

# Student-Led Improvement Science Projects: a praxiographic, actor-network theory study

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## ABSTRACT

Improvement science methodology is promoted in the National Health Service (NHS)<sup>1</sup> in Scotland for implementing rapid change in hospital practices. Student-Led Improvement Science Projects (SLISPs) have been developed as a result of this, where medical students work with clinical teams to identify, implement and monitor quality improvements in the workplace. Working with improvement science in real-life working practices in a hospital environment presents opportunities for different ways to conceptualise learning, for both educators and students. This paper draws from ethnographic and praxiographic methods combined with the sociomaterial approach of actor-network theory (ANT) to investigate the pedagogies of improvement science. The research concludes with three implications for medical education and education in general: (1) conceptualising learning as a network effect can guide educators and students towards a broader range of pedagogies for improvement science; (2) treating human and non-human elements of the network equally can lead to noticing details of practice that might otherwise be overlooked; (3), instead of collapsing improvement science into a singular meaning, multiple worlds allows for different enactments of improvement science to co-exist.

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## Introduction

Improvement science methodology is increasingly being promoted in the National Health Service (NHS) in Scotland as an approach to improve hospital practices. In 2015, the Scottish Improvement Science Collaborating Centre (SISCC)<sup>2</sup> was set up to coordinate the practices of improvement science in healthcare. This has encouraged the development of improvement science projects. I have coined the term ‘Student-Led Improvement Science Projects’ (SLISPs) for this paper to describe the projects undertaken and led by medical and pharmacy students that use improvement science methodology.

Improvement science is an approach that is used to implement and test small scale improvements in a rapid, systematic way. It is an emerging field in healthcare, drawing from quality improvement methods from manufacturing and management approaches

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(Peden and Rooney 2009; The Evidence Centre 2011; Paterson et al. 2012; Askew et al. 2015). These methods include ‘plan, do, study, act’ (PDSA) cycles to structure and test an improvement; process diagrams to clarify existing procedures; ‘cause and affect’ diagrams to identify areas of improvement; and run charts to monitor changes. More broadly, improvement science is defined as ‘a body of knowledge that describes how to improve safely and consistently’ (The Evidence Centre 2011, 6).

## Student-Led Improvement Science Projects

The Institute for Healthcare Improvement (IHI)<sup>3</sup> provide guidance for the application and coordination of improvement science approaches around the world, including the US, Canada, England, Scotland, Denmark, Sweden, Singapore, Latin America, New Zealand, Ghana, Malawi, South Africa, the Middle East, and elsewhere. In Scotland, SLISPs have been developed using the IHI Open School Practicum.<sup>4</sup> SLISPs are reported in a scientific and systematic way, and can be published as IHI Completed Practicum Projects on the IHI website.<sup>5</sup> Quality improvement projects are also regularly published in the British Medical Journal and Cochrane Reviews. SLISPs follow a specific process to collect and record information, using the improvement science models mentioned previously. This provides focus and direction for the students but might also be considered as being restrictive. SLISPs reportedly demonstrate scientific rigour by following the systematic pedagogical methods of improvement science. This paper argues that it is necessary to employ pedagogical approaches that accommodate the relations, complexity and materiality of the workplace. The aim of this paper is therefore to present an alternative to the pedagogical approaches espoused by improvement science.

