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Towards a social studies of mathematics: numeracy and actor-network theory

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Introduction

Theoretical developments in numeracy which have been described in many of the other chapters of this book express the interests of researchers in understanding the practice and learning of mathematics in the context of people's everyday lives, and the use of numeracy as a critical social tool. These interests are related – if numeracy is a critical social tool, then we need to understand how people's identities and life options are shaped by mathematics. In this chapter I report briefly on a work in progress on why we may benefit from a 'social studies' of mathematics in order to make sense of a 'strong' definition of numeracy that incorporates possibilities of social action. What I mean by the latter is a numeracy that focuses not only on the mathematical learning and practices of individuals within their own communities of practice, but also on the broader social shaping of these practices. Most importantly it is numeracy that focuses on possibilities for people to transgress the boundaries of their local communities of practice and that disturbs existing relationships of power which may be working to limit their lives. This is an ambitious project but one that I am keenly interested in. Working with engineers in part of my work, I am aware of tensions between expert and lay knowledge, especially when it involves decisions about risks and the introduction of new technologies, and how expert knowledge often plays a dominant role over people's local knowledge in shaping their lives and practices.

Actor-network Theory (ANT) is a possible analytical framework for a social studies of mathematics. ANT can offer a way of analysing the interactions between groups of people, their mathematical practices, and their broader socio-political interests, and consequently identify possible points of intervention which may lead to shifts of power, enabling particular interests to gain greater power. ANT, normally attributed to Bruno Latour and John Law (1999) and Michel Callon (1995) has been the subject of much interest, criticism and reflection over the last decade and a half since it first came into being. It is not possible to give a definitive story of what ANT is about; however, I will attempt in the following section to

outline the reason for a social studies of mathematics, and then what ANT may be able to contribute in a project such as that which I have identified above. I will then try to illustrate the possibilities of ANT through two case studies. This work is part of a larger project I am pursuing with Ole Skovsmose (2002) in developing ways of thinking about a sociology of mathematics.

Why a social studies of mathematics?

Both the philosophies of science and mathematics have engaged in debates about their respective bodies of knowledge being a social construction. In mathematics education, the thesis of the social construction of mathematics has been a crucial one in arguing a constructivist framework for understanding and designing the learning of mathematics (Ernest 1991). The constructivist view of mathematics also supports an interest in numeracy as social practices. The 'social construction of mathematics' therefore has helped to provoke new research foci for understanding mathematics in people's lives, and different teaching and learning practices in mathematics education. What this view of mathematics in itself does not and can not do is to identify ways in which to disturb the social and political structures that maintain the trust and power that are enshrined in certain mathematical claims, or decisions or technological systems resulting from certain mathematical models. Many numeracy theorists have talked about critical numeracy [see for example Johnston 1995; Webber 1987/88; and Yasukawa 1995 in this publication, Ed.] but they have mainly talked about the importance of examining mathematically or statistically based claims or processes with a questioning stance – who says; have they considered x, y and z; what other interpretations can be made of these data; what does this mean for x, y and z; whose interests do they represent?

From a social justice perspective, numeracy has to go beyond recognising injustices and vested interests in the ways in which mathematics is used and practised in society. But to go beyond a critical deconstruction of mathematical claims and processes, one has to examine more closely the other social factors which have shaped these claims and processes, and the dynamics which help to maintain the power vested in different interest groups. If mathematics is to be understood in social contexts, then it is not sufficient to study what the mathematics means, and how it may impact on people; that is, a view of mathematics as a cause of social effects does not give us a full understanding of the relationship between mathematics and society. We need to understand how it is being shaped and in doing so, how it can be reshaped.

I have argued previously (1998; 2001) that mathematical theories and models can be considered to be examples of technologies. Like technical artifacts, they are designed with a purpose – to describe, sometimes predict, and in some cases take control over natural and human-made processes and phenomena. This view of mathematics as a technology, or as part of larger technological systems shifts the focus from that of mathematics simply acting or impacting on society, to that of mathematics acting within and through other elements within a socio-technical system. This then provides a reason to look at theoretical developments in the social studies of science and technology for ideas on how we can better understand the relationship between the social and mathematics within a larger socio-technical system, and what are the 'right' questions to be asking about this relationship.

