Approaches to Educational Research Essay

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Research Question

Something I have always found of interest is why the cutting edge advancements in Mathematics seem to usually be achieved by Old World Europeans (i.e. including European Russia), and furthermore, that this apparent correlation has somehow not changed[1] to date despite the ongoing decline of European cultural and economic dominance in favour of firstly the United States and subsequently Asia during the past century (see Figure 1 for a population density weighted aggregate and Figure 2 for a temporal history of the awards of the International Medal for Outstanding Discoveries in Mathematics[2]). Moreover, as Figure 2 shows, in this metric the United States is in terminal decline – indeed, much of its historical performance in Fields Medals is associated with those born very near World War II (see Appendix A).

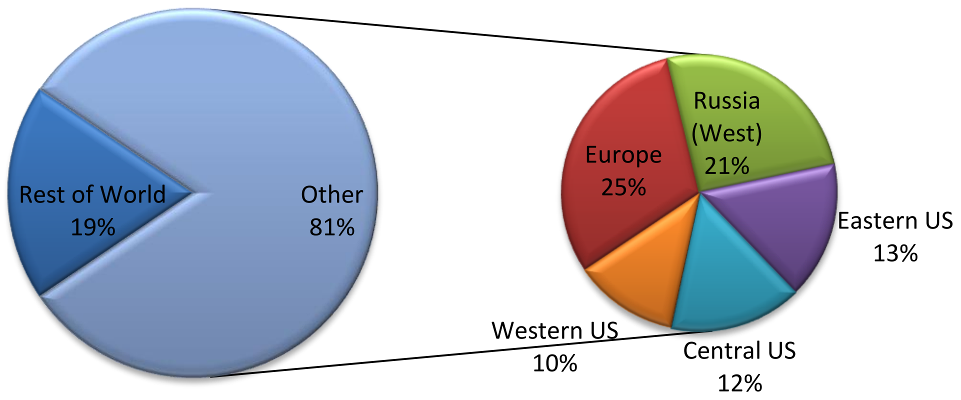

Figure 1: Fields Medals Awarded Classed By Macro-Regionality (with breakout adjusted for population density)

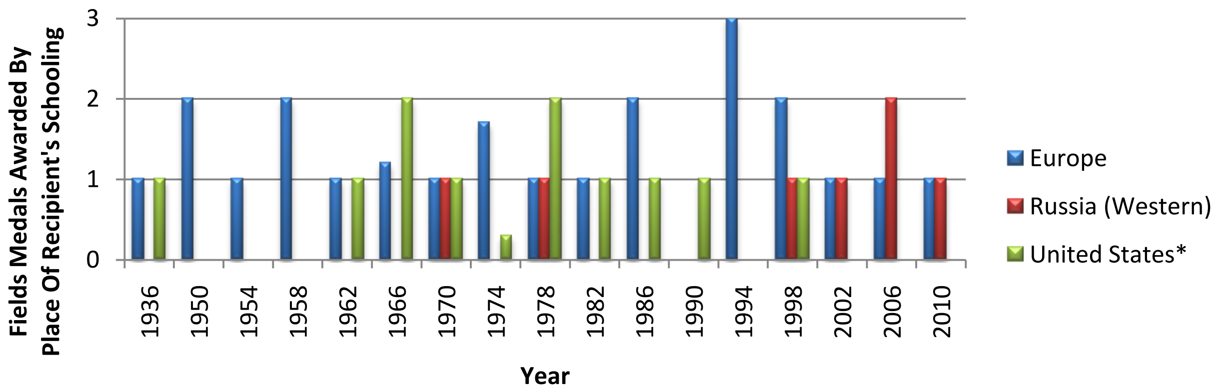

Figure 2: Fields Medals Awarded By Year

[1] To a statistically significant degree. Note that the average age of a Fields Medal recipient is 35.5 years, so these results necessarily lag present day reality by around thirty years.