## The ‘antibiotic story’ SLISP

The SLISP investigated in this paper is part of a broader piece of research investigating professional learning in improvement science. I decided to focus on a particular SLISP for this paper in order to describe the research process and findings in more detail. The improvement focus of the SLISP was to improve the antimicrobial prescribing procedures carried out by junior doctors.<sup>6</sup> Although protocols are in place, antimicrobial prescribing procedures can be challenging for junior doctors (Mattick, Kelly, and Rees 2014). Junior doctors are required to prescribe appropriate antibiotics for patients and to produce a plan. Sometimes junior doctors are required to review prescribing decisions made by colleagues; staff rotation on wards mean that the same doctor might not be available to follow the prescribing plan from beginning to end. Challenges and disputes sometimes occur, as different stages in the plan are carried out by different members of staff. There are cultural expectations, or an ‘etiquette’ associated with antimicrobial prescribing. Role hierarchy can affect decisions, where the opinion of a senior staff member can undermine the authority of a junior colleague (Charani et al. 2013). Antimicrobial prescribing is also affected by the increasing prevalence of antimicrobial resistance (Davey et al. 2017). The medical student who was leading the SLISP decided that an investigation of current antimicrobial prescribing practices carried out by junior doctors would be a helpful area of improvement, contributing to patient safety.

This paper describes how I researched the SLISP process using actor-network theory. This is complementary to studies that have explored the educative practices in

improvement projects (Paterson et al. 2012; James et al. 2016) and quality improvement in curriculum development (Armstrong, Lauder, and Shepherd 2015). This paper adds to the growing body of research in the field of improvement science pedagogy by drawing from actor-network theory as an alternative way of describing practice.

## Actor-network theory as a methodology

My study is situated in practice and professional learning. Learning in this field is conceptualised as dispersed, situated and emergent and opposed to linear, individual and transferrable (Hager, Lee, and Reich 2012). More specifically, I draw from the notion that learning is an effect of the relations within assemblages of human and non-human entities (Fenwick and Edwards 2010). Pedagogical approaches in this field have been investigated in the literature as part of sociomaterial practices in medical education (Bleakley, Bligh, and Browne 2011; Ahn et al. 2015; Falk, Hopwood, and Dahlgren 2016; McMurtry, Rohse, and Kilgour 2016) and other areas of professional education (Fenwick and Nerland 2014).

My study draws from Actor-network theory (ANT), as a theoretical perspective and methodological approach to investigate learning and knowledge around the implementation of improvement science. ANT provides a means of appreciating and exploring phenomenon (Bleakley 2012), to allow the minutiae and nuance of practice to be foregrounded. This provides a complimentary narrative to the potentially restrictive IHI reports, and to provide a particular focus on the pedagogies of SLISPs as these were carried out in practice. ANT follows mess and unfolds, as opposed to smoothing out and closing down (Fenwick and Edwards 2010) making it appropriate for a study of the nuance and minutiae of student learning in clinical work settings. This study adds to the growing application of ANT in medical education, and offers a way of applying the methodology to inform future studies.

## A brief overview of actor-network theory

ANT is part of a suite of sociomaterial theories that combines collective human activity (social) with the material (environment, bodies, technologies, objects) without privileging what is commonly considered to be more important, such as human activity. ANT's status as 'theory' has sparked discussion and debate (Law and Hassard 1999; Latour 1999a; Law 2006; Mol 2010) as the word 'theory' does not adequately describe the fluidity of the approach and preference for the local rather than the general. A thorough treatment of ANT and sociomaterial theories in the context of medical education can be found in Fenwick (2014) and Bleakley (2012).

The idea of assemblage is key to ANT, as this describes how the social (e.g. negotiations around meaning and knowledge within groups) and the material (spaces, objects etc.) are incorporated (Latour 2005). ANT is focused on how the relations between heterogeneous human and non-human 'actants' produce affects, such as learning. An actant refers to an entity that brings about an affect in relation to other entities (Latour 2005). As such, ANT eschews traditional conceptualisations of learning as acquisitional and individualised in favour of learning as a network effect (Fenwick and Edwards 2010). In this paper, learning

is considered as relational, with the focus on ‘*associations, or connections, or relations* through which matter and meaning, object and subject, co-emerge’ (Mulcahy 2014, 56).

The analysis in this paper is guided by three dimensions of ANT (Fenwick and Edwards 2010): networks, symmetry and multiple worlds. These three dimensions are not discrete and there is overlap. However, I have treated these as different ways to focus on facets of the research.