What is ANT?

> ... there are four things that do not work with actor-network theory; the word actor, the word network, the word theory and the hyphen! Four nails in the coffin. (Latour 1999: 16)

This quote reflects the degree of confusion, frustration and struggle people who have tried to engage with ANT have experienced. ANT represents one of the developments in the social studies of science and technology which have emerged out of the initial claim of science and technology being social constructions. Related theoretical developments include Bijker and Pinch's social construction of technology (Bijker 1995; Pinch and Bijker 1987) and Hughes' theory of the evolution of socio-technical systems (1987). These theories and ANT shifted the gaze on science and technology from their impacts on society to their shaping by society, but remember that that shaping is two-way.

Crucial to the understanding (and misunderstanding) of ANT is the word network. According to Latour (1999), one has to go back to its original intended meaning to understand its use in the naming of the theory. The word network was intended to mean 'a series of transformations – translations, transductions' (Latour 1999: 16). ANT focuses on how the different goals and interests of different groups of people, as well as the intended purposes of non-human actors such as technological artifacts are transformed through the chains of relations which form between these human and non-human actors. Through the dynamics of new relationships, people's goals and interests, as well as the goals of an innovation can form alignments and the chain of aligned interests can be extended until it converges into a system with stable interconnections formed for some common purpose. ANT thus focuses on the dynamics of how networks diverge from existing systems and converge into new systems of relationships, and how the interests of the actors within the network are transformed through the dynamics of the interactions.

In the terminology of ANT, actors include not only the people involved in a process of technological development, but also material artifacts and elements such as the law, the market, and environmental constraints – and in relation to our concern, mathematical theorems and claims which the people have to interact with in this process. Actor-network theorists would say that ignoring the non-human actors, would lead to an asymmetrical theory that ignores one dimension of the mutual constitutiveness of technology and social relations (MacKenzie and Wajcman 1999). By following and examining the chains of translations in a network, ANT seeks to explain local phenomena and concerns in relation to global phenomena and concerns.

The theory originally arose in the social studies of science and technology. It has been used to explain, for example, how the intended goal and the artifact associated with a particular technological innovation might be transformed into something quite different from conception to widespread adoption in society. The transformations arise out of complex interactions between the innovator(s), users, producers and manufacturers, consumers, as well as regulators and legislators, existing technologies and practices. These may all have a part in shaping the trajectory of the development of a new technology. ANT focuses on the interactions and the translations of goals, and less on the technical or other merits of the 'end product' and its impact. For example, in his book *Aramis* or the *Love of Technology* (1996), Latour conducts a sociological investigation of the failure of 'a technologically superb but also politically impeccable' (ix) automated transport system project, involving extensive examination of documents and interviews with different actors in the project.

ANT provides an analytical framework for understanding the emergence of new technological (and other) systems. The stages of development of the system, according to this theory are:

1. the problematization stage, where a point of intervention or a problem is identified, and the various actors needed to enable the problem are identified;
2. the interessement stage, where existing relations between human groups and between human groups and existing technologies start to be replaced by new relations which are seen to be needed for the solution of the problem, that is persuading groups to align their interests with those who have identified the problem;
3. enrolment stage, where the interests of the actors within the network are aligned; and
4. mobilisation stage, where the network has achieved a certain level of stability and irreversibility (Latour 1987).

A term that occurs in the ANT literature is inscription. When a network reaches a state of irreversibility, a new practice or knowledge is 'inscribed', that is it becomes part and parcel of the ways in which actors in the network operate. For example, while probability theory in its early formulations in the 17th century was treated with suspicion, probabilistic thinking is now 'inscribed' as a way of assessing risks and other statistics. Bloomfield (1991) describes a process in the health sector in the UK where the introduction of a new management software served to inscribe a new set of medical practice ethic among the doctors, dictated more by efficiency rather than quality of patient care.