[2] Better known as the Fields Medal; its recipients are chosen by the International Mathematical Union for having significantly advanced the state of the art in mathematics but with the major proviso that the recipient must be under the age of forty. Despite its low cash prize, this is generally considered the highest honour that a mathematician can receive.

Question: *is there something immanent to European patterns of thought and/or its structure of society which especially gives forth to advancing the cutting edge of mathematics?*

Literature Review

There is very ample and much cited literature studying clusters of excellence in information technology and biotechnology [1,2], which tend to be the most strongly associated with the knowledge economy[3]. While development in cutting edge mathematics is widely viewed as highly important to all cutting edge scientific advancement[4], there were only a few mentions in the literature of clusters of excellence regarding mathematics. For example, found only two authors in the literature to geographically assess Fields Medals. The first was Charlton [3,4,5,6] who used a combined metric[5] as a measure of "revolutionary science", but his study is unhelpful for determining clusters of excellence[6]. In contrast, May [7], publishing in *Science*, performs a very comprehensive summary of measures of revolutionary advances (mostly via citation counts) based on the biographies of their authors and concludes that when adjusted for population size, on average across all fields the United Kingdom was by far the most potent and consistent overall performer in the 20th century[7]. While not measuring mathematics exclusively, he did at least give some detail of the *sources* of clusters of excellence in science in general where advances in maths were one of many advances counted – however, in this focus on sources of excellence his paper was unique in my search, with nothing else comparable published since the 1970s.

Among other literature I found a seminal study by Scribner and Cole [8] of the Vai people in Liberia. This study compared the cognitive abilities of the Vai when illiterate and when literate in their writing or English. They found significant cognitive improvement[8] in those literate in English compared with a negligible difference of those literate in their writing and those illiterate[9], thus implying the routine frequency in European literacy of complex abstraction.

From where therefore do cutting edge developments in mathematics stem? As Figure 3 shows, there is clearly a cluster in France centred around Paris (and indeed the secondary school Lycée Louis-le-Grand)[10] and another in

[3] For example, this week's *The Economist* has MIT's President Susan Hockfield as saying "In the 20th century technological progress was driven by the convergence of engineering and physics, which yielded electronics. In the 21st century the hot area will be the convergence of engineering and biology, she predicts." [27, p. 14]

[4] Hence the many well funded cash prizes for achievements in maths e.g. the Fields Medal, the Abel Prize, the Millennium Prize etc.

[5] The metric combined the geography of awards in Nobel Prizes with Fields Medals, Lasker Awards (awarded for medical advances) and Turing Awards (awarded for computer science advances).

[6] He found that the United States is supremely dominant in all prize awards, but he counted the institution and country of the winner *at the time of the award*, **not** where the winning research was performed nor where the winner was born or educated. This obviously means that his results are a good measure of *where prize winners end up later in life* but little more.

[7] And that moreover, the UK consistently maintained approximately a 10% share of the global revolutionary science output.

[8] The tests included geometric sorting tasks, taxonomic categorisation tasks, memory tasks and syllogistic reasoning problems. The study was able to separate the effects of schooling from literacy among many other confounding factors and is generally considered since to be a pristine example of how to conduct empirical anthropology [29, p. 285].

[9] In other words, language literacy alone has little effect on cognitive function: it is what we do with that literacy is what matters e.g. do we use it to construct elaborate abstractions and if so, how frequently in common parlance.

[10] In order, the French Fields Medal winners were educated (childhood, university) at (Paris [Lycée Louis-le-Grand], École Normale Supérieure); (Nîmes, École Normale Supérieure); (Paris, École Normale Supérieure); (Paris, University of Nancy); (?, École Normale Supérieure); (Nancy, École Normale Supérieure); (Paris [Lycée Louis-le-Grand], École Normale Supérieure); (Versailles, École Normale Supérieure); (Paris [Lycée Louis-le-Grand], École Normale Supérieure).

European Russia centred around Moscow[11]. What features of these organisations' cultures discover, develop and direct gifted individuals towards making advancements in mathematics?