Firstly, the concept of actor-networks is well documented in the literature in relation to learning and pedagogy, and has been explored empirically in education settings (For example, Sørensen 2009; Nespør 2014). I therefore considered it to be a reliable entry-point to the data. In ANT, the term ‘network’ is used to describe the translations and effects that take place when elements come together (Latour 2005). Networks are a way of tracing power relations and observing practice by conceptualising networks that stabilise or mutate (Fenwick and Edwards 2010). Networks provide a way to articulate what happens when new ideas collide with existing practices. Whereas improvement science presents a process diagram to map existing procedures in general, ANT focuses on local practices. My research explores the SLISP as a situated, practice-based, entwined experience, from which learning emerges through network effects (Fenwick and Edwards 2010) rather than being a social or cognitive phenomenon (Ahn et al. 2015) or a process in general.

Secondly, the notion of symmetry is much contested and debated in ANT because of the implications of decentering the human by treating humans and non-humans equally (Collins and Yearly 1992; Miettinen 1999; McLean and Hassard 2004). It is an important thread in ANT-thinking, as symmetry challenges assumptions of what is important in a situation, which can obscure what is noticed in practice. Symmetry describes how dualisms are challenged; for example, the treatment of humans and non-humans. In many sociological theories, the human is privileged, whereas ANT treats entities equally and focuses on relations and their effects. An ANT sensibility considers what things *do* rather than what they *are*; what effects are produced within their particular networks and what associations are formed. This sensibility can highlight details that might otherwise be overlooked. Thirdly, the after-ANT ‘turn’ in the literature offers more opportunity to explore fluid and dynamic concepts of learning through multiple worlds and ‘ontological politics’ (Mol 1998). The idea of multiplicity allows complexity to be opened out rather than shut down. This unfolding leads to coexisting or competing worlds that interact politically, leading to the notion of ‘ontological politics’ (Mol 2002). Bleakley (2012) describes multiple worlds as performing the opposite function to triangulation: instead of focusing different perspectives on a single object, the object is allowed to open out into how it would perform in different worlds. For approaches such as improvement science, there is pressure to tie practices down to a single term or singularity, which can then be measured and evaluated. This study makes a case for holding terms open, and allowing improvement science to be enacted in different ways.

## Method

As described previously, the fieldwork for this study was based on one SLISP which was led by a medical student whose project investigated the improvement of antimicrobial

prescribing practices. My study explored the process of how the student carried out the SLISP on a hospital ward.

As the sole researcher, I physically followed the student around the wards as they carried out activities relating to the SLISP. ANT methodology guided my detailed observations of the minutiae of practices involving assemblages of humans and non-humans. Although I spent as much time as possible observing the SLISPs being carried out, I recognised that there were associations that would not be seen, as they would have taken place at other times. I conducted interviews with the student to gain further insights into the connections and relations as experienced from inside the networks. I also asked the student to identify key contacts who could elucidate connections. During the study, I conducted observations as frequently as I could and for as long as possible. I carried out interviews with participants to allow for validation through the participants themselves (emic) to avoid imposing my own (etic) categorisations (Harris 1976). I conducted over 30 h direct observation, and six interviews with the student and their key contacts. I annotated PDF scans of the field notes and fully transcribed the interviews. The fieldwork for the SLISP described in this paper took place over the space of two months. Direct participants (the student and interviewees) signed consent forms and were given an information form. I briefed the medical student who was carrying out the SLISP prior to their participation to ensure they were comfortable being observed. I checked at regular intervals to ensure they were still comfortable with the process. Indirect participants (consultants, clinical leads, senior ward nurses) were given staff information forms. I collected blank medical documents as part of the field analysis, and as a reminder of the information that was collected by the student. I also took photographs, with permission from the senior charge nurse, of material arrangements such as paperwork, furniture and the layout of equipment. These allowed for visual analysis to be conducted later on.

