our convictions, but to "attack one's convictions" (p. 630), to shed light into our blindness, "while unveiling the blindness of others" (Santos, 2001, p. 2). This implies shaking our bourgeois posture often hidden behind our sweet and good theoretic-methodological choices, our desires (or duty) to save what has no cure. In this presentation, more than disserting about what I know or what I have been doing, I will invite colleagues to share their own experiences of situationality, and to reflect upon ourselves and the small enterprises that we can develop in our daily lives that are not completely attuned with the current trend towards dehumanisation.

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“CRISIS” AND INTERFACE WITH MATHEMATICS EDUCATION RESEARCH AND PRACTICE: AN EVERYDAY ISSUE

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Here, by the downslope of hills, facing the sunset
and times’ muzzle,
near gardens with severed shadows,
we do what the prisoners do,
and what the unemployed do:
we nurture hope.

Mahmoud Darwish,
State of Siege (2002)

AIMS AND INTRODUCTION

This symposium aims at engaging MES-9 participants to an intense, critical discussion to brainstorm and problematize the notion of crisis within mathematics education. Panelists from “developing” countries will reflect on how theoretical traditions are absent from acknowledging and delving into crisis situations that become so normalised and seasoned in “developing” and “underdeveloped” world contexts that those living in such conditions often do not see them as crisis situations. This symposium will focus around two possible meanings of crises (among many others):

1. A discourse being enacted through regulatory devices, like standardised international tests, rankings and studies. This normalizing discourse comes from international instances by creating a permanent situation of deficit for our countries, while offers of remedial measures to implement recommendations emerging from those instances are prescribed as the only possible way out. This has also been an ICME agenda since the first congress in 1969 in Lyon, France: "(…) the 'advanced' countries should continue to collaborate with developing countries in

search for solutions appropriate to them" (Resolutions of the First International Congress on Mathematical Education, 1969, p. 284), and which still persists, as Marcone (forthcoming) discusses.

2. A permanent condition of lack of resources, poverty and hunger, constant denial of rights and access by the State or a foreign military occupation, traversing difficult terrains of sustained conflict situations, fear of bullets and physical, psychological and financial trauma, and so on. Thereby, uncertainty and unpredictability turn into ordinary conditions that we are forced to take into account when exploring crisis in the literature on research and practice in mathematics education.

RATIONALE AND RELEVANCE TO MES

Crisis is often presented as something extra-ordinary and unnatural, that breaks away any continuity and replaces one tradition or set of rules with another. Mathematics educators in developing and underdeveloped countries have built their own ways of research and practice of teaching and learning of mathematics despite the existence of (and according to) such conditions of crisis. In this symposium, we want to share part of our experiences addressing the crises, by showing several ways of resilience within several strands of mathematics education including research, pedagogical and evaluative practices. MES conference presents a platform for wider discussion on socio-political issues of mathematics education that creates an apt situation for problematising this issue.

The call for this MES conference states, "social and cultural diversities, immigration, growing unequal distribution of wealth, persistence of poverty, and also depleted nature and devastated environment" -as if such terrible conditions were new! But for many of us the only difference is just that now the first world countries are facing a third-world experience in their own land. Then we consider a discussion on crisis relevant as well as timely to highlight the risks of approaching crisis situations through an on-going colonial perspective. Such a perspective could (unconsciously) reinforce the narrative of success, progressivism and danger that usually came from the mainstream discourses in mathematics education (Ernst, 2009; Valero, forthcoming), many often focused on prototypical classrooms (Skovsmose, 2011). So it is important to add a self-critical insight to such sociopolitical interests in crisis.

Sociology of crisis: places of its enunciation

We consider it relevant to problematise with the MES-community the use of the concept "crisis" in itself, by raising simple questions like, crisis for whom? where is the crisis? crisis since when? and crisis for what? We suspect that crisis could be becoming an "automatically-good" concept, without any past, neither any point of departure nor an agenda.

"Automatically good" concepts like democracy, peace, social justice and many others have with the passage of time become deprived of their original meaning and turned to be used against the people who supposedly try to defend. In other words, "automatically good" concepts act like an empty signifier and remain functional to the creation of a feeling of change, but continue maintaining the order and *status quo* and hiding their place of enunciation (for instance, colonialism in research).

It becomes important for us to note where "crisis" is enunciated in the contemporary world context. From where are those voices of concern coming? Places of enunciation of crisis are noteworthy since they guide the hegemonic power struggle and further (de)acknowledge crisis situations that "others" are facing or not. Deliberations of sociology of crisis are yet to be noticed in mathematics education, in mathematics teaching and learning and also in curriculum development processes.

Presenting and contrasting the local and contingent ways to address the critical conditions of our educational environments, we want to visualize the rooted approaches to (and understandings of) the sociopolitics of mathematics education. Those approaches can lead to overcoming the dichotomy that seems to emerge when some theories in mathematics education address critical situations through economy (Pais, 2014) or humanism (D'Ambrosio, 2010). The proposed barter of insights and developments aims to continue the way proposed by Fasheh (2015) in MES-8 to find the rooted words that each person and community can use to heal and mutually nurture.

We all come from different cultures and different places in the world but we, interestingly, share a brilliant and beautiful heritage to build on, such as Freire, Gandhi, Márquez, Said, Sakakini, Fals-Borda among many others. Helped with their thoughts, we take a standpoint that is perfectly aware about the many economic and political constraints of education, but at the same time, is coated with hope, not a naive one that romanticizes our deprived condition, but a hope that finds its strength in the dignity of the defeated. Our parents and ancestors knew much more than us what to live in crisis could mean, and they encouraged us to not simply complain or blame, but to resist and survive. This does not imply a position of "lamb" conformity, in which we, people from '"non-rich" countries, believe and act as if we do not deserve much improvement. The non-naive hope we are talking about might also live between these two positions, not so cynical but never with non-critical conformity.

HOW THE SYMPOSIUM WILL BE CONDUCTED

This symposium expects to foster an interactive discussion among participants, not relying in a formal speech by the discussants, but to digging into the almost invisible tactics that people develop to cope with critical situations. In order to achieve this, we want to structure the symposium divided in three defining moments:

Moment 1: We present a gallery of diverse objects from media, policies and research that have addressed crisis in relation with mathematics education. Considering those objects, the audience in groups of two or three make statements or drawings/sketches about their views on crisis. This is to allow free flow of ideas emerging from participants' encounter with crisis situations and problematising them.

Moment 2: We, the panelists, present our views about crisis, introducing the experiences that we have witnessed in our countries, to cope with critical situations and how they have developed endemic conceptualizations and practices.

Moment 3: Connecting the above two moments, a group discussion on the panelists' presentations and raising of questions. Questions are jointly addressed by the panelists. Summing up and considering a way forward.

The symposium will see each panelist presenting data and resources from her/his country and will try to raise concerns that links mathematics education in countries signed by "crisis".

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RACE, RACISM, AND MATHEMATICS EDUCATION: LOCAL AND GLOBAL PERSPECTIVES

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In this symposium we are interested in analyzing the ways wherein particular racial formations across societies manifest in the social space of mathematics education practices. It is aimed at facilitating discussion with colleagues to explore the current state of research directed to analyze and uncover the mechanisms and practices responsible for the reproduction and maintenance of racial domination within mathematics education as well as how mathematics education contributes to various forms of domination in local and global contexts.

RATIONALE

Racism and race continue to be controversial topics (Martin, Rousseau & Shah, in press) to the extent that some societies have tacitly agreed on almost making these terms be set in disuse and almost oblivion (Weiner, 2014). As a contingent and socially constructed category of social identity, race is not a static, rigid concept with a single meaning but malleable. Its very deep roots can be found in locally situated scientific, political, cultural and economic structures. Meanings of race and comprehensions of racial discrimination and inequality vary across racial systems (Bonilla-Silva, 2010). This manifests differently in the U.S., Latin America and Europe. In contrast to Latin America, in the U.S. society there exist a much clearer definition of racial categories (white, black, native) and a strong color line demarcation (Wade, 2008). Within the context of Latin American countries, the racial order responds to what Bonilla-Silva and Glover (2004) denominates *Pigmentocracy*, or the structuration of a racial hierarchy dominated by diffused in-between racial categories such as *pardos*, *morenos* and *mulatos*. Additionally, in contrast to the dominance of colorblind ideologies in the U.S. (Bonilla-Silva, 2010), nation-building ideologies such as that of *mestizaje* (Wade, 2005) have been prevalent in Brazil, Colombia and Peru among other Latin American countries. *Mestizaje*, as an "all-inclusive ideology of exclusion" (Wade, 2005) helps to configure the interpretations of racial affairs in Latin America in ways that make racism invisible or even appear non-existent and difficult to overly talk about racial inequity. In Europe, the colonial history of many countries has generated long-standing categories to refer to the “other” as inferior and in need of civilization. A differential positioning of “whiteness” and “colorness” has been present in institutions and everyday practices. The extermination of certain populations during Second World War, –e.g., Jews and Roma– on the grounds of racial biology and eugenics connect to the desire of eliminating race as a category. Instead, ethnicity became a category to talk about differentiation on the grounds of culture. Such differentiation, nevertheless operates in everyday institutional practices and certainly have effects in access and participation to education (e.g., Dovemark, 2013). In conclusion, the processes of racialization as well as the ways wherein people´s racial experiences are interpreted and configured diverge in great extent in different parts of the world.

As a social institution, school is not exempt from racism and issues of power, but rather one in which racial ideologies, practices, hierarchies, and stereotypes find a fertile soil to grow and reproduce. Moreover, the field of mathematics education is a racialized domain, an instantiation of white institutional space controlled primarily by White and male researchers. Mathematics education is also a political project that serves larger racial projects (Martin, 2013). Yet, critical reviews of the extant research literature suggest that the realities and consequences of racism are not globally reflected as considerations in mathematics education research. Even in countries such as Denmark with an important tradition in critical mathematics education (e.g. Skovsmose 1994), these realities have not been addressed in research emanating from that context.

Our own research points out the ways in which mathematics education as a social institution and a field of social practices comes to be situated within the racial histories, prevailing racial order, and web of social meanings for race in our societies (e.g., Spencer & Hand, 2015; Valoyes-Chávez, 2015; Valoyes-Chávez & Martin, 2016). Yet, we do not assume that mathematics education simply mirrors the particular racial system in which it is embedded. Racial dynamics are complex, unstable, and permanently interwoven with other social phenomena such as class and gender conflict. However, we do contend that mathematics education tends to maintain and reproduce the dominant racial order by unequally ascribing knowledge, abilities, and opportunities along racial lines.

It is in this context that we intent to discuss and explore the ways wherein these particularities manifest in the social space of mathematics education practices. As a racialized domain of social practices, mathematics education is considered as a racial and political project that would contribute to the production of ideologies and mechanisms responsible for the reproduction of racism during the practices of teaching and learning mathematics.

AIMS

The symposium is aimed at facilitating discussion with colleagues to explore the current state of research directed to analyze and uncover the mechanisms and practices responsible for the reproduction and maintenance of racial domination within mathematics education as well as how mathematics education contributes to various forms of domination in local and global contexts.

The workgroup format will encourage participants to engage both the structural and material realities of White supremacy and anti-Black racism (Bonilla-Silva, 2010). A structural perspective is fundamental to the process of moving interpretations of racism beyond individual prejudices and psychological pathologies. Likewise, the materiality of racism in everyday life constitutes a cornerstone in understanding racial dynamics at different social and institutional levels. One key to understanding these dynamics is to unravel how the meanings for blackness (and Whiteness) have emerged and have been negotiated within and across global contexts and understanding the racial projects that give rise to these meanings and racial dynamics. For example, what are the implications of the emergence of a far-right, conservative racial project for mathematics education in Denmark and for immigrant families and their children who find themselves under attack by the right-wing Danish People's party (Wren, 2001)? How do experiences with everyday racism by Malays and Indians in Singapore –groups who occupy very different positions in the social hierarchy– play out in the context of mathematics education (Velayutham, 2007)? What are the implications for mathematics education of the maintenance of white supremacy in Brazil, a country that prides itself on maintaining a racial democracy even in the face of empirical research and everyday experiences that suggest otherwise?

The symposium will alternate three papers focusing on the issue in three different contexts with discussions. We invite participants to join us in discussing these difficult and unsettling topics to find ways of making visible racism in society and mathematics education in order to take a more active stance to fight against its reality.

PLAN OF THE SYMPOSIUM

The 90-minute symposium will be structured as follows:

1. Welcome and brief introduction of the goals the symposium.
2. Symposium organizers will present their respective papers:
   - *Valoyes-Chávez: Race, racism and math education in Latin America*
   - *Martin & Spencer: Race, racism and math education in North America*

- *Valero & Chronaki: Race, racism and math education in Europe.*

3. Short Q&A session about the papers.

4. Symposium organizers will facilitate a whole group discussion about conceptualizations on race and racism within mathematics education. Possible questions would be:
    - *How does race locally shape and configure the social space of mathematics education?*
    - *In what ways do other identity markers, such as ethnicity and gender, intersect with race to shape the mathematics experiences of learners at school?*

5. Conclusions/ Plans for further collaborations/Organizers.

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BEYOND THE BOX: RETHINKING GENDER IN MATHEMATICS EDUCATION RESEARCH PROPOSAL FOR A SYMPOSIUM

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Massey University[1], *University of Thessaly & Malmö University*[2], *Vanderbilt University*[3], *University of Georgia*[4], *University of Regina*[5], *freelance Academic*[6]

The present symposium is an attempt to rethink gender in mathematics education research beyond the box, and specifically the box of binaries. We consider the importance in contemporary neoliberal times of doing research in mathematics education with and through the perspective of gender and, equally, we advocate ways in which gender could be key towards discerning relations amongst mathematics, science and life. To that end the symposium will address specific questions and issues surrounding gender presently confronting researchers, as well as educators, and policy makers. Organized around presentations in dialogue with reactions, discussion and debate, the symposium is intended not only to enhance understanding but also to stimulate fresh thinking and to initiate ongoing critique about research on and with gender in reconfiguring the subject in mathematics education, reimagining classroom learning, or, reconsidering mathematics education research.

RETHINKING GENDER RESEARCH

'Rethinking Gender in Mathematics Education Research' represents an attempt to understand the way we might consider gender research in mathematics education in contemporary neoliberal times and, equally, the ways in which gender could be key to discern relations amongst mathematics, science and societal life. By gender we mean socially and discursively produced constructs of sexual difference with which people identify and which offer them ways of being and performing in the world (Butler, 2011). These constructs are characterised not only by a normative binary approach to describing gendered performance as male or female but also by gendered practices such as mothering, educating, and caring. It also includes non-binary gendered ways of being such as bi-gender, tri-gender, or pan-gender, gender-fluid, and a-gender (Butler, 2010). As a multi characterised construct, gender is socially and discursively produced at specific historical and political contexts. The process of gender-work takes into account ways of thinking and acting made available and generated within the physical, social, cultural, discursive and historical practices of the communities organised around fixed identity categories.

RATIONALE FOR A FOCUS ON AND WITH GENDER

We believe that research on and with gender within mathematics education is at a crossroads. The harsh reality is that some gendered identities are continually denied a presence within mathematics education research. Patterns of gendered inequity provide a sobering counterpoint to claims of an equitable mathematical experience. Troubling and disrupting given gender performances within these contexts and conditions is more relevant than ever. Of no less importance is the need for a new 'vocabulary' for talking about how gender is being performed, embodied, acted, and materialized. "Rethinking Gender in Mathematics Education Research" takes those points seriously and engages symposium participants in highlighting and responding to key contemporary gender issues.

In the broader literature, developments in gender research endeavour to think differently about the division between females and males. In moving the status of gender towards negotiable discursive relations, contemporary researchers understand gender as emerging from social, cultural and economic contexts, processes and actions that are always relational and intersectional. Hence, gendered identity-work is constituted by many others, including teachers, the family or the wider society. The politics around financial crisis make the reading and negotiation of those constructions a complex endeavour. Importantly, other constructs of social difference such as class, race, ethnicity also become significant, as do histories of mathematical access, success, production, underachievement or exclusion.

WHAT WE PROPOSE

The symposium will be a key medium and space for interrogating taken for granted meanings of gender in mathematics education. Working from the premise that new understandings of gender are too important and complex to be ignored, presenters raise thorny questions about the generalised discourse of gender and its relationship with scientific thinking. In offering important new knowledge, they examine the concrete, material and human specificities of gendered experiences. In facilitating new meanings their analyses expose the conditions in which some people are caught up. They explore how gendered identity is lived by individual students, teachers or researchers, encompassing the struggle for self within wider meanings and investments in gendered identity-work. Their analyses might also reveal the significant part that mathematics education researchers play in the subtle politics around regulating normative constructions of themselves and others as gendered learners, educators or mediators.

The symposium presentations will highlight new territory for researchers within mathematics education and, because of this new ground, the presentations are designed to interrogate gendered work in mathematics education. By offering conceptual resources to stimulate thinking beyond the 'box' of binaries the presenters aim to develop a new sensitivity to everyday gendered practice. Relational, contextualised, and in some ways provocative, the presentations (both short and long) will provide, above all, an opportunity to explore alternative responses to how we conceptualize gender. But the presentations allow more than discovery: they are also able to highlight weak points located in practices where it might be possible to imagine a space for creative, tangible effects.

SYMPOSIUM ORGANISATION and STRUCTURE

The symposium will represent a coherent set of theoretical, narrative, empirical and practical applications of contemporary thinking in relation to gender and mathematics education. Three main objectives structure this organization. One objective is a theoretical perspective that highlights concepts useful for developing knowledge about gendered identity-work. A second objective is for an application of these theoretical understandings in a way that enables a more comprehensive research praxis in mathematics education research. A third objective is to stimulate debate amongst participants. The symposium we have planned will offer presentations that both (i) examine key concepts and (ii) apply those theoretical terms to gendered identities within specific historical, cultural, and social contexts and (iii) discuss and debate the usefulness of the concepts and their applications.

To that end, three presenters will speak on issues relevant to contemporary research on and with gender in mathematics education. To open up the exploratory potential of discussion, after each presentation, a dialogue with the presenter will be orchestrated. All contributors are deeply involved in working with new ideas in their research in mathematics education and represent a range of geographical regions and countries. Their presentations are not intended to provide analytic consensus in their attempts to understand the gendered experience within mathematics education. Rather, in seeking inspiration from a range of theorists, the presenters trace out carefully sequenced and systematic approaches, illustrating shifts in emphases from available gender research, and offering analyses of previously un-thought of and unexplained processes. Importantly, they offer ideas about gender that might assist in investigating an increasingly plural and uncertain mathematics education at a time of social crisis.

The symposium will start with an opening that introduces key issues concerning contemporary gender research in mathematics education by the organisers, and, it will be followed by presentations which will, then, be placed in dialogue with colleagues and the audience. The presentations are as follows:

Presentation 1: Going Beyond the Binary: Next Steps for Rethinking Gender Research in Post-Secondary Mathematics Education. **Luis Leyva**, Vanderbilt University, USA

Gender research in post-secondary mathematics education has remained largely stagnant conceptually and methodologically. This paper reviews research on gender in post-secondary mathematics education organized by three cross-cutting units of analysis: retention factors across the mathematics pipeline, student perceptions of mathematics ability and performance, and narratives of mathematics experiences. Much of this research conceptualized gender as a binary trait resulting in sex-based comparisons that left variation in mathematics achievement and participation implicit. Thus, there remains room for analysing gender as socially constructed and shaped by other identities (e.g., race/ethnicity, sexuality) to further advance approaches toward gender equity in post-secondary mathematics education.

Presentation 1 in dialogue with: David Stinson, University of Georgia, USA

Presentation 2: Gender, intersectionality, and a critical postcolonial critique: Mathematics and STEM education. **Dalene Swanson**, University of Stirling, Scotland

Much has been said about gender in mathematics education across the last several decades, with an increase in variety of theoretical and argumentative positions from which issues have been researched. Recently, there has been more critical engagement from poststructural and social justice positions beyond questions of mere access. I argue that it may be time to include intersectionality and postcolonial theories to the mix to attend to the more complex issues of mathematics and STEM learning in the gendered contexts of crises of economic development, global conflict and displacement, and the hyper-realities of 21st century modernism.

Presentation 2 in dialogue with: Kathy Nolan, University of Regina, Canada

Presentation 3: Wired in the kitchen-table: In-between cyborgs and subalterns for the production of mathematics education research. Anna Chronaki, University of Thessaly, GR & University of Malmö, SE

Being 'wired in the kitchen-table' is a familiar image denoting fe/male contemporary connectivity to work cultures at neoliberal times. It signifies a chronotope where we produce work for mathematics education research as we prepare food, mother children or care for others at the same time. How do we embody this complex neoliberal gendered subjectivity of 'homo oeconomicus', or 'knowledge economy' wo/man? What could the constructs of cyborg and subaltern, based on feminist SST studies and postcolonial critiques offer? And, what might be their effects for our work and research practices in teacher education, children's learning and curriculum?

Presentation 3 in dialogue with: Heather Mendick, freelance academic, United Kingdom

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DISCUSSION GROUPS & OPEN FORUM

ASSESSING AND ACCESSING EXPERIENCES OF NEWLY ARRIVED STUDENTS AND TEACHERS

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Malmö University[1], *University of Thessaly & Malmö University*[2], *University of Stirling*[3]

There is a great risk that children's possibilities to experience education are strongly reduced in time of crisis. Within this context we aim to convene a discussion group aiming to address and discuss migration in relation to practices of assessing and accessing newly arrived students within three European contexts. Taking into account that they come from conflict-ridden and economically-deprived parts of the world we are interested to explore how the entanglements of mathematics and science education with the lives of young refugees speak to their realities, aspirations and wellbeing. Presenters in the workshop are researchers, teacher educators and student teachers who are involved in work-in-progress projects with refugees. The discussion group will be an initial step to start up a network that can elaborate on issues of migration and education at an international level.

AIM OF THE DISCUSSION GROUP

As stated in the call for the MES 9 conference, and as we experience, the economic and political crises worldwide have effects on all aspects of life and education. Children are especially vulnerable in time of crisis. The trauma of leaving home and the struggles of making 'home' in a foreign country is not easily overcome. Food, water, safety, health and habitation are amongst prime priorities. But, what about education and creative activity? Are these merely 'niceties', further up Maslow's hierarchy for which there is no space for consideration? There is a great risk that children's possibilities to experience educative activities are strongly reduced under conditions of crisis and threat to wellbeing. Children that flee war, political insecurity and poverty will undoubtedly experience their cultural, social and economic conditions fundamentally change forever. Some would argue that these children risk 'being left behind' when entering a new school system due to conservative attitudes for cultural and linguistic diversity but also due to lack of adequate attention given to educational policies (e.g. knowledge assessment, access to learning contexts, resourcing) that prevent creativity or expansion of their horizons (Carlone & Johnson, 2007; Marks, 2005; Skolverket 2016). Within this context the present proposal is designed with the intention of initiating discussion at the MES 9 conference about issues that contemporary institutions in Europe face in an era of mass European migration as a result of increasing conflict, crisis and economic hardship felt in flashpoints across the globe. An example is the National screening exercise that the Swedish National Agency of Education (furthermore called Skolverket) has set up to assess newly arrived students' competences, skills and knowledge. This screening exercise has been created to assess first and foremost numeracy and literacy, but also other subjects. Of special interest in this proposal are the subjects of mathematics and science that often have been embedded within discourses that construct them as entangled with almost all aspects of life, relate them to innovation that signify societal progress, and practices that use them actively to stratify students in certain career paths in schools through the streaming system as well as higher education (e.g. engineering, medicine, health and life sciences). The aim of the discussion group is also to start up a network that can elaborate on issues of migration, education and assessment on a broader level.

PRESENTATIONS

Presenters in the discussion group are researchers, teacher educators and pre-service teachers from three European institutions, one in each of Sweden, Germany and Greece. The presentations report on their experiences of dealing with issues related to assessing and accessing newly arrived students and teachers. Their contributions are as following:

The Swedish national screening exercise, hinders and possibilities *by **Anna Jobér**, Malmö University*: From April 15th, 2016, it will be mandatory in Sweden for teachers at school or migrant students to use a 'screening exercise' to assess their 'level of knowledge' and school experiences of newly arrived students. The present contribution will discuss the phenomenon of such a national assessment of students' competences in relation to a lack of international and national research and discussions regarding migration and assessment on large-scale levels. (10 min)

Making the newly arrived teachers in the Swedish context *by **Lena Andersson**, Malmö University:* Malmö University is one of six universities in Sweden participating in the fast track of newly arrived teachers at preschool and primary levels. This track works towards developing programmes, mainly in the Arabic language, that trains them into the Swedish system of schooling, curriculum and didactics. Access to a teacher certification varies greatly depending on previous education and work experience, but also individual assessment based on the 26-month experience. This presentation will discuss the potentials and limitations of such a fast track training course, as well as, its ethical conundrums. (10 min)

Embracing competencies *by* ***Peter Bengtsson****, Malmö University:* This contribution provides an historical overview of reforms in relation to how competencies have been embraced in Swedish education. This will be discussed mainly as a response to broader societal demands to create and offer supplementary education courses with an eye to critique technocratic and instrumental policies devoid of ethical and political considerations. (10 min)

Reduced-language assessment of students' mathematical competencies *by* ***Christine Knipping****, Bremen University:* Investigating young refugees' mathematical competencies can be helpful for teachers, students, parents and enterprises. Language can at first be an obstacle in this process as teachers and potential employers might not speak more than the national language. This problematique came up in a course on diagnostics of mathematical competencies I teach in our teacher education program in Bremen. Several students raised questions around this and wondered if it might be possible to examine mathematical competencies without or with limited language. We have founded a group of students, and math educators from schools in Bremen and the university to work on this. After a year of work on assessment tasks we plan to explore their use together with teachers in migrant classes in Bremen this year. In my presentation, I will outline the goals and accomplishments of our group, so far. (15 min)

Accessing Newly Arrived Students' Experiences with Interdisciplinary Project Work *by* ***Eirini Lazaridou Efthalia, Balla, Ismini Sotiri, Eirini Avgoustaki, Olga Ntasioti*** *and* ***Anna Chronaki,*** *University of Thessaly*: As part of two different in-situ research projects with newly arrived refugee children in the city of Volos, we explore the potential of a collaborative design for interdisciplinary work aiming to access children's experiences, knowledges and ways of knowing. Both projects are based on the use of mixed media including technologies and arts-based resources that aim to overcome the barrier of 'language' or 'culture' or 'race' in the course of pedagogic praxis. Our presentation discusses the emerging potentials, as well as, the ethical dilemmas embedded in such endevours. (15 min).

DISCUSSION GROUP ORGANISATION

How we might engage with newly arrived children from contexts of conflict and crisis, is already a deeply ethically-fraught issue for consideration in a global and European context of mass migration. How we engage with them educationally takes these tensions and ethical considerations further. But, how we may survey, audit and assess them increases the possibility of symbolic violence on an ethical front dramatically. How might critical theories help us to interrogate our assumptions and the potential for ethical violence in this context of migration crises in ways that offer viable ways forward (Ahmed, 2000, Popkewitz, 2004). The discussion group will start with the above presentations (i.e. 10 to 15 min each) followed by commentaries from the discussants and from the audience. After this, the rest of the time will proceed where people will be expected to work in small groups with certain questions in relation to assessment, language, interculturalism, ethics and migrant issues before sharing at the assembly.

DISCUSSANTS: Candia Morgan, Institute of Education, London, **Nuria Planas**, University of Barcelona, **Dalene Swanson**, University of Stirling

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TRAJECTORIES OF MATHEMATICS EDUCATION RESEARCH IN GREECE

Sonia Kafoussi[1], **Anna Chronaki**[2], **Takis Spyrou**[3]

University of the Aegean[1], *University of Thessaly*[2],
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The present discussion group aims to explore aspects concerning the current state of affairs of Mathematics Education Research in Greece as they are related to issues of curriculum design, teacher education and multicultural contexts of schooling. Emphasis will be given, on the one hand, to provide some overall description of major research efforts and, on the other hand, to communicate reflections on ongoing experiences. The presenters are academics and researchers in mathematics education research community in Greece who, amongst others, have also actively contributed towards setting the field of 'mathematics education' in the country. They will be involved in short presentations of around 15 to 20 minutes concerning key topics such as the state of affairs in mathematics education research in the local context, curriculum development for specific mathematical concepts, professional development of teachers and mathematics education and multiculturalism. Each of them will arrive at some key questions as the result of their own experience concerning the potentials, obstacles and boundaries of such endeavors. In consequence, an open discussion will continue with MES 9 participants aiming to explore further these questions. The schedule of presentations will be as following:

1. Research in Mathematics Education in Greece: experiences from GARME: Greek Association of Researchers in Mathematics Education, by **Marianna Tzekaki**, Aristotle University of Thessaloniki.
2. Mathematics curriculum development: the case of rational numbers in primary education, by **Charalambos Lemonidis**, University of West Macedonia.
3. Professional development of mathematics teachers in the Greek context, by **Despoina Potari,** National and Kapodistrian University of Athens.
4. Mathematics education in a multicultural environment in the north part of Greece, by **Charalambos Sakonidis,** Democritus University of Thrace.