Another concept that is used in ANT is that of boundary objects or mediators that 'enable [diverse] translation networks to coexist peacefully ..., and serve to link disjointed networks without necessarily fusing them into one' (Callon 1995: 59). If ANT is seen as a resource for transgression and shifting existing power relations, a focus on these boundary objects or mediators can provide a key as will be suggested in the examples provided in the next section.

I offer a proposition that if we were to take a radical (or extremist?) view that being numerate means not just having a critical understanding of mathematics, but using that understanding for some form of social action; a framework such as

ANT is a resource for numeracy. ANT allows us to focus on how existing interests are translated into something different as a result of interactions across a network of human and non-human actors, including mathematics.

Case studies of an actor-network theoretic study of mathematics

Workload formula in academia

Example 1: The first example of using actor-network theory to understand a relationship between mathematics and society is located in academia. It is about the relationship between academics, their work practices, and workload formulae.

Up until the last decade or so in the Australian higher education sector, formal regulation of academic workload was something that was resisted. However, government funding per student decreased during this period, and workload increasingly became an issue for academic staff. As a result, the academics' union which in the past resisted prescriptive measures of academic workload started to reconsider its position on this matter. For other reasons, university management also started to take an interest in codifying workload.

Staff salaries and conditions in Australian universities are negotiated locally at each university between the local branch of the academics' union and the university management through the process of enterprise bargaining, approximately every three years. During the last round of enterprise bargaining, many universities negotiated a workload clause in their enterprise agreements (see for example the Enterprise Agreements which can be accessed from the union's web site http://www.nteu.org.au). Many of these clauses required individual academic units to develop a workload policy or formula to be applied in the area, and they outlined general principles such as the need for transparent, equitable and reasonable workload allocation systems.

One of the reasons why, despite common perceptions of inequity in workload allocation, academics and their unions have resisted prescriptive and legally enforceable mechanisms of workload allocation, is the nature of academic work itself. Academic work is diverse in nature, and difficult to quantify. Part of the nature of academic work is the self-management that is required in terms of prioritisation of time and energy that goes into teaching, research, administration and other aspects of the work. Some academics would spend a greater proportion of their time in the preparation of their teaching material than on writing papers for publication; while others would allocate more of their energy on research than teaching. Even for the same academic, their focus could shift at different points in their career.

A workload formula that is intended to be transparent, equitable and reasonable serves different interests. It not only introduces parameters which give measures, however crudely, for the time that academics should be spending on different types of activities but for union members, its primary purpose is to prevent the need to overwork and to ensure that people are treated fairly. For the university, the goal, in a climate of decreasing funding, is to ensure that (human) resources are spent efficiently. This creates a tension for both parties, and the enterprise agreement acts as a boundary object or mediator that can and is used by each of

the parties to shift the balance of power towards themselves. While a document like an enterprise agreement which is legally binding can be assumed to be unambiguous, each party to the agreement can use their interpretation of the wording of the clause to argue their case – words such as equitable, reasonable and transparent can mean different things to different people, depending on what they want it to mean.

With a mediating instrument such as an enterprise agreement, in a climate of diminishing resources, the parties can agree to limit the number of hours that should be spent on different types of activities - for example preparation of lectures or assessment of students' work. While the goal of such a decision may be, on the surface, to contain an academic's workload, it can also serve to inscribe new practices and ethos. An academic who may have been inclined to spend, say half an hour reading and commenting on a particular student essay, may be given recognition for only a quarter of an hour for that same task according to the formula. The academic is then faced with the dilemma of their academic practice being shaped by economic imperatives or maintaining their own academic practice without given recognition for the above load hours that they put into their work.