Ethical approval was granted by the University of Stirling, School of Education. As with all qualitative studies in healthcare settings, I also sought approval from the Health Board Authority and from the specific health board for the hospital. Clearance and access were granted by the host hospital. The student and interviewees granted consent for recording observations and interviews and were given the option to withdraw at any time. Patients were not included in the study because of patient confidentiality; I did not consider it necessary to include patients, as the study was centred on education practices. I selected a gender-neutral pseudonym, 'Chris', for the medical student who was leading the SLISP described in this paper to maintain confidentiality.

### **Praxiography as ANT methodology**

This study focused on practices, and there was a risk that my position as a researcher became one of explaining, rather than describing the realities produced *in* practice (Latour and Woolgar 2013). I therefore chose an emic ethnographic approach to examine and describe these realities directly through observation. Furthermore, I felt it was necessary in this investigation to examine the enactment of practices rather than to record essentialisms. In other words, following an actor-network sensibility that seeks to find out what things *do* rather than what they *are* (Fenwick and Edwards 2010). I therefore followed a praxiographic approach (Mol 2002).

Praxiography is derived from Mol's (2002) work, and describes a way of performing research with a focus on practice (praxis) rather than culture (ethno) (Bueger 2014). This approach allows for associations and enactments to be made explicit through the story of practice. Praxiography also allows for materials to be noticed and not dominated by human activity. As Mol (2002) states, 'You can't talk about the disease without thinking about the microscope' (p.32). This is congruent with the ANT dimension of symmetry, which seeks to trace agency in relations rather than attributing this as a human trait. This approach also requires consideration of spatiality and location, and a preference for the local rather than the universal. This was particularly important for following paper-work on a hospital ward, as it becomes easy to conflate 'the' medical form with particular medical forms in different locations and at different stages. In other words, '... there is not a single object in practice, but ... every practice produces its own variant of the object' (Clever and Ruberg 2014, 3) Again, this contrasts with the generalised process diagram used in improvement science approaches.

### Analytical process

For this paper, I have focused on one 'anecdote' from the SLISP, the 'antibiotic story', to allow for detail to be adequately explored. The anecdote was constructed by drawing from the methodology of Adams and Thompson (2016), which is a tailored approach for post-humanist and ANT studies. The anecdote allows for a detailed description of relations between heterogeneous human and non-human entities that does not emanate from human experience alone. I have used the term 'anecdote' to describe events in practice; this provided an alternative to 'story', which would imply a coherent narrative (Mol 2002). I constructed the anecdote by identifying an 'actor' to 'follow the actor' (Latour 2005). The actor identified in the anecdote for this study is a medical form used to record details of a specific antibiotic: the gentamycin form. Rather than being essentialised by focusing on the 'actor', this initial stage of following the actor provided a way of attuning to networks through forces and processes associated with the gentamycin form. The next stage in the anecdote involved noticing the physical properties, effects, and assemblages of actants, to identify details that might otherwise have been overlooked. These properties drew out the dimension of symmetry by attending equally to human and non-human actants. The final stage attended to the ways in which practices formed realities, which were either reconciled or 'hung together' (Mol 2002).

The analytical process involved reading through the materials collected from the field repeatedly; organising and reorganising the data; avoiding 'shutting down' possibilities through the imposition of categories and themes too early on. I used photographs and collage to interrupt and disrupt linear readings of the data (Cragg 2003). I included diagrams and figures as analytical tools, rather than representations or simplifications, as might be found in a process diagram or concept map (Decuyper and Simons 2016).

An ANT analysis requires a divergent approach to unfold the data, which might be referred to as 'untriangulation' as mentioned previously as an extension of Bleakley's (2012) idea of ANT working in the opposite way to triangulation. I drew from praxiography to look for uncertainties and ambiguities in the data, which sometimes led to opening out multiple enactments of a singularity (Fenwick and Edwards 2010). For example, Mol (2002) wrote about the multiple enactments of atherosclerosis, which describes the

condition as being performed in different ways but referred to as a single term. In my study, I explored how these multiple enactments, or multiple worlds, existed together. In some cases, multiple worlds are incommensurate but operate alongside each other; in other cases, one world might dominate another. This draws from the idea of ontological politics (Mol 1998).