MUJAAWARAH: BEING TOGETHER IN WISDOM OR RECLAIMING LIFE FOR MATHEMATICS

Open Forum

Munir Fasheh[1], **Yasmine Abtahi**[2], **Anna Chronaki**[3]

Arab Education Forum[1], *University of Ottawa*[2], *University of Thesally*[3]

In this forum we want to stress the importance of 'being together in wisdom' in mathematics learning, teaching and researching. This necessarily means reclaiming life for and in mathematics through unsettling subtle issues of knowledge, power and authority and through troubling existing hierarchies, hegemonies, myths, truths, canons or orders. As the field develops into endeavours for curriculum and policy reformations, we wish to stress the importance of wisdom and rootedness with cultures, natures and siblings. Mujaawarah -which takes different names in different cultures- has been throughout history and much prior to industrial, modernist or neoliberal times the main space for learning by encountering the value of emancipatory experimentations with knowledge, as knowledge to act with. We see this forum as a bridge to the last MES at Portland, Oregon, where Munir Fasheh placed the seeds of this conversation in his keynote, but also to create a collective amongst equals not as a goal to be reached, but, primarily, as a standpoint.

What is Mujaawarah?

Mujaawarah is the Arabic word for being together –a collectivity. It forms a most basic natural 'unit' in society, an 'assemblage'formed and owned by people with no internal or external authority. It embodies wisdom and functions without the need of a permit, budget, hierarchy, rule etc. It is based on collective thinking and acting situated in specific conte xtual concerns, instead of merely abstract analytical or critical thinking. Every person joins the *mujaawarah* with what s/he does well, useful, beautiful, giving, and respectful as one's own worth rather than being part of a hierarchical or normative evaluation of worth. It embodies the logic of *muthanna*: 'you are, therefore I am'. Of all things to be sought –via mathematics and mathematics education in our case– the most important is wisdom (in ancient Greek: φρόνησις, *phronēsis* as coined by Isocrates). The word denotes agency to act through phronesis as the person's capacity to discern how or why to act virtuously and how to encourage virtue as praxis –a capacity rooted in the everyday care of self and others. Munir has explained: '*that's what I became aware of and have been working on since 1971, when my search for wisdom started with regaining my arms, legs, and fingers in living and learning. Learning started to feel as a synonym to living with wisdom. Wisdom is the compass we need in steering our waythrough the turbulent times we live in today. What is beautiful about a compass is that it makes sense in the place where it is; there is no universal direction for all people. Similarly, wisdom can only be lived locally, personally, and communally*'. Our modest, yet dramatically ambitious, aim in this forum is to share what might the practice of 'mujaawarah' mean today by tapping into what might 'being in wisdom' mean for each one of us. How could 'mujaawarah' ever be possible, and what is its emergence, in the presence of risky neoliberal governing has become a globalized agenda normalizing a continuous endemic uncertainty and configuring the precarious subject?

Munir: Teaching with wisdom: roots, soils and memory

Meaningful teaching requires being personal about what one teaches. A rooted teacher is one who has gone through a long period of diverse experiences, reflected upon them and put an effort to make sense out of them, and who is ready to share one's experiences, doubts and concerns with others as open matters –rather than delivers them as ready information and skills or fixed capacities to be consumed.Teaching any subject wisely (and not only math) requires reclaiming two other ignored aspects in living and learning: soil and memory. Community consists of several soils that enrich one another and nurture the intellectual growth in community: earth soil; cultural soil; social soil; and economic soil –all of which necessarily embody memory. Nurturing these soils and memories, and being nurtured by them, is our vocation as teachers. The difference between a *screen* on a computer and a *sheet of paper* is that the latter is closer to soil: when you write on it with a pen or pencil, words and thoughts will be like seeds that one plants and become nutritious to others who harvest them. This means handwriting is more precious than typing on keyboard: it includes feelings and connectedness with the words and thoughts (which become part of one's memory). Reflective books are connected to these soils and memories; textbooks are more like hard rocks.

Memory has been a most important tool in my understanding and moving along the path of wisdom, whether in relation to math, religion, politics, or working with youth. In relation to education, the American University of Beirut (established in 1869) which was the first 'knowledge base' in our region (followed by smaller bases in the form of schools) preceded military and financial bases, and paved the way for both. Those 'knowledge bases' decided for us (for the past 150 years) what is allowed in knowledge and what is not; they wiped out wisdom, for example, from our consciousness and memory. Wisdom cannot flourish outside local soils. They wiped wisdom despite the fact that the first university Arabs built was the House of Wisdom in Baghdad more than 1100 years ago, where various civilizations (Arab, Persian, Greek, Egyptian, Indian…) interacted and produced a lot of what we lack today, but very much needed. It is worth mentioning here that, unlike military and financial agencies, academicians and educators who came to our region produced also a lot of harmdespite their good intentions. They were not aware of the 'viruses' in their thinking. In this case the 'virus' is the passion for controlling, measuring and imposing knowledge mastery. Living without wisdom robs people of their internal immunity..

Yasmine: Rooted-ness of mathematics, its education, and its research

"Maybe we are searching among the branches, for what only appears in the roots?" (Molavi, 1253). But where are my roots? Why do I need to be aware of them? Why does this matter for me and for mathematics and its education? There is a saying in Cree, an Algonquian language spoken by groups of Canadian indigenous communities: *"You need to know where you are coming from to know where you are going, to give you hope to move forward".* My roots are in the culture, history and the soil of where I am coming from. They carry within them the perception and wisdom of generations who have lived and created the knowing(s) that, throughout thousands of years, was passed on to me as my *culture*. Among many, I am a branch of such roots -roots that not only give me hope to move forward but also guide my living and my actions.

In *Masnavi-e Ma'navi,* Molavi (1253) likened living to a compass with one of its legs fixed while the other wanders around, drawing circle(s) around the rooted leg. That is, in our living we have a part that is strongly based in our local roots (our cultures and history) and a part that moves to connect to others people around us and, to feelings, and places. As it is the case of a compass and its two legs, if our rooted leg is not strong enough in the soil of our past, the circles created by the other moving leg –to connect to others and to places– will not be beautiful, or useful. Likewise, mathematics needs to be rooted in the soils of our cultures and histories – but also within cultures where we move and seek to create new roots. Anon-rooted mathematicscan be neither beautiful nor useful –just because it is too detached, too impersonal. Mathematics that detaches itself from the realities of local communities –or that is treated to be detached from the local values and needs– and tries constantly to abstract and standardize, could be hurtful. Hurtful for people, nature, culture and children are the communities. As a new generation to come, our childrenare growing up having one leg strongly rooted in their places, with their local culture, history and beliefs and are growing up learning mathematics as a way of thinking, about their values and concerns. Munir's presentation at MES8 in 2015 at Portland, made it clear, for me, that laying out paths for a journey towards having wiser and rooted mathematics is everybody's responsibility, including mine. Munir's talks reconfirmed how privileged we are, having access to thousands of years of accumulated wisdom, through our diverse cultures and available texts.

Anna: Polis, autonomy, paideia: Reclaiming life for mathematics

Working with Gypsy children, early years' children or student-teachers one cannot avoid but to observe the fresh ideas they offer. Being outsiders, they question boldly -beyond the ruling canons. In fact, their stance serves to trouble essentialist identities and to interrogate the normative as the only possible image for a school-subject's economy. The same is not experienced with 'well' trained educators or 'highly' qualified experts who turn into methods for quick fixes of conceptual problems. Teaching as such can be a violent act reproducing social inequality, enslavement or obedience and remains an elitist posture assuming that only certain expertise support us think, speak and make decisions. A blind obedience to 'disciplinary knowledge' make us distrust the assumed 'naïve consciousness' of those subjected to oppressive systems (Ranciere, 1991). The result of this distrust is a 'syllogism of suspicion' that reinforces the stultifying practices they are arguing against. Expertise might serve, with all good intentions, to create a relational space where authority becomes the measure for betterment, development or progress. Through this line, the 'virus' of 'distrust' gets into the skin and runs through blood infecting our research choicesand writings. Distrust becomes the basis for a continuous need for speculative proof, reason or rationality, as well as, for improvising the 'syllogism of suspicion' game as exemplified in the well known Socrates-Menon sophist dialogue. But, this ethic can be catastrophic for 'mujaawarah'. Instead, one needs to trust the ability of all to think, speak and act without calling the need for explication.

In Ancient Greece, polis (πολιτεία:city) was built on the idea of a continuous autonomy where common people (δήμος:demos) had not only to vote on matters of government and law, but they had to create their own laws (i.e. *auto*- means by itself and <u>*nomos*</u> means law). Common people, although being primarily the free-born male citizens, spent much of their time discussing politics in the agora -an open place of assembly and a meeting space for craftspeople, merchants, traders or philosophers. Crucial to developing autonomy politics was the notion of paideia. Paideia, as discussed by Isocrates (353 BC), is in contrast to a sophist view of education, and is conceived as a process of character growth in which political activity is not a means to an end, but, an end in itself. Emphasis was placed to re-create the aesthetic possibility of acting 'as if…'. Could we, take seriously an 'as if...' posture. As if... we have invited a risky experimentation of thoughts, ideas and acts with our siblings, with our soils and memories of our past and future virtualities, as well as, with our own mathematics or the mathematics we owe. As if... such rootedness can help us re/configure the subject itself in *mujaawarah*.

Living Mujaawarah

We suggest living *mujaawarah* in our contribution as a group at MES9 in Greece where every participant shares one's reflections on experiences of how to deal with math more wisely in a globalised world where soils, roots and memories take a different form for each one. We aim for living conversations, and just like yeast in dough: our aliveness will be 'contagious'. We will come out with rich diverse ways of how to embody wisdom in perceiving and working with math. By following this path, we will use a value that is ignored namely wisdom and a space that is ignored namely *mujaawarah*. This means that our contribution to the conference will not be an outcome as much as reminding people of and reclaiming two extremely important aspects in learning: wisdom as a governing value and *mujaawarah* as space for learning. For the first part, we start the mujaawarah by Munir's story, followed by Yasmine's and Anna's. We share segments of our stories to show that the most important conviction in living wisely is that every person is a source of meaning making, sensing and acting (including that of math). This short introduction will be followed by some of the participants who would wish to come in-dialogue in our mujaawarah and will continue with their own stories (i.e. a small number of colleagues will be contacted upon acceptance of this proposal). This will be then followed by small group discussions in which colleagues who are in mujaawarah with us will be part and support the story sharing process through examples and expansion. The last part of the session will be devoted to bring up issues related to wisdom, rooted-ness and ethics within mathematics, its teaching, learning and research. We encourage participants to bring along their own stories that would support us to reflect on two questions: what does mathematics mean to us? and what does learning mean to us? But, also: why, where and for whom?

This open forum will take place at the outskirts of the academic program after the agora or during lunch-time. In this sense, the living mujaawarah as conceived by Munir could be seen as working along or within other events in MES9 for creating collectivity. Lastly, some material might be uploaded at the website or distributed at the conference space to include information that would give the participants a chance to think about and feel some of the issues we are going to bring forth.

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PROJECT PAPERS

DEVELOPMENT AND CONTEXTUALIZATION OF TASKS FROM AN ETHNOMATHEMATICAL PERSPECTIVE

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We propose incorporating an ethnomathematical perspective in primary school teacher education to facilitate a meaningful contextualization for the tasks they develop. We consider a meaningful contextualization from an ethnomathematical standpoint to be one that respects the studied culture from an emic approach, rather than an etic approach. We observe that studying cultural characteristics (Moroccan dishes in the examples provided) used as context seems to favor a better understanding and relation to the mathematical concepts that show mathematical complexity of the designed tasks, as far as developing the different components of the corresponding mathematical sense (sense of measurement in the analyzed cases).

INTRODUCTION

In this article, we put forward an introductory experience in Ethnomathematics involving a group of university students studying for a Bachelor of Primary Education. Such future teachers have a hard time contextualizing the tasks they develop for their students in a meaningful way and situating them in an environment close to that of the one the children live in. To do so, they have to get used to looking around and seeing mathematics in their daily experiences such that they can then incorporate these tasks creatively into their lesson plans.

We asked a group of prospective Primary school teachers to study cultural characteristics in their surroundings and later to contextualize these in tasks they develop. Using an ethnomathematical framework, this is a proposal for a research program focusing on mathematical practices of specific cultural groups, such as populations or guilds (Barton, 2008).

Context

At the Education and Humanities Department of Melilla, of the University of Granada, in the framework of a course called "Mathematical Education for a Bachelor in Primary Education", we proposed contextualizing the development of tasks from an ethnomathematical standpoint. In the third year of the Education degree future teachers have to develop a teaching unit and design tasks based on instructions from the Spanish curriculum such as mathematical conceptual teaching and learning tools taught in previous classes, specifically the concept of mathematical sense that will be described further on.

It should be noted that the city of Melilla has a unique history and geographical location. It is a Spanish city located on the coast of North Africa and with a surface area of approximately 12 square kilometers bordering Morocco on all sides. Historically the city has alternated between Catholic reigns (Duchy of Medina Sidonia belonging to the Kingdom of Spain) and Muslim reigns (the Cordoba Caliphate connected to the kingdom of Al-Andalus), as well as being the sought refuge for Jews fleeing persecution on the Iberian Peninsula. Nowadays the city limits are those established in the 1860 Treaty which also states that it currently belongs to Spain. This situation affects the fabric of society in the city. A little over half of the population is Muslim, and speaks *Tamazight Chelja*, a language that originally lacked a writing system. *Tamazight Chelja* is a Berber dialect from the Rif region, which geographically includes Melilla. It is worth mentioning that this language is not officially recognized by the Spanish organisms in the city. This part of the population, besides the language, shows other cultural characteristics typical of Berbers, as shown in their attire, cuisine and family structure.

THEORETICAL BASES

Background

A key idea in Ethnomathematics is that mathematics is a practice within and is part of a culture. Mathematics is the product of a socio-historical and cultural process that has evolved with contributions from different societies and cultures, which have built what we understand as mathematics today in a school context. Below, we describe our proposal of studying different ways of doing and looking at mathematics as a tool to delve deeper into the concepts that have been shaped throughout the construction of school mathematics. We value this practical mathematics as inspiration to improve the understanding of school mathematics and classroom practice. Investigating mathematics by looking at close cultural features or daily activities is something that was first proposed by Bishop (1991) and was carried out in practice by several authors.

When teaching future American teachers, Presmeg (1998) has them study a personal interest of theirs to later develop mathematical tasks. Gavarrete (2012), in a teacher training course in an indigenous setting in Costa Rica, suggested searching for mathematics in indigenous cultural characteristics to design contextualized tasks. Albanese and Perales

(2014) worked on the development of mathematical tasks based on Argentinian folk dancing with a group of future teachers in Argentina. Finally, in Spain with a group of teachers in training, Oliveras (1996) proposed developing tasks based on Andalusian artisanship.

Mathematical sense and curricula blocks

The Spanish school curriculum (Ministry of Education, Culture and Sport, 2014) is based on a socio-constructivist theory of education and a functional focus of mathematics teaching in which learning takes places in a relevant context. Mathematics is considered to be a social construction and students construct the meanings of the concepts by structuring them and relating them to applications in different situations. The development of a *mathematical sense* (the ability to use mathematics with sense) is the learning objective. In the same way that a curriculum organizes content into blocks, we can divide mathematical sense into four senses: number sense, spatial sense, sense of measurement, and stochastic sense (Flores and Rico, 2015).

The specific group of future teachers analyzed in this article focused their tasks on the sense of measurement, defined as "the identification of measurable attributes and characteristics, such as knowing, choosing and identifying units of measurement in different situations, be they conventional or nonconventional" (Rico y Flores, 2015, p. 45). They were expected to apply measurement strategies, and choose the most appropriate techniques to estimate.

Contextualization

Research into the mathematics of cultural characteristics or activities can be accomplished in two ways: an emic or etic approach (Rosa y Orey, 2012; Albanese, Adamuz-Povedano, and Bracho-Lopez, 2016). In the emic approach, the vision of the cultural group being studied is taken into account and the categories and framework in that culture are respected. There is a broad and comprehensive understanding of what mathematics is, exemplified by the concept of Barton's QRS system (2008). That is to say mathematics is every "system for dealing with quantitative, relational, or spatial aspects of human experience" (p. 10). In the etic approach, the researcher's point of view prevails and the analysis is carried out within the categories and framework of the researcher's culture. Here mathematics alone is considered the NUC system (Barton, 2008), the near-universal conventional system.

We deem contextualization of tasks meaningful if the point of view of the studied culture is respected from an emic approach. This means we consider that a task is contextualized if the situation created for the problem is consistent with situations that may effectively arise in a real context, and the mathematical concepts or procedures come into practice in the same way as the cultural group does.

OBJECTIVES

The objective of this research is to assess whether the participants developed mathematical tasks that were: 1. contextualized in a meaningful way; 2. suitable to develop the children's mathematical sense.

METHODOLOGY

At the end of the class, the students were required to turn in a final project, which makes up a large percentage of their overall grade. The project consists of a teaching unit that contributes to the development of one of the four mathematical senses listed above by means of three contextualized tasks.

Contextualization is based on an ethnographic approach to the chosen cultural characteristic. In the case of the analyzed group, that characteristic is Moroccan cuisine, in particular the couscous dish. The students interviewed Moroccan people who frequently cook this dish.

The analysis carried out here consists of: 1. determining if the contextualization of the task is meaningful in an ethnomathematical sense (emic) or not (etic). 2. Identifying which components of mathematical sense (in this case sense of measurement) the tasks work on.

For the sense of measurement we consider these components (Rico y Flores, 2015): 1. identifying measurable features 2. selecting units of measurement 3. doing measurement techniques 4. applying estimating strategies

RESULTS

The following is a detailed description of the analysis of two tasks developed by two students that focused on the same cultural characteristic: couscous[1], a traditional dish in Moroccan cuisine. As stated earlier, both respective teaching units were built around developing a sense of measurement.

Task 1 designed by student J.

M_J1: If 200 grams of couscous is needed to feed one person, would 1kg of couscous be enough for 4 people? How many people could 1 kg feed? How many bags would we need to feed 10 people? How many kilograms of semolina would we need to feed 15 people? If a 1kg pack of couscous costs 1 euro, and we use seven vegetables for each bag of couscous, if each vegetable costs 30 cents, and each plastic plate costs

1. A wheat semolina, cooked with steam, and usually served with different combinations of vegetable and meat.

15 cents, how much would it cost to feed 5 people? How much would it cost to feed 10 people? How much would it cost to feed 15 people?

This problem arose from a comment made during an interview with a cook when discussing how much couscous would be needed to feed a whole family. The first part of contextualization follows the cook's customs and so is meaningful (emic), but later other factors do not, for instance using plastic plates (etic). The couscous is sold in packs of 1kg, so the cook calculates how many pack she has to buy, and how much money she needs to buy all ingredients. But there is a factor that does not respect the culture: couscous is usually served on a large platter set in the center of the table, and each person serves him/herself using a piece of bread (or a fork). It is not customary to serve each person on an individual plate. So plastic dishes are not necessary. This task is useful for applying indirect measurement techniques, since it is not necessarily crucial to work with manipulative materials because it can be solved with mathematical operations. It is worth noting the use of different magnitudes, on the one hand weight and on the other cost.

Task 2 developed by student P.

M_P3: If 200 grams of couscous fit in a small water glass, how many grams of couscous would fit in a tall glass? How many would fit in a wine glass? How many would fit in a pitcher? How many would fit in a soup bowl? How many would fit in a ladle?

To carry out this task, the children are given a bag of couscous (usually sold in 1 kg packs) and the previously mentioned containers. The contextualization of the task is meaningful (emic): in the interviews done by the students they described cooks using specific containers or cups to measure the quantity of couscous, water and oil to use. This means that the task respects the mathematical procedures that the cooks use.

From the point of view of the sense of measurement, this tasks means the children should develop estimating strategies to approximate the capacity of the different containers (component 4 of sense of measurement). It also involves using different units of measurement, some which are conventional (grams and kilograms) and some which are unconventional (cups and containers). It is interesting that this student proposed an estimation task, the likes of which are not usually found in Spanish text books, and the contextualization gave the student the idea of working with materials, in this case couscous which is easy to manipulate and preferable to using water, which is more commonly used for this purpose.

Below is a comparative analysis of all the tasks, not only the two described above (M_P3 and M_J1) but also those not analyzed in detail here.

In the first row uppercase X represents meaningful contextualization (emic) in all aspects of the task, while lowercase x represents the tasks that contain some aspect in which the contextualization is not meaningful (etic).

Table 1. Analysis of the tasks developed by the two students who focused on Moroccan cuisine.

Categories of Analysis/Tasks		M_P1 portions	M_P2 Nutritious recipe	M_P3 containers	M_J1 portions	M_J2 Recipe price	M_J3 purchases
Meaningful contextualization		X	x	X	x	X	X
Measurement system components	Relating measurable features		X		X		X
	Working with different units of measurement	X		X		X	X
	Measuring techniques	X	X		X	X	X
	Estimating strategies			X			

FINAL REFLECTIONS

In almost all the tasks the contextualization was meaningful, at least in the general idea (except small details as the one mentioned above). From a mathematical perspective the tasks contributed to the development of a sense of measurement and had a certain degree of complexity, either because of relating different magnitudes or because they required estimating with direct measurements and comparing traditional and nontraditional units of measurement. Likewise we can point out that all the tasks involved more than one component of sense of measurement. This is further proof of their complexity. Such complexity is not present in most tasks developed by students who have not worked with cultural characteristics and thus have not pondered the use of mathematics in daily life, or at the very least have not delved as deeply as the students who developed these tasks did.

The interviews were an opportunity of encounter and dialogue “between cultures”. The comments of the students relating the interviews to the cooks have been revealing in their progressive awareness of the cultural context of their environment, besides the mathematics involved. The cooks interviewed were the students’ Berber housemaids who have little schooling. The students admitted that for the first time they were interested in the chores of these women who had almost reared them but about whose culture they did not know much. A first challenge was represented by the increase of performance necessary to carry out the work. Fortunately the enthusiasm and motivation of the students has been the key factor to facilitate the realization of the whole project. Once the students were interested in their "cultural" discoveries, another challenge arises. It has been quite difficult to come back and focus again on the mathematics of the curriculum as the attention was dispersed on cultural elements. We believe that the main implications of the experience for mathematics teacher education are: 1) to show how important it is to investigate first the context then to design tasks that are significantly contextualized. 2) to reinforce our hypothesis that studying mathematics in context allows students to reflect and deepen mathematical concepts (Albanese and Perales, 2014).

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NO, WE DIDN'T LIGHT IT, BUT WE TRIED TO FIGHT IT: ACKNOWLEDGING AND CONNECTING AN ACUTE CRISIS

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We claim that at least two types of crises affect the classroom. An acute crisis has an immediacy of time and space and might be characterized in education as something that requires acknowledgement or it may be affecting students so that no other ideas deserve their attention. In contrast, chronic crises underscore the existence of historically persistent social problems. Chronic crises such as injustice, hatred, and war arguably deserve to be the curriculum of all schooling, including mathematics. In this paper, we explore a case study of the first author's (Jeffrey's) experiences trying to acknowledge an acute crisis, the 2016 Pulse Nightclub shooting in Orlando, Florida, into a post-secondary quantitative literacy classroom.

> "Yeah, Yeah, Yeah, but it's different than for you. You were a kid in the fifties and everybody knows that nothing happened in the fifties."
> "Wait a minute, didn't you hear of the Korean War or the Suez Canal Crisis?"
>
> (billyjoelVEVO, 2013)

Singer-songwriter Billy Joel claimed that the above conversation was his inspiration for his song "We Didn't Start the Fire," which chronicled forty years of international events with a focus on the United States. He wanted to make clear that humanity faced crisis, change, and upheaval before - and would again, saying, "There's an element of malevolence in the song; it's like waiting for the other shoe to drop."

If Joel updated his song to the present, what might he include? Certainly, he would not have a short list of choices and we would argue that he would be choosing among what were acute crises when they occurred. If both acute and chronic crises affect the classroom, we argue that specific attention should be given to their connections. In the following, we write about Jeffrey's experiences trying to acknowledge an acute crisis in his class and adjust his curriculum to connect with it. We purposefully use first person to highlight Jeffrey's personal experiences, but we want to acknowledge that this paper was written collaboratively by two mathematics education researchers. This paper is meant to describe an ongoing project to better understand the role of curriculum in helping to define the classroom as a space of healing.

NO, IT WAS ALWAYS BURNING, SINCE THE WORLD'S BEEN TURNING

In mathematics education, many scholars have arguably included a focus on chronic crises in their work under different names: teaching mathematics for social justice (e.g. Gutstein, 2006), criticalmathematical literacy (e.g. Frankenstein, 1990), mathematical literacy (e.g. Jablonka, 2003), and critical mathematics education. These scholars, along with quantitative literacy scholars, such as Steen et al. (2001) inspired the development of two courses in quantitative literacy at Michigan State University that attempt to provide another space to discuss relevant and important problems facing the world with mathematics and statistics as tools. One course goal is to unpack some ways that mathematics and statistics can affect our understandings of the world. For example, in The World and Its Peoples module, we predict, research, and reflect on our perceptions of the world in terms of concepts such as literacy rates and poverty rates, as well as question the measurement of those concepts. When teaching, I encouraged my students to attend to issues and ideas that they considered most important and adapt our course content in ways that helped them think about those issues. In our course long project, I claimed the best criteria for choosing a topic was to pick something that moves and affects you, and about which you are passionate. Unsurprisingly, many of the choices for topics might be described as chronic crises, for example: gun violence, racism, overdosing, and treatment of mental illness.

During our Numbers and the Media module, we read and discussed Himmelstein (2014) who completed an historical case study of media coverage of the so-called crack cocaine scare in the United States in the middle of the 1980s. He reported on his findings related to how the media used numbers when constructing the storyline of an acute crisis. We discussed his work, calling particular attention to how the media that students collected and investigated regarding their project topic used "claim[s] apparently crying out for numerical support" (Himmelstein, 2014, p. 5). In some ways, our media module involved a focus on chronic crises: we discussed past and present histories, connected things we know with what others say, and thought about ways to address big problems in the world. We completed the media module on Friday, 10 June, 2016.

NO, WE DIDN'T LIGHT IT: AN ACUTE CRISIS IN ORLANDO

On Sunday, 12 June, 2016, a tragedy occurred at *Pulse* Nightclub in Orlando, Florida, United States, where a lone gunman killed 50 people. Our next class meeting was Monday, 13 June, 2016, and we were beginning our Health and Risk module with a discussion of *micromorts*, a unit meant to represent a one-in-one-million chance of dying from an activity. I felt that it would have been inappropriate for me not to acknowledge that we were affected by this acute crisis, given our planned content. Additionally, we had gun violence come up in previous class discussions. In the 24 hours between the tragedy in Orlando and our course, however, the connection between acute crises, chronic crises, and our course became more apparent. We were told a lot about the crisis: the shooter was apparently a practitioner of Islam, *Pulse* Nightclub was frequented by LGBTQ people, it was Latin Night at the club, and the particular guns the murderer used. National news media and social media attention grew and reconstructed common chronic crises, using Orlando, to recreate dominant narratives about gun control, islamophobia, terrorism and wars, homophobia, xenophobia and immigration policy, and the “politicization” of tragedy.

Often accompanying those narratives were quantitative claims [italicized for emphasis], for example: that the tragedy would have been *lessened* if club-goers carried guns, that these types of attacks were occurring *more frequently*, that the *rate* of fire of the guns used was a factor in the *amount of lives lost*, that this was the *worst* mass shooting in United States’ history. Margaret Sullivan, a media columnist for *The Washington Post,* summarized the complicated relationship of this tragedy, these claims, and the media, stating:

> If you favored gun control, this was further evidence of the legislative failures to stop slaughter. If you were wary of Muslims, this was an opportunity to paint an entire faith as terrorists. If you supported gay rights, this was a hate crime targeting the LGBT community. (Sullivan, 2016)

BUT WE TRIED TO FIGHT IT: CONNECTING TO THE COURSE

My general plan for acknowledging the Orlando shooting in class had two phases. First, an immediate chance to voice pain, reflect, and attempt to begin healing, and second, a focused redesigning of our upcoming Health and Risk module to explicitly address the Orlando shooting through the chronic crises underlying the planned curriculum. In class on Monday, 13 June, I began with showing pictures of my social media trending feeds and with media headlines about the tragedy, followed by trying to name the various narratives I had heard in the day following the tragedy. No students chose to vocalize at the beginning of class. I was unfazed, however, because (1) I knew my students to be thoughtful, (2) I suggested that they reflect on Orlando in their feedback opportunities for the day and that they could discuss it with me or each other at any time, and (3) I had begun planning a two-day lesson specifically on the claims surrounding the shooting for the following week.

In their reflections, students in my class included statements that helped me connect several of our course ideas to my lesson plans. Below, I share some excerpts from different students' written reflections on Monday that I found helpful to use in my lesson plans and connect to course content we had learned and discussed.

> "Found myself looking at numbers for the Orlando situation when it came to how many deaths, how many injuries, how many shooters things like that"
>
> "It was bad enough when the public thought the death toll was 20 but you could hear the audible gasps of the media when the police captain told those assembled that the death toll was now 50."
>
> "These types of mass violence are happening so frequently these days"
>
> "Because we have a massive violence problem in the U.S."

WE DIDN'T START THE FIRE: A PERSONAL ACUTE CRISIS

The lesson plans I developed included groups selecting and investigating particular claims made by members of the media about Orlando. I would suggest attentiveness to quantitative rhetoric, claims that were calling out for quantitative support, connections among chronic crises, and suggestions for action to address problems. I had replaced a lesson plan on investigating and discussing the question of whether climbing Mount Everest should be illegal (as a recent expedition had ended fatally). Unfortunately, the day before these lessons began, in the final week of class, my grandfather suddenly died. Because I had another person (who was also teaching the course) substituting for me, I suggested he implement the lessons he had previously planned for his students, rather than trying to implement the Orlando lesson plans he did not help create with people he did not know. This intentional choice connects to Gutstein's (2003) work that centers relationships and classroom environment as fundamental for discussing important issues of inequity and injustice.