In the above example, we see a situation where the interests of academic staff, their unions and university management are being mediated by a legal document in the form of an enterprise agreement. The implementation of a clause in the enterprise agreement produces a mathematical artifact in the form of a workload formula. This presents a means for each of the parties to pursue their own interests; if one actor succeeds, then this could have the effect of translating the goals of other actors with competing interests and goals. And the mathematical artifact can be used by the actors to inscribe new forms of academic work practices in their area.

In considering possibilities of intervention, say to resist the inscription for an economically driven academic practice, one could consider manipulating the workload formula to achieve better outcomes. In order to do this, one would have to have a mathematical understanding of the formula, and also have the mathematical skills to derive a new formula that achieves the desired outcomes. This approach, however, means that academics accept their work being defined by a formula, rather than by their individual or even collectively determined values and beliefs about their work. In order to shift the power away from a mathematically prescribed practice, there is a need to find other points or avenues for intervention, for example, in the processes whereby the workload policy is determined. This requires not so much mathematical knowledge and skills, but political knowledge and skills that are needed to translate the formula-driven goals of the management into something that aligns more comfortably with the values and ethos of academics' own practices.

Socialisation of number theory

The second example is about the social construction of mathematics as a technology of trust. It is a study of the 'socialisation of number theory' (Skovsmose and Yasukawa 2002).

The Cambridge mathematician GH Hardy (1967: 121) maintained that the mathematical field of number theory was one area that would remain 'gentle and clean' from any real world applications (and therefore was a more serious area of mathematics than some others which were appropriated by engineers and other users of mathematics). However, one of the turning points in the area of Internet security in the late 1970s came about as a result of people making connections between classical results of number theory, and a seemingly unsolveable problem with existing methods of encryption – keeping confidential information secure by encrypting them in secret codes.

In this case, a mathematical result which remained 'gentle and clean' from contamination by earthly concerns became enrolled into an actor-network along with computer technologies, including the internet, in order to solve looming problems for businesses and other groups who needed mechanisms of transmitting information through computer networks securely. The goal that Hardy had of keeping number theory 'gentle and clean' failed when some of the key results gave birth to algorithms which came to be known as public-key encryption systems. Through the use of public-key encryption, people could exchange confidential information over computer networks including the internet with less fear of interception and unauthorised disclosure of the information. The mathematics embedded in the algorithm became the core of the trust invested by the people exchanging encrypted messages. However, the mathematics itself was invisible to the people using the encryption package. The number theoretic results which was the basis of people's trust was packaged in a complex software package (Skovsmose and Yasukawa 2002).

What was translated from a symbol of purity and innocence to a critical player in electronic commerce later also got translated into a source of political tension between of political activists in third world countries and the US government. The same algorithm which became an indispensable tool for commerce, also became available, by virtue of the openness of the Internet environment, to political activists throughout the world. Phil Zimmerman (1996), who produced and released a public-key encryption software known as PGP (Pretty Good Privacy) reported on the use of PGP by social activists who used it to organise and exchange vital information. This in turn was perceived by the US government as a political threat, and a 'weapon' for terrorists, leading to attempts to restrict the dissemination of public-key encryption packages (without success). Neither the activists nor the law enforcers in the US would have understood the mathematical basis of PGP; however, for the activists, the mathematics underpinning PGP provided them with means of organising social movements, and for the law enforcers, a source of threat to their control over political activities and dissemination of information. For one, number theory was a tool for political freedom; for the other a threat to authority. Neither reflects the original vision of purity and innocence held by number theorists such as GH Hardy.

We see in the above example, how mathematical actors are transformed through and within a larger technological artifact as a result of the different uses of the technology, determined by the interests of the different users. In this case, the victory of the third world social activists over the US government restrictions

came as a result of the openness of the world wide web environment, and the inability of even the US government to fully control the information that is made available through the web. Although it is the mathematical basis of the algorithm that is key to securing the confidential transmission of the information, it has been the nature of the environment that has been the critical player in giving access to this critical tool.