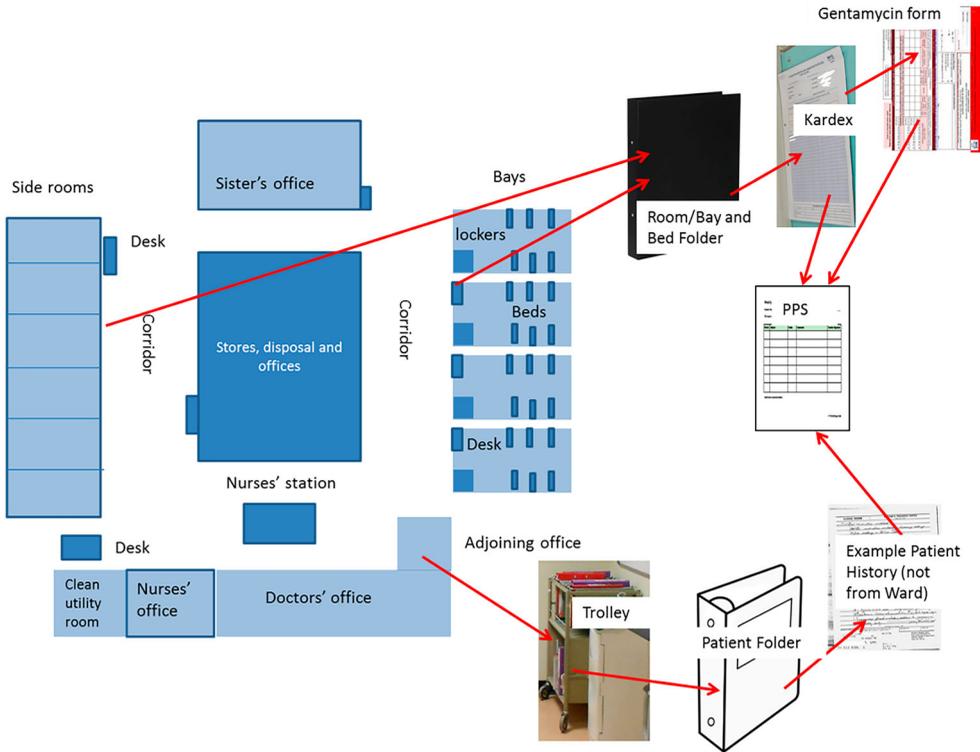
## Results

There are three parts to the results section, which draw from the anecdote described. The anecdote begins by following the student's SLISP as they piece together the information they need to construct the story of how, why and when antibiotics were prescribed to the patient. This was carried out through finding information from different forms, such as the gentamycin form and the Kardex (prescription chart), in different parts of the ward, onto a Point Prevalence Survey. This first section on the 'antibiotic story' describes the student's project through the conceptualisation of networks, and how connections and translations form, mutate and break, disrupting and changing practice. The gentamycin form is identified as an actor, to 'follow the actor' and sensitise to relations and effects. The second section of the anecdote continues to follow the gentamycin form with a focus on the ANT concept of symmetry to describe how materials assemble, and to identify phenomenon that might otherwise be overlooked, or examined in a different way. The third section of the anecdote focuses on the recording of 'duration' on the Kardex and gentamycin form as part of the 'how, why and when' antibiotics were prescribed. The recording of duration ('was duration recorded?') began as a simple yes/no response, but increased in complexity as the student realised there were uncertainties related to recording duration. This was identified as an ambiguity signposting to multiple worlds.