Despite this personal acute crisis disrupting my plan to unpack the Orlando tragedy in terms of the class, the course itself often highlighted chronic crises. In general, the course is concerned explicitly with "the politics of mathematical knowledge" and the "mathematics of political knowledge" (Frankenstein, 2001, p. 53). The planned content of my quantitative literacy course was suitable to acknowledge, learn from, and contribute to healing from, acute crises. Since finishing the course, we have continued questioning mathematics curricula. In particular, we believe that a curriculum should be planned so that teachers can not only acknowledge acute crises, but humanize their subject by using it to understand acute crises and help in healing. We believe this is excessively difficult in mathematics courses where the curriculum remains abstracted and avoids chronic crises, and hope this brief narrative contributes a case study which continues validating critical mathematics education.

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MATHEMATICS TEACHERS' PROFESSIONAL LEARNING

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When teachers learn from and develop their practices, they do so under many influences and constraints, one of which is their professional education. Better understanding of these processes could improve teacher education, as well as inform support for novice teachers. The study will be conducted with novice mathematics teachers from two universities, using multiple data sources. Undertaking this study as a collaborative project across institutions in more and less economically developed countries, with very different histories and cultures, ensures that the findings will be more widely relevant and applicable. Insights from the project will be synthesized to develop both a broader perspective of practices and contribute to theory building about mathematics teacher learning, which enable/hinder desired teacher learning.

FOCUS AND SIGNIFICANCE OF THE PROJECT

This project is part of a larger cross-cultural multi-site cohort study project on teacher-learning, which includes Sweden, South Africa, Greece, and Rwanda. The larger study aims to contribute to the understanding and improvement of teacher education practices in the participating countries and engages how content and experience from teacher education are recontextualized by student and novice teachers, and under which conditions and constraints. However, this specific project concerns the Swedish and South African contexts, a focus that can strengthen the larger project theoretically, practically, methodologically and developmentally.

THEORETICAL BACKGROUND

We view teaching as knowledgeable action, requiring professional judgment/decision-making informed by specialized knowledge (Shalem, 2014). Thus, while content knowledge is widely recognized as necessary for good teaching, it is not sufficient. After Shulman (1986), substantial attention has been given to *pedagogical content knowledge* (PCK). Elements of PCK is therefore often taught in teacher education programmes, but few studies have explored how –and indeed whether– this informs novice teachers' practices.

Engaging empirically with pre-service teacher education, researchers have studied the *opportunities to learn* offered, and degrees of take-up by students within and across countries (Adler & Davis, 2006; Christiansen, 2012). Other have evaluated approaches to teacher education (Santagata & Yeh, 2014), specific elements of teacher education (Mena, García, Clarke, & Barkatsas, 2016), or the learning of specific skills or confidence (Charalambous, Hill, & Ball, 2011; Stockero, 2014).

A recent review claimed that most research on the learning of in-service teachers focused on program effectiveness where "teachers' learning is treated as an indicator of the effectiveness of the program rather than as the primary object of inquiry. (...) they have little to say about how teachers develop knowledge, beliefs, or instructional practices" (Goldsmith, Doerr, & Lewis, 2014, p. 21). Studies of how teachers shift participation and recontextualise knowledge and skills across social practices are few (see, however, Clandinin et al., 2015; Skott, 2013), and generally local.

Working with South African high school teachers over five years, Adler (Adler & Ronda, 2014) mostly saw incremental changes to practice. The teachers found it easier to change their examples than to change the nature of tasks or forms of engagement with learners. The strength of this study is the development of an instrumentalisation of the notion of *mathematical discourse in instruction* (MDI) which provides a way to interrogate changes to practice. This approach is relevant in our study, even though the project does not concern in-service teacher training. For a detailed description of MDI and its instrumentalisation, see Adler and Ronda (2014).

There is some indication that teachers learn through practice, both skills and a range of knowledge types (Brodie & Sanni, 2014; Leikin & Zazkis, 2010). Though teacher learning can be formal or informal, planned or unplanned, voluntary or compulsory (Kennedy, 2002), it is recognized that teacher learning in schools may depend on the presence of a mentor or community (Andersson, 2011). Therefore, it is important to explore how student and novice teachers' classroom practices are shaped by shift of participation in practices (Skott, 2013) and identity work (Švaříček, 2014; Skog, 2014).

It has been suggested that teachers may adapt, imitate, modify or avoid content from their education (Bauml, 2011) and past practices (Skott, 2013). We know little about how student teachers and novice teachers recontextualise knowledge/participation in practices, and under which constraints and conditions. In particular, studies of teachers' learning outside of professional development initiatives is not a common research approach, least at all across sites and over time. Yet it is crucial in developing our understanding of the long term impact –or absence of such– of teacher education programmes. This points to the importance and relevance of the current study. In addition, working across national contexts serves to generate a more comprehensive understanding of teacher learning which recognizes its context sensitivity.

RATIONALE AND RESEARCH QUESTIONS

As the background section suggests, there have been suggestions as to what should be foregrounded in mathematics teacher education, based on various studies of the relationship between teachers' knowledge and beliefs and learners' performance (Campbell et al., 2014). However, there has been significantly less attention on the actual learning processes of student and novice teachers, and on the ways in which novice teachers utilize –or not– what they learned in their teacher education. An increased understanding of novice teachers' practices carries the potential to inform an approach to teacher education which best supports learning conducive to improving teaching. Hence, the main research question is: *How does student/novice teachers'* mathematical discourse in instruction (MDI) *change through shift in participation in practices of education and work?*

The study will track learning from the last year in teacher education through to the second year of teaching and focus on the following, more specified research questions: How do student and novice teachers' *MDIs* change over time? What narratives do student & novice teachers construct around their MDI? How do these narratives relate to their past and present practices? and What conditions and constraints do student and novice teachers identify as impacting their teaching and professional learning?

METHODOLOGY

In trying to explore the learning experiences of novice mathematics teachers, six novice mathematics teachers from South African and six from Sweden will be visited at their schools, twice a year for two years of the project. In each *observation cycle*, we will, video record four to five consecutive lessons in two classes and conduct two interviews. The teachers will be observed in their classrooms and interviewed at their schools. We may include teachers' lesson plans and tasks as supporting data sources. Teachers will also be invited to submit recordings of their verbal reflections at regular intervals, as a form of teacher logs (Rowan, Harrison, & Hayes, 2004).

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SOCIOPOLITICAL MATHEMATICS TEACHER IDENTITY: MATHOGRAPHY AS WINDOW

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This project is a study of sociopolitical mathematics teacher identity. Twelve prospective math teachers (PMTs) wrote multistage mathematics autobiographies (mathographies) in a mathematics methods course. We propose an analysis of their narratives, making use of two distinct theoretical lenses, to consider how the PMTs may be negotiating emergent sociopolitical mathematics teacher identities.

PROPOSED INQUIRY

Often, concern for equity issues in mathematics education orients one to a sociopolitical viewpoint, in which traditional dimensions of identity interact with agency, authority, and power. Prospective mathematics teachers (PMTs) bring to their teacher preparation programs tacit ideological assumptions about education and mathematics, informed by societal views as well as by their own experiences in mathematics classrooms. Mathematics teacher educators with sociopolitical goals endeavour to disrupt these assumptions and to prepare future teachers with an awareness of themselves and their students as sociopolitical actors in a complex world. We call this orientation, when taken up as one's own, or, when sustained and performed over time, a sociopolitical mathematics teacher identity.

In some teacher education courses, though few mathematics methods courses, autobiographical projects are used as part of a sequence of activities designed to promote critical thinking, challenging ideological assumptions. The writing and other work produced through these projects can provide a unique window into the ways that PMTs are negotiating their emerging identities as teachers. In this study we are particularly interested in how twelve secondary PMTs envision and articulate what it might mean to be, become, or act as a critically conscious mathematics teacher through an autobiographical writing project, or "mathography." Specifically:

1. How are the PMTs negotiating emergent sociopolitical mathematical teacher identities, and
2. In what ways are they thinking about future students' mathematical identities?

IDENTITY

Identity, as an analytic tool, provides a way to focus on the dialectical relationships between cognitive and social views on learning (Stentoft & Valero, 2009), possibly erasing the distinction. In critical mathematics scholarship, identity is understood to inherently entail the negotiation of agency, authority, and power as it plays out both in and outside the classroom, and draws on social, cultural, and political discourses of both mathematics and belonging. A sociopolitical mathematics teacher identity suggests a critical orientation to the work of teaching, schooling, and mathematics, recognizing that mathematics and schools produce people, even as they are simultaneously constructed by people. As such, a sociopolitical mathematics teacher identity entails, at least in part, attending to the emerging and performed mathematical identities (Aguirre, Mayfield-Ingram, & Martin, 2013) of one's own students.

In this project the authors situate themselves theoretically and analytically with two different approaches to identity, Positional and Poststructural. Emma takes a sociocultural and dialogic approach to identity, focusing specifically on positional identities. Positioning theory (Davies & Harre, 1990) describes the construction of self as a negotiation of available "subject positions" and "storylines," often pre-existing. As individuals position themselves or are positioned by others toward available subject positions, the ways in which they take up or reject those positions in turn shapes the positions. Over time, repeated positionings may thicken into identification with certain positions and storylines over others. However, as with any discursively constructed position, these positions are always open to disruption.

The use of Positioning Theory for inquiry into identity has been identified as appropriate to sociopolitical goals in the mathematics education research field in that it affords attention to both individual agency and pre-existing sociopolitical structures (Herbel-Eisenmann, Wagner, Johnson, Suh, & Figueras, 2016; Langer-Osuna & Esmonde, 2016). As PMTs position themselves and their students through their autobiographical writing and reflection, they may articulate, accept, reject, and alter particular notions of what it means to be, become or act as a sociopolitical mathematics teacher.

Brian narrows his interest in identity to personal epistemology, specifically an individual's conceptions of mathematical knowing and knowledge. He is interested in when and how a generative orientation to mathematics is sustained through adolescence while the broader sociocultural discourse seemingly works in opposition. While many adolescents seem to express an epistemology of *external authority*, or sometimes *silence* (Belenky, Clinchy, Goldberger, & Tarule, 1986), Povey and Burton (1999) argue that the personal epistemology of *author/ity* may be an emancipatory identity. “If mathematics is understood as the ‘telling of a story,’ then each of us gains greater autonomy as an author of that mathematics, but not at the expense of a deep commitment to the social context of life and meaning making” (p. 236).

Brian’s focus resembles a discursive/poststructural orientation to identity as characterised by Langer-Osuna and Esmonde (2016), but is distinctly poststructural in his attention to knowledge and identity as they are bound up in and enacted in power relations. Identity is not the sum of multiple categorizations; rather, identity is discursive, negotiable, and thus fragile and dynamic, better characterized by “discontinuities and disruptions” (Stentoft & Valero, 2009, p. 58). Through the discursive opportunities of their autobiographical writing and reflection, PMTs negotiate ideas of mathematics and knowledge construction for themselves, and may position their future students as authors of their own mathematics, creators of knowledge (Povey & Burton, 1999).

MATHOGRAPHY AS WINDOW TO IDENTITY

Autobiographical and auto-ethnographic work (e.g. Dunn, 2005) has been used to support PMTs in becoming aware of and reflecting on their own mathematics experiences in order to think critically about their attitudes and beliefs about mathematics teaching and learning. Mathematics teacher educators make use of autobiographical writing in mathematics methods courses to push PMTs to examine social, cultural and ideological assumptions as they learn to teach for diversity through mathematics (e.g. de Freitas, 2008; Aguirre et al., 2013). In this study, we make use of the autobiographical writing produced in a mathematics methods course that explicitly engages PMTs in questions from a critical mathematics tradition of teaching for equity and social justice, to better understand how PMTs engaged in this work envision and articulate what it might mean to be or become a critically conscious mathematics teacher. Analytically, the autobiographical reflection work of PMTs provides a lens into the ways they negotiate their own ever-evolving identities as critically conscious educators.

METHODS

This qualitative study will draw upon the autobiographical narratives of PMTs to consider their negotiation of sociopolitical mathematics teacher identities. We will pursue a method of narrative inquiry in which we systematically gather, analyse, and represent PMTs’ stories as told by them. Stories, in this case autobiographies, are reconstructions of a person’s experiences, remembered in a particular context / moment in time, and for a particular purpose. This has a bearing on which stories are told, and how they are told. They are not stories of life as lived, but a representation of one's life as told by the person. As a result, subjective meanings and sense of self and identity are negotiated as the stories unfold. Narrative inquirers strive to attend to the ways in which a story is constructed, for whom and why, as well as the cultural discourses that it draws upon.

The twelve participants in the study were enrolled in Brian's Fall 2016 course "Teaching Mathematics in the Middle Grades." Drawing from a critical orientation to issues of equity and social justice, one of Brian's course goals was to broaden PMTs ideas about mathematics education. This effort to expand the image of themselves as mathematics teachers may occasion identity work in PMTs. Additionally, PMTs performed identity work as they negotiated their own sense of teacher-selves through their mathographies.

To address assumptions about teaching mathematics PMTs bring to the methods class, Brian utilized a multistage mathematics autobiography (mathography) to draw out PST's awareness of their own identity as a person who does (and learns and creates) mathematics, and as a person who teaches mathematics. This explicit attention to the sociopolitical mathematics teacher identities of the PMTs also may encourage them in turn to become more attuned to their own future students' mathematical identities.

Emma and Brian will separately examine the data collected, relying primarily on emergent coding to identify themes across the writings of all twelve students. As certain themes become particularly salient such as the linkages between how PMTs discuss the mathematical and sociopolitical identities of themselves or their students, Emma will "zoom in" to analyse the micro-interactional positioning accomplished within the writing itself that tells these stories, likely focusing on the work of only one or two students. Similarly, Brian will draw upon a small number of students to capture how each develops an epistemological perspective of author/ity and/or positions their future students as mathematical authors.

This investigation will serve two purposes, primarily to understand better the sociopolitical mathematics teacher identities of PMTs. Second, to inform future work examining the ways mathematical autobiographies can begin a sequence of activities in the mathematics methods course to address PMTs tacit ideological assumptions and provide a structure for the mathematics teacher educator to promote sociopolitical goals.

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FEARS AND DESIRES: RESEARCHING TEACHERS IN NEOLIBERAL CONTEXTS

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Chile and New Zealand are both countries whose educational policies reflect the neoliberal project, although they are two countries with very different histories. As researchers we are always caught up by our own contexts and past experiences; the data we produce is always in part defined by these histories. In this paper I describe my attempt to make myself a part of the research data; I take into consideration my personal reactions to the interview responses of mathematics teachers in Chile. I find myself reacting with fear and inspired by desires for New Zealand as I notice, in particular, teachers' comments which speak to the neoliberal context of mathematics teaching in Chile.

INTRODUCTION: GLOBAL AND LOCAL CONTEXT

Chile is considered by some to be the neoliberal experiment of the world. Pinochet's dictatorship brought in sweeping changes based on the recommendations of University of Chicago's Milton Friedman and his Chilean PhD students, known as the "Chicago Boys", during the 1970s (Cabalin, 2012). These policies of individualization, competitiveness, and the free market deeply influenced education (Valenzuela, Bellei, & de los Ríos, 2014) and teacher identity (Avalos & Assael, 2006). We can see evidence of these policies in the privatisation of schooling, voucher systems, and a law titled "*libertad de enseñanza*" (freedom of teaching) which gives almost unfettered rights to any group to open, organize and maintain an educational establishment and guaranteeing freedom of choice for parents[1].

Even though Chile today remains a neoliberal state, it has undergone much educational reform over the past decades (Avalos & de Los Rios, 2013; Cabalin, 2012). Current reforms include the phasing out of the semi-private system and a law of inclusion preventing the selection of students into public schools. However whilst Chile is toning down some of these policies of privatisation and exclusion, other countries – particularly in the western world, have been hurtling towards the same situation, implementing many neoliberal policies in education despite the cautionary

1. See http://www.cehum.cl/2015/03/31/titularidad-de-la-libertad-de-ensenanza-en-chile-en-la-constitucion-del-80/

calls of teacher unions and university academics (see for example Apple, 2000; Ball, 2003; Robertson, 2012).

INTRODUCTION: PERSONAL

It was within this general world context I found myself leaving New Zealand and headed to Chile to take up a post-doctoral position in mathematics education. Previously I had felt a vague sense of unease and concern regarding the various educational changes I had experienced over my ten years of teaching and during my doctoral research. On arrival in Chile it seemed to me that I was seeing how the policies of current and past New Zealand governments may be implemented and may evolve over time.

This move awakened me to the neoliberal project in education. In New Zealand I was like the frog in the pot, working away without much awareness of the ever heating water around me, slowly coming to a neoliberal boil. Moving to Chile has scooped me out of the water and allowed me a glimpse of Chilean frogs, now boiling and trying desperately to lower the temperature. This is an extreme and emotive metaphor; indicative of my own emotional response to the situation. The metaphor may seem very out of place in an ultra-rational neo-liberal world.

Towards the end of 2015 I began a research project in Chile which traced teachers' experiences in the years following their participation in a professional development program. I found myself drawn in particular to their comments which I felt reflected the neoliberal teaching context in which they worked.

METHODS

I take as a starting point data from my current research project (in progress) which is sponsored by the Chilean government[2]. The investigation aimed to illuminate and understand the experiences and perspectives of 15 volunteer teachers from over 200 who had undertaken a yearlong in-service professional development (PD) program to implement problem-solving strategies in their mathematics classes. In particular I wanted to learn about the wider affordances and constraints acting on teachers as they continued to develop professionally and also to explore whether the teachers would enact teacher identity change due to their participation in the program.

The teachers completed the PD during 2015 and in 2016 they engaged with me in a series of five semi-structured interview questions, sent by email. With each email I asked general and specific questions about their teaching of mathematics and implementation of problem-solving in

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2. Fondecyt Project ID # 3160469. Note: all views expressed are my own and do not necessarily represent this agency.

their classes. Each email series developed from the responses of the previous. As themes emerged from the initial analyses, these shaped both my ideas and generated further questions. Some questions were individualized as I attempted to explore an earlier response made by the teacher; others were general and I asked them of every teacher in the study. Through this process I became enmeshed in the data. The directions in which I took the questions related as much to my own background and experiences, particularly as a teacher in New Zealand, as to the responses given by teachers. I made the decision to amplify my own position as a co-constructor of the data, for example with questions such as:

> I am from New Zealand and so I do not know much about what it is to be a teacher in Chile. Can you describe for me how it is to teach and learn mathematics in this country?

With questions such as these I was making a conscious decision to make myself a part of the data. I positioned the research participants as representatives of Chile and my teachers, and simultaneously positioned myself as the outsider and learner, trying to gain insight into their situation. In this way I blurred the distinctions between 'self' and 'other' as at times I myself took on the role of 'other' (see also Chronaki, 2004). I tried to reflect on not only their responses but also my reactions to their responses. This changed my conception of the data. For example rather than informing me about these teachers sense of self as teachers of mathematics, instead the data revealed *my* recognition of the Chilean mathematics teacher identity in relation to my own expectations and experiences of teaching.

In the presentation I will provide for discussion a selection of these teachers' comments and some of my personal interpretations and reactions. I do not claim these to constitute the major theme in teachers' reflections about their professional situation; rather, this data is highlighted because it is important to me. My own desires (Walshaw, 2010) are implicated in my noticing of these parts of the data.

REACTING TO DATA, SEEING NEOLIBERALISM

On many occasions during analysis I found myself reacting with surprise or confusion to responses of the teachers. The cause of my surprise became a part of the analysis; the solution to my confusion was further and additional research into educational policy in Chile. In particular I found myself reacting strongly to comments made by teachers which spoke to the neoliberal teaching experience. My response was emotional and driven by fear that New Zealand was(is) heading to the same situation and my desire to gather data and produce results that may in fact help steer New Zealand in a different direction.

> "Here it is taught to rich to poor, we are a society of entrepreneurs and consumers. In private schools they teach well and in public schools they teach what they can, they must meet other needs of the children; their food, family relationships, health, etc., in subsidized schools it is the same. Each new need of the Chilean children is transferred to the schools, therefore to learn mathematics alongside this is difficult." (Teacher P, subsidised charity school).

In order to understand such comments I needed to be aware of the different experiences for teachers in public (municipal) schools or in semi-privatized schools, as the teachers in my project taught in both of these types of schools. The public schools catered to populations with high numbers of 'vulnerable' (at risk) students. Many of the semi-private schools in this school also catered to the same population demographics as these were schools owned and run by charitable foundations. However the experiences for these teachers were distinct as these schools currently do not need to comply with the teacher evaluation system of public school teachers. These semi-private schools were also able to adapt the curriculum in line with any particular philosophy of teaching held by the organization which owned the school.

> "…there are some [schools] which have different approaches … Mine is very academic, they care about the results of [standardised national] tests such as SIMCE and PSU" (Teacher J, subsidised charity school)

These quotes reflect realities that are both outside my experience and yet familiar to me. I fear the emergence of a system with extreme levels of SES segregation and the creation of high poverty schools where "to learn mathematics alongside is difficult". I also fear nationalized testing regimes limiting mathematics pedagogy.

However I also worry that I may cast a colonizing gaze on the data; adopting a sense of 'superiority' (Chronaki, 2004) and failing to read the data objectively or even empathetically. The two teachers quoted above work in schools from similar communities and yet their responses are different, their mathematics curriculum development distinct. This demonstrates the spaces available within neoliberalism and the agency possible for these schools. In this there is hope for the boiling frogs.

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PERFORMING GIRL *AND* GOOD AT MATHEMATICS: SCRIPTS IN YOUNG ADULT FICTION

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There are many different scripts available for performing various identities, such as 'girl' or 'good at mathematics'. Some scripts may derive from people in an individual's social circle or community whilst other scripts are derived from popular culture and the media. This presentation reports on an investigation into the representations of good at mathematics in popular Young Adult fiction novels, with a focus on the intersection of gender with this identity. While there appear to be scripts for performing both girl and good at mathematics there are limitations on who may be cast in this role and potentially negative consequences for these characters.

INTRODUCTION

Historically there has been much research regarding girls' relationships with, and participation in, mathematics education (Forgasz, Leder, & Tan, 2014). There is a Facebook group for the network IOWME[1] and gender is included as part of an ICME topic study group[2]. However, at the last MES conference[3] there were comparatively very few presentations regarding gender; does this mean gender is no longer a social or political issue?

Current scholarship finds little difference in *achievement* for girls and suggests rather that they may be edged out of *participation* (Forgasz et al., 2014). This is perhaps due to mathematics being considered masculine and the corresponding difficulties girls may face in performing other important identities, such as 'feminine', in this domain (Damarin, 2000; Mendick, 2005; Solomon, Radovic, & Black, 2015). It is this work within the field of identity that suggests gender issues in mathematics education are a war not yet won, rather that the battlefield has moved.

To understand identity I take as a starting point Butler's conception of identity as performative (Butler, 1988). This view sees gender (and mathematical) identity not as biologically determined, but performed in

1. International Organisation for Women in Mathematics Education: https://www.facebook.com/groups/247108762072768/?ref

2. International Congress for Mathematics Education: TSG 33 "Equity in mathematics education (including gender)"

3. MES8 2015 Portland, Oregan, US.

the moment. I find a theatre metaphor useful as it incorporates these ideas of performance but may also consider other aspects, such as context (the stage and theatre as the wider situation), as being influential and often constraining on identity performances. I assume that performances are also affected by an individual's repertoire of past performances and also by available *scripts* for performance that are available as a model. For the purpose of this discussion I focus on this aspect of scripts.

Scripts for identity performances are widely available, they can be found in local communities and in the wider media. For example a girl's mother, sister, cousin, friends, and popular culture such as television all provide scripts for performing girl, including the sorts of clothes to wear, ways of speaking, and how to conduct relationships. Of course these scripts may be very different depending on the community context. On the other hand these same sources, and others, all may provide scripts for performing other identities, such as the school mathematics learner. An individual may 'choose' to follow the performance script of any of these models and they may choose to improvise. Regardless, it is worthwhile to examine the features of these scripts for performing girl and able mathematics learner.

In this presentation I share results of a study that examined scripts for performing girl and 'good at mathematics' in young adult (YA) fiction novels. The study builds on other work in the mathematics education community which has explored popular culture and views of mathematics, including gender perspectives (Esmonde, 2013; Mendick, Epstein, & Moreau, 2008). One objective of the study was to examine the scripts for performing the mathematics learner. In particular I wondered if performing good at mathematics appeared related to gender within these popular texts.

It should be noted that up to this point a binary understanding of gender is implied. In fact I do not wish to suggest that gender actually is binary; there is increasing understanding that there are a range of other ways of performing gender identity (Hall, 2014). Yet in the YA fiction analysed for this study gender was portrayed in this binary manner in all but one book[4]. However, I acknowledge that the framing of the question may contribute to this dominant binary view. My question for the study was: *How are girls represented as mathematics learners in popular YA fiction?*

METHODS

This research question is one part of a larger study looking more generally at portrayals of school mathematics in YA fiction. For this study I obtained

4. In this one novel the main character did not have a body and assumed either male or female gender identities depending on the body occupied at the time. See "Every Day" by David Levithian.

lists of the “Teen Top Ten” as voted by readers in the U.S. and available on the American Library Association website[5]. These books are available throughout much of the English speaking world; I accessed most of the novels from Auckland University library and the e-book collection at Auckland City libraries in New Zealand. I read all 136 books on the list, representing all books voted by teenage readers from the inception of the list in 2003 through to and including the top ten for 2015. Any book which contained a reference to school mathematics or was set at school was included in the study, a total of 67 novels.

Alongside a thematic analysis (Braun & Clarke, 2006) of all the references to school mathematics, I also noted the gender of main and secondary characters and whether these characters were portrayed as being good at mathematics (see the table below). To critically analyse these findings I took into consideration wider aspects of characterization and plot.

RESULTS AND DISCUSSION

The table below gives a summary of gender and good at mathematics as portrayed in the novels. I have only included the data which explicitly stated or obviously implied the ability of a particular character. Not all of the 67 novels mentioned this (recall that these books are not about mathematics *per se*; mathematics only features because the majority of books are set in high school). However some books mentioned ability of secondary characters in additional to the protagonists.

Protagonist			**Secondary Character**		**Total**
Male	Good at math	2	Good at math	9	11
	Bad at math	9	Bad at math	2	11
Female	Good at math	10	Good at math	3	13
	Bad at math	8	Bad at math	4	12

Below are some quotes to give examples of these categorisations:

> "We were sitting in the library during our free. I was doing math homework; Josh was helping because he's good at math ....” (To all the boys I’ve loved before, ch. 6): Good at math, male, secondary character.

> "Amalie stood up. ‘I'm sorry, I can't cope with this course any more. I'm leaving.' She burst into tears. ... 'I'm useless,' wailed Amalie. 'I don't understand any of this theorem stuff, and it's frightening...." (Earth Girl, ch. 26): Bad at math, female, secondary character

> "I was practically a straight-A student; I aced everything but math" (Butter, p. 15) Bad at math, male, protagonist

5. http://www.ala.org/yalsa/teenstopten

> "… 'Math's my best subject, you know.' (Wake, p. 58) … "She has no idea what she wants to do with her future. But science, math … maybe research." (Wake, p. 111): Good at math, female, protagonist

A superficial reading of these results would suggest that males and females enjoy an equally positive representation with the YA fiction, as evidenced by the figures in the column headed 'Total'. However these results may be questioned further. When we consider the difference between representations of main versus secondary characters the results appear rather different. Whilst it appears acceptable that a female protagonist be good at mathematics and male protagonists bad at this subject, the typical stereotypes are much more evident in the secondary characters.

It is important to consider inter-sectionality; being girl is certainly a different experience depending on race, class, able-bodiedness, sexuality, and various other markers of identity. The protagonists in these books are almost exclusively white and middle- to upper-class. They are also able-bodied, heterosexual, and beautiful. Damarin (2000) suggests girls do not identify with mathematics due to their being "doubly marked", marked as mathematician and also marked by gender. In contrast to this, perhaps in these novels we can read scripts for girls to identify with mathematics – but to be triply marked appears impossible. If a girl is also a member of an additional marginalized group, able mathematics learner scripts do not exist for them in these novels.

Finally we should also consider the plot development to investigate the cost for those girls who provide the script for good at mathematics. There are some surprising plot developments (read punishments) for those girls who are secondary characters yet break script by being good at mathematics. I aim to further discuss these various limitations on performing girl and good at mathematics during the conference presentation.

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THE CONSTRUCTION OF THE MATHEMATICAL CHILD IN SWEDISH PRESCHOOL

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Mathematics education in Swedish preschool can be considered as a discourse produced through educational public policies, classroom practice, curriculum, research, teacher's education, and literatures. This different spheres interact with one another in the production of a "truth" according to Valero and Knijnik (2015). Using Foucault's concept of governmentality, and Popkevitz concept of construction, I focus in this article on what kind of "truth" are produced when preschool teachers talk about mathematics. This article is a part of a doctoral thesis.