Implications for numeracy

I have tried to examine actor-network theory as a resource for a critical numeracy that looks beyond the technical mathematical details and its claims and impacts. I have argued that ANT provides us with a way of studying the mutual shaping of society and mathematics, while at the same time, helping us to identify points of intervention that may help to disturb the ways in which people's lives and practices are shaped by mathematics. These points of intervention may not necessarily require us to exercise mathematical knowledge and skills; they may require political, legal or other knowledge and skills. By understanding the dynamics of the mutual shaping of mathematics and social practices by legal, political, cultural, environmental and other actors, possibilities of disturbing the power relationships at a global level between institutions and groups, rather than at a local level between competing individuals may emerge. ANT also helps us to observe the formation and possible shifting of people's mathematical practices. While it is important to understand the historical origins and the local 'logic' of people's mathematical practices, it is also useful to be able to recognise how new practices can emerge and lead to greater empowerment of those same people. By understanding processes of inscription of practices, we are able to consider the possibilities of shifting practices to meet desired goals.

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CONTENTS

INTRODUCTION

The authors and work included in this collection represent key directions in the development of adult numeracy research and practice in Australia over the last fifteen years. The publication can be seen from a number of perspectives: as an historical snapshot of the development of adult numeracy research in Australia; as a celebration of the impacts that the relatively small community of numeracy researchers and practitioners in Australia have made both locally and internationally; as a resource for new researchers; and, as a window into emerging research.

Adult numeracy research in Australia has been shaped by influences from a number of different directions. It owes a substantial debt to mathematics education, to theories about literacy and more widely to the field of adult education. Johnston (2003), traces some historical and policy aspects of the landscape of adult numeracy in the opening paper. Adult numeracy itself began in adult education in the early 1980s as a catching up on what had not been done at school. It was remedial maths, where the maths was the same but where the teaching recognised that adult learning is in some important ways different from school learning. Gradually numeracy education began to incorporate newer ideas from maths education in schools as that changed too, and teachers began to understand and trial the idea that although there was a place for transmission teaching, people might learn better if in some way they could construct and own the learning (Ernest 1991). The concept of numeracy, in the schools context, was brought well and truly to the fore in Sue Willis' 1990 collection, *Being numerate: what counts?* The book marked the beginning of a theoretical discussion about the nature and practice of numeracy in schools (eg. Willis 1998, Hogan et al 1998), parallel to the conversations being engaged in simultaneously in the adult sphere.

In the early 1990s we began to see the importance of articulating more clearly the idea of numeracy in context. Because of the close relationship between the adult literacy and adult numeracy fields, much of this move to thinking about numeracy as mathematics in context came from thinking about context specific language use, and systemic functional linguistics. Theories of situated cognition (Lave & Wenger 1991), of literacy as social practice (Scribner and Cole 1981; Brice-Heath 1983), and social practice theory (Connell 1987) also influenced research into the numeracy practices of adults. The article by Kelly and colleagues, reviews the research base of numeracy as social practice, drawing parallels with theoretical concepts of literacy, while the articles by Helme, Bishop, Lukin, and Lee and her colleagues address its sometimes problematic implications for practice. The Garth Boomer text is included for historical reasons. Boomer was an influential schools curriculum innovator whose specialism was English and his address to maths teachers is of particular interest as he was asking provocative questions about contextualising maths teaching and drawing parallels with English, well before this challenge was taken up by most mainstream maths teachers.

Understanding numeracy as mathematics in context was part of a move towards appreciating numeracy as a critical social resource that draws on mathematics not only to interpret but also to question and challenge the existing social order – a move that was clearly influenced by developments in the area of critical literacy. Articles by Barnes, Johnston (1995), Webber (1987/98) and Yasukawa (1995), take up this issue of the 'critical' aspect of numeracy, while the work of Baynham and colleagues, Brew, Deakin, Marr, and Zevenbergen examine the role of language in understanding maths, the sorts of mathematics that people actually use and how they construct themselves in relation to maths. All the surrounding theoretical territories that these issues occupy have enriched the debates that are informing numeracy.