### *The 'antibiotic story' network*

The medical student, from now on referred to as Chris, conducted a SLISP with the aim of improving prescribing procedures. Chris followed the methodology of improvement science by using the stages of the PDSA cycle. The planning (P) stage was carried out using a Point Prevalence Survey (PPS), which formed the main part of data gathering for the SLISP, and the main part of my observations. The information for the PPS was distributed on different forms, including the Kardex for all medications, and the gentamycin form, which were kept in different parts of the wards. Separate information was required for the prescription, administering and monitoring of some antibiotics such as gentamycin, as this is a high risk antibiotic. Decisions on whether to stop or continue with a medication are recorded in the patient history notes. The distribution of information required Chris to collate information to form the 'antibiotic story' of the patient.

I examined this process by observing practices whilst the student carried out the SLISP. To do this, as mentioned previously, I carried out the first stage of constructing an anecdote by following an actor, for which purpose I chose the gentamycin form. It was problematic to physically follow a gentamycin form around the wards, but I was able to trace the forms through my field notes and interviews. To help me follow the gentamycin form, I drew a 'narrative pathway' (Figure 1). This diagram was produced to describe the physical locations of the paperwork and associated stationery (ring-



**Figure 1.** Narrative pathway.

binders, clipboards, files and so on). The diagram was not intended as a representation of a network, such as a process diagram, but as a description (Decuypere and Simons 2016) of how practices ‘hang together’ (Mol 2002). The localised nature of the processes was reflected in the way that the diagrams differed for different wards. Drawing the diagram also helped me to identify connections and associations between elements that worked upon a network, and to attend to non-human effects on practice. For example, the SLISP introduced improvement science as a set of practices with links to other networks (such as the IHI Practicum), and the SLISP itself formed links between existing practices and the IHI to form a new network that would become the improvement. The ‘antibiotic story’ formed its own network, with links through medical forms relating back to antibiotic prescribing.

### ***Assemblages of materials in ward practices: a symmetrical approach***

The next stage in the anecdote drew from the ANT notion of symmetry by attending to assemblages of humans and non-humans and the culminating effects. This involved noticing details of entities and relations such as the gentamycin form. The gentamycin form had a sticky strip that prevented the form from becoming lost and detached from the patient’s other notes on the way to surgery. This was highly important, as this can lead to ‘double dosing’: too much gentamycin can lead to Acute Kidney Failure, a risk to the patient.

The physical properties of the medical forms influenced Chris's behaviour in terms of collecting baseline data for the PPS. The physical gentamycin form related to the other forms kept with it, such as the Kardex, the Sepsis Early Warning Score (SEWS) chart, and other forms:

*Fieldnotes, 5th October, Book 1 pages 10–12*

In front of each room a double clipboard hangs on the wall at waist height. [Chris] checks the Kardex from one of these, seated on a small wheeled table and chair ... Some clipboards are fiddly, papers could fall out ... Some notes on Kardex are difficult to interpret ... Gentamycin chart: stuck onto drug chart with sellotape.

This field note extract describes the assemblages of forms that are physically held together on clipboards, or stuck together with the sticky strip or sellotape. The physical manipulation of the clipboards to extract the gentamycin form is combined with the complexity of reading the notes on the forms. This illustrates some of the effects of the configuration of the forms and the significance of ring-binders and clipboards to reinforce the connections between forms. From the above examples it is shown that paperwork is frequently manipulated, inscribed upon, inspected and moved.

Chris could not collect everything in one place and had to become familiar with the layout of the ward, where the paperwork was kept, who was using it, and when. The stationery that was used to contain medical forms on the ward invited different forms of practice; for example, it was more difficult to move clipboards and the forms clipped onto them, as it was difficult to prop the boards up or stack them. It was easier, however, to move ring-binders around the ward. The most current, critical forms on the clipboard therefore stayed in proximity to the patient..

### ***'Duration': an ambiguity signposting to multiple worlds***

In the last section, the materiality of handling information in different places and in different forms was explored in terms of how this configured practices for staff, and for Chris in conducting the SLISP. One piece of information that Chris collected for the PPS was the 'duration' of an antibiotic, and if this had been recorded according to protocol. 'Duration', recorded on the Kardex and gentamycin chart, is part of the 'antibiotic story'. When an antibiotic is prescribed to a patient, the prescriber is required to record certain details relating to the dose, time of administration, the medication plan, and when the drug needs to be stopped or reviewed. Recording duration at first appears to be a simple act of writing a number in a box, but as Chris realised, this is not always the case. The way Chris recorded 'duration' started as an ambiguity and then flagged up an ambivalence in working practices that highlighted the tension between professional judgement and protocol.