INTRODUCTION

The idea that children grow up in a society that makes greater demands than before on mathematical comprehension and math skills can be found in a number of rapports. The idea that mathematics are the motor of progress and therefore, improving mathematics teaching and learning should be a priority can be found in a number of political discussions (Valero, 2016). According to Foucault, it is only when things have been formulated as a problem that they become possible to control, for example through education, legislation, or different types of interventions (Axelsson & Qvarsebo, 2017). The "problem" was formulated in Sweden, based on several studies showing that children at school have difficulties to assert themselves in mathematics internationally. To solve this problem, bureaucrats in many countries have been willing to argue about what return the investment in the younger child development can provide a society. Attention have therefore turned toward preschool in an attempt to investigate whether an early contact with math can make a difference. The urge of mathematics education has become a truth that is seldom problematized argue Valero (2016) and to play my part I will problematize the teaching of mathematics at preschool. The ideas of a modern society where globalization, equity and access to knowledge are in focus, formulate the discourses about how the mathematics or the preschool teacher should be. My focus will therefore be on the teacher's narrative. As the development of mathematics seems to be strongly related to the development of the social welfare, the teacher become a product of social demands (Montecino and Valero, 2015). The mathematics teacher fulfil the task of bringing light to children for the benefit and progress of the nation and is responsible to provide answers to the social demands of our times. Preschool teachers, may be considered as discourse carriers and serve as gatekeepers for the knowledge included or excluded in society (Axelsson & Qvarsebo, 2017).

When a revised curriculum (Lpfö-2010) for preschool came up in 2010 in Sweden, the mathematical goals was increased but mathematics was known among preschool teachers long before. Some of them had worked with mathematical concepts earlier in everyday situations, but after 2010, mathematics for younger children has been a subject of major focus in many parts of the society and research about mathematics for young children are increased significantly. How children are to create, explore, and use mathematics is not specified in the curriculum, as it is a goal-oriented document without suggestions on how to teach. In the mission of Swedish preschools, caring, education, and learning form an integrated whole. Although the focus on caring is unchanged in the new document, more emphasis is placed on learning and knowledge (Vallberg-Roth, 2011). To help preschool teachers to find a way to work with young children and mathematics, a compulsory course is now a part of the education of preschool teachers and working preschool teachers have been offered training in the field. In this article, I highlight what "regime of truth" about young children, and mathematics appea,r when I analyze how the preschool teachers talk about their work with mathematics. Truths, according to Foucault, do not just happen. They are produced to give a meaning to our way of acting and thinking or in this case, to define what is a normal way of teaching and learning mathematics among young children and what is not. This discourses or "regimes of truth" construct the meanings of one's actions, thoughts, and feeling (Foucault, 1980) and alternative discourses are often marginalized. While the discourses seems to reflect an intention of inclusion, it can also provoke the exclusion of those who distance from the expectation of the teachers (Popkewitz, 2004). The study will even focus on the multilingual mathematical child as a growing number of children with different cultural backgrounds are admitted to preschool. In Sweden assessed every five preschoolers who use more than one language daily (National Agency for Education, 2013), and the number is steadily increasing. Diversity among children is not a new phenomenon but is more visible when the children and teachers have different cultural, religious and linguistic backgrounds. Discourses about this specific group in relation to mathematics may be the same or may be different.

The purpose of the study is not to make a constructive contribution to how the teaching of mathematics in preschool should be improved or to construct a better child. The analysis focus on discourses about how the mathematical child is produced and what the consequences will be for groups and individuals, not if they are reasonable, true or real in themselves.

I hope that the result of this study will destabilize what is usually taking for granted about the teaching of mathematics in preschool and open for other possible ways of thinking, acting and being but without suggestion on how to think, act and be instead. The purpose of the study presented in this article is to highlight and problematize the ways in which a certain kind of child is constructed in relation to mathematics in Swedish preschool. The article will show what "regime of truth" are present when preschool teacher talk about mathematics and how a kind of mathematical child is constructed and governed.

THEORETICAL FRAMEWORK AND ANALYSE

I take Foucault's concept of "governmentality" and "regimes of truth" as a key theoretical tool and analyse a corpus of empirical data consisting of interviews with ten preschool teachers working in four different preschools. The children are between three and five years old. Two of the preschools are monocultural and two are multicultural where both teachers and children speak or understand more than one language. Some of the children do not speak the majority language or very little. How much they understand is not possible to know. According to Deleuze (1988, p. 64), Foucault state that the author is not the origin of the discourse. When I analyse the narative of the preschool teachers, I am not interested to judge their ideas and evaluate them but I examine their statements.

The idea of power and domination is a central concept in Foucault's work and it shows how some discourses dominate and how society defines and organizes themselves. However, Foucault talk about power relation rather than about structures. Power is seen as something productive that shape and organize social life in different ways, explain Axelsson & Qvarsebo (2017). Power is nothing that come from a dominant part and is static; instead, Foucault see power relations as dynamic and an interplay between people, discourses and institutional arrangements. At a preschool, for instance, there is a constant negotiation between the headmaster, preschool teachers, educators, parents and children. Different parts interpret various policy documents differently (Delacour, 2016); parents and children are given more or less influence, and a variety of factors influence how the activities can be organized. There is no power relation without resistance, according to Foucault (Foucault 1997) and many forces will challenged each other's.

In my data, I can notice:

Resistance between headmaster and teachers. Some of the preschool teachers explain that the decision to work with mathematics at a certain time was taken by the headmaster but not all of them agreed that it is to be prioritized. Others think mathematics is important and work with it even though the headmaster has decided that other things should be prioritized.

Resistance between teachers and policy documents. A preschool teacher says she is obliged to follow the curriculum, though she does not think it is relevant and she use to ignore some parts of it. One compare, with a ironic ton, the curriculum as a bible. Some witness that one cannot work with mathematics with children who do not understand Swedish, or have traumatic experiences behind. They are working to provide a sense of security instead.

Resistance between teachers and parents; Preschool teachers say that most parents that speak another language than Swedish at home, want the teachers to speak Swedish with their children and work a lot with the development of the Swedish language. Some preschool teachers agree while some try to convince parents about the importance for their children to learn their native language and work with mathematics. Some parents do not seems to be interesting about the work of the teachers with mathematics or understand how important it is according to most of the teachers and keep their children at home to often. They refer to research and curriculum when they try to “teach” parents. The teachers disagree about which parents are not interesting; the “Swedish” or the “foreigners”.

Resistance between colleagues; Colleagues complain when they believe that a language other than Swedish are taking up too much space. Colleagues are different view about how mathematics should be teach.

Resistance between teachers and children. Children are not interested about what the teacher wants them to do or they want do it in their own way.

Resistance with the teachers own feeling. Mathematics is boring or are not its place at preschool. Views on how the relationship between a teacher and the children are expected to be in a learning situation discord with their own views.

Resistance between needs/believes and institutional arrangements. The teachers are no time to plane, evaluate or document their work. The headmaster do not match teacher and children that speak the same languages and mother Tongue teachers are not available anymore. Large groups prevents teachers and children to work with math those way teachers want.

Which “regime of truth” appears in my data?

Which subject formed within different discourses?

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"HOW DID YOU GET TO THAT RESULT?": THE PROCESS OF HOLDING A DIALOGUE IN MATH CLASSES OF THE EARLY YEARS OF PRIMARY SCHOOL

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This work present a research project aimed at to discuss the elements that favour the process of dialogue in math classes in the early years of Primary School. Data collection will be held in three classrooms of this level of education in a public school, having the teachers interacting with the students as the participants of the research. As data production tools, a journal will be kept and a tape recorder as well as a video camera will be used to capture the discursive interactions to take place during the classes of the participating teachers. As for the data analysis, the perspective of dialogue based on critical pedagogy and on critical mathematics education will be employed. The research is believed to be relevant to Mathematics Education as it seeks to investigate possible ways to build a dialogic math of Primary School.

INTRODUCTION

For years, teachers have imparted the content of the school curriculum to students assuming that their learning was guaranteed only by the fact that they have been discoursing on such content. In the field of Education, Freire (2014) have sought to overcome this vision of education based on the transmission of knowledge, emphasizing the importance of dialogue in the classroom. For him, in a way, education must be linked with equality, humanization and democratization through a permanent and horizontal relationship between teacher and student which is based on dialogue. According to Freire (2011, p. 37), "[...] man is in the world and with the world. If man was only in the world there would be no transcendence nor would he be able to objectify himself. But in the same way he can objectify himself he can also distinguish between a self and a non-self". In this sense, the author conceives man as a being of relationship. Therefore, as he is conscious about his own "self" that differs from the "non-self", the possibility to interact with others is established. According to the above statement, teaching and learning are closely linked with the interaction processes that might take place between student and the object being known, students and the teacher and between the pairs of students. The position of the quoted author emphasizes the need for students to engage in dialogic processes of teaching and learning dialogic and it is also noteworthy the need to experience such processes in math classes.

According to Morgan et al. (2014, p. 843), language and communication have visibility in the field of Mathematics Education. However, it is essential that researchers engage in investigating the role of language and communication in the teaching and learning of mathematics. Danish authors Alrø and Skovsmose (2004) study the connection between dialogue and the learning of mathematics. For them the bond established between teacher and student is key to building a dialogic math class. According to Skovsmose (2007, p. 231- 232),

> A teacher and a student might be different, but they can, anyway, engage in dialogue as equals. [...] Any discussion or statement can gather strength only from their own content and not from the people (or positions) that hold them.

The bond between teacher and student shall be based on respect, careful listening, exposition of the ways the student went through to reach a certain result and on the building of arguments for a better understanding, thereby changing the dynamics of interaction in the classroom. In this sense, the main question of the research is translated as: "How do teachers of the early years of Primary School put dialogue into action in math classes?".

THEORETICAL FRAMEWORK

As a theoretical framework for the research herein, the support of dialogic theories that could contribute to the discussion of the selected theme was sought. In the light of such observations and findings, the classroom is considered to be a complex environment which encompasses conflicts, interactions, voices, noises and where the learning process is experienced by a group of human beings and not only by a single individual. As a result of the foregoing, the theorists Freire (2011, 2014), Skovsmose (2007) and Alrø and Skovsmose (2004) were initially selected as theoretical support for this project as they developed theories in which the concept of dialogue and interaction are fundamental. In accordance with such significance, this study addresses the importance of dialogue in math classes for the establishment of a humanized education. It can also be noted that theorist Freire (1983) helps us to understand how communication can be established in different ways, taking dialogicity as a fundamental part of the learning process. The author presents the notions of "communication" and "extension" as representing opposite ideas, and he emphasize that the role of the educator should be based on communication. In an education based on extension, the educators seek to extend their knowledge to students by objectifying them through a vertical relationship between educator and student, in which the first wants the latter to become increasingly similar to him as his knowledge is perceived as superior and the student's world view is not taken into account as it is considered to be inferior. It does not contribute to a critical reading of the world and does not allow students to see themselves as beings of social transformation.

Contrary to this view of extension, Freire (1983) develops the concept of communication. In order that communication takes place, teachers build a horizontal relationship with students, thus allowing different ways of knowing the world to be valued. This way, students' world view starts to be valued because it is based on that view that the educator will eventually overcome it. In this sense, the individual is no longer conceived as a storing object and becomes a subject of knowledge. In this sense, Freire conceives dialogicity as a fundamental practice to human nature and democracy and conceives it as an epistemological requirement. It is noteworthy that the research conducted by Alrø and Skovsmose (2004, 2010) and Freire (2011) addresses the concept of dialogue in the field Education of the final years of Primary School. Neither of them, however, addresses the dialogical approach in the early years of Primary School, which is the educational level investigated in this research. For these reasons, a doctoral thesis which proposes the study of elements that favour the construction of a dialogic math class in the early years of Primary School constitutes a significant contribution to research in Mathematics Education.

METHODOLOGY AND PROCEDURES

In accordance with the objectives established, this research is characterized as a qualitative research, which aims at the interpretation and understanding of the studied phenomenon. The context of data collection will be formed based on three classrooms in the early years of Primary School, specifically a class of the first year, year 3 and year 5. The participants will be the teachers interacting with the students. Three teachers will have their classes observed during a semester. The corpus of analysis and interpretation will be formed based on the researcher's journal and on the audio and video recordings of the dialogues established during the math lessons alongside with the short stories produced by the researcher. The field diary will result from the set of notes that the researcher will take by observing the classes of the three teachers participating in the research. The notes will be related to ideas, feelings and perceptions of the connections between the communication established between teacher and students, between the pairs of students and the dialogue elements present in these interactions, as well as other situations that might occur. In this sense, the researcher will use the field diary and, additionally, the verbal interactions between teachers and students will be recorded with the consent of the participants for transcription afterwards.

Apart from the procedures described above, a question still remains: How to explain the richness of verbal and non-verbal communication only through the resulting transcripts from the audio and video recording of such classes? A more enriching description of the dialogues is needed. That's the reason why we chose to write short stories that will ensure that gestures, the environment of the classroom and the dialogues are present in a more lively form. On addressing the qualities of a short story, Tchekhov (2011, p.10) emphasizes that "the author must draw attention to small details, grouping them so that the reader, when closing his eyes, is able to 'see' the whole picture". In this sense, the short story meets precisely the proposed objectives and will be the literary genre used for the compilation of data. During the transcribing experience, the gestures of both students and teachers, which are regarded as important in the dialogue, process will be described; thus, no reference will be made to eye colour, nose size, but to interaction, the way interaction takes place and even to gestures and which are observable. For instance, when a student is referred to, it can be described that he "quickly performed the tasks and solved everything correctly"; his behavior can be described and yet not by using an adjective such as "smart". When mentioning a particular a student, it can be observed that his cheeks are flushed, but he cannot be described as being embarrassed. "Their psychological states should not be described by the author, but deduced by the reader based on their actions" (Tchekhov, 2011, p.10). The speeches will all be transcribed from the audio recording and will always appear after the identification of the student or teacher who produced it. This resource, although it is not used in short stories, will enable the reader and the researcher to spot the dialogue and the research participants more easily.

ANALYSIS OF RESULTS

As for the data analysis, the dialogue perspective in critical pedagogy and in critical mathematics education will be referred to as both of them are based on dialogic theories. In this sense, the dialogic perspective will also be used in the analysis and understanding of the data. The entire analysis process will be based on dialogue and on the validation of data with the research participants. In order to answer the main question of the research several readings of the data will be carried out so that the relevant episodes can be highlighted. Likewise, in order to achieve the proposed objectives a discussion and a reflection on the communication patterns present in math classes in the early years of Primary School will be conducted based on literature.

CONSIDERATIONS

The preliminary results of this study indicate the presence of two communication pattern in math classes of the early years of primary school. The first one is the "sandwich" pattern, in which the teacher asks a question, the students responds and then the teacher evaluates the student's response and gives feedback. This pattern usually emerges in a classroom where the teacher has a predominant role in the communication process. The second pattern is dialogue, which has emerged in interactions permeated by elements considered important in the literature, such as making an inquiry, presenting arguments, being engaged, running risks and maintaining equality.

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IDENTITY CHANGE THROUGH INNER AND OUTER DRIVING FORCES FOR STUDYING MATHEMATICS IN THE SWEDISH PRISON EDUCATION PROGRAM

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In the Swedish mathematics prison education program, students with a history of failure in the regular school system get a second chance to recapture lost years of education. Experience from teaching paint a picture of motivated, goal-oriented students that perform very well in this extraordinary context. How can that be? Our study aims to investigate and capture the inner and outer driving forces for their motivation. Our hypothesis is that taking this second chance for schooling bring forth an identity change in two steps; firstly when deciding to take the opportunity to study mathematics, and secondly when succeeding. This identity change may give the imprisoned students increased opportunities for reentry in society.

INTRODUCTION

What motivates a person to study mathematics when life is in crisis and he or she is serving a prison sentence? Deprived of one of your most obvious human rights, freedom, and often with bad experiences from previous education, many prisoners deliberately choose to undertake studies in mathematics. In this project we aim to explore the inner and outer driving forces for studying mathematics in prison and how the identity as a learner of mathematics can develop in the special context of prison education.

THE SWEDISH PRISON MATHEMATICS EDUCATIONAL PROGRAM

In all of Sweden's 47 prisons, convicts are offered the possibility to study lower and/or upper secondary level mathematics. The target group is convicts without an upper secondary diploma, and of special focus are young people who have difficulties in entering the job market. All teaching in the Swedish prison and probation service is individualized. Personalized programs are planned in consultation with a study -and careers adviser on basis of the convict's goals for education. At the moment 23 mathematics teachers are employed by the Swedish prison and probation service. Teaching is organized as one-to-one teaching when there is a teacher employed at the prison where the convict is following his or her mathematics course. Otherwise, teaching is organized as distance education, where the teacher and student communicate through an intranet and by telephone. In Sweden it is quite common that convicts serve their time in more than one prison and transitions are often made for security reasons. Well behaving convicts will be moved to prisons with lower security and vice versa. This may have as a consequence that a student who began a mathematics course with one-to-one teaching may have to finish the course with distance education. For the sake of continuity in education, teachers "follow" their students through transitions in the prison system.

A fair share of the students chose mathematics without really wanting to study the subject, but simply because mathematics is a prerequisite for entering both employment training programs provided by the government and for entering many tertiary educational programs. Still, they are often highly motivated to pass their math courses in order to reach their future educational goals, even though they might, at least initially, lack interest in mathematics as a subject.

THEORETICAL FRAMING

Our starting-point for theoretical framing will be learning as identity formation. However, we keep our minds open for the need of complementary explanatory frameworks as the study proceeds. The relation between identity formation and mathematics learning has been researched by several scholars in mathematics education, perhaps most notably in Boaler's work (1997; 2002; Boaler & Greeno, 2000), together with other important contributions from Bartholomew (2005); Sfard & Prusak (2005) and Lerman (2006). Many of these follow the lead of Lave and Wenger. They state:

> We have argued that, from the perspective we have developed here, learning and a sense of identity are inseparable: They are the same phenomenon. (Lave & Wenger, 1991, p. 115)

A multitude of studies with identity perspective has focused on how perceiving oneself as belonging to one or several groups relate to one's identity as a learner of mathematics. For example, Boaler and Greeno (2000) illustrate how female students refrain from continuing mathematical studies because they perceive the identity of mathematicians as not compatible with their own identities. Similarly, ideas about the identity of a successful learner in a particular educational setting may also clash with personal ideas about current or preferred identities. This has for example been researched in relation to gender, ethnicity and social class (c.f. Kehily, 2001; Reay, 2002).

In most cases students' identity formation in relation to mathematics has been researched in relation to the mathematics classrooms. However, as indicated above, other aspects of students' identities may come to the fore at any time and interact with their identities as mathematics learners. In the setting of this project, both general identities and learner identities becomes particularly interesting. The students share a non-successful school background, but apart from that, they have few common traits. This educational context offers no traditional classroom. While studying together, each student follows an individual program. This, together with the imprisonment, makes it likely that the formation of identities as mathematics learners follow different paths compared to what is known from standard schooling situations.

METHOD

Data is collected through semi-structured interviews with students in the Swedish prison education program, during August to October 2016. The interview questions are organized around 4 themes. Since we are interested in the students' experiences as mathematics learners, rather than their general ideas about education, theme 1 sets the interview up by discussing the mathematical work the student is currently engaged in. Theme 2 revolves around the student's feelings when working with mathematics now. Theme 3 concerns what the student thinks about the current teaching arrangements and theme 4 concern the student's previous experiences as a mathematics learner and as a user of mathematics in everyday life. The first three themes are then revisited, but now in relation to what was earlier said about the student's previous life experience. For this project we have conducted interviews with two female students at Sweden's largest high security women's prison, three male students on a high security prison and two male students on a low security prison. Video recordings are not possible due to security regulations in the Swedish prison and probation service. The interviews are therefor audio recorded and will be transcribed in whole or in parts, depending on how we proceed our study and our analysis. The data will be analyzed using a framework built on Mellin-Olsen's concepts of S- and I-rationales for learning (Mellin-Olsen, 1981).

REFLECTION ON EXPECTED OUTCOMES

The second author of this project presentation has 9 years of teaching experience from the Swedish prison education system. She has met many motivated, goal-orientated students, whose prior experiences from school could be described as a total failure. How can it be that, for many students, the motivation for education shifts in two steps when serving a prison sentence? Firstly when taking the opportunity to engage in studies, and secondly when succeeding with their studies. For many students this is a new experience that often makes them reflect on themselves as successful learners of mathematics, which is often a new experience. What impact does this new experience have on their self image? Their stories often describe compulsory school as an institution of oppression. When actually being imprisoned, many students describe the educational setting in prison as a place where they can exercise a certain freedom. Also, many students say that they believe that education is an opportunity to a better life after prison. Our hypothesis is that this shift in how education is positioned in the stories of their past and present life experiences relate, in important and hopefully identifiable ways, to how they develop their identities as mathematics learners. A further hypothesis is that a novel experience of being a successful, learner of mathematics will also influence the students' identities more generally (Boaler & Staples 2008). It is probable that different individuals will have completely different stories. We hope that this will both provide us with a wide spectrum of examples of identity formations, as well as possible common themes for identity change related to opportunities to recapture lost years of education.

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STRENGTHENING THE WAYS OF MATHEMATIZE OF THE MAPUCHE PEOPLE AT THE SCHOOL[1]

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The understanding of the educational needs in mathematics of the Mapuche people and their way of effective, ethical and appropriate development for the students of today are the basis that put this work in motion. Thus, through an ethnographic methodology, which focuses on the inclusion and participation of the people involved, a development cycle of classroom research is fostered which provides results for reflection, guidelines of needs and strategies, validated by the Mapuche community and the Mapuche school community. The analysis that the Grounded Theory promotes shows the first dimensions of results as for the general way of planning the instruction and the development of appropriate mathematical activities, which are relevant to the characteristics and needs of the Mapuche people today.

CHILEAN EDUCATIONAL SYSTEM AND THE LOSS OF THE MAPUCHE KNOWLEDGE

Ever since, the first Organic Law on Primary and Normal Education (In Spanish: Ley Orgánica de Enseñanza Primaria y Normal) in 1980 was implemented, it started the work to unify a national curricula for all "Chilean" people. In response, several Mapuche organizations were formed to defend their rights. For example, the Sociedad Caupolicán Defensora de la Araucanía created in 1911 demands the defense of the race and the right to education in order to help the integration of the Mapuche people into Chilean society (Bengoa 1985). Other more critical groups emphasized the need to contextualize schools according to the cultural reality of the Mapuche people, and how to prepare students to defend themselves against the "new conquest" (Foerster and Montecino, 1988).

Nowadays, the Intercultural Bilingual Education in Chile, grounded on the Indigenous Law N°19.253 and launched on a pilot scheme in 1996, has contributed with important elements of linguistic and sociocultural revitalization and recognition for the students belonging to the indigenous

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group in the context of state education. The results of these efforts indicate that Chilean indigenous students underperformed non-indigenous students in general. These results increase in the subject of mathematics (McEwan, 2008; Undurraga, 2014) and high concentrations of indigenous students (Canales and Webb, under review).

Thus, it is necessary to understand the mathematical educational needs of the Mapuche people and their way of effective, ethical and appropriate development for students nowadays.

UNDERSTANDING THE NEEDS OF THE MAPUCHE PEOPLE OF TODAY

To achieve the mentioned goal, the work has been conducted in three rural Mapuche communities, in the Araucanía region, Chile. The project begins with the ethnographic work developed with the *Kimche* (wise people) of the three communities. Their narrative allows to understand a way of teaching-learning and different forms of mathematize appropriate to the people.

Each of these three Mapuche communities has an educational institution located within its geographic area. Most of their teachers are Mapuche and live in the same community, and are part of it. Here, the teachers' needs are recognized and complemented with the guidelines established by the *Kimche*. Representatives of *Kimche* at the school, teachers and the researcher create didactic material cooperatively, responding to the Mapuche and school communities' needs (Goodchild, 2008).

Once applied the material with students of each school, the triad among the wise person of the community, teachers and the researcher analyse the results and prepare a validation plan concerning each of the three Mapuche communities from where the information for this work was obtained. The data analysis is made through the Grounded Theory (Strauss and Corbin, 2008).

STRENGTHENING THE WAYS OF MATHEMATIZE OF THE MAPUCHE PEOPLE AT THE SCHOOL: PRELIMINARY RESULTS

In the general and transversal field of teaching, and since acquisition of knowledge through traditional ways, taught by Mapuche community throughout life is not currently transferred by it, the idea that school must strengthen the ancestral knowledge is valued and reinforced. There is an underrated value and interest that new generations of Mapuche learn ancestral practices and knowledge, as these are almost obsolete processes even for the current *Kimche*.

> "My grandfather sent me to school. He said that I had to learn to read and write in Spanish. Also I had to learn to add and subtract Wuinca (non-

> Mapuche) numbers. (...) My grandfather wrote down the numbers in a wool, with knots, when I learned to write numbers (Western system), he stopped using wool." (J, 82 years old).

In the same way, the current generation of parents of Mapuche students validate the knowledge that school gives them. They do not want to be excluded from it and they do not want an education that considers only the knowledge of the people[3].

Thus, the need of dialog in classrooms, promotes the determination of a coherent teaching method for the people (Knijnik, 2009), and transferable in the national educational system (Blanco-Alvarez, 2012). The main elements considered for planning educational activities are:

-To promote support from the students' family and wise people of the community in understanding the knowledge to be strengthened and in the concrete educational task to perform in the classroom.

- The Mapuche knowledge to be developed must be contextualized in its traditional use and project its current importance in a practical and scientific way, always linking the Mapudungun (Mapuche language) and the epistemic distance with the Spanish.

- Traditional teaching-learning begins with listening a narrative or observing a practice. It develops from imitation, evaluation, testing the concepts after the narrative or practice. It concludes with communicating the conflicts and/or adaptations that arise from the development of the activity.

- To integrate the students diversity and complexity in the educative task.

From these mathematical elements to be developed in classroom, some indicators of what should be displayed in the development of the proposed mathematical task can be differentiated, like:

- The use of Mapudungun in the mathematical outcome of the proposed task. Source of critical analysis between the mathematical Western language and the Mapuche. e.g the *Rakin* (mapuche numerical system) is used from the oral form of the mapuche language.

- To include mathematical analysis of different Mapuche Culture's representations or procedures. Incorporation of the cultural sign. e.g. The use of the *Purön* (registry of the numeric data through knots)

- Negotiation of meanings, establishing a common terminology according to the students' productions or arguments. e.g. Students construct a registry code for numbers of 4 digits using Purön.

- To promote thinking, through questions and arguments emerged from language orally. (Mapudungun or Spanish). e.g. Comparison between two registries. Which one registers a greater number? How greater?

3. Under the preliminary results of this Project. There are known territories where the educational autonomy is moving forward.

How many times greater?

- To value and respect diverse mathematical contributions, extending them until the conflict in its outcome promotes a different outcome. Error use. e.g. Complication when evaluating "How many time grater?" implies lowering the complexity of the question and move forward. Six-year-old students manage to initiate the partition in the area of precise and non-precise division.
- Equitable (absence of bias and stereotypes) and collaborative participation. Creation of collective constructs connecting math use with the ancestral and contemporary culture, projecting and putting it at the service of the community's problems. e.g. Students value the use of Purön nowadays and project its reincorporation in their community's needs.

In this way, this project seeks to be a contribution, since it, generates guidelines in teachers' educational practices that promote strengthening Mapuche mathematical knowledge, stimulate the development of didactic research of Mapuche mathematical knowledge, and provides the basis for an Intercultural Mathematical Education in context of indigenous people enabling the appropriate mobilization of current educational policies in Chile.

Hence, a long-term paradigmatic change is needed, in terms of educational public policies. To move from the thesis of the coverage, which orientates, in an exclusive way, the development of public policies, to think of the triad, which links the participation, recognition, and redistribution (Greer, 2013), like a basic triad for the development of inclusive policies, and consider how we move from the integration-focused paradigms towards a full inclusion ones. In this matter, the recognition of the certification and validation of the informal knowledge for our mono-cultural curriculum is crucial.

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WORKING WITH PEERS AS A MEANS FOR ENHANCING MATHEMATICAL LEARNING AT UNIVERSITY LEVEL: PRELIMINARY INVESTIGATION OF STUDENT PERCEPTIONS

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This study focuses on the undergraduate mathematics students' perceptions regarding the collaboration with peers, as a means of enhancing their learning process in university level. For this purpose, I examine students' learning in the context of Abstract Algebra. The preliminary analysis suggests that the great majority of students have expressed their preference to working with their peers. This collaboration allows them to communicate freely, using a simpler vocabulary in a significantly more comfortable communicational environment, which allows them to discuss repeatedly their own cognitive difficulties and through this communication to resolve any difficulties that might occur.

INTRODUCTION

Research in the learning of Abstract Algebra is relatively scarce compared to other university mathematics fields. The first reports on the learning of Abstract Algebra appeared in the early 1990's. Several studies, following mostly a constructivist approach, and within the Piagetian tradition of studying the cognitive processes, examined students' cognitive development and analysed the emerging difficulties According to Gallian (1990), Abstract Algebra is very important for mathematically trained individuals because of its wide use in other parts of mathematics and other disciplines. Furthermore, the construction of the newly introduced abstract algebraic concepts is often an arduous task for novice students and causes serious difficulties in the transition from the informal secondary education mathematics to the formalism of undergraduate mathematics (Nardi, 2000). Nowadays, the presentation of the 'fundamental concepts' of Group Theory, namely group, subgroup, coset, quotient group, etc. is "historically decontextualized" (Nardi, 2000, p. 169), since historically the fundamental concepts of Group Theory were permutation and symmetry. Nardi (2000) suggests that there are both linguistic and conceptual interpretations of students' difficulty with the notion of order of an element of the group. In addition, an important means for coping with the level of abstraction in the context of Abstract Algebra is the use of visual images. In fact their use plays a significant role, since they serve as a meaning-bestowing tool (Ioannou and Nardi, 2009). This study aims to investigate undergraduate mathematics students' perceptions about working with peers, using the Commognitive Theoretical Framework (Sfard, 2008), which has proved particularly appropriate for the purposes of this study, since, as Presmeg (2016, p. 423) suggests, it is a theoretical framework of unrealised potential, designed to consider not only issues of teaching and learning of mathematics per se, but to investigate "the entire fabric of human development and what it means to be human."