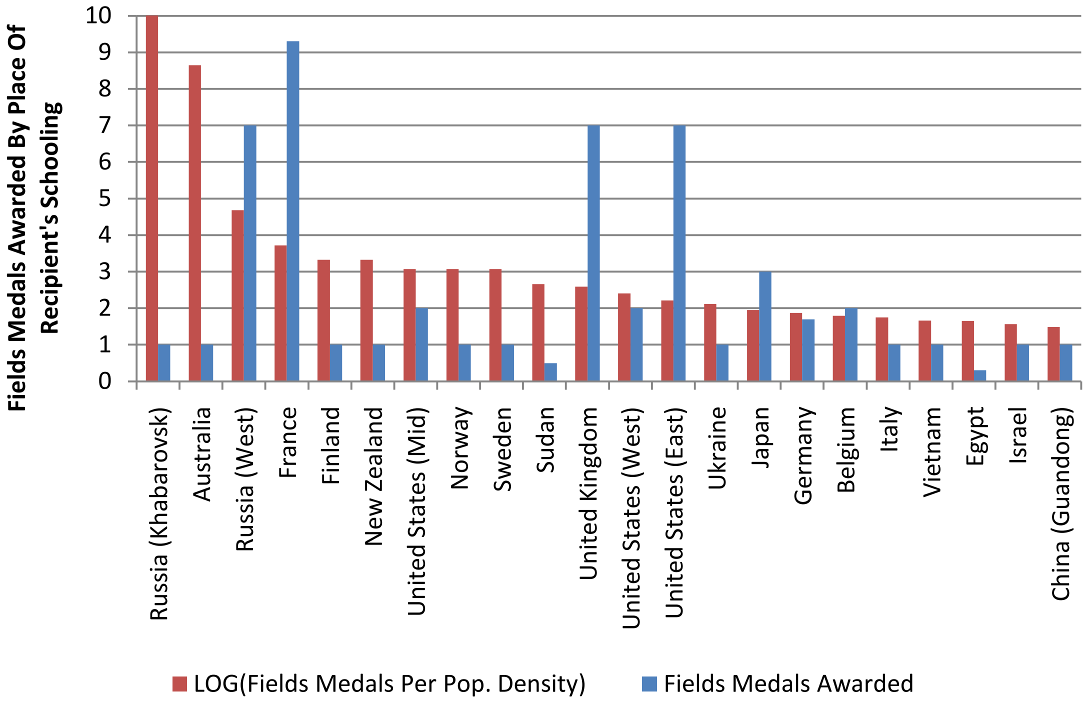

Figure 3: Number of Fields Medals Awarded By Place Of Recipient's Schooling[12]

Research Approach

Focusing on the first nine of the eleven stage naturalistic research planning process [9, p. 171-186]:

Stage 1: Locating field of study

Let us assume that we have funding for just one ethnographic study and that we are based in London. Studying the cluster in Paris is much cheaper to frequently reach than Moscow, so we would probably prefer that. Now ought we study the DMA-ENS[13] which is common to all but one of the nine winners, or the school *Lycée Louis-le-Grand* which is common to one third of the winners?

This choice as part of structuring, narrowing down and focusing the scope of subsequent enquiries ("progressive focusing" [10,11]) is a particularly difficult though necessary one. On the one hand, the DMA-ENS is the most common factor but its entrance requirements are so selective as to have already proven your mettle just by getting admitted – therefore I think defining the field primarily around the *lycée* stage (containing 800 students per year aged 15-18[14]) is likely the most worthwhile of study[15]. Secondarily, the field would include where the school's

[11] In order, the Russian Fields Medal winners were educated (childhood, university) at (Moscow, Moscow State University); (Ukraine [Karkov], Moscow State University); (Moscow, Moscow State University); (?, Moscow State University); (Moscow, Moscow State University); (Leningrad, Leningrad State University); (Leningrad, Leningrad State University).

[12] Note that the LOG(Fields Medals Per Pop. Density) has been scaled for clarity of display purposes such that the first item equals ten.

