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Passing the baton? Handing over digital data from the project to operations

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ABSTRACT

From fieldwork conducted ahead of the London Olympic Games, we develop new understanding of how organizations hand over digital data from the project to operations. Prior research explains how practitioners negotiate meaning across boundaries in ongoing work. However, it gives little attention to hand-over, where one group disengages as another engages. We use the analogy of the baton pass in a relay race to articulate how hand-over requires attention to sequence, timing, passing technique and communication within a time-constrained window of opportunity. In our case study, the project delivery team transfer responsibility for sports venues and other facilities, and their associated digital data, to Games operators. We show how delivery professionals both project the nature of future work; and probe how meanings will be interpreted. They seek to extend the window to discuss and negotiate meaning with operators. Our study contributes to research on engineering projects and on the coordination of knowledge work by articulating the baton pass, window of opportunity and projection and probing activities involved in hand-over. Understanding and improving the hand-over of digital data from the project to operations is important to enable owners and operators to better manage built infrastructure.

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Introduction

As an international celebration of exceptional performance in sport, the Olympic Games provide a context in which, for a few short weeks every four years, human achievement is rewarded through medals and world records. Yet, behind the success of these Games are not only the international competitors and their trainers but also the organizations that build and operate the Olympic Park. The London Olympic Games opened on Friday 27 July 2012 in a ceremony attended by heads of state and watched on television by an estimated 900 million people.[1] To enable this opening ceremony, the project had to rapidly deliver and hand over the sports venues and facilities, and their associated digital data, to operators. Drawing inspiration from sport, we use the analogy of passing the baton in a relay race to examine this time-critical handover of Olympic Park venues and infrastructure. Such organizational handing over is not a single event, but an unfolding practice, made up of many instances of handover within a programme, through which knowledge is coordinated as operators engage, getting up to speed in their work, as delivery teams disengage, finishing tasks and disbanding.

Using this baton-passing analogy, this paper builds a new theory about organizational handover from the project to operations. At handover, the distinctly future-oriented approach of the delivery professional (Pitsis *et al.*, 2003) meets the infrastructure owner's concerns with ongoing operations. Recent research on engineering projects has examined coordination across the groups involved in delivery (Dossick and Neff, 2011), noting the short-term focus on the project as opposed to the long-term view of the project's output (Edkins *et al.*, 2013). The organizational handover of data from project to operations is of significant practical importance in obtaining value, as complex projects increasingly use building information modelling (BIM) and Geographic Information Systems, and owners begin to procure both physical infrastructure and related digital data that they can use through the life cycle. There is a need for better understanding of coordination in the close-out phase of projects, as these data are handed over to infrastructure owners. In the next section, we describe our theoretical starting points in the literature on knowledge coordination. We then outline the methods used in our empirical study, which was conducted while digital

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information was being transferred to operators at the end of the Olympic delivery programme. A first section of findings uses the analogy of a baton pass to articulate the sequence, timing, handover technique and communication involved in the transfer of digital data within a time-constrained window of opportunity. We then show how the delivery professionals both *project* the nature of future work and *probe* how meanings will be understood, before exploring how they also seek to extend the temporal windows that provide greater opportunities for negotiating meaning when they handover a set of digital data. We discuss how understanding handover is important as data management systems create new inter-dependencies between the knowledge work of different groups over time. We conclude by suggesting directions for further research.

Theoretical starting points: Coordination of knowledge work

Ongoing and temporally separated work

Literature on the coordination of knowledge work focuses on diverse groups working in parallel (Okhuysen and Bechky, 2009). Figure 1(a) shows this coordination of knowledge between groups engaged in *ongoing* work. Such groups may have different understandings of knowledge (Cook and Brown, 1999) and negotiate meaning across boundaries. In this negotiation, they mobilize resources such as technological objects (Carlile, 2004; Levina and Vaast, 2005; Miettinen and Virkkunen, 2005; Nicolini *et al.*, 2012), as well as direct relationships between individuals (Lervik *et al.*, 2010). While some authors see the practices of different groups as remaining largely distinct, others propose a "trading zone", in which a new form of practice emerges (Chrisman, 1999; Kellogg *et al.*, 2006) or articulate how the mediating objects are themselves changed through shared knowledge work (Ewenstein and Whyte, 2009; Mcgivern and Dopson, 2010). What such explanations share is an understanding that coordination unfolds over time (Boisot, 2011; Swart *et al.*, 2011) as groups work in parallel. The limit of these rich explanations is where knowledge is coordinated across an organizational handover process, as shown in Figure 1(b). Depending on the scenario, there may be little or no overlap between the engagement and disengagement of these groups, with a temporal separation between their knowledge work. Insufficient is known about how knowledge is coordinated in cases when there is a time-limited window of opportunity as one group completes their activities and disengages, handing over to another group that engages to conduct related but different activities. Better understanding of this handover is important, as large engineering projects hand over both physical infrastructure and digital data to owners and operators in the close-out phase of projects.