METHODOLOGICAL AND THEORETICAL FRAMEWORK

This study is part of a larger research project, which conducted a close examination of Year 2 mathematics students' conceptual difficulties and the emerging learning and communicational aspects in their first encounter with Abstract Algebra. The module was taught in a research-intensive mathematics department in the UK in the spring semester of a recent academic year. This module was mandatory for Year 2 mathematics undergraduate students, and a total of 78 students attended it. The module was spread over 10 weeks, with 20 one-hour lectures and three cycles of seminars in weeks 3, 6 and 10 of the semester. The role of the seminars was mainly to support the students with their coursework. The module assessment was predominantly exam-based (80%). In addition, the students had to hand in a threefold piece of coursework (20%) by the end of the semester. The gathered data includes the following: Lecture observation field notes, lecture notes, audio-recordings of the 20 lectures, audio-recordings of the 21 seminars, 39 student interviews (13 volunteers who gave 3 interviews each), 15 members of staff's interviews (5 members of staff, student coursework, and student examination scripts. Moreover, for the purposes of this study, the collected data of the 13 volunteers has been analysed, with main focus on the student interviews, following the principles of Grounded Theory.

For the purposes of data analysis, I am using the Commognitive Theoretical Framework (CTF). According to CTF, mathematics is considered an autopoietic system of discourse, namely "a system that contains the objects of talk along with the talk itself and that grows incessantly 'from inside' when new objects are added one after another" (Sfard, 2008, p129). CTF defines discursive characteristics of mathematics as the *word use*, *visual mediators*, *narratives*, and *routines* with their associated *metarules*, namely the *how* and the *when* of the routine. Sfard (2008) describes two distinct categories of learning, namely the object-level learning (expansion of the existing discourse attained through extending a vocabulary, constructing new routines, and producing new endorsed narratives) and the metalevel learning (involves changes in metarules of the discourse). Moreover, learning involves a discursive shift that often causes commognitive conflicts (hurdles occurring due to the introduction of a new mathematical discourse).

DATA ANALYSIS

Data analysis suggests that students react favourably to the idea of social interaction with peers. Twelve out of thirteen students find this collaboration very helpful, for several reasons. According to Student A, it is more convenient working with peers, since she feels comfortable to discuss something repeatedly and without adjusting her schedule according to the lecturer's office hours. The context of the communicational interaction between peers has different characteristics than a discussion with an experienced mathematician. Communication among peers does not require the precise use of the 'formal' terminology and has a wider spectrum of acceptable reactions (the repertoire of acceptable reactions may include erroneous or not so complete and precise responses), whereas a discussion with the lecturer would imply, from the students' perspective, that their reaction should be more 'appropriate'.

> Really helpful... Cos if I don't have to spend of time figuring out when my lecturers have office hours and I can go see them, instead I can just – ask like, say we have an hour off or something, I can just ask one of my friends to just explain it to me? [...] If I don't understand something, and I know they do, I often get them to try and explain it in a different way, like a different point of view and – see if I understand it better, so, with - especially with the coursework, I'll – like – talk to other people like – cos if – it makes me feel better sometimes if I know they're finding it hard as well. Student A

As the above excerpt suggests, working with peers allows students to express themselves more freely, using perhaps a simpler mathematical vocabulary, not hesitating to ask something which might sound naïve, repeat their questions or even argue, as in a colloquial discussion among equals, and in this way achieving, perhaps, better object level understanding of the newly introduced discursive concepts. Students feel comfortable to insist when they do not understand something and require an explanation from a different viewpoint; something that they do not do so easily in the seminars or meetings with the lecturer. It seems that the freedom of expression and comfort among the peers improves the effectiveness of communication and consequently students' learning. Moreover, while peers cannot substitute the lecturer or the seminar staff, they significantly contribute to joint mathematical learning, both in the first and second attempt to solve the coursework, as the excerpt below suggests.

> I normally meet up with some friends and go through the sheet and write down the problems that I had… […] If I am unsure or unclear and don't really understand then I will ask the seminar leader I just ask what I don't understand! […] Always try out the exercises then go to the seminar, and then after the seminar, I work with some friends, like, to go over it a bit more, so… Student B

According to the above excerpt, working with peers has a dual role. It possibly helps the students to precisely locate the emerging commognitive conflicts and points in a proof (metalevel aspects of learning) that they cannot overcome by themselves, yet also to establish the newly acquired knowledge. Working with peers contributes to the development of a mathematical learning, since the sessions can be repeated several times, without following a certain schedule or having a fixed duration.

Nevertheless, while, ideally, the students are able to resolve any difficulties through an act of communication by exposing their thinking to their peers, the communication with experienced mathematicians also enables them to learn how to utilise the language of a certain mathematical discourse, use visual mediators or be obliged to produce illustrations to clarify their reasoning –in general learning the norms of a particular mathematical theory. Four of the thirteen students expressed their need for more frequent communication with the staff, as the following excerpt suggests.

> Yeah. And then give you feedback, instead of three –we were three coursework, and three seminars at the moment, say, three coursework and six seminars? So one seminar is for the coursework and one seminar is for… discuss and if anyone have any questions, ask them there, and sort of like… small test, like, 10 minutes test and summarize whether you understand everything you done from –previous section or something? Student C

The above expresses students' need for more opportunities for communication both for working on the coursework problems and for discussing the theory taught in the lectures, providing students with the opportunity to resolve any commognitive conflicts. In addition, Student C expresses the need for testing mathematical learning during these seminars, with the lecturer recording students' learning and adjusting his teaching practices.

CONCLUSION

In sum, this study has focused on students' perceptions on social aspects of mathematical learning at university level, with main focus the collaboration with peers. The great majority of students have expressed their preference to working with their peers instead, and having solely the support of seminar. Working with peers allows students to communicate more freely, using a simpler vocabulary in a significantly more comfortable communicational environment, which allows them to discuss repeatedly their own conceptual difficulties and through this communication to resolve any commognitive conflicts. Students in their interviews would often focus on the quality of their communication with other mathematicians and the importance of such communicational activity. Such communicational interaction allows students to overcome such commognitive conflicts, learn how to utilise the mathematical language, use visual mediators, clarify their reasoning and improve their overall object-level and metalevel learning of the particular, newly introduced, discourse.

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THE SHAPE OF TAPING SHAPE: VISITOR EXPERIENCES WITH AN IMMERSIVE MATHEMATICS EXHIBITION

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The field of informal mathematics education experiments with new ways of engaging the public with mathematics, with the aim of broadening how mathematical ideas, images, and experiences might intermingle with social life. We describe ongoing ethnographic research on Taping Shape, an immersive mathematics exhibition. Based on qualitative analyses of naturalistic video records and visitor interviews, we examine how visitors (a) develop spatial familiarity with the exhibition and (b) navigate between local, immersive and global, extrinsic perspectives on the shape of Taping Shape.

INTRODUCTION

Within the growing field of informal mathematics education, diverse educators are experimenting with new ways of engaging the public with mathematics. Much of this work aims to transform and broaden the ways in which mathematical ideas, images, and experiences might intermingle with social life. In this project presentation, we describe ongoing ethnographic research on visitor experiences at Taping Shape, an immersive exhibition about geometry and topology made of packing tape, installed in a US science museum. Based on qualitative analyses of naturalistic video records and visitor interviews, we examine the questions of *how visitors (a) develop spatial familiarity with the exhibition through talk, touch, and ambulation and (b) navigate between local and global perspectives on the shape of Taping Shape.*

INFORMAL MATHEMATICS EDUCATION: TAPING SHAPE

We locate this study within the broader growth of informal mathematics learning environments, defined here as designed out-of-school-settings that deliberately engage learners with mathematics while emphasizing free choice, open-ended exploration, inter-disciplinarity, and, in some cases, disruptions to normative assumptions about the nature of mathematics and mathematical sense-making (Nemirovsky, Kelton, & Civil, 2016). Specifically, this work is situated within the growth of mathematics exhibitions in US museums and worldwide, and attendant research on visitor learning and experience in these spaces (Ibid.). In this study we focus on one such exhibition, Taping Shape, installed at a US interactive science museum and developed by the Informal Mathematics Collaborative, a partnership of educational researchers and art and science museums funded by the US National Science Foundation.

Taping Shape is a large, immersive installation containing numerous corridors, twists, and bends through which visitors can walk, crawl, and slide. Made entirely out of packing tape and structural scaffolding, the exhibition immerses visitors in unusual geometries while simultaneously engaging them with the aesthetics and material science of design. The shape of Taping Shape is loosely inspired by several geometric objects: (a) the torus, (b) a type of minimal surface called the Schwarz P surface, and (c) a 'pair of pants,' which is a surface that is homeomorphic to a three-holed sphere and can be used to decompose other more complex surfaces (referred to sometimes as a 'pants decomposition'). Thus, from the perspective of the designers, visitors to Taping Shape are presented with the unusual opportunity to, say, walk around on the inside of a torus or slide down the leg of a twisted 3-holed sphere (i.e. a giant pair of pants with crossed legs) (Figure 1a-b).

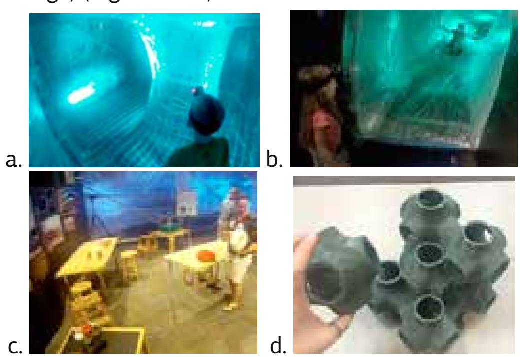


Figure 1: Taping Shape images. a: A double torus.
b: One leg of the pair of pants. c: Table-top exhibit area.
d: Example table-top activity: printed Schwarz P surfaces.

The exhibition also includes accompanying smaller-scale, table-top pieces, including: (a) 3D-printed Schwarz P surfaces and pairs of pants that can be concatenated to form more complex surfaces, (b) 3D-printed torus 'puzzles' that 'slice' the torus in various ways, and (c) bubble tanks housing soap-film minimal surfaces (Figure 1c-d).

METHODOLOGY: STUDYING VISITOR EXPERIENCE AT TAPING SHAPE

To investigate visitor experiences with Taping Shape, we use methods from video-based field studies of museums (Vom Lehn, Heath, & Hindmarsh, 2002). Using 3rd- and 1st-person (e.g. head-mounted cameras) video technologies, we collected information-rich naturalistic records of visits to Taping Shape. Visitors were recruited at the exhibition entrance and included seven multi-generational family groups. Following the visit, they participated in a debriefing interview with a research team member. The interview was video-recorded and typically included (a) video-mediated reflection using head-camera footage (e.g. Stevens & Hall, 1997), (b) a drawing activity in which visitors sketched maps of the overall immersive structure, and (c) a discussion of associations made between Taping Shape and other life experiences. Qualitative data analyses are ongoing and include grounded thematic analysis (Corbin & Strauss, 2008) and multi-modal interaction analysis (Jordan & Henderson, 1995).

We began this study with a broad interest in characterizing visitor experience with Taping Shape. Following qualitative research traditions (Maxwell, 2005), we are refining research questions and thematic foci in response to initial analyses. We describe here two inter-related research foci emerging from the data.

BECOMING FAMILIAR WITH THE SHAPE OF TAPING SHAPE

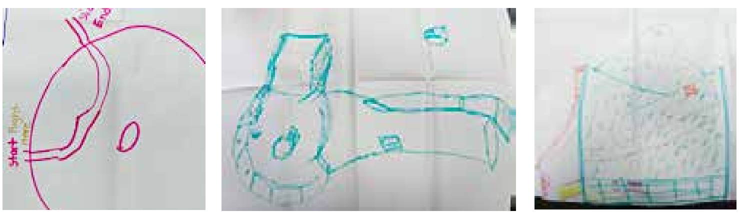
A striking feature of visits to Taping Shape is that the visitors we observed circulated through the immersive structure multiple times, often charting different courses through the Schwarz P, torus, and pair of pants with each pass. Thus, while museums typically struggle to lure people to stay at or return to an exhibit, Taping Shape visitors opted to loop through the immersive space repeatedly. One question that we are investigating is how visitors build a sense of spatial familiarity and layered meanings for the immersive structure with each pass. Taking the perspective that people "know as they go, as they journey through the world along paths of travel" (Ingold, 2011, p. 154), we are examining how visitors come to 'dwell' (Heidegger, 1971) in Taping Shape through inter-articulated sequences of walking, talking, touching, and listening.

For example, one participating family passed through three times. On the first pass, they paused at explicit geometry labels, discussed the curvature of the torus hole, and frequently commented on the installation's materiality (e.g., "It's just tape, tape, tape!"). During subsequent passes, they moved more quickly and parted ways to explore previously unseen corridors. They noticed other environmental features (e.g. music playing), related the exhibition to other spaces and life experiences (e.g. PE class or playing the clarinet), and stopped at additional labels. They expressed an emergent familiarity with the space, labelling one of the pant legs as "the fun way to go." This emerging spatial familiarity developed further on the last pass when the mother leveraged the topology of the torus to chase her son in circles around the hole. In analyzing moments like this, we view this kind of emergent familiarity with the shape of Taping Shape as both a salient aspect of visitors' overall experiences with the exhibition, as well as a key component of their mathematical engagement with it.

MULTIPLE PERSPECTIVES ON THE SHAPE OF TAPING SHAPE

Taping Shape's exterior was visually occluded by other exhibits and walls placed to shape the flow of visitors. Thus, like Flatlanders (Weeks, 2002), Taping Shape visitors could only discern the global shape of the immersive installation from walking on its interior surface. A second question we are currently investigating, then, is how visitors develop a global sense of the shape of Taping Shape based on local, immersive experiences inside it. While other research on immersive mathematics exhibits has compared table-top vs. immersive scales (Dancstep, Gutwill, & Sindorf, 2015), we are interested in how these two perspectives might interrelate for learners.

To explore this issue we are examining visitors' drawings or maps of the immersive installation produced during the debriefing interviews (Figure 2).



a. b. c.

Figure 2: Select maps of Taping Shape drawn by visitors.

Rather than assessing whether these maps are "correct" or "incorrect," we are interested in what they reveal about visitors' spatial experience. For example, visitors might imagine different vantages on the structure's exterior, such as from the top (Figure 2a-b) or side (Figure 2c). And while some visitors drew two-dimensional cross sections, others attempted to portray depth (Figure 2a vs. 2b). Some made considerable effort to render the exhibition's materiality (e.g. Figure 2c) or unique details that were of interest (e.g. a textual label drawn in Figure 2b). In examining these nuanced differences, we hope to sharpen our understandings of visitors' spatial sense-making and unique experiential relevancies in relation to the exhibition.

SIGNIFICANCE

Mathematics education consistently struggles with what we might regard as a crisis of perceived public relevance. Despite numerous and varied efforts to connect mathematics with the rich heterogeneity of public life, the field continues to struggle with widespread perceptions of mathematics as a narrow, esoteric discipline. This is particularly the case for areas of mathematics, such as topology, that are often regarded as reserved for an advanced elite. This study represents one attempt to understand new museum-based efforts to engage the public with a mathematics that many would consider out of reach. By examining the details of visitor experiences with Taping Shape, we hope to contribute to understandings of how exhibitions and other forms of public pedagogy might create new openings for mathematics to surface in social life.

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SOCIAL CREATIVITY IN THE DESIGN OF DIGITAL RESOURCES TO AFFORD CREATIVE MATHEMATICAL THINKING

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The M C Squared European FP7 project was about supporting social creativity in the design of resources ambitioning a new genre of mediation in mathematics education. The resources were e-books meshing narrative with dynamic and constructionist digital artefacts. The project generated four socio-technical environments, each involving a Community of Interest producing 64 very diverse c-books. Embedding mathematics in narratives with a constructionist interactive element is considered as an activity re-addressing teacher, learner and material identity in a context of critique of mathematics education paradigms tightly associated with conformity, accountability, austerity and revelatory approaches.

RATIONALE, OBJECTIVE AND METHOD

In Mathematics Education there is a growing appreciation for the need of a paradigm shift in institutionalized approaches from a 'guide to the knowledge monument' to a 'meaning-making' and 'creativity' approach (Chevallard, 2012). Restrictions to meaning making and creativity mostly stem from the priorities of a pre-digital industrial age and are greatly enhanced by a culture of austerity, conformity, accountability and standardization in testing in our age of crisis.

The Mathematical Creativity Squared (MC2)[1] project was funded to build technologies, methods and communities supporting social creativity in designing resources ambitioning a new genre of mediating mathematical ideas and processes in education and enhancing teacher, learner and material identities (Chronaki, 2016). We called the resources in question 'c-books'. C-books allow for the unrestricted meshing of narrative and dynamic -constructionist digital artifacts coming from any authoring tool (Kynigos, 2015). Our question was; How can we imagine (in the sense of

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1. The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 610467 - project "M C Squared", http://mc2-project.eu. The c-book technology is based on the widely used Freudenthal Institute's DME portal and is being developed by a consortium of nine partner organisations, led by CTI&Press 'Diophantus'.

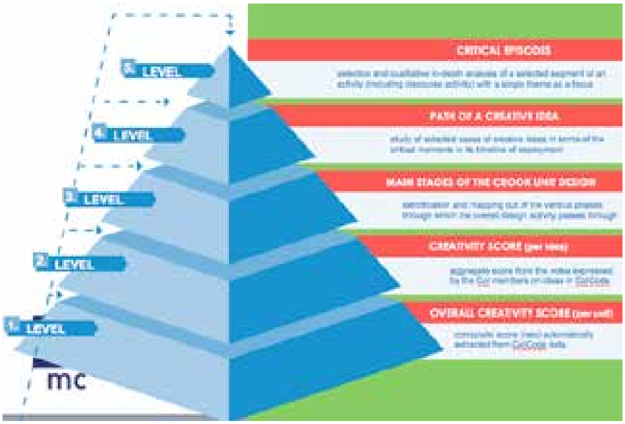
Skovsmose, 2015) a resource addressing a reader who can use it to also tinker, construct and explore with? Is there a way to facilitate the emergence of such designs? In the MC2 project we looked at the case of c-books affording creativity in mathematical thinking. As pedagogists, we asked the question: how can we foster creativity in the design and writing of c-books aiming to engage 'readers' in creative Constructionist activity for mathematical thinking? We perceived of the design process as collaborative in order to boost the flow and generation of new ideas. We saw pedagogical imagination as connected to the enhancement of teacher identity. We engaged a creative group of designers with diverse expertise –and coming from different communities of practice- to think outside-the-box about what a Constructionist book may look like. The project focused on the question of how we can study the design process and assess its potential for generating a new kind of mediation such as the c-book. The means to achieve this were based on the generation of Communities of Interest (CoI) (Fischer, 2011). To help design the c-book and its associated data-analytics tools as well as enhance our understanding of social creativity in pedagogical design, the project generated and support four such CoI who operated as a *socio-technical environment*, a living entity where the roles of "designer" and "consumer" are blurred and intermixed involving everyone (including learners) in the co-design of *dynamic re-useable and re-constructible,* educational materials for CMT.

In order to study the process of collaborative design and the meanings and identity interactions generated by the CoI members two constructs were employed in conjunction to make sense of such cultures for professional design, the 'documentational approach' (Gueudet & Trouche, 2012) and the 'boundary crossing with digital media as boundary objects' approach (Akkerman & Bakker, 2011; Kynigos & Kalogeria, 2011).

RESULTS AND PRODUCTIONS

The project's operational definition of creativity in CMT when addressing the affordances of a c-book was based on (Liljedahl & Sriraman, 2006) involving: fluency, flexibility, novelty/originality and elaboration. The integration of the 'problem -solving and- posing' view with the four cognitive components of math creativity was a key element in operationalising the defiition in the context of the project. The project's operational definition of Social Creativity in collaborative c-book design was defined in the M C Squared project as a complex phenomenon taking place in a particular context, a socio-technical environment where diversity within its social component becomes generator of creative processes and productions, while also novelty appropriateness and usability are core features of a creative idea or product.

The project developed a five-level method to evaluate social creativity in collaborative design based on the unit of a creative idea and the illumination (level 5) versus measurability (level 1) dimension. Theory networking within the context of this project yielded some interesting aspects of the process of forging connections between theories, which were rather implicit in previous networking ventures.



The nested structure which we adopted to think of diverse frames, implied that there was a core research challenge which in our case was to illuminate social creativity by developing a more explicit language to understand its manifestations in the project's specific socio-technical environment. What permeated the M C Squared work was the dynamics of the forged connections between theories which emerged in a functional way to facilitate the project's objective to elucidate the core challenge. The two connectivity dynamics identified in the M C Squared project, 'directionality' and 'complementarity', yield two different kinds of connections. The former, directionality, places existing frameworks in a structured, hierarchical system, where any decision is taken with regards to the order of importance or closeness of frameworks to the research problem at hand. The latter, complementarity, places two frameworks at an equal distance. The important thing here is however that each of the two frameworks is used to explain a different aspect of an overarching parent frame.

The project's productions were:

- technologies: a c-book author , data analutics module and a tool to support social creativity in collaborative design (called 'CoICode').
- resources: 64 c-books stemming from primary to tertiary, from

algebra to spatial geometry, from story driven to task driven.
- four CoI engaged in an impressive productivity and a rich meshing of expertise and viewpoints
- a contribution to the definition, the evaluation method, the theoretical underpinnings regarding social creativity in this context
- the quest for integrating approaches to theory.

CONCLUSIONS

The project set out to empower mathematics teachers in education by means of engaging CoI to ambition the generation of a new kind of mediation in mathematics education. This was considered a challenge both in relation to inherent resisting paradigms in mathematics education and in relation to an era of societal crisis focusing on conformity, accountability and austerity. The project's initiating of a search for new identities for teachers as collaborating designers of potentially new genres of resources, learners and materials can be seen as culturally responsive in the sense of Greer (2010). The aim for critical, imaginative, contextualized meaning making in situations where mathematics is a socially mediated tool, process and object in itself may help to generate sustainable identities in the context of societal crisis.

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THE RELEVANCE OF PRE-SERVICE TEACHERS' FUNDS OF KNOWLEDGE IN THEIR ADAPTATIONS OF MATHEMATICS LESSONS

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Pre-service teachers' (PSTs) adaptation of mathematical tasks to children's funds of knowledge (FOK) seem to be more successful when the context of children's FOK are more similar to PSTs' own FOK. This presentation will discuss the processes, challenges, and reflections that 35 PSTs experienced in making these connections. Future pedagogical practices will be discussed in the presentation.

INTRODUCTION

The teaching and learning of minoritized students in the United States has mostly rested in the hands of white female teachers (Berchini, 2015). Mathematics education especially has evolved as a white institutional space (Martin, 2012). As a result, the process of supporting a more equitable teaching and learning of minoritized students in mathematics has become a central aspect of social justice (Gutstein, 2003; Ukpukodu, 2011). This issue has been targeted during teacher preparation. In this paper, I present the experiences of pre-service teachers (PSTs) (a total of 35) from diverse backgrounds learning how to develop and adapt mathematical tasks relevant to their students from minoritized backgrounds.

Culturally Relevant Pedagogy (CRP) approaches capitalize on minoritized students' life experiences and communities as assets by ''using the cultural knowledge, prior experiences, frames of reference, and performance styles of ethnically diverse students to make learning encounters more relevant and effective for them'' (Gay 2000, p. 29). CRP challenges the status quo (Ladson-Billings, 1995) by promoting a *sustainable* cultural and academic competence through which students of color access simultaneously their and dominant cultural competences (Paris, 2012). Minoritized students' funds of knowledge (FOK) can be mobilized to learn mathematics. *Funds of knowledge* (Moll & Greenberg, 1990) include "the knowledge base that underlies the productive and exchange activities of households" (Moll & Gonzalez, 2004, p. 700). They are not possessions of people in the family, instead funds of knowledge are "part of what people do in activities" (Moll, 1992, p. 222); they refer "to the content and the social relationships that facilitate the exchange" (Moll, 1992, p. 231). Such knowledge and social relationships are flexible and adaptive, so they can be mobilized across contexts and activities, including mathematics learning and teaching (González, Andrade, Civil, & Moll, 2001; Moll & Greenberg, 1990; Moll, 1992).

Previous works with PSTs have addressed these issues in mathematics education. For example, Drake and Norton-Meier (2007), in a math methods course with 51 PSTs, promoted PSTs' linking of family and community FOK with integrated school-based content (mathematics and literacy) by running evening family events to learn about children's parents, and then develop and implement lesson plans. PSTs linked mathematics and literacy, but FOK and academic content were limited. Aguirre, Zavala, and Katanyoutanant (2012), also in a math methods course, emphasized connections among mathematics, children's mathematical thinking, children's FOK, and mathematics for social justice. Using a guiding rubric tool, 40 PSTs paid more attention to issues associated with children's mathematical thinking and their academic language by integrating cultural FOK, than including issues related to mathematics for social justice. Finally, Aguirre et al. (2013) describe how through community visits, 70 PSTs developed problem solving mathematics lessons linked to the community settings. As a result, PSTs developed emergent, transitional, and meaningful connections between children's mathematical thinking and FOK. This study elaborates on this work by focusing on the level of cognitive demand of the PSTs developed tasks and PSTs' FOK as a variable to consider in the process of PSTs' learning to establish links between mathematics and children's FOK.

THEORETICAL FRAME

In addition to FOK, I use a Realistic Mathematics Education (RME) approach. In RME, the out-of-school context becomes the context of learning so that "students connect prior knowledge to new mathematical representations, concepts, and skills. As a result, a more robust way of knowing and doing mathematics is constructed from the student's perspective" (Webb, van der Kooij, & Geist, 2011, p. 48); where the realistic portion does not necessarily imply connections "with real world contexts, but it is related to the emphasis that RME puts on offering students problem situations which are imaginable" (p. 48) or what is realistic in the view of the students. RME links community practices (FOK) with school mathematics.

METHODS

This study is part of the Teacher Education Collaborative in Language Diversity and Arts Integration (TECLA) project. Through a 3-semester period, PSTs learn how to apply an arts-integration-CRP-multiliteracy approach in their teaching. To explore PSTs' FOK and their integration of children's FOK with math tasks, I applied a content analysis to qualitatively examine the first-semester PSTs' work, such as module reflections, self-portrait autobiographies (SPA), the community-based lesson (CBL) paper, reflection journal, and the instructors' notes. In CBL paper, PSTs observed, and interviewed with a student to develop a relationship and learn about their FOK and accordingly develop math lessons. PSTs' reflections and SPA yielded information about their own FOK. Content analysis is a "technique for making inferences by objectively and systematically identifying specified characteristics of messages" (Holsti, 1969, p. 14). Initial analysis yielded themes on how PSTs' linked their students' FOK with mathematics. FOK activities that PSTs found and connected to RME included: cooking 50% (of students), playing and designing sports 45%, watching TV 25%, using money 20%, owning animals 15%, planning parties 15%, going shopping 15%, understanding sci-fi movies 15%, playing board games 15%, music 10%, seamstress work 10%, and everyday geometry 10%. The analysis of tasks' level of cognitive demand of the mathematized students' FOK practices varied across PSTs. Further, analysis of PSTs' self-informed FOK through reflective assignments yielded contrasting patterns with mathematized students' FOK. The second level coding of PSTs' rationales in their work with minoritized students and the relevance of FOK and RME in school mathematics helped explain PSTs' perspectives on teaching mathematics. The overarching themes are described below.

RESULTS

Three themes permeated PSTs' transformative knowledge, caring, and actions in mathematics education: (a) *students come first*, when designing mathematical tasks and engaging in problem solving, students' evolving ideas, knowledge, and/or errors are foundational to supporting learning; (b) *mathematics is everywhere*, while it is important that students learn about school mathematics, mathematics applications are present everywhere, so students can learn from and apply mathematics in and outside of the classroom; and (c) *mathematics is inclusive*, while mathematics is taught as an isolated subject, in real-life projects and applications, mathematics is linked to other subjects, so subject integration presents a great potential. PSTs made greater links between mathematics and children's FOK when PSTs own FOK matched children's FOK. For example, Susana –Latina PST familiar through personal experiences with "*El Chavo del 8*" a Mexican comedy show– developed a mathematics problem that included the essence of the characters and wit in the show while linking it to an open-ended problem addressing fraction concepts. With high-levels of thinking, multiple entry points and solutions, this task supported the use of translanguaging practices and engagement in meaningful conversations about fractions of a piece of chocolate shared by El Chavo and his friends. This link between FOK and mathematics seemed constrained when PSTs were unfamiliar with FOK activities with potential for RME (e.g. soccer). More examples will be discussed during the presentation. Discussion of PSTs' ethnographic approach to understand FOK community practices and activities that are unfamiliar to them, so they can obtain greater information/experience to establish these links will be discussed. A way to nurture connections with unfamiliar activities could be through an Extended Related Activity (see LópezLeiva, 2014).