Perhaps because of the generous funding given to provision and professional development in adult numeracy in the early to mid 1990s, pedagogy, policy and practice have intersected closely with the research developments described above. Some of the pedagogical practices that developed from these research interests are described in the texts of Allan, Baynham, Dziedzic, Marr, McRae, Webber (1998). FitzSimons critiques the practices and professional development needs of maths teachers in the Vocational Education and Training (VET) sector while Chapman and Pyvis make a valuable analysis of the maths requirements of Tertiary and Further Education (TAFE) students wishing to articulate to university. In a workplace context Buckingham's paper demonstrates the nexus between power relations and the levels of training offered to workers.

Before the establishment of the international research forum Adults Learning Mathematics (ALM) in 1994, there was little international cooperation or awareness of what other countries were doing. Using the international adult literacy surveys (IALS, mid 1990s), Cumming sketches a picture of Australia's place in terms of numeracy as a set of skills, using test results to tell us that we are somewhere near the middle of the industrialised countries included in the surveys. With the growth of ALM, Australian researchers and practitioners have been actively involved in international events and have received international recognition for their work, particularly in the field of professional development. The article by Johnston, Marr and Tout describes a major professional development project which was influenced by a contextualised and critical approach to numeracy, and which in turn influenced further research. Australians have been key-note speakers at international conferences, guest facilitators at professional development summer schools, contributors to international handbooks, newsletter editors, journal editors, members of the Adult Literacy and Life-skills (ALL) numeracy assessment committee, participants in international research teams and book editors. Tout reports on his involvement with the ALL project, describing the process of developing the numeracy framework for this project. Just 10 years ago it would have been almost impossible to find any book at all on adult numeracy: in the last 3 years at least four have been published (Coben et al 2000; Evans 2001; FitzSimons et al 2001; Gal 2000), and we are now offering a fifth.

The collection has been arranged into three broad categories. In Part One, Theories and Frameworks, the authors theorise the notion of numeracy as social practice from a number of perspectives; in Part Two, Needs and Practices, the authors report on measures of numeracy skill in the community and examine people's actual numeracy practices in a variety of contexts; and Part Three, Learning, Teaching and Professsional Development, provides insights into classroom pedagogy and tools for teachers to use for their own development. Most of the 29 entries have been published in other forums, from international journals and conference proceedings, commissioned papers and seminar presentations to national, state or local journals, bulletins or curricula. Some can be found on-line, others in government funded research reports, still others again are locally distributed 'unpublished' works. The rationale for bringing them together here is that many of them are relatively inaccessible to the broad national and international readership of practitioners, researchers and relevant policy makers we envisage.

We have acknowledged all original publication sources. Where extracts have been used or some editing has occurred, we have retained original reference lists and in some instances we have added further readings at the end of the text, thus providing a unique bibliography of adult numeracy research and practice. We have attempted some cross referencing of texts within the collection. This is noted with square brackets [Ed.]. Because many of the texts in Part Three report classroom practices we have not added further readings to these texts separately but refer readers to the ARIS website (see below) for a comprehensive listing of adult numeracy resources. In light of the edited nature of this collection we have not attempted to standardize the referencing systems used by contributors. Brief notes on contributors can be found at the end of this volume.

We do not pretend that the collection is exhaustive or comprehensive. Much of the work represented in the area is ongoing and we include also glimpses of new directions for research. Kanes, for example, suggests how cultural-historical activity theory can provide a framework for analysing numeracy in use, while Yasukawa (2003), argues for the possibility of using actor-network theory as a tool for developing a social studies of mathematics. The collection is limited not only by the size of the publication, but by our biases and preferences. Nevertheless, we hope that the book will provide an historical background to newcomers into the field of adult numeracy, giving some insight into the current state of the field. We hope that new researchers will see gaps and contradictions in the existing research and use them as springboards for finding new directions.

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