Passing the baton

Using the analogy of passing the baton, we see there being a window of opportunity for knowledge coordination in handover that is similar to the exchange zone on the running track within which the outgoing runner must receive the baton from an incoming runner. This analogy, illustrated in Figure 2, draws attention to sequence, timing, handover technique and communication (Dyck *et al.*, 2002). In the relay race, the *sequence* of activities involves the baton arriving at the 20-metre exchange zone, in which it is passed from the incoming runner to the outgoing runner, who may have started accelerating 10 metres earlier. *Timing* is critical, so that when the incoming runner arrives at the "go" marker, this signals the outgoing runner to start accelerating (Dyck *et al.*, 2002). The handover *technique*, through which the baton passes from one hand of the incoming runner to the other hand of the outgoing runner, is a focus of significant attention in training (e.g. Boyadjian and Bootsma, 1999; Ward-Smith and Radford, 2002). It is often a point of failure for teams in the relay race, with over a quarter of relay teams in one world championship disqualified or failing to finish as a result of poor handovers (Radford and Ward-Smith, 2003). Good *communication* between the runners is required, so that the incoming runner can comprehend and act on cues about the outgoing runner, passing the baton in such a way that they can grasp it and take it rapidly forward, without letting it drop.

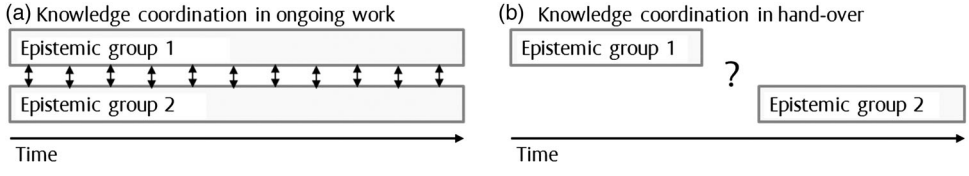

Figure 1 (a) knowledge coordination between groups engaged in *ongoing* work; (b) knowledge coordination in *handover* between temporally separated groups

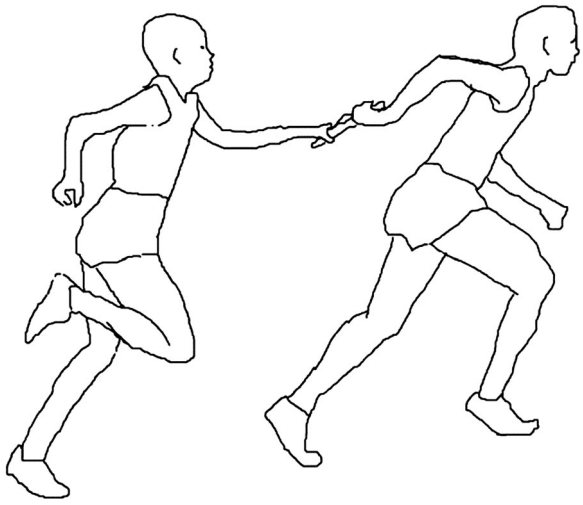

Figure 2 The act of passing the baton in the relay race

Rapid hand-offs between professionals

The analogy of passing the baton draws attention to sequence, timing, handover technique and communication. These are also important in studying the organizational handover from the project to operations. We see the project as analogous to the incoming runner seeking to hand over to the owner or operator as the outgoing runner. Such organizational handover involves many instances where data are handed off from one professional to another, with the participation of many individuals who work across different firms, professions and roles.

While there is a lack of research on organizational handover, there has been research on medical hand-offs as a patient passes through a hospital and is transferred from one professional to another, or between small groups with ongoing relationships (e.g. Mostaghimi and Crotty, 2011). Here, responsibility for the patient is transferred along with explanations of their condition and diagnostic information. Coordination involves both standardized processes and face-to-face interaction between professionals (e.g. Solet *et al.*, 2005). Such professional hand-offs are short and local, taking about 10 minutes to run through (Catchpole *et al.*, 2007). However, in the hand-off from an emergency medical services crew to the trauma team, professionals often fail to follow a particular structure and hence to report important information. Sarcevic and Burd (2009