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DEVELOPING CONCEPTS IN A STUDY OF MATHEMATICS LEARNING PATHWAYS

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Studies of mathematics learning as a cross-setting phenomenon have the potential to advance research and practice related to equity by making visible how multiple in- and out-of-school environments might be leveraged to better support non-dominant mathematics learners. In this project presentation we report on emerging findings from multi-sited ethnographies of urban youths' mathematics learning pathways across the many formal and informal settings in which they spend their time. We take up the question of how a cross-setting paradigm can open up new theory for the field.

Educational inequity is one of the most enduring and pervasive social challenges facing the field of mathematics education. There is a great need for continued research that investigates the causes, consequences, and potential solutions to systemic inequality in mathematics education. This study is motivated by the conjecture that understanding and addressing educational inequity in mathematics education requires a more multi-sited approach than has typically characterized research in this area, an approach that takes into account the multiplicity of formal and informal settings in which mathematics learners spend their time, as well as the diverse pathways they chart across these settings. In this project presentation we report on findings and theoretical issues that are emerging from ongoing multi-sited ethnographies of low-income, urban youths' opportunities to engage with mathematics across heterogeneous school- and out-of-school environments.

A major line of research on equity in mathematics education includes studies of practices of communities that are marginalized in schooling (e.g., Mukhopadhyay, 2013), school instruction that deliberately supports non-dominant students (e.g., Moses & Cobb, 2001), and design that bridges the two (e.g., González, Andrade, Civil, & Moll, 2009). We describe here a program of ethnographic case studies that both contributes to this line of inquiry and critically moves beyond this tradition through a focus on the multi-setting quality of learners' lives. Rather than focusing on one site for mathematical practice, we focus on youths' mathematical learning pathways *across* diverse settings, and seek new understandings of continuities and disjunctures they may experience as they participate in the many contexts that constitute their lives, including but not limited to school mathematics learning.

BACKGROUND

Research has produced evidence that the modes, or ways that we teach mathematics, and even the content itself of the mathematics we teach may be inherently inequitable, systematically resulting in success for certain groups while marginalizing others. Sociocultural accounts of mathematics learning have revealed it not to be culture free, but rather embedded in social worlds constituted by discourse practices, social relations, and local tools for meaning-making (e.g., Cobb, Stephan, McClain, & Gravemeijer, 2001; González et al., 2009). These social worlds have been historically constructed within power relations that result in the privileging of certain cultural groups and associated modes and content, and therefore the exclusion of others (Martin, 2015). Rochelle Gutiérrez (2002) characterized the modes and content of school mathematics in the United States as a “dominant mathematics,” one that “reflects the status quo in society, that gets valued in high-stakes testing and credentialing, that privileges a static formalism in mathematics, and that is involved in making sense of a world that favors the views and perspectives of a relatively elite group” (p. 150-1).

Our study seeks to disrupt and expand beyond the dominant mathematics by developing alternative theories of how people learn mathematics, and how to support learning. Theories of learning and their development have been expanding with respect to units and sites of analysis, from psychological studies that focus on mental activity, to more ecologically attentive studies investigating formal learning settings, to projects that consider mathematical activity and learning in diverse out-of-school settings. We follow this tradition of broadening our analytical lens to investigate mathematics learning “outdoors” (Lave, 1988), “from the laboratory into the everyday world” (p. 170). We acknowledge that this everyday world is large and complex, and as others before us have, we wonder how we might identify, capture, and make sense of valuable aspects of individuals’ experiences in this world.

We draw from current learning sciences and education research on cultural learning pathways, defined by Bell, Tzou, Bricker, and Baines (2012) as “connected chains of personally consequential activity and sense-making” (p. 270) that unfold in time, across settings, and involve multiple intersecting social practices and values. Learning is situated in evolving participation in sociomaterial practices, is both an individual and collective process, and “is accomplished across settings (i.e. translocally) by persons acting within diversities of structures of social practice” (p. 272). The cultural learning pathways framework directs analytic attention to how “constellations of situated events” (p. 273) in youths’ lives produce and are produced by evolving participation in heterogeneous activity. This study looks across settings, including home, community, school, and after-school spaces, and over time to characterize what we call youths' mathematics learning pathways. Describing and analyzing these pathways will illuminate how students' experiences constitute resources for mathematics learning as well as disjunctures that produce missed opportunities. In this presentation we discuss preliminary findings for the research question: *How do youths' pathways through heterogeneous school and out-of-school settings constitute different types of resources for learning mathematics?*

METHODS

The study follows four low-income, urban ninth grade students, observing them in school, afterschool programming, home, and other sites that either they or the research team identify as important to them. Following ethnographic methods, data collected from these observations include participant observation, field notes, naturalistic video and audio records, images of relevant artifacts, and regular ethnographic interviews with participants and relevant family members, peers, and mentors. In addition, we employ techniques from human geography –including daily round interviews and GPS tracking– to gain an understanding of youth's physical pathways through the city in relation to mathematics learning. Analysis follows Charmaz's (2006) methods for the construction of grounded theory. While analysis will inevitably be informed by existing research on resources for learning and doing mathematics, we pay particular attention to how participants construct meaning within and across multiple sites, treating settings as connected, and constructing youths' learning as within and through movements rather than in static slices of space and time (Vossoughi & Gutiérrez, 2014).

DISCUSSION OF ANTICIPATED FINDINGS

The study presented here examines youths' experiences holistically across a variety of settings, developing new cross-setting ways of conceptualizing resources for doing and learning mathematics. Mathematics education has typically been restricted to single settings, even in research on out-of-school learning such as studies of resources for identity development in track athletics (Nasir and Cooks, 2009) or the distribution of mathematics problem solving across people and artifacts during purchasing exchanges (Taylor, 2009). Because of this, mathematics education research has produced theoretical constructs that are most useful in interrogating and supporting children's learning in single settings. A major aim of this work, then, is to develop theoretical concepts by looking at learners' activity across multiple settings, rather than within a single setting. We conjecture that some of the patterns of activity that become visible across settings may be usefully conceptualized as some of the forms of resources listed above (e.g., resources for building identity or the distribution of cognitive labor across multiple tools and actors). More likely, we expect it will be refinements, revisions, remixes, or altogether new categories previously obscured in studies of discrete contexts bound by space or activity (Vossoughi & Gutiérrez, 2014) that will emerge in analysis.

We look to the concept of "translanguaging" from the field of bilingual and multilingual education as an example of a cross-setting conceptual category. García and Wei (2014) describe translanguaging as "an approach to the use of language, bilingualism, and the education of bilinguals that considers the language practices of bilinguals not as two autonomous language systems as has been traditionally the case, but as one linguistic repertoire with features that have been societally constructed as belonging to two separate languages" (p. 2). The concept of translanguaging emphasizes language as dynamic practice, and avoids deficit views associated with evaluating students in relation to fixed categories of language use and learning produced by a privileged few. By analogy, our analysis of youths' mathematics learning pathways will consider and construct categories for the different repertoires of practice they may draw from in dynamic ways across settings. We argue that a cross-setting investigation of mathematics learning has potential for informing more equitable modes and contents of mathematics instruction. At the time of the conference we will have preliminary analysis to share, extending this discussion.

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RESOLVING CHALLENGES WHEN TEACHING PRE-SERVICE MATHEMATICS TEACHERS THROUGH A LENS OF EQUITY

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This paper describes ongoing inquiries into instructional practices when teaching mathematics through a lens of equity. We focus on a framework that emerged through an initial inquiry, which was used to a) classify challenges that mathematics teacher educators (MTEs) face when they teach through an equity lens, and b) identify appropriate strategies to resolve these challenges. We will discuss how we have used this framework to analyze the challenges and resolutions of 23 MTEs, to resolve challenges in our own instructional practice, and to analyze and revise mathematics lessons for potential challenges related to issues of equity and access.

OVERVIEW

Most mathematics teacher educators (MTEs) would agree that teachers must be prepared to provide equitable mathematics instruction to all their students. However, while the preparation of teachers to work with diverse student populations has been the subject of a growing body of research (e.g., Cochran-Smith, Fieman-Nemser, McIntyre, & Demers, 2008; Cochran-Smith & Zeichner, 2005), where several mathematics teacher educators MTEs have focused on examining elements of practice aimed to help teachers develop equitable mathematics pedagogy (e.g., Aguirre, 2009; Gutiérrez, 2009), few studies to date have explored conditions under which mathematics teacher educators (MTEs) can help teachers[1] develop equitable mathematics pedagogy (McLeman & Vomvoridi-Ivanović, 2012; Strutchens et al., 2012). Previously (McLeman & Vomvoridi-Ivanović, 2012), we have argued that a systematic and broad-scale examination of these practices of MTEs who teach through an equity lens, including potential challenges, could inform mathematics teacher education by unpacking commonalities and differences in ways that MTEs address equity in their courses. We further argued that by gaining insight into possible patterns regarding different resolution strategies, the field can begin to develop structures to prepare and support teacher educators who choose to make equity a priority in their practice.

1. We use the term *teachers* to refer to both practicing teachers of mathematics and those individuals preparing to become mathematics teachers.

To begin addressing these issues, we conducted a qualitative study on the challenges MTEs face when teaching a mathematics methods course through a lens of equity and the resolution strategies they employ to address those challenges (Vomvoridi-Ivanović & McLeman, 2015). Our work centered on a learning domains framework as a mechanism to classify the 23 MTEs' self-reported challenges and resolutions. In what follows, we describe the learning domains framework in more detail, as well related work using this framework. We conclude by sharing our goals for our session.

LEARNING DOMAINS FRAMEWORK

In our inquiry of MTEs' challenges and resolution strategies we framed each challenge and resolution as having two components: a locus and a nature. Locus refers to the *source* of the challenge or resolution; nature refers to the *characteristics* that are necessary for the challenges and resolutions to hold meaning. Both the locus and nature can be either external or internal to an individual, where internal is dependent on the motivation or actions of an individual.

We posit that MTEs must aid pre-service teachers (PSTs) in the development of certain processes to teach mathematics through a lens of equity. For example, while planning for or facilitating classroom activities centered on issues of social justice, MTEs might support PSTs in acquiring knowledge about political events, scrutinizing their beliefs and emotions about the relevance of political events to mathematics teaching and learning, and/or developing interpersonal communication skills to discuss emotionally charged topics. Therefore, to understand the internal challenges and resolutions that MTEs might encounter and enact, we developed a framework that focuses on the cognitive, affective, and social domains of learning. The *cognitive domain* focuses on the acquisition of different forms of knowledge as a way to know the specifics of a discipline, such as terminology and how basic elements are intertwined within a larger structure (Krathwohl, 2002). For example, reading about different ways of teaching math (Bornstein, 2011) relates to the cognitive domain of learning. The *affective domain* represents the emotional processes within learning, (Jagger, 2013), such as grappling with beliefs, values, attitudes, and dispositions about and towards particular groups of learners. The *social domain* concerns the interpersonal functions necessary in public environments, including communication, participation, negotiation, and collaboration (Dettner, 2006), all of which are central to the dev 1velopment of equitable teaching practices.

It is important to note that the learning domains framework does not categorize information in a hierarchal manner as is so often associated with these domains. Instead, the framework simply affords the ability to look for patterns. Within our work, we have used the framework in several ways, including as a way to examine commonalities among the self-reported challenges and resolutions from MTEs who make equity central to their work. We now turn to discussing the different ways that the learning domains framework has been utilized.

OUR INQUIRIES

The findings from our initial inquiry (Vomvoridi-Ivanović & McLeman, 2015) using the learning domains framework demonstrated that the nature of the MTEs' self-reported internal challenges did not match the nature of their resolutions. In particular, the majority of these challenges were of an affective nature, while the majority of the self-reported resolutions were of a social nature. We suggested that resolution strategies that focus on the cognitive or social domains of learning may not be as effective in challenging PSTs' values and/or beliefs as a resolution strategy that focuses on the affective domain of learning. We also conjectured that it might be more beneficial to match the nature of resolution strategies to the nature of the challenges.

To better understand our findings, as well to explore our conjecture, we have undertaken a second inquiry using the learning domains framework. Specifically, we are examining the effectiveness of a variety of resolution strategies for specific pre-identified challenges when working with PSTs around the teaching of mathematics through issues related to gun control and food consumption. We identified the challenges related to these issues through a consultation of relevant literature, the challenges shared by MTEs (Vomvoridi-Ivanović & McLeman, 2015), and our own practice. We then planned for and enacted several resolution strategies for each challenge, where the different strategies targeted a specific different learning domain. PSTs' written reflections to each of the resolution strategies, as well as our own personal reflections, were used as indicators of effectiveness.

As a third inquiry, we shifted our lens from research to consider how middle grades mathematics teachers might be able to use the learning domains framework within their own practice. To demonstrate this, we analyzed several middle grade mathematics lessons for potential challenges related to issues of equity and access (McLeman & Vomvoridi-Ivanović, in press). Further, we shared appropriate resolutions to these challenges and discussed strategies for undertaking lesson plan analyses as a form of professional development.

OUR SESSION

In our session, we will first present an overview of the learning domains framework and how it was developed. We then will discuss initial findings related to resolving challenges when working with PSTs around controversial topics. We will conclude with an overview of the benefits of undertaking lesson plan analyses as a mechanism to unearth potential challenges related to teaching mathematics through a lens of equity and access.

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ECONOMIC CRISIS- THE EDUCATIONAL GAME EURO-AXIO-POLIS: GENDER ISSUES

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This project presentation will be focused on empirical data and future research questions which have been revealed from a)40 university students playing the educational game Euro-Axio-Polis and the game Monopoly to investigate differences between the two games, and writing five key words that characterized each game and b)19 sixth grade pupils playing only the Euro-Axio-Polis game during students' teaching practice and writing five key words about the game. The research results suggest that students' engagement with Monopoly reflected capitalist economic termswhile students' and pupils' engagement with Euro-Axio-Polis reflected social values such as solidarity and equity. Pupils were more likely than students to make reference to socio-political issues such as parliament, education, democracy, elections and political power. As far as mathematics was concerned, most students and half of 6th grade pupils recalled the mathematical concepts percentages and interest rates while they played Euro-Axio-Polis.

BRIEF OVERVIEW

Research on university students' prospectiveteachers' engagement in deep reflective work with pupils has focused on the enhancement of new pedagogical and epistemological approaches to learning and teaching mathematics. However, the shift from a positivist paradigm about mathematics as well as from the teacher-centered instructional models towards constructivist and emancipatory processes is a challenging task for many mathematics education students and educators. University students prospective teachers often face difficulties on a) how to relate theory with practice in mathematics education (Jaworski, 2006; Rowland et al., 2009) b) how to deal with complexity while creating and managing a meaningful and flexible learning environment (Potari & Jaworski, 2002) c) how to realize critical epistemological concepts, such as Leone's Burton "four epistemological challenges" (2004) and) how mathematics is related to cultural issues and ideas that may affect peoples' everyday lives (Burton, 2004; Chassapis, 1996).

In an attempt to facilitate university students' professional empowerment towards all the above-mentioned directions, an educational game has been designed by 4th year university students prospective teachers and the first author (Chionidou- Moskofoglou, 2012) during spring semester 2012. This game, called Euro-Axio-Polis (Euro=Euro, Axio=Value, Polis=City), can be used as an alternative approach to mathematical instruction for 6th grade pupilsand makes connections between mathematics and socio-economic problem solving procedures. As far as society is concerned, human rights, promotion of democratic and participatory systems and processes are among the issues which play a key role inthis game.

DESCRIPTION OF THE EURO-AXIO-POLIS GAME

One of the objectives of the Euro-Axio-Polis game is to suggest a way of teachingthe concepts of 'percentage' and 'interest rate' to 6th grade pupils by 4th year university students prospective teachers during their two weeks teaching practice in primary schools. Additional aims of Euro-Axio-Polis are: a) challenging the prevailing function of mathematics as a means of reproduction of the dominant ideology and the market economy, b) contributing to the students' social empowerment and emancipation concerning teaching stereotypes in learning mathematics.

YOU DECIDE

What does your country choose?

-To pay Doctors Without Borders 170 million € (A) or

-To receive for its treasury 170 million € by cutting pension funds for the health of its citizens (B)

Euro-Axio-Polis is a game board (see appendix image 1) like Monopoly but has very different kind items on the squares as players move around the board. Its rules have been designed to suit a classroom of approximately 20 pupils. Duration of the game is 40-50 minutes. Players are divided into five groups of four. Each team chooses to represent one of the 29 European Union countries that have financial transactions with the European Central Bank (ECB). All teams start from the STARTING POINT with one billion Euros in cash. Each country plays throwing the dice and, depending on the number it gets, places the pawn on the corresponding box. According to the options given in the particular box, the team decides on its actions. In the frames with the mark "YOU DECIDE", the country gets a card and decides on its next actions depending on the given options – dilemmas (e.g. What does your country choose? (A) To pay Doctors without Borders 170 million € or (B) To receive for its treasury 170 million € by cutting pension funds for the health of its citizens (See appendix).

After the 50-minute duration,winning countries are those that have raised the most money having the greatest number of (A)s decisions (sewage installation, financial aid to Child's Smile, construction of nursing homes and sport centers, maintenance and enhancement of monuments and archaeological sites, financial support to doctors without borders) or (B)s decisions (sale of hazardous electronic waste, sale of state land, pensions reduce, non-participation in the Olympics, sales of work of Art, cuts in pension funds for public health). Thus, the group with the largest amount of money is the winner of Euro-Polis and the team that collected the most cards marked 'A' is the winner of Axio-Polis. At the end of the game, the winning teams are confronted with a Dialogic Argumentation process, with objective to convince each other about the correctness of their choices. The ultimate judge is the other teams which will decide after discussion and vote who is the final winner of the Euro-Axio-Polisaccording to their own criteria.

SOME RESULTS AND FUTURE RESEARCH QUESTION

This research process followed action research methodology withwritten questionnaire, from which conceptual connections (made by university students and 6th grade pupils) emerged. The questionnaire for university students, who were familiar to classic form of Monopoly, included two open-ended questions, asking them to write at least five words which, in their opinion, characterize the Monopoly game and Euro-Axio-Polis game respectively. Pupils after having played only Euro-Axio-Polis game, where also asked to answer one open-ended question on a given questionnaire by characterizing Euro-Axio-Polis with key words.

Having played the Euro-Axio-Polis game, students and pupils answered spontaneously and without having been affected by predefined concepts of the researchers nor guided to specific answers. Data gathered from the above questions were based on the written responses of participants.They were organized in thematic areas which appointed the classification of responses. Four categories were formed covering totally all the words that were recorded: a) financial terms b) game components c) values and d) mathematical concepts. Beside the four categories that emerged during the analysis of participant players' answers, two new ones were added by the analysis of pupils' answers': e) socio-political issues and f) emotions.

Data from the category a), b), d), e) f) are analytically presented in Chionidou-Moskofoglou (2012). It is remarkable that from students' recorded keywords, about Monopoly in its classical form, which were grouped into the third category (values), two only subcategories: competition and individualism were created (see table1 below). Both of these subcategories (competition and individualism) can be related to the capitalist economic model (Bishop, 2001; Chassapis & Chatzivasileiou, 2008; Tatsis & Koleza, 2008; Ernest, 2009).

Table 1. 3d category-values

<table>
<tr><th colspan="2">4TH YEAR UNIVERSITY STUDENTS PROSPECTIVE TEACHERS' KEYWORDS</th><th>6TH GRADE PUPILS' KEYWORDS</th></tr>
<tr><th>Monopoly in its classical form</th><th>Euro-Axio-Polis</th><th>Euro-Axio-Polis</th></tr>
<tr><td>Competition
Individualism</td><td>Equity
Solidarity
Charity
Respect
Active participation
Fellow
Justice
Altruism</td><td>Charity</td></tr>
</table>

In the second question, in which university students and pupils were asked to write down words that characterize the Euro-Axio-Polis, the picture was different as table 1 above shows. Eight different subcategories were recorded such as equity, solidarity, charity, respect, active participation and fellowship, justice and altruism.

One of the objectives of the educational game Euro-Axio-Polis was to create an authentic, mathematics instructional environment. Within such an environment, concepts such as percentages and interest rates were embedded in some realistic and playful learning activities. At the same time, mathematics education was meaningfully integrated in a realistic cultural context. The prevailing idea of mathematics as a politically neutral instrument, at the service of a dominant capitalistic values reproduction ideology, is under question. The latter is achieved when the players of this game are confronted with dilemmas and decision making situations in which socio-cultural issues, such as sustainability vs. economic investment and profit, as well as value judgment discourse, were involved.

Future research should focus not only on the investigation of how games like Euro-Axio-Polis can be embedded in school and lifelong learning approaches, but can also support practicesin developing meaningful mathematics in a socio-political context. During our project presentation, we will focus on gender research questions as reflected in Solar's (1995) inclusive pedagogy (see next table 2), that are revealing from data of the above-mentioned students and pupils playing Euro-Axio-Polis and we are currently working on.

Table 2. Solar (1995) Dialectical aspects of an inclusive education in a mathematics classroom

	PASSIVE/ACTIVE PARTICIPATION	OMISSION/ INCLUSION	SILENCE/ SPEECH	POWERLNESS/ EMPOWERMENT
TEACHING	Having high expectations for all women. Using pedagogical approaches that encourage participation. Introducing cooperation. Asking women high-level cognitive questions	Paying attention to all students regardless of sex, race, age. Monitoring speech in order to include women. Using examples which relate to women. Describing mathematicians and scientists as both male and female. Valuing intuition and emotions.	Using inclusive language. Forbidding sexist and racist humour. Using pedagogical settings that make it easier for students to speak. Limiting extended conversations with male students.	Avoiding stereotypes. Naming differences and explaining them. Giving women the time and means to solve problems by themselves. Praising women's achievements. Sharing power.
LEARNING	Sharing the thinking process. Sharing understanding of mathematics. Learning cooperatively.	Solving problems that deal with women's situations. Receiving feedback and learning from mistakes.	Speaking about the learning of mathematics. Giving time for women to respond.	Demystifying mathematics: more than one solution and process. Receiving appropriate feedback. Learning about women's participation in mathematics and science.

CURRICULUM	Having women participate in defining the content.	Referring to the contributions of women. Using situations relevant to women's lives Using non-stereotypical material. Including ethnomathematics. Revealing the omission of women.	Explaining the construction of mathematics and its use in society.	Demystifying mathematical constructs. Mathematics as a process, not a set of rules. Including the lives of women scientists. Including women's perspectives.
EDUCATIONAL ENVIRONMENT	Allowing women to participate in defining their learning process. Having women participate in defining the goals of the school. Addressing the issue of gender difference.	Including and valuing women. Making women visible.	Valuing women's contributions and concerns. Setting school goals which include women. Using inclusive language.	Creating a warm and supportive climate. Working out men's beliefs about women and denouncing stereotypes.

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APPENDIX

RULES OF EURO-AXIO-POLI

The players are divided into five groups of four. Then each team sets its representative. Each team represent a country after draw.
Rules:
29 European Union countries that have financial transactions with the European Central Bank (ECB) participate in the game.

Each team throws the dice and the team that brought the greatest number starts first the game. All teams start from the STARTING POINT having one billion euros in cash.

Each team plays throwing the dice and, depending on the number it gets, places the pawn on the corresponding box and decides for its actions, according to the options given in this context.

In the blue frames with the mark "YOU DECIDE", the group gets a card and decides its next actions depending on the given options.
Duration of the game: 40 minutes
The winner country

A) Each country calculates the amount of money it has.

B) According the table below count up how many A and B you totally have.

Sewage installation	A	Sale of Hazardous electronic waste	B
Financial aid to Child's Smile	A	Sale of state land	B
Construction of Nursing homes	A	Pensions reduce	B
Construction of sports centers	A	Non-participation in the Olympics	B
Maintenance and enhancement of monuments and archeological sites	A	Sale of works of Art	B
Financial Support to Doctors Without Borders	A	Cuts in pension funds for public health	B
Total	???		???

The winning countries are those that will raise the most money having the greatest number of (A)s decisions or (B)s decisions.The team with the largest amount of money is the winner of Euro-Polis and the team that collected the most cards marked 'A' is the winner of Axio-Polis. At the end of the game, the winning teams are confronted with a Dialogic Argumentation process, with objective to convince each other about the correctness of their choices. The ultimate judge is the other teams which will decide after discussion and vote who is the final winner of the Euro-Axio-Polisaccording to their own criteria.

THE PROCESS OF DIALOGUE IN TEACHING AND LEARNING MATHEMATICS WITH DEAF AND HEARING STUDENTS

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The paper presents a research project related to the process of teaching and learning of mathematics in the context of inclusive school and aims at understanding the process of dialogue in mathematics classes with deaf and hearing students. Using a qualitative approach to research, the data will be produced from observations on the interactions stimulated by investigative tasks. In general, a contribution is expected so that the inclusive school proposal goes beyond the access to the classroom stablishing situations that promote equitable learning environments.

BACKGROUND

Inclusive education has become one of the most controversial and troubling issues for educators in Brazil in recent years. Even though there are special education schools, the Brazilian educational policy provides and encourages that students with special needs are enrolled in mainstream schools of education, called inclusive schools. This implies the presence of these students in regular classrooms.

Therefore, it is common for deaf students to be allocated in classrooms with hearing students. Faced with such a situation, the presence of an interpreter of Brazilian Sign Language (Libras) is necessary, as an important person that allows deaf students (Libras users), to have access to information and educational contents taught by the teacher in the classroom. However, only the presence of an interpreter does not guarantee that the specific conditions of deafness are addressed and respected during educational activities. The role of the interpreter depends on the partnership established with the teacher.

It is important to highlight that most of the teachers during their education does not have the opportunity to experience discussions about the education of deaf students. Such fact ends up compromising the emergence of strategies that can contribute to the learning of these students, as well as the planning and organization of educational practices that include the sign language interpreter.

Within this context, it is common for deaf students to feel excluded, mainly because of the difficulty in communicating. Thus, the focus of our project is in teaching and learning environments of mathematics organized for classes where deaf and hearing students are together. We are concerned in particular with communication during math class, and we aim to understand how the dialogue process in mathematics classes happens; including deaf students who use sign language, interpreters and hearing teachers and also students. We believe that a dialogical relationship between teachers, students and interpreters can contribute to the quality of teaching and learning of mathematics in the context of inclusive school, as well as providing a more equitable learning environment.

THEORETICAL FRAMEWORK

Our main theoretical inspirations are related to landscapes of investigation and dialogue in math classes. The proposal of landscapes of investigation in mathematics classes arises from the need to create learning spaces that favor communication forms different of the usual, in which the teacher asks questions to students and evaluate the given answers (Skovsmose, 2000).

For the author, these spaces would be from different references: the pure mathematic, the imagined situations or the reality. For the first reference, the student is invited to explore mathematical concepts and hypotheses, or create other ways of approaching the subject, beyond simply to solve exercises. In other references, the data presented is related to situations that could happened or have happened in fact. It is worth noting that working with investigations makes room for questioning about the role of mathematics in society and about mathematics itself.

Alrø and Skovsmose (2010) highlight that the communication qualities in mathematic classes influence the quality of mathematics learning. In the landscapes of investigation, the typical communication pattern is dialogue, which is understood as a conversation that aims at learning. As Alrø and Skovsmose (2010) state, "dialogue is not designed as a conversation whatsoever, but rather like a conversation with certain qualities" (p.119). Through this, each participant has the opportunity to expose their ideas and defend their point of view, in order to collaborate with the collective thinking and the creation of new perspectives.

These authors developed a model named Inquiry Cooperation Model, which determines different acts of participants who are in a dialogue situation. They are: getting in contact, locating, identifying, advocating, thinking aloud, reformulating, challenging and evaluating. These elements are specific and were established from empirical observations of interaction between teachers and students and among students in mathematics classes. It is worth highlighting there was no deaf student involved in these observations.

Milani (2015) expanded the understanding about dialogue during the studies on the dialogue in the perspective of mathematics education. According to her, dialogue is "a form of interaction between teacher and students, engaged in a learning activity, in which speech and active listening are shared, ideas are discussed and the understanding of what one says is essential" (p. 202). She points out that there is no way to guarantee learning, since the dialogue is unpredictable and surrounded by uncertainties. However, knowing one's thought, it is an important step towards the establishment of new meanings. The teaching and learning processes are complex and there are several factors that can influence them, being communication a key element. Through communication it is possible to compose a scenario in which one can put a number of actions into practice in a cooperative manner. Trying to understand what the other says favors equality among the learners. Thus, this type of dialogue becomes fundamental when one has to do with inclusive practices.

According Milani (2015, p. 202) "dialogue means to be with the other, it is to move toward each other, interested in what the other is saying." But how is it possible to promote this equality in the classroom, when the parties do not share the same language? The parties in this case refer to teachers and hearing students (that do not master Libras) and deaf students (Libras users). Is it possible that a hearing teacher who does not know Libras start a dialogue situation with a deaf student who communicates in Libras? How to move towards this other by a third person, an interpreter? How to promote dialogues between deaf and hearing students?

METHODS AND ANALYSIS

The research has a qualitative approach and the field is a public school which attends deaf and hearing students enrolled in the early years of elementary school, where they rely on the help of interpreters during the classes.

For the data production, a professional development group involving teachers and interpreters was established. The objective of the group is to discuss about teaching and learning of mathematics based on dialogue. We intend to prepare and perform tasks involving landscapes of investigations considering the diversity of the classroom and attending the curriculum. The tasks will be carried out in the classroom. It will be used a video recorder in order to capture interactions among student-teacher-interpreter.

In addition, reports made by teachers, interpreters and students during the activities will also be part of the data. We consider that this will make possible to understand the constitution of the dialogue during the classes.