[13] *Département de mathématiques et applications de l'École Normale Supérieure.*

[14] Source: http://fr.wikipedia.org/wiki/Lycée_Louis-le-Grand. I could find no information about student numbers on the school's website or anywhere else.

[15] The *Lycée Louis-le-Grand*[15] combines a *lycée* (sixth-form college) and a *classes préparatoires* for entry into the ENS which are two years of specialised cramming for the ENS entrance exams. Given that the *classes préparatoires* would likely be perceived by

boundary interfaces with the DMA-ENS and where it interfaces with how and why the mathematically gifted students decided to attend.

One would, of course, do considerable desk research before beginning in order to be fully knowledgeable of the structure of the French education system as well as French mathematical community. This would facilitate the *ad hoc* inquiry sampling typical of ethnographic study [9, p. 175].

Stage 2: Ethical issues

I do not foresee much difficulty here: firstly, without informed consent [9, p. 174] one would not be allowed access to such a highly esteemed institution. Secondly, there would be likely little gain from covert research given the sophistication of staff – perhaps the only difficulty would be the school's particular interest in the results such that they could either use them for marketing and/or as a tool for internal reorganisation which could introduce reluctance on the part of staff members whom may fear the consequences of being too open. There is the concern, however, that the school would be extremely unlikely to permit the research without having a veto on data used.

Stage 3: Sampling

I would semi-structure interviews on these bases: ownership (who owns success and failure), identity (roles with regard to the school), ideology (a set of ideas and their underpinning logic which inform the organisation [12, p. 122]). I would look especially for (with regard to maths):

1. Intersubjective negotiation (how is meaning evolved).
2. Alienation (is the student driven too hard? Does the student dislike having to do subjects other than maths? Does the parent feel they are kept away from the education of their child?)
3. Power relations (how much might the student like maths because they are told to like them? Is the student coerced into adhering to the school's culture? Is a Foucauldian panopticon [13] symbolically enforced within the school as a method of observation and normalisation to the organisation's *esprit de corps*?)
4. Cultural tools (what symbolic devices are used to support the learning of maths)
5. To what extent math students and teachers are individually-contained self (independent entities with mostly fixed qualities) vs. relational self (continually self-constructs through relationships with others) [14, p. 114]. Also, what happened when things went wrong and how did the organisation react?

Stage 4: Managing entry

One ought to start with a series of exploratory interviews with leaders primarily within the *lycée* as well as secondarily the DMA-ENS. One would hope to concurrently get a tour of the school and university maths department in order to gain an overview of its internal processes and structure.

Stage 5 & 6: Informants

These should be easy to identify in such a small organisation: the mathematics teachers, and perhaps someone well connected in the DMA-ENS looking in from outside are the obvious candidates.

Stages 7 & 8: Data collection

Conduct a series of semi-structured interviews with high potential students as earlier identified by the informants. Also conduct a series of semi-structured interviews with the parents of students interviewed earlier as well as students and teachers at the DMA-ENS. If the school has kept sufficient data, see if there might be patterns in the records related to past Fields Medal winners – use these to refine structure for a second round of more selective and

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both students and teachers as a Leont'ev type activity system [28] incorporating the ENS – i.e. a group which defines and orientates itself around the achievement of a common goal, hence those within the *classes préparatoires* would surely define their boundary as including the ENS. Hence, of these two options, the *lycée* looks a more productive choice, not least that the free time of the students would be less constrained.

deeper interviews which may be used to form case studies. Also, observation of classes; review of marking schemes of exam papers; sociogramming students and teachers.

Stage 9: Analysis

Organisational culture is tricky to analyse: a common method is discourse analysis which hopes to reveal recurrent patterns of activity which embody rules, precepts and orders/understandings ("social practices") – Schatzki's "nexus of doings and sayings" [15]. As advanced by Schatzki [15], Garfinkel [16], Bourdieu [17] and Giddens [18], a particular social order is established and propagated when communities reproduce particular social practices which are both signifiers and signified meanings generating a "teleoaffective structure" (what makes sense to do beyond particular understandings or rules) inimical to that community – in other words, they are an aspect of its organisational culture.