*Interview 2 with Chris, 21st October, 2015:*

... it's quite difficult to tell whether ... they've written down the total duration because they might not have said anything for the first week and then on day 8, they've said, oh yes, 5 more days ... It's like, yes, there's a duration now, but there wasn't for a whole week. So, is that yes or no? ... it gets very complicated!

The quote illustrates the difficulty Chris found in identifying 'duration' as a singularity. Using a praxiographic approach, the 'is' in this sentence is open, contested and local

(Mol 2002). It might be more accurate to say that duration is *enacted* differently in different practices. For a nurse, duration indicates if and when a drug is to be administered; for a pharmacist, duration is a recommendation that is to be signed off by the doctor; for the doctor, duration is to do with when they intervened with the patient on their journey, and what they record for the next shift. For Chris, the medical student, duration is a specific recording procedure that takes into consideration a treatment plan, a record of what has passed, response to treatment, and when the drug is to be administered or stopped.

In this example, Chris noticed the recording of duration as an ambiguity: the recording of a simple number became unclear, and this was a surprise to the student. The ambiguity prompted Chris to explore duration further, asking staff and supervisors, consulting patient notes and medical records. Ambivalence contributed to the oscillating forces, tensions and 'strain' (Fenwick and Edwards 2010) that became enacted as a result of Chris attempting to record duration into another form (the PPS). Chris's actions unfolded the singular term of duration into a multiplicity that reflected the different worlds it inhabited. Chris pursued and accepted the multiplicity of 'duration' instead of attempting to force or smooth over details for consensus.

## Discussion

The anecdote of the 'antibiotic story' illustrates how ANT affords insights into the pedagogical approaches of SLISPs and improvement science that might otherwise be overlooked. By applying a praxiographic approach, it was possible to focus on the minutiae of local practice to follow relations and associations. Drawing from the ANT concept of networks, existing networks of antimicrobial prescribing related information from distributed medical documents, connecting to different treatments, patients and ward priorities. The SLISP formed its own network through assembling the 'antibiotic story'. Improvement science approaches formed associations with the SLISP, but these became unstable as the SLISP progressed. From this reading of networks, learning is conceptualised as the effects that occur as these networks 'persist, decline and mutate' (Fenwick, Sawchuk, and Edwards 2011, 94). The benefit of conceptualising learning in this way is that it provides an alternative to the restrictive view of learning as fixed, individualised and acquisitional, opening up more opportunities for working with messy and situated practices in the workplace. This provides a way of working with improvement science that acknowledges the effects in different networks. The implications for Chris were that learning was conceptualised through connections, rather than a linear progression from what is unknown to known. The broader implications are that the enactment of improvement science need not be restricted to a pre/post evaluation of an 'improvement' using PDSA cycles and so on, but there is the capacity to identify nuances in existing practices to make for more meaningful and appropriate improvements.

The concept of symmetry provided a way of considering pedagogical approaches that focus on the effects produced as humans and non-humans assemble, rather than purely human-centric activities. Treating human and non-human elements of the network equally can lead to noticing details of practice, significant to learning, which might otherwise be overlooked. In the case of this study, symmetry allowed for noticing how materials such as ring-binders and clipboards invited or excluded practice, shaping the activities for

the student carrying out the SLISP. Learning is conceptualised as situated and dispersed through heterogeneous assemblages of human and non-human entities such as the gentamycin form, ring-binders, paperwork and clinical spaces. The significance of drawing from ANT has brought a more fluid, dynamic approach to conceptualisations of learning, by de-centring the human and bringing into focus the constant movement of learning effects through assemblages of human and non-human entities. For Chris, using symmetry as a sensitising concept of ANT could help to attune to materials and relations.