The Inquiry Cooperation Model developed by Alrø and Skovsmose (2010) will direct the researcher's perspective to analyze the data. The characterization given to dialogue through this model has been the theoretical foundation for this research. However, the eight acts that constitute such a model (getting in contact, locating, identifying, advocating, thinking aloud, reformulating, challenging and evaluating) were identified from the interaction among only hearing people. Thus, a first action for analysis will focus on the dialogic acts, paying attention to the existence of other acts not characterized yet by Alrø and Skovsmose.

The research seeks to contribute to the teaching and learning of mathematics in the context of inclusive education, especially favoring the *encounter*[1] between deaf and hearing in the classroom.

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1. The idea of "encounters" was presented by Ole Skovsmose during in a Conference presented at the VI SIPEM - Seminário Internacional de Pesquisa em Educação Matemática, Pirenópolis, 2015. For him it is important to consider that the notion of disability can be replaced for the notion of difference, thus, we can see the inclusive education as forms of encounters among differences.

EMPOWERING STUDENTS IN CITIZENSHIP: TEACHING MATHEMATICS AND LEARNING FINANCIAL CONCEPTS

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This paper presents a study of six learning situations developed by four Mathematics middle school teachers to support their students to learn probabilistic concepts in order to develop critical thinking toward gambling. The findings shed lights on the articulation of the use of mathematics to develop critical thinking in order to make financial decisions, and thus, contribute to develop citizenship. This work contributes to explore the support of Mathematics Education in Financial Literacy Education.

FINANCIAL LITERACY EDUCATION AS A STRONG NEED

Financial literacy education is growing around the world. The financial crash in 2008 and a subsequent global recession raised legitimate concerns, but also a general agreement that financial literacy education deserves a place in today's schools (Lusardi & Mitchell, 2014). The world is changing and individual responsibilities in regards to pension plan, health insurance and unemployment are increasing (Atkinson, McKay, Collard, & Kempson, 2007). Since 2012, the Organization for Economic Cooperation and Development (OECD) has administered a financial literacy assessment via their triennial Program for International Student Assessment (PISA). Results of PISA's 2012 financial literacy assessment, which examined the financial knowledge of 15-year-olds from 13 member countries of the OECD, revealed that many young people lack an understanding of basic financial concepts (OECD, 2014). In fact, citizens from all ages need to be financially literate, including and especially youth.

DEVELOPING CITIZENSHIP CONTEXTS

Each member of a society should have the right to participate in debates and social issues. A democratic participation involves members of the society contribute by making personal and collective choices (ten Dam & Volman, 2004). Specifically, it is about making choices using critical thinking: why this choice was made between all alternatives generated and evaluated by the citizen (Halpern, 2003; Paul & Elder, 2001). It also takes the context into consideration, as well as the issue and outcomes of the decision (Lipman, 2003). In order to support students to develop skills to participate in society, mathematical problems presented to them should involve the study of an object or phenomenon coming from a sociocultural context (Mukhopadhyay & Greer, 2001). This study should lead to create a mathematical model, which one is situated in a mathematical context (Savard, 2015). The mathematical model allows making sense of the object or the phenomenon studied in the sociocultural context. Another context might overlap the sociocultural and the mathematical contexts, namely the digital context. In this context, digital tools are used for learning and are also learning objects (Savard & Freiman, 2016). A citizenship context is present, where critical thinking and decision-making are articulated into the capacity to act as a citizen (ten Dam & Volman, 2004).

The research questions are: How mathematical knowledge might support the understanding of financial concepts? In what way this mathematical knowledge contributes to citizenship competencies?

BACKGROUND OF THE PROJECT

A research project on probability using virtual tools was implemented in Québec, Canada. The project aimed to support grades 7 and 8 students in learning probability and develop critical thinking in regard to gambling activities using virtual tools. The tools are in fact simulators of gambling activities, also named games of chance. The researchers, in collaboration with four mathematics teachers and their school board consultant, developed and implemented six learning situations to be used with the simulators (Theis & Savard, 2010). Six whole-day meetings were held with the teachers. During these meetings, the researchers presented to them some theoretical background on the teaching and learning of probability, along information about gambling addictions. Through the meetings, the simulators were tested and adapted by the teachers and the school-board consultant. All the six learning situations used different gambling activities as context to be studied by students. Three of them required the use of the simulators to generate many trials (up to 10 000 trials).

1. Making money to buy a bicycle or gambling;
2. Running a casino to make profit for a donation;
3. Playing Heads or Tails with friends;
4. Buying 6/49 Lottery tickets;
5. Gambling at the roulette;
6. Making a casino party to raise money for a trip.

FINDINGS

All the tasks presented different gambling activities as socio-cultural contexts to be studied: dice, card deck, drawing, Head or Tails, lottery, spinners, Casino: Black Jack, Roulettes (Us & English), Wheel of fortune.

Gambling involves making financial decision; therefore they were presented with some financial concepts in order to study the risk of losing money. The mathematical context focused on theoretical and frequentist probabilities. The digital context was used to modelize the mathematical concepts in the case of frequentist probability. Table 1 presents the mathematical concepts to be learnt by students and the financial concepts displayed in the problems:

Table 1. The mathematical knowledge needed to support some financial concepts

Mathematical Knowledge	Financial Knowledge
Theoretical probability: - Expected value	Consumerism, money, profit, risk, salary, saving
Frequentist probability: - Expected value -Independence	Donation, profit, risk

This mathematical knowledge was the content to be learnt, while the financial knowledge was used to provide a rationale to perform the task in the situations:

- Which option (gambling or saving) (gambling or paying) should the character choose?
- Which gambling option makes more money for the casino?

Thus, the sociocultural contexts on gambling activities provided financial concepts to be understood by students to perform the task at first, and making sense of them at the end when justifying the solutions. The mathematical knowledge developed was used to be critical thinker toward gambling activities when making a financial decision. Thus, participating in gambling activities involve higher risk to lose than making money. An informed decision about participation involves knowing the risk.

DISCUSSION AND CONCLUDING REMARKS

The learning situations developed by those four middle school teachers were designed to attain mathematical goals. However, they were also designed to addresses some issues in regard to gambling addictions: the teachers wanted students to used their mathematical knowledge about expected value to see that they are against the odds when it is time to participate in gambling activities. In this sense, students needed to develop a critical thinking stance in regard to decide to participate or not. Assessing the risks in order to make a decision is a strong component of the decision making process (Halpern, 2003). Having a mathematical model to assess the risks makes this assessment more accurate and allows making informed decision, which is required to have a productive life (ten Dam & Volman, 2004). Although that some financial concepts could be understood qualitatively, mathematics quantifies and measures important financial phenomenon that goes beyond the concepts: it could lead to citizenship. This claim is aligned by OECD (2014), who defines Financial Literacy as:

> *Financial literacy is knowledge and understanding of financial concepts and risks, and the skills, motivation and confidence to apply such knowledge and understanding in order to make effective decisions across a range of financial contexts, to improve the financial well-being of individuals and society, and to enable participation in economic life* (p. 33).

Thus, the financial concepts displayed in the learning situations were not just contextual elements; they were a lever to participate in debates and social issues such as ways to make money (profit, salary, saving), sharing wealth (donation), and participate in gambling activities (consumerism, risk). In this case, those learning situations focused on gambling and risks, but there are plenty of other financial concepts to be mathematically studied, for examples: investment, credit, borrowing. As Mathematics educators and researchers, it is time to take our responsibilities.

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POSTER PAPERS

ANTHROPOGEOMETRIES IN THE URBANSCAPE: INTERROGATING THE ECHO OF GEOMETRY

Anna Chronaki, Chrysa Papasarantou, Irene Lazaridi, Efi Manioti, Magda Koumparelou, Giorgos Giannikis

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What else could geometry may mean besides a detailed and systematic metric encounter with earth (i.e. γεωμετρία = μέτρηση γης*), as the etymology of the word suggests? Could notions of 'geometry' become supportive towards opening up how, today, we may reconfigure our relation with space and place at a time of crisis? And for whom? Could geometry enable us to reconfigure this relation as entailing a variety of topologies, figurations and meanings? Could we, with our student-teachers, children and locals endure a confrontation with the 'echo' of geometry in the urban scape as a continuum amongst the dis/appearance of its particularities, features, values, valorisations or, even, violations? A confrontation that involves a subtle interrogation of geometry's echo today.*

INITIAL THOUGHTS

Inspired by Lefebvre's urge to open up fixed container images of a city, a house, or a street and to consider them as *"a complex of nobilities, a nexus of in and out conduits"* (Lefebvre, 1991, 92) we have been engaged into an urban (mathematical) intervention that aims for opening up not only the city, but also our experience with mathematics in the urban-scape of Volos. Based on the digital archive of 'street mathematics'[1] where the artwork of de Chirico geometric allegories are assembled, as well as, the contemporaneity of a small scale commercial urban neighbourhood at the centre of Volos, the AnthropoGeometries intervention was planned and implemented in a series of workshops with student-teachers, students and locals in this area (see Figures 1 and 2) with the intention to see the *horizon* and not just its objects as indicated by Merleau-Ponty (2003) in his notes on Husserl's Origin of Geometry.

1. See Chronaki, 2015 and http://streetmathematics.ece.uth.gr.

Figure 1: de Chirico gallery (outside) **Figure 2:** The Metamorphosis street

The choice to focus on de Chirico's artwork was due to the artist's connection to Volos as his birthplace and local eminence to the extend that a cultural gallery has been named after him. Since the gallery had no real artwork of Giorgio de Chirico at possession (i.e. all of de Chirico artwork exist at his museum at Rome), it was of particular interest for our project to emphasize a virtual revival of his work (see Figures 2 and 3) but also to explore how locals may connect with him, his artwork, the vibrant visibility of geometry's 'voice' in it, and through this channel, to explore the 'echo' of geometry in the everyday of the urban neighbourhood (see Figures 4 and 5).

Figure 3: A virtual space of de Chirico gallery (inside) **Figure 4:** Assembling Geometries

STEPS INTO THE NEIGHBORHOOD

Based on the above materiality, a group of student-teachers and young students became co-participants in a research project where they had to get into the streets of the neighbourhood to meet the people who live and work there but also the passers and discuss with them de Chirico, his artwork, and geometry[2]. Having worked with an interdisciplinary team

2. The research team comprised by mathematicians, educators, historian of art, artists, computer scientist, architect and thirty-two students from two different junior high schools (the 3rd junior high school of Volos and the Music School of Volos), as well as a team from the Roma minority collaborated in a two-month workshop. The average age of student-participants was 14 years old (see also Chronaki & Papasarantou, 2016, Chronaki, this volume).

in the de Chirico gallery they got to know his artwork as well as to explore what questions to ask locals, why and how, student-teachers along with students moved out in the streets of the neighbourhood (Figure 5).

Figure 5: Student-teachers and students in the workshop and the neighbourhood

As a way of initiating their detour into the urban scape of Metamorphosis area they used of a number of de Chirico artwork images (see Figure 4). The gesture of starting a dialogue with locals invited a spur-of-the-moment re-entering into a manifold of mathematical 'epistemologies' and 'ontologies' that people's responses might carry. What are the memories that showing the artwork images might evoke in people's minds and feelings? What is that they can say about geometry as they become invited to revisit the artwork of a painter who had spent time in their city? How such a gesture does open new avenues for imagining mathematical activity and its impact in our contemporary times and spaces?

Figure 6: Artwork by de Chirico for street interventions (Trobadour, El placer del Poeta, La Melancholie d' une belle journée, and Masks)

WITH THE LOCALS

Talking with locals a number of issues emerged around not only geometry, but geometry in relation to art and people's life and work. First of all, despite the legend around the artist, most people, even-though they knew de Chirico's name were not in position to recall any more information of either the artist or his art –denoting how not only mathematics but also art may remain inaccessible. However, describing his artwork, and especially the geometry's allegories was not only pleasant and interesting, but also revealing.

Figure 7: Locals and the Echo of Geometry

Particularly descriptions referring to the artwork of "Trobadour" and "Masks" were vibrant and related directly to their experiences. According to a local dressmaker's words, "Masks" represent two women from Renaissance. Her main argument was the shape of their heads. In her words "*The heads are oval-shaped so they can't belong to a man. Men's heads are more edged. These two figures are probably two women from the period of Renaissance because in those days women used to shave their heads in order to wear wigs*". A local photographer made a lighter approach by comparing and connecting the two paintings: "*Ah! These are the robots! (Masks)... and this is his nose... oh! And this person (Trabadour) holds the spare nose of this guy while he is listening to music. He has a Walkman here and a pair of hands-free".* In the view of "Masks", a bookseller talked about an effort of the artist to represent an animated form through unanimated materials while an undergraduate student claimed that is a hollow face that tries to interpret his/her existence through geometry. For the pet shop owner "Trobadour" is a knight that we need today to save our lives while for the agriculturist it resembles a human Trojan Horse.

Most locals recognized geometric shapes or relations on the presented artwork and this act provided access to talk about worklife. All of them noticed at least one basic shape such as triangles, rectangles and/ or circles. Few of them (5 out of 26) noticed geometric relations such as symmetry, parallels, as well as the use of geometry as a way to represent the dimension of depth. One of them (an immigrant builder) referred to the work of Evaristo de Chirico, the father of Giorgio de Chirico, and the impact he had to his son's paintings. A dressmaker related the presence of geometry to her own work in dress-design. In 'Trovadour' for instance she said that she did recognize geometric shapes but for her all these use of geometry is connected with the procedure of designing a cloth. Moreover, she perceived the presence of the train on the background of this painting as a metaphor for fashion –relating it to certain fashion trends that come and go. Some of them compared geometry to reality. A merchant/trader said that all this sharp geometry reminds her of the cruelty that sometimes characterizes real life. On the contrary, an undergraduate student said that in all this geometry he recognizes the practical aspects of everyday life.

A variety of emotions and thoughts were expressed as a reaction to observing closely the paintings. Some of them expressed positive feelings mostly due to the use/presence of vivid colours. Few claimed that they felt melancholic due to lack of animate entities such as people, trees and sea. Others had mixed feeling. Describing "El placer de poeta" for example, the dressmaker stated that even though the deserted landscape evokes loneliness the presence of vivid yellow reverses this feeling to a wormer one. Most of the participants expressed negative feelings for "La Melancholie d' une belle Journée" mostly due to the dark colours. However, according to the photographer, this image is funny because he felt an irony between the statue and the depicted human figure. He didn't like so much this particular image though. Pleasant feelings, such as happiness or even nostalgia, were also expressed from those who recognized certain elements which refer to the city of Volos (e.g. the train, the arches, the mountain etc.). Several participants connected their emotions to particular geometries. A secretary said that the mannequin depicted in "Troubadour" seems sad due to the position of its head. However, the same geometry was identified by the photographer as less hostile (in comparison with the mannequins depicted in "Masks"). A woman that works on public services stated that the entire geometry of "Trobadour" evoke her fear because it reminds her robot. The builder felt that "Trobadour" is a person trapped in geometry while he argued that there are several mistakes on the representation of some components constituting "El Placer de Poeta".

Concerning the significance of geometry in their work, seventeen out of twenty-six of the locals answered positively. Nine of them were strongly positive for the presence of geometry in their lives, five of them expressed ambivalence and only three answered negatively. One of the two dressmakers met stated that the entire procedure of designing a cloth is totally based on the use of geometry. She even demonstrated the designing process to students and presented them with the standard tools that she uses –a ruler and a triangle with embedded curves. On the contrary, the other dressmaker wasn't aware of the presence of geometry in her work so she almost avoided the question. The shoemaker stated that his profession is not related in any way to geometry. The same statement was made by a female trader, but she recognized the presence of mathematics in her work as money-exchange. The builder claimed that a person with limited knowledge of geometry cannot really become a builder. Geometry is of significant importance for the professions of electrician and agriculturist. They both stated that they apply geometry in order to design systems related to their work (i.e. elevators, irrigation networks). A pedestrian claimed that geometry is omnipresent and a pet shop owner that geometry is the beginning and the end of the entire universe.

Various ambivalent and negative responses came from school based subjects such as teachers, parents and students. Specifically, a young teacher reported that she used a lot of geometry in her profession since she has to teach it to young children, sounding as if she tight to this obligation. A mother said that she uses geometry only when she has to help her kids for school homework. And the most spontaneous response came from a student who said that sometimes she does geometry when she draws shapes on her notebook, when she gets bored during the class.

ECHOES OF GEOMETRY

According to de Sanna (2004) de Chirico's metaphysical spaces and landscapes manage to aggregate "two extremities of history", meaning Pythagorean harmony and modern mathematical physics. Therefore, apart from representations related implicitly or explicitly to the city of Volos that recreate connections with present time, a semblance of platonic solids and non-Euclidean geometries can be traced in his paintings existing together but not always in harmony. It was interestingly revealing how student-teachers, students and locals together as part of the AnthropoGeometries project were able to tap into complex ideas concerning the horizons of geometry through geo-body political languages. We cannot claim that disruptions to mainstream hegemonic discourses such as 'geometry is everywhere' or 'we all use geometry in daily life' could come easily as the result of such place-based encounters. However, the hybrid of people's spontaneous responses has provided a rich tapestry to continue work with towards interrogating the polyphonic echoes of geometry as presented above.

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ENHANCING STUDENTS QUANTITATIVE LITERACY SKILLS: USING GOOGLE DRIVE AS A COLLABORATION TOOL FOR INTERACTIVE ONLINE FEEDBACK

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Digital literacy (DL) is an emerging phenomenon that is loosely described as the "capabilities required to thrive in and beyond education, in an age when digital forms of information and communication predominate". Our project investigated whether the integration of DL into the curriculum of a foundation course that aimed at giving students an understanding of mathematical and statistical ideas within social science contexts could enhance the development of students' academic and quantitative literacy abilities. This presentation outlines the process, the students' experience of the process and outcomes of a Teaching with Technology project that utilised Google Docs as a tool for interactive online feedback on an essay assignment. Students who utilized the online collaboration system showed a greater improvement in marks from the draft to final essay. However, there were common misconceptions amongst students about certain QL concepts.

INTRODUCTION

Digital literacy (DL) is an emerging phenomenon, and technology is increasingly being used for educational purposes. Paul Gilster (1997, p. 1) defines digital literacy as "the ability to understand and use information in multiple formats from a wide range of sources when it is presented via computers." While school mathematics has played a vital role in preparing youth around the world to face the various economic, technological and social challenges and changes (Seah & Bishop, 1999), teaching in higher education in a post-apartheid South Africa has raised new questions and possibilities about educating students for effective citizenship. At the Numeracy Centre at the University of Cape Town, we maintain that a quantitatively literate student is important for creating a more effectively functioning society. Therefore, we believe in preparing individuals to function as informed global citizens using quantitative information as a key analytical tool (Frith et al., 2010).

As a result we developed a project to investigate how the integration of DL into the quantitative literacy (QL) course: Numbers in the Humanities curriculum could enhance the development of students' academic and QL abilities. This foundation course is offered to students on an extended degree program to help them understand the mathematics and statistics in social science contexts. In this first year, first semester course, the students learn how to engage with quantitative ideas and think critically while supporting claims with data. Students are also exposed to supervised hands-on computer-based interactive Excel tutorials. As the majority of the students on the programme are from poorly resourced schools and disadvantaged socio-economic backgrounds, these sessions prove to be very beneficial to students.

This poster outlines the process, students' experience of the process and the outcomes of a Teaching with Technology project that utilised Google Drive (GD) as a collaboration tool for interactive online feedback on an essay assignment in the Numbers in the Humanities course. We also examine some of the challenges that have emerged, and describe the ways in which the course might adapt to these challenges in the future.

METHOD

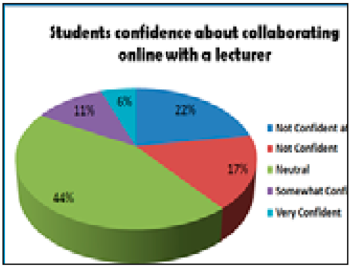
There were 180 students who completed a short essay (500 words) as part of their MAM1022F coursework. Students were required to use data from a journal article to compare the status of HIV/AIDS in two South African provinces. The aim was for students to be able to use QL to critically evaluate the article. To teach students how to use Google Drive workshops were held outside of lecture times. The assignment was shared with students via Google Drive. Doctopus was used for the management and marking of the assignments.

Draft copies of students' essays were submitted for marking via Google Drive. Lecturers marked the essays and provided feedback on both the QL content and the structure of the essay. Students were then given several opportunities to asynchronously collaborate on Google Drive with their lecturer before submitting their final copy of their essay. The study follows the Activity Theory which draws on Vygotsky's concept of 'mediation' (Vygotsky, 1978). This triangular model shows the relationship between the student, lecturer and tool. Furthermore, this sociocultural theory allows for examining an individual in a larger activity system.

RESULTS

Eighty six percent of students had never used Google Drive before the start of the project. Before the project, approximately two-fifths of the students in the cohort indicated that they were not confident about collaborating online with their lecturers while only 17% stated otherwise.

However, after the project, more than half the cohort (52%) reported that they were confident about collaborating online with their lecturers.



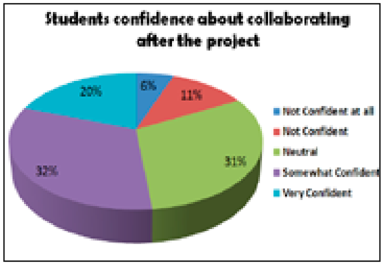


Figure 1 **Figure 2**

All students submitted their draft essays for marking via Google Drive. However, 25% of them did not collaborate with their lecturers after receiving comments on their essays while three-quarter of the students either interacted with the lecturer to resolve comments, made further comments to the lecturer or resolved comments made by the lecturer.

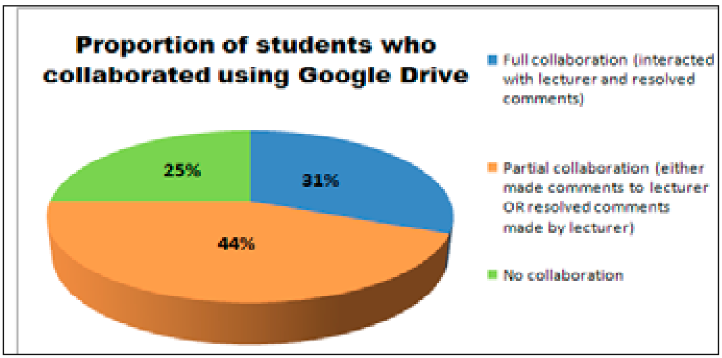


Figure 3

Figure 4 shows that students who made use of the online collaboration showed a significantly larger increase in marks between the draft and final essays compared to students who never collaborated (p = 0.03). This increase in marks is not just an indication of students' ability to mechanically compose an essay but rather their ability to construct a critical argument and support their claims with data.

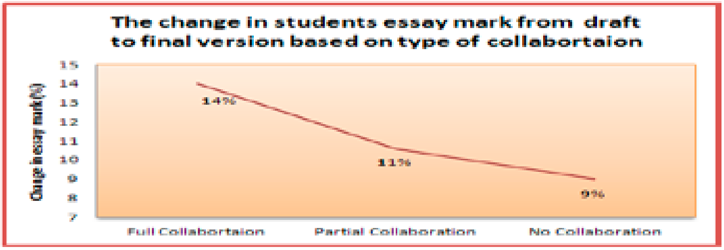


Figure 4

Thirty percent of the students are now using Google Drive outside of the course. Approximately three quarters (72%) of students felt using online collaboration was more time efficient than face-to-face consultations with 80% of them indicating that would use online collaboration again and found the whole experience great. Nonetheless, there were a small proportion of students who still preferred a face-to-face collaboration with their lecturers to clarify comments and suggestions.

CONCLUSION

Online collaboration was a useful tool for interacting with students. It allowed for a quicker turnaround time in feedback to students. Students were able to interact more frequently with their lecturers affording them the opportunity to resolve queries as they arose. An improvement in students' marks as well as their quantitative literacy, academic literacy and digital literacy skills was noted. However, further analyses need to be conducted on the type of questions students asked during the collaboration, and how their quantitative literacy abilities developed.

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MATH, SOCIAL JUSTICE, AND PROSPECTIVE TEACHERS IN U.S.A. AND URUGUAY: LEARNING TOGETHER

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In this study prospective teachers from the United States and Uruguay participated in a Teaching Mathematics for Social Justice (TMfSJ) project. The authors analysed data using discourse analysis with a critical mathematics approach in order to examine initial self-perceptions demonstrated by the participants and their conceptualizations of TMfSJ. Our findings indicate that while participants in both countries needed help supporting their emerging skills in creating effective lessons to teach social justice in the classroom, U.S. participants demonstrated resistance to social justice teaching, whereas Uruguayan participants showed interest and embraced the social justice curriculum.

INTRODUCTION

It is crucial that children learn mathematics as a tool to understand and change the world (Freire, 1979/2000; Gutstein, 2006). In order for children to participate in this kind of experience, teachers need support to recognize the power of mathematics as a social tool (Moses, 2001). To do this, teacher preparation programs need to provide prospective teachers with meaningful opportunities to experience mathematics as a social tool and reflect on teaching mathematics for social justice for themselves. Part of our efforts to provide such opportunities have included a project in which prospective teachers in the U.S. interact with prospective teachers in Uruguay to learn more about TMfSJ.

In this study prospective teachers in the U.S. and Uruguay shared their perspectives on TMfSJ and attempted to construct social justice curriculum by writing a lesson plan. The dialogues that took place throughout the project enabled the authors to understand the participants' perceptions, changes, and experiences. In addition, the data were used to analyse the nature of context that could cause participants' interest, awareness, or resistance to social justice learning. The comparisons between prospective teachers in different settings helped the authors make sense of social and cultural factors associated with cultural competency for social justice.

Studies like this can provide teacher educators interested in advancing the practice and curriculum of TMfSJ with a richer context of social justice curriculum in teacher education programs with predominantly White prospective teachers. The findings can provide teacher educators with concrete pedagogical ideas to implement in their classrooms as well as help prospective teachers develop appropriate social justice advocacy by overcoming cultural attitudes and biases.

THEORETICAL FRAMEWORK

Critical Mathematics: Teaching Math for Social Justice

Teachers need to be "a threat to inequity" wherever they are and whatever the form of inequity it may be, developing their critical literacy to be an advocate for access and equity, said Gorski (2016). Not only should mathematics be part of such critical literacy, the discipline does and should serve as a tool to tackle inequities. Called "a weapon in the struggle" by Gutstein (2012), mathematics education in the traditional framework may not achieve this goal of equipping people with the awareness and knowledge to reduce social and economic inequality. Our students as well as prospective teachers need access to critical mathematics (CM). Therefore, TMfSJ is an ethical and moral imperative (Stinson, 2014).

Prospective teachers and their future students have much to benefit from learning CM, which is equitable and socially empowering (Gutstein, 2003, 2006; Stinson and Wager, 2012). The aim of CM through TMfSJ is to empower students to read and re-write the world using mathematics (Gutstein, 2006) –especially those who have been traditionally underserved– to change the world and overcome rising inequities in society.

Such empowerment can be established in the minds of students only after they develop what Freire (1979/2000) calls "concientizacao" (critical consciousness). This connection of CM to concientizacao is important, as Frankestein (1983) articulated CM as a re-invention of Freire's theory for mathematics education (Gutstein, 2013; Freire, 1979/2000).

While Critical Mathematics and Mathematics for Social Justice it is not a new idea in the States, it is for Uruguay. The literature in Latin America in regards to teaching Mathematics for Social Justice just starts to bloom. Authors throughout the continent are concerned with inequities in the mathematics classrooms and its consequences. They mostly talk about issues of gender and class, but they do not explore ways to address those while teaching mathematics. In conversations with Uruguayan Mathematics educators the authors found that they also find these ideas interesting and new. These educators also were eager to embrace and learn more, and were in the stages of experimenting with their students.

METHODS

Participants of this study were prospective elementary teachers in the U.S. (n=20) and Uruguay (n=9). All participants were in their senior year and taking mathematics methods courses at the time of the study. The U.S. participants were students in a state university in the South of the U.S., and the Uruguayan participants were students of a public normal school located in a city 33 km from the capital, Montevideo.

This study collected lesson plans, reflections, notes from class discussions, and videotaped interactions and interview data at the end of the project, which were analysed using discourse analysis (Gee, 2010). Participants were provided with the same readings (Education for liberation: towards a framework to teach mathematics for social justice -chapter 2 in Gutstein, 2006-, and Learning to teach mathematics for social justice: negotiating social justice and mathematical goals -Bartell, 2013-), lesson plan template, writing prompts for reflection, and instructions prior to the participants' "confession cams". The confession cams are videotaped interactions between a U.S. participant and a Uruguayan participant, where individual views on social justice issues are discussed confidentially with no access from the researchers or instructor until official course grades are decided.

RESULTS

Our preliminary results show that prospective teachers in the U.S. were resistant to TMfSJ. The data from group discussions and reflective writings pointed to various reasons why U.S. participants believed social justice was "inappropriate" content in the mathematics classroom. For a couple, they were concerned that the teacher would unnecessarily be "introducing" children to hardship in life; second, students could misunderstand the teacher as being racist; third, it was not the teacher's responsibility to teach social justice at school but the parents' job to teach at home; finally, students were not mature enough to share their views of "justice" or "social justice". Some participants mentioned that they did not trust the instructor's intent to introduce social justice in mathematics teacher training. It was also found that the lesson plans provided by participants were evaluated as demonstrating little connection to TMfSJ.