Obviously I, as the researcher coming in from outside, would surely perceive things somewhat or even very differently to those within the organisation (the "emic/etic" dichotomy [19]): where they see a benign teleoaffective structure, I might see an artefact of an insipid symbolic violence embedding false consciousness as part of inculcating a Bourdieuian "paradox of doxa" [20, p. 1-2] into the next generation as attendance at the school at all is clearly about acquiring superior cultural capital and its subsequent privilege to be supported by the state (as a civil servant of some form) which is really a form of justifying parasitisation. If one were perceived to be thinking such things during interviews, it would surely have a reflexive consequence upon the data gathered e.g. if an interviewee became upset with the tone of the questions, or indeed if one's presuppositions caused the interviewee to supply substantiating data which biases the outcome.

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Appendix A: Data for Fields Medal Winners

Source for winners: http://en.wikipedia.org/wiki/Fields_medal. Birth years and schooling history retrieved from Wikipedia article for each medal winner.

Weights were assigned as follows: 0.5 for schooling 0-10 (primary), 0.3 for schooling 11-15 (early secondary), 0.2 for schooling 16-18 (late secondary).

Sources for population densities: http://en.wikipedia.org/wiki/List_of_U.S._states_by_population_density, http://en.wikipedia.org/wiki/European_Union_statistics, http://en.wikipedia.org/wiki/European_Russia, http://en.wikipedia.org/wiki/List_of_sovereign_states_and_dependent_territories_by_population_density.

Year	Name	Birth year	Age	Weight	School Nationality	Latitude	Longitude	Population Density (people/km^2)	Adj. Weight
1936	Lars Valerian Ahlfors	1907	29	1	Finland	60.169812	24.93824	16	62.50
1936	Jesse Douglas	1897	39	1	United States (New York)	40.058324	-74.405661	159.8	6.26
1950	Laurent Schwartz	1915	35	1	France	48.856667	2.350987	111	9.01
1950	Atle Selberg	1917	33	1	Norway	59.912726	10.746092	20	50.00
1954	Kunihiko Kodaira	1915	39	1	Japan	35.689488	139.691706	336	2.98
1954	Jean-Pierre Serre	1926	28	1	France	48.856667	2.350987	111	9.01
1958	Klaus Roth	1925	33	1	United Kingdom	51.500152	-0.126236	246	4.07
1958	René Thom	1923	35	1	France	48.856667	2.350987	111	9.01
1962	Lars Hörmander	1931	31	1	Sweden	59.332788	18.064488	20	50.00
1962	John Milnor	1931	31	1	United States (New Jersey)	40.058324	-74.405661	453.3	2.21
1966	Paul Cohen	1934	32	1	United States (New Jersey)	40.058324	-74.405661	453.3	2.21
1966	Alexander Grothendieck	1928	38	0.5	Germany	52.523405	13.4114	231	2.16
				0.5	France	48.856667	2.350987	111	4.50
1966	Michael Atiyah	1929	37	0.5	Sudan	15.550101	32.532241	16	31.25
				0.3	Egypt	30.064742	31.249509	79	3.80
				0.2	United Kingdom	51.500152	-0.126236	246	0.81
1966	Stephen Smale	1930	36	1	United States (Michigan)	44.314844	-85.602364	67.77	14.76
1970	Alan Baker	1939	31	1	United Kingdom	51.500152	-0.126236	246	4.07
1970	Heisuke Hironaka	1931	39	1	Japan	35.689488	139.691706	336	2.98
1970	Sergei Novikov	1938	32	1	Russia (Western)	55.755786	37.617633	50	20.00
1970	John G. Thompson	1932	38	1	United States (Kansas)	39.011902	-98.484246	13.3	75.19
1974	Enrico Bombieri	1940	34	1	Italy	41.895466	12.482324	195	5.13
1974	David Mumford	1937	37	0.7	United Kingdom	51.500152	-0.126236	246	2.85
				0.3	United States	40.058324	-74.405661	159.8	1.88
1978	Pierre Deligne	1944	34	1	Belgium	50.8503	4.35171	344	2.91
1978	Charles Fefferman	1949	29	1	United States (Maryland)	39.045755	-76.641271	225.1	4.44