Finally, instead of collapsing improvement science into a singularity through PDSA cycles, run charts, process diagrams and so on, multiple worlds allowed for different enactments of improvement science to co-exist, to challenge the conditions of possibility. In the anecdote, the recording of duration on the gentamycin form was identified as an ambiguity, which pointed to diverse practices on the ward that ‘hung together’ (Mol 2002). For Chris, learning was contingent in the meanings suspended between worlds, rather than in the reconciliation of diverse practices into a single numeric. ANT provides a legitimate and robust methodology to allow students to follow an ambiguity rather than attempt to shut it down.

## Conclusion

This study investigated learning as sociomaterial, drawing from ANT to conceptualise learning as a network effect. In the anecdote, interconnections and associations were described through observing practice and then ‘following the actor’ as an entry point to the data. This was then followed through by drawing from the ANT dimensions of symmetry, to identify practices that might otherwise be overlooked. Finally, an after-ANT analysis drawing from multiple worlds demonstrated how a seemingly straightforward numeric recording unfolded into diverse worlds of practice that hang together. Although contrasting, this approach served to compliment the improvement science approach by offering a way of following complexity rather than shutting it down. It was clear in the final section of the anecdote, recording duration, that the student noticed ambiguity and followed this.

The three ANT dimensions contribute to medical education in the following ways: networks can help educators and students conceptualise learning as dynamic and complex, creating shifting connections and disruption: pedagogies of improvement science can be adapted to help students appreciate mess and complexity without attempting to capture the whole. Symmetry can help students and educators to see what would otherwise be overlooked: by challenging the assumption that humans are the sole source of agency, the human is decentred and more relational conceptualisations can be accessed. Finally, accepting the existence of multiple worlds that co-exist without pulling everything, including improvement science, into a singularity, can help educators and students to appreciate multiplicities without having to reduce them. As well as providing insights for improvement science practices in the NHS in Scotland, this paper challenges the conditions of possibility for how innovative practices are enacted in the workplace.

In terms of the SLISP described in this paper, improvements to antimicrobial prescribing required the student to investigate existing practices, relations and assemblages of materials, and sometimes incommensurate practices that ‘hang together’ (in this case, the recording of ‘duration’). The pedagogical approach of improvement science required

an emphasis on demonstrating the proposed improvement through scientific method and an emphasis on generalising the outputs, whereas ANT allowed for local practices to be investigated in more detail. The specific ANT method described in this paper could help students undertaking improvement science projects to notice and follow ambiguities and to appreciate the messiness, fluidity and contingency of existing practices. The significance in the future of improvement activities is to highlight learning as dynamic, contingent and ambiguous; to accept that some of the effects of learning might not be captured in a report; and to celebrate the importance of ambiguity in learning. These conceptualisations challenge the scientific and systematic ideology of improvement science, and offer a more critical pedagogical approach for medical students in the future.

## Notes

1. The NHS is a publicly funded service in the United Kingdom, free at the point of use. There are separate bodies providing care in the NHS in England, Scotland and Wales.
2. <http://www.siscc.dundee.ac.uk/>
3. <http://www.ihl.org/Pages/default.aspx>
4. <http://www.ihl.org/education/IHIOpenSchool/Pages/default.aspx>
5. <http://www.ihl.org/education/IHIOpenSchool/Courses/Pages/PracticumCompletedProjects.aspx>
6. Antibiotics are made from microorganisms to kill other microbes, and antimicrobials are a wider term relating to substances, synthetic or otherwise, that kill microbes or prevent growth. Antimicrobial prescribing practices relate to preventing infection, but also avoiding unnecessary harm to the patient by prolonged use of particular antimicrobials. In Scotland, these relate to the Health, Efficiency, Access and Treatment (HEAT) targets: <http://www.gov.scot/About/Performance/scotPerforms/NHSScotlandperformance/CDI-LDP>

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