The students who were concerned about "introducing" children to hardship in life thought that they would be "damaging" the innocence of children by talking about certain issues. For example one of them claimed: "I don't think talking about racism to children will help them understand anything at their age. They may just feel bad about it. Why would I do that to them?" (US female student 1, class discussion). Another one added: "It would be to so sad to talk about these things knowing some of them have to endure them outside of school. Why also bring it to the class?" (US female student 2, class discussion). Examples provided to them about the knowledge children actually have and what they want to talk about, did not change these students minds.

Students also thought children could misunderstand the teacher as being racist. This was a big concern for students who were doing their field experience in higher grade levels. One commented: "They [the children] will wonder who am I, the while teacher, to tell them what is fair and teach them about justice? That can cause more resentment." (US female student 3, class discussion). To this, an older classmate added: Exactly! What good can come from it? If you keep scratching and scratching the surface… what will you find?" (US male student 1, class discussion).

Social justice was for most of the participants something they would be teaching to the children. Even though they recognized this was problematic, and it was discussed in class, going back to the readings, that this was not the process to teach for social justice, they kept going back to this idea. This is also clear in the quote shared above by US female student 3. Because participants thought about teaching for social justice as a way to "convince" students of a certain view, they thought this should be dealt by parents at home. This was particularly clear when we discussed examples connected to gender identity and religion. "These are not things that we should talk at school. Teachers are there to teach about math and reading. Parents can take care of the rest at home" (US female student 4, class discussion).

The reflection and lesson plan data showed that prospective teachers in Uruguay did not demonstrate resistance. However, like their U.S. peers, their lessons plans were evaluated as demonstrating little connection to support TMfSJ. We found that the Uruguayan participants were interested in social justice as a tool to teach mathematics and expressed a high degree of willingness to learn more about TMfSJ and the work of Gutstein in the future. The participants found it interesting that Freire's theory could influence U.S. classroom practice.

All but one of the Uruguayan students said in their reflection that the topic was "interesting". After the experiment was over, some students approached their instructor and asked her to continue with this relationship and work the next semester (personal communication with Uruguayan instructor). They also thanked the authors of this paper for "…the opportunity to learn about something new that we can use in our classrooms." (UY female student 1, reflection).

Students in Uruguay also claimed being interested in eventually trying teaching for social justice in their classrooms. After completing the readings they prepared questions for the authors of this paper. A good amount of those questions showed curiosity as to why US authors would be interested in Freire. For that reason they wanted to know more in particular about Gutstein and what took him to do this kind of work based on the Brazilian pedagogue. They also mentioned both in the direct conversation with the authors and in their reflections, that they needed to see more examples that they can adapt to begin with, so later they could come up with more original ideas.

DISCUSSION

Our findings underscore the challenges for teacher educators in the U.S. in introducing social justice to prospective mathematics teachers, who have difficulty viewing racism, oppression, or injustice as a structural and cultural barrier to student success. The fact that most White prospective teachers in the study were concerned about being called racist for discussing race, class, or privilege in the classroom is a telling sign that the prospective teacher feels vulnerable in the classroom and lacks certainty in seeing social justice as a moral imperative and foundation of student success. This, in contrast with the reaction of Uruguayan students, also uncovers that these future teachers see their future students as “others” with whom, it seemed, finding middle ground and things in common was hard.

On the other hand Uruguayan students brought up (in conversation) themes that they would use for their social justice lessons that made sense for their students and for themselves. They in particular focused on class and violence against women. Sadly none of these ideas made it to the lesson plan. The authors believe that working with the students for longer time, and providing them with examples so they built their confidence, would have been useful. Yet the authors would like to highlight that in conversation or reflection, the Uruguayan students did not position themselves or their potential students as “others”. The author believes this is key to the introduction of teaching for social justice.

We note that some U.S. prospective teachers mentioned that they considered their instructor as someone from “a socialist country” with “unrealistic agendas”, while their peers in Uruguay took pride in Freire’s (a South American like them) support of the social justice framework to teach mathematics in a new way. With that said, perhaps prospective teachers who will be introduced to TMfSJ for the first time need to connect with the instructors in trust and respect, especially when the teacher educator and prospective teachers do not have similar social or cultural backgrounds.

On the other hand, it was noteworthy that the U.S. participants believed they would “teach” their students what is “just”. Despite the readings and conversations in class, the participants related social justice as a skill set to be taught, rather than recognizing the importance of teacher effort in getting to know the students and their cultures, building relationship with students and family, and preparing students to use mathematics to understand and analyse social and economic inequalities while challenging them to overcome structural barriers to have a better future.

RATIONAL TO THE CONFERENCE THEME

Preparing prospective teachers for cultural competency for social justice in today's classroom means creating learning opportunities in various contexts that culminate in a change in attitude and growth in enlightenment. Teachers need training must have opportunities to examine their privilege, especially their conception of social justice. For one, prospective teachers can benefit from interacting with peers from other countries or with different cultural backgrounds and grappling with integrating social justice into their mathematics teaching. Critical mathematics may be one answer to mathematics education in times of crisis. For this reason, discussing effective and affective ways for mathematics teacher educators to encourage prospective teachers in learning about CM, as well as attempting to write a lesson plan integrating social justice into the curriculum, is crucial.

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WHY DO WE NEED THEM TO BE DIFFERENT? LOW ACHIEVING CHILDREN'S CONCEPTIONS OF UNIT FRACTION

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A critical issue in mathematics education rests in the question of why research locates the problem of low achievement within the minds of children. In this paper, we continue our efforts to challenge a longstanding assumption about the type of mathematics children with low achievement in mathematics "need" along with how these children are positioned in terms of mathematical thinking and reasoning. Our aim in this work is to identify ways of reasoning evident in the partitioning activity of 43 fifth-grade children as they solved equal sharing situations independent of instruction over a ten-week period. Results reveal three themes of reasoning. We discuss the results in terms of the problem of a continued conceptualization of low achieving students as "different" in terms of their need for specific kinds of teaching and learning experiences and/or detached instructional experiences in school.

This paper illustrates variations of mathematical reasoning of 43 elementary school children identified as having low achievement in mathematics as evidenced through their problem solving in equal sharing tasks. Addressing this problem is important because illustrating the ways of reasoning these children DO possess (as opposed to describing what they do not know or defining knowledge as a level of performance) can inform the field about the rich mathematics these children *can* engage in. Unfortunately, this information stands in sharp contrast to the current literature base and policy recommendations for math instruction for children who experience sustained low achievement in mathematics (Gersten, Chard, Jayanthi, Baker, Morphy, & Flojo, 2009).

Previous research clearly illustrates that mathematics instruction in classrooms designated for these children has been dominated by explicit instruction and practice computing basic facts (Lewis & Fisher, 2016; Kurz, Elliott, Wehby, & Smithson, 2010). Moreover, a recent review (Lambert & Tan, 2016) of articles researching the mathematics learning of Kindergarten through 12th grade students found significant differences between the mathematical teaching practices used with children with and without sustained low mathematics achievement (i.e., children with learning differences in mathematics). Mathematical teaching and learning was informed largely through constructivist and sociocultural perspectives *with* children *without* an achievement or learning difference. For children *with* low achievement or learning differences, mathematical teaching and learning was informed primarily by medical and behavioral perspectives. The research divide suggests two categories of mathematics learners who "need" different kinds of mathematics (Lambert & Tan, 2016).

Consequently, rather than discuss how to increase the participation of these children in inclusive mathematics instruction, current research and policy suggests a replacement of participation with more directive teaching approaches (Gersten et al., 2009). We argue that attempts to remediate and "fix" children with procedural training is a poor replacement for supporting children to develop mathematical conceptions in a classroom community (Hunt & Empson, 2015). In fact, we argue that positioning some children as "normal" and others as "deficient" due to arbitrary cut off scores and then delivering mathematics onto them does nothing to uncover the rich knowledge these children *do* possess and can build from in the classroom. Instead, we propose that researchers seeking to increase these children's mathematics competence might begin by uncovering, or documenting, the conceptions that already exist and can be cultivated as children "solve problems that are within [their] reach [while] grappling with key mathematical ideas that are comprehendible but not yet well formed" (Hiebert & Grouws, 2007, pp. 387). Such work might begin to build a counter narrative to deficit perspectives by documenting that children labeled low achieving *have* rich conceptions. In this way, we hope to support a case for an increase in research examining these children's participation in mathematics classrooms and a critical examination of the source of "difference".

In this study, we begin such a documentation by examining ways of reasoning for 43 children with low achievement as they solved fraction problems. Specifically, we present themes of reasoning evident in children's partitioning activity in problem contexts not directly taught by the teacher (i.e., equal sharing contexts) over a period of 10 weeks. Our aim in this work is to continue to challenge a longstanding assumption about the type of mathematics children with low achievement "need" (Gersten et al., 2009) and their potential as mathematical learners. The following research questions guided our work:

(1) What is the fractional reasoning of 43 children with low mathematical achievement as evidenced by their partitioning activity used in equal sharing problems over ten occurrences?

(2) What differences, if any, seem apparent in the children's reasoning from what we know about children without low mathematics achievement?

METHOD

A total of 43 fifth-grade children (N=43) from four suburban schools in a western United States school district participated in the study. A larger population of 182 children in the participating classrooms across the four schools completed a pre-test dealing largely with equivalent fractions. Children's scores ranged from 5% correct to 100% with a mean score of 51.1%. Children who both scored below 40% on the pre-test and were identified by teachers as having low achievement in mathematics were asked to participate in the study.

Data were collected from children's responses to the equal sharing question within the daily assessment children completed at the end of a math lesson. An equal share task was included in the assessment in each lesson; all questions used the same format with only the amounts being changed (i.e., *You have n pizzas which you want to share with friends. Including yourself there are m people. How much pizza will each person receive? Draw your work.*). Although included as a question on the daily assessment, thee equal sharing problem tasks or the context of fractions as equal sharing division was not included in the intervention in any part of any lesson (see description of intervention above). Children never partitioned quantities themselves during the lessons nor did they take part in equal sharing situations; the context of fractions as a result of equals sharing an item or items was not a part of the intervention lessons.

To analyze the data, researchers employed a constant comparative approach to delineate the ways of reasoning children used to solve the equal sharing problems through examining two indicators evident in the children's work: the employed partitioning strategy and associated representation. First, the second author gathered and organized all daily assessments from all 43 children taken across the 10 intervention sessions. The first and second author met as a team and examined the full set of the children's responses. Then, researchers began with a batch of approximately 40 assessments and independently labeled each response with a descriptive code that encapsulated the employed partitioning strategy and representation. The codes were based on the synopsis of prior research on the ways of reasoning children without low mathematics achievement displayed in equal sharing (Leech & Onwuegbuzie, 2007).

Researchers then compared their codes using peer debriefing (Miles & Huberman, 1994). That is, researchers met to compare assigned codes for each assessment coded. Disagreements in coding were handled using collaborative work (Leech & Onwuegbuzie, 2007). That is, when coders' scores differed, a discussion took place and a decision on coding was reached. Through this process, the researchers resolved all disagreements. Researchers compared each new problem solution and its code with previously coded data to ensure consistency (Leech & Onwuegbuzie, 2007).

As the researchers worked to code all remaining assessments, major categories of reasoning were established through the constant comparison approach (Miles & Huberman, 1994).

We also considered overall trends in reference to partitioning across all children's work. To that end, a content analysis was used to determine the number of times each way of reasoning was evident both as a function of the total sample and as a function of each equal sharing problem given in each daily assessment (i.e., per session). This descriptive information about the data also complements the constant comparative analysis used earlier (Leech & Onwuegbuzie, 2007). Researchers used the thematic codes for the analysis. For the name given to each theme, researchers counted how many occurrences comprised each grouping. Percentages were calculated by dividing the total number of occurrences of each grouping by the total sample. Researchers heat maps of children's partitioning were prepared and descriptive statistics were summarized. The next section of paper presents the results of the study as they emerged through the analysis.

RESULTS AND IMPLICATIONS

Generally, we found three broad categories, or themes: *(a) Not linking between the number of objects and or parts to the question context*, (b) *partitioning of all objects into halves*, and (c) *partitioning all objects into the number of sharers*. Importantly, our results show a resemblance between the children's reasoning and that of existing frameworks of reasoning in equal sharing problems found in prior research among children who did not show low achievement in mathematics (e.g., Charles & Nason, 2000; Empson, Junk, Dominguez, & Turner, 2011). Each way of reasoning will be described in depth in the poster presentation. The ways of reasoning uncovered in the study provide a window into what conceptions children with low performance in mathematics DO have when immersed in solving problems that supports the *active use of partitioning* and subsequent reasoning about the resulting quantity. These were ways of reasoning that the children already possessed, not a result of a teacher modeled strategy or thought process.

The results of the study hold implications for the type of instruction children labeled as low achieving "need" due to their low mathematical achievement. When working with children, there is often a tendency to use black and white categories to view "knowing" as performance –children's learning and subsequent conceptions seem to be labeled as either right or wrong. Based on this assessment, children with sustained low achievement are often times given labels of "deficient", "not ready", and "unable" (Lambert & Tao, 2016; Kroesgergen & Van Luit, 2003; McDermott, Golden, & Varenne, 2006). Mathematical knowledge, then, also takes on an altered form and is interpreted for these children as something that needs to be poured in rather than something that already exists (Piaget, 1977/2001), can grow and change, and can be supported and extended in interaction in society (Vygotsky, 1978). In other words, the more children are placed into instructional situations that remove the responsibility for reasoning from the child and place it onto the teacher, the more these children experience an altered means of knowing and learning mathematics in school (Baglieri, Valle, Connor, & Gallagher, 2010). Arguably, such an experience might work to further marginalize and separate these children (e.g., Balu et al., 2015).

In this way, we challenge the deficit perspective on mathematical knowing and learning for children labeled as low achieving. If the ways of reasoning evidenced by these children are similar to those without such labels, then perhaps what needs "intervened" upon is not the child but the instructional environment. We argue increase in research examining these children's participation in mathematics classrooms and a critical examination of the source of "difference".

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MATHEMATICAL FICTION IN EDUCATION: TEXT IN ACTION

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In this text we attempt to explore how mathematical fiction interacts with basic ideas for the teaching of mathematics and specifically the idea of interdisciplinarity. Efforts have been made -according to current national curriculum reforms in Greece- for a focus on interdisciplinary activity. Towards this end, mathematical fiction, a new literary genre for children, adolescent and adult literature has provided an inspiring context for diversified ways of teaching the ensemble of mathematics and literature. The aim of this poster is to indicate through two distinct research projects how mathematical fiction could be moved in action for primary, secondary or higher education through interdisciplinarity.

INTRODUCTION

Over the past years in Greece many attempts have been made to reform the school curriculum at all educational levels through a focus of interdisciplinarity (Interdisciplinary Framework of Studies for Kindergarten-DEPPS, Analytical Programme Study for Kindergarten-APS, 2011; DEPPS-APS for High School, 2003). This poster originally outlines that mathematical fiction, in terms of the educational system and according to the recent national curriculum guidelines, can actually constitute –even though if it is not separately taught– an alternative context for mathematical education and to foster more positive attitudes towards the disciplinary fields of mathematics and literature. Secondly, our research-in-progress indicates how interdisciplinary activities can be organized around inspiration out of work with mathematical fiction texts. The interdisciplinary activities discussed here indicate how mathematical fiction can function creatively along with other disciplinary curricular subjects as being inscribed in the national documents (DEPPS-APS, 2003) and they can create a dynamic and effective framework for teaching in terms of knowledge outcomes. However, we wish to outline that mathematical fiction can also constitute an autonomous space itself, since it combines diverse subdomains, fields of interest and features an interdisciplinary character itself which allows it to converse with many different learning areas, achieving goals relevant to not only mathematical knowledge per se but also language, history and aesthetics. In other words, mathematical fiction provides a textual narrative space where mathematics becomes entangled with a vast variety of knowledge fields.

THEORETICAL FRAMEWORK

Mathematical fiction has the potential of connecting and relating students with sophisticated (mathematical) ideas while, at the same time, it provokes general philosophical questions concerning the substance of mathematics itself through cultivating imagination (Sriraman & Beckmann, 2007; Sriraman 2004). In addition, since the texts represent aspects of the physical, social and spiritual world and they serve to establish social relationships amongst heroes and protagonists in each occurrence (Fairclough, 1995) the mathematical novel, being the most dominant and representative genre of literature (Bakhtin, 1995), stands for multi-voiced relationships of polyphonic characters. At the same time, it provides narrative entries and stories of subtractive and abstract mathematic thought and its varied logic(s). Thus, mathematics ontogenesis can be incorporated functionally into the social action of heroes and plots conversing with individuals in fields of activities.

TWO RESEARCH PROJECTS, THEIR METHODS AND THEIR RESULTS

In the following two research projects will be presented. The first text, *The Number Devil: A Mathematical Adventure* by Hans Magnus Enzensberger (2014, *Der Zahlenteufel*) belonging to the mathematical fiction genre has been chosen as the base of a lesson plan addressing students who are in the 5^{th}-6^{th} grade primary school and 1^{st}-3^{rd} class of junior high school. Taking into consideration that this specific narrative piece of work is characterized by a humorous style, it was used as a lesson plan for the mathematical definition of the very first numbers for both 5^{th}-6^{th} graders in the school classroom, during their summer school in Volos 2015 for 1^{st} year high school students in the terms of an interdisciplinarity project in the subject of mathematics.

At the beginning and end of the activity, two questionnaires were handed out to 72 students of the 1^{st} class of junior High School in order to explore their beliefs and attitudes towards Mathematics and Literature so that to determine the extent to which they have changed views. The procedure begun by practicing the operation of division and gradually the students discovered that there are two kinds of numbers, the prime and the non-prime numbers. Then they were engaged with an activity about the "Sieve of Eratosthenes" –a simple algorithm finding prime numbers. In the second task the students are asked to find a prime number between a given number and his double number –which is Bertrand's second conjecture and in the third and fourth task the participants were involved with Goldbach's conjectures. In the 5th task many questions arise as for the cardinality of prime numbers and the proof of their infinity by Euclid, using the method of contradiction. The activity also refers to Mersenne's and Fermat's prime numbers and finally to the applications of prime numbers, especially in the field of cryptography, as RSA asymmetric key encryption is based on them.

As a result, in the initial questionnaire, the majority of students answered that they enjoy keeping busy with mathematics at a percentage of 81%, they read literature at a percentage of 44% but 96% of them had never read mathematical fiction. In the second questionnaire, after the implementation of the task, the majority of students answered that the specific activity increased their awareness of the prime numbers (80%) and that mathematics had become more familiar to them. They also enjoyed the fact that the activity was carried out as a team and not individually. Collaborative activity was paramount in changing their attitudes towards mathematics and they all expressed interest for more activities of this kind (87%).

In the second research project, *Flatland* (2008) by Edwin Abbott, *Alice in Wonderland* by Lewis Carroll (2003) and *Metoikos and the Symmetry* (2012) by Tefkros Michailides consisted part of the study in the subject "Mathematics and Literature" taught in the Early Childhood Education Department in the University of Thessaly (academic year 2015-2016). The above mentioned texts are part of young adult literature and they are fictional. The young adult literature in this case plays a double role in the training of student-teachers. On the one hand, it is employed as a context for entering mathematical ideas in their social and historical backgrounds. On the other hand, it encourages the creative cooperation with other disciplinary fields in accordance to some guidelines of the reformed national curriculum framework creating a setting where mathematics can be discussed as part of the world (Ward, 2005, p. 134). One basic idea of designing activities was that students should become active beyond the traditional lecturing and task design and move into a critical mathematics stance (Skovsmose, 2014, 40). All these served into performing mathematics as part of a more complex perspective denoting and also challenging its wider significance and value.

Ten groups consisting of approximately two or three students each were set up for processing small scale research and activity design projects. All groups, excluding one, after having studied one of the above mentioned books, designed interdisciplinary activities which were either based on or inspired in interdisciplinary themes. All study groups planned their activities by making explicit specific learning goals based on the three above mentioned pieces of mathematical fiction by taking into account the curricular guidelines provided in the documentary of "Child and Mathematics" in the early years. The majority of study plans on interdisciplinary activities were submitted including modules such as "Children and Language" (47.2%), "Children and Creative Expression" (Art, Physical Education, 77.7%), "Children and Technology" (25%). The methods used included narration (36.1%), questions and answers (83.3%), discussion (63.8%), observation (27.7%), organized play (38.8%), dramatization (22.2%). Through all the planned interdisciplinary activities with the help of the specific works of mathematical fiction the goals of connecting mathematical fiction with the rest of the suggested learning units, have been achieved successfully. The design of these activities and tasks helped for the deepening of mathematical ideas in a creative way, which shows a potential for integration in a wider framework of relations and connections.

AS A WAY OF CONCLUSION

With the completion of the first task the students have reaped multiple benefits according to the questionnaires' outcomes. Learning has become more interesting and appealing and they all have adopted a more positive attitude towards mathematics. Apart from specific learning outcomes concerning the prime numbers and their divisibility, students are urged to indulge into the history of mathematics –the history that incorporates and reflects human thinking as part of society development. Moreover, the contemporary applications of mathematical sciences, at the peak of technology connect the field of mathematics with the current needs of humanity. Meanwhile, many questions about the role of mathematics in contemporary societies arise. We talk about economics-based societies, the economy recession and the dominant role that mathematics seems to play in this economic social, cultural and political reality.

Considering the part of the second project concerning activity and task development, it turned out that mathematical fiction functioned as a rich autonomous context, which can be interdisciplinarily implemented through its relation with the rest of the subject modules of the national curriculum [language, mathematics, personal and social development, physical education, arts, information and communication technologies and environment]. The flexibility and wholeness of mathematical fiction subjects triggered all these subject areas. The literary text worked as a cluster context with the potential of not only consolidating and developing mathematical thinking but also developing the rest of the subject related fields. Integrating mathematics in a fictionally social net of ideas –as it has been noted by the variety of tasks– mathematical fiction contributed to its function as coherent social notion and as a multi-dimensional experience, as well as, to its powerful conjunction with the related fields without isolating mathematics. Finally, through task design based on mathematical fiction the organization and setting up of a scenario –which is still in progress– we are examining the impact mathematical fiction has on children and student-teachers who are already motivated in doing mathematics and to what extent mathematical fiction might create a context for cultivating positive attitudes towards literature, as well as, reinforcing positive impacts on their personal and social development.

To sum up, mathematical fiction could be used as a rich context for the teaching of mathematics, but also for the teaching of literature. Literary texts resulting from activity and task design related to school curriculum guidelines have been explored in action. Research has shown that mathematical fiction can be a fertile ground for the development of activities regarding varied fields of knowledge. At the same time, it can function as an innovative space for interdisciplinarily work serving to make, but also to challenge, connections amongst wider societal goals of education and citizenship.

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DOING RESEARCH WITH TEACHERS: ETHICAL CONSIDERATIONS THAT SHAPED THE RESEARCHER STANCE

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This paper presents three research projects in Mathematics Education where ethically important moments raised ethical dilemmas that threated the success of them, along with the life of the researcher. The three research projects were conducted among minority and post-colonialist populations in which ethical dilemmas emerged and impacted the researcher stance.

COLLABORATIVE RESEARCH WITH TEACHERS

Doing research with teachers implies a shared collaboration. Deblois (2009) defines collaborative research as a shared construction between teachers and researchers that allows finding answers to important questions to them. Desgagné (2007) identifies three phases. The first phase is named the co-situation and allows teachers and researchers to define their roles and identify the goals for the project. They negotiate their engagement in this phase and plan out the project itself, including the resources needed (funding) and the collection of data. The second phase is the cooperation phase, where the action takes place, including the data collection. The third phase is the co-construction phase, which constitutes constructing new knowledge by analyzing the data collected. As a researcher doing research among minority and post-colonialist populations, I have been confronted to extreme situations while collaborating with teachers, where the project were compromised. I feel the need to revisit those challenges in order to reflect on my researcher stance.

THE RESEARCHER STANCE

There are different epistemological stances identified in the Mathematics Education literature: the former elementary school student stance, the university student stance, the teacher stance (DeBlois & Squalli, 2002; DeBlois, 2006; Savard 2014a), the former elementary school teacher stance, the teacher educator stance, the researcher stance (Savard, 2014b), and the educator-researcher stance (Bednarz & Proulx, 2010). An epistemological stance is not a psychological condition or an emotion: it is a dominant perspective adopted by an individual, depending of the context and the perceptions he or she has of her role. For instances, the researcher stance is influenced by the important responsibilities researchers have: design and carry out all steps of research projects, manage budget and resources, collect and analyse data, communicate the findings. In addition to that, doing research involves ethical considerations that are related to the researcher conduct and the respect for the subjects (Martineau, 2007). At this end, Guillemin & Gillam (2004) pointed out that two major dimensions of ethics: procedural ethics and ethics in practice. While procedural ethics is seen as the administrative process to get ethics approval from a relevant ethics committee, ethics in practice is related to difficult and unpredictable situations that arise in the doing of research: the ethically important moments. Those ethically important moments might conduct to an ethical dilemma, where the situation generates conflicting moral decisions to make, where each decision has obstacles that hind the course to pursue (Shapira-Lishchinsky, 2011). In this paper, I am interested to look at some moments in my career were some ethically important moments threated the success of my research projects by creating ethical dilemmas. I am wondering how those dilemmas influenced my researcher stance.

THREE DIFFERENT RESEARCH PROJECTS

The first research project was conducted in a circumpolar region in Canada, in an Inuit Community. The only way to get there is by plane and by ship, the latest one only available few weeks by year. The communities live very far to each other and the weather is so cold, that there is no tree up there. I went there few times, and I had to face many problems with transportation because of the bad weather. One time, my flight was not able to land, so we had to go in another community, where there were no facilitations available: taxi, restaurant, and hotel. With a weather of -36^{0} Celsius and no place to go, it was a very difficult situation to be in. In addition to that, I was supposed to be in school working with a teacher the morning after. My place on the next flight was uncertain and I didn't know how to solve this difficult situation. I had a short amount of time to work with the teacher, so each moment was very important. Another concern I had was about some tensions between these communities and white people. First Nations in Canada suffered badly from political decisions made in the past (such as residential schools), and it is somewhat hard to build relationships on trust. I wanted to position the Inuk teacher I worked with competently, but we had a different epistemology about mathematics, due to cultural differences. The fact that I have a white skin threated the success of the project, because I was seen as an outsider of the Community and a possible "colonialist". The different epistemology created confusion and misunderstanding about the vision and the goals of the research project, while the fact that I have white skin created a reaction among the grade 3 students: they positioned me as an expert because of my skin and talked about me in their community. Because it was a small community of 600 people, I was easily recognisable and other people told me about it. Parents talked with the teacher about the research project. She was on the spotlight with this project and at risk to lose the consideration of prominent members of the community.

The second research project was conducted in a middle town of an Atlantic province, where a linguistic minority live. I was housing on the university campus with my research assistant and 2 teachers who were living in two far cities. Two teachers were living in town. After the first day of work together, the plan was to continue for 2 more days. In the evening, a man shot policemen and then escaped in the surroundings woods, 3 km away from the university. The city was closed down: all public services were closed, along with the majority of stores. We were caught on the campus, with noting to eat. The two teachers had their car, but it was not ethical to ask them to drive us somewhere to get food. In addition to that, it was dangerous for the two other teachers to come joining us on the campus. It was thus impossible to conduct the research project as it was planned: we didn't know how long it would take to catch the armed man.

The third research project was conducted in an African country, where a civil war was still active in some regions. The country was and is still unsafe for people, especially for foreigners who are easily targeted by gangs. In fact, a gang attacked me when circulating in a car. Corruption ruled the society and money was hard to find for people living there. The cost of life was expensive and the poverty was everywhere. I was working in partnership with the government in research project funded by an international agency. Although the money was budgeted for food and resources, nothing was provided to teachers. They had to work all day long without any food or drink, any money for their transportation and any paper and pen. The success of the research project was compromised by the fact they were not working efficiently because of those conditions. I was not able to eat in front of them or to go at a restaurant and live them hungry: I fought for their rights (getting food and the money for transportation) ten days until they received what was promised. I considered myself part of the team and I everyday, I argued, bothered and threated many people at different levels in order to have my team correctly treated.

ETHICAL DILEMMAS

Table 1. Ethical dilemmas

Teachers' community	For the teachers	For the researcher	For the success of the research project
First Nation	Risk about her position in the community;	Security for her life;	Not the same vision of the project; not having enough time; the researcher life.
Language minority population	Security for their life;	Security for her life;	Not having enough time; changing the methodology; the researcher and the teachers' life.
An African country	Security for their well being;	Security for her life;	Not having enough time; the researcher life.

INFLUENCES ON THE RESEARCHER STANCE

The ethical dilemmas identified in Table 1 shed lights on the implications of the researcher, but also on the teacher collaborator(s) involved in the collaborative research projects. Although the ethically important moments were unpredictable in most of the cases, they forced the researcher to consider other aspects of the research project and the well being of the participants: it involves preserving human life. In fact, those moments bring ethical dilemmas toward the success of the research projects, because conducting the research project was the ultimate role of the researcher. Thus, the important responsibilities the researcher has are contextualized within his or her context, but also within the contexts where the collaborators and thus the communities live. It implies that the researcher stance was not just prominent while collecting the data: it was also active when traveling and visiting those communities. It is when making decision about ethically dilemmas that the researcher stance faces the biggest tensions: How to stay responsible toward the grant agencies and toward the collaborators involved in those research projects, while considering his or her own well being and safety? Thus, the researcher stance is not only oriented to his or her role in conducting research project, it is also oriented by being human.

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