1978	Grigory Margulis	1946	32	1	Russia (Western)	55.755786	37.617633	50	20.00
1978	Daniel Quillen	1940	38	1	United States (New Jersey)	40.058324	-74.405661	453.3	2.21
1982	Alain Connes	1947	35	1	France	48.856667	2.350987	111	9.01
1982	William Thurston	1946	36	1	United States (Washington D.C.)	39.045755	-76.641271	159.8	6.26
1982	Shing-Tung Yau	1949	33	1	China (Guandong)	6.742645	13.952637	486	2.06
1986	Simon Donaldson	1957	29	1	United Kingdom	51.500152	-0.126236	246	4.07
1986	Gerd Faltings	1954	32	1	Germany	52.523405	13.4114	231	4.33
1986	Michael Freedman	1951	35	1	United States (California)	36.778261	-119.417932	91.5	10.93
1990	Vladimir Drinfel'd	1954	36	1	Ukraine	4.659589	13.952637	78	12.82
1990	Vaughan Jones	1952	38	1	New Zealand	-36.84846	174.763332	16	62.50
1990	Shigefumi Mori	1951	39	1	Japan	35.689488	139.691706	336	2.98
1990	Edward Witten	1951	39	1	United States (Maryland)	39.045755	-76.641271	225.1	4.44
1994	Jean Bourgain	1954	40	1	Belgium	50.8503	4.35171	344	2.91
1994	Pierre-Louis Lions	1956	38	1	France	48.856667	2.350987	111	9.01
1994	Jean-Christophe Yoccoz	1957	37	1	France	48.856667	2.350987	111	9.01
1994	Efim Zelmanov	1955	39	1	Russia (Khabarovsk)	77.307784	223.242188	2.5	400.00
1998	Richard Borcherds	1959	39	1	United Kingdom	51.500152	-0.126236	246	4.07
1998	Timothy Gowers	1963	35	1	United Kingdom	51.500152	-0.126236	246	4.07
1998	Maxim Kontsevich	1964	34	1	Russia (Western)	55.755786	37.617633	50	20.00
1998	Curtis T. McMullen	1958	40	1	United States (California)	36.778261	-119.417932	91.5	10.93
2002	Laurent Lafforgue	1966	36	1	France	48.856667	2.350987	111	9.01
2002	Vladimir Voevodsky	1966	36	1	Russia (Western)	55.755786	37.617633	50	20.00
2006	Andrei Okounkov	1969	37	1	Russia (Western)	55.755786	37.617633	50	20.00
2006	Grigori Perelman	1966	40	1	Russia (Western)	55.755786	37.617633	50	20.00
2006	Terence Tao	1975	31	1	Australia	-33.859972	151.211111	2.9	344.83
2006	Wendelin Werner	1968	38	0.2	Germany	52.523405	13.4114	231	0.87
				0.8	France	48.856667	2.350987	111	7.21
2010	Elon Lindenstrauss	1970	40	1	Israel	32.059925	34.785126	365	2.74
2010	Ngô Bảo Châu	1972	38	1	Vietnam	21.033333	105.85	259	3.86
2010	Stanislav Smirnov	1970	40	1	Russia (Western)	55.755786	37.617633	50	20.00
2010	Cédric Villani	1973	37	1	France	48.856667	2.350987	111	9.01

Note how for the US winners they are clustered together with a mean birth year of 1938. Removing the outliers (the first and last items), one gets a mean of 1940±5.84@95% C.I. which is approximately 1934-1946. The fact that this period immediately precedes and lasts for the duration of World War II is surely significant – but why I cannot tell from the data available to me.

Appendix B: World Population Density

Source: http://commons.wikimedia.org/wiki/File:World_population_density_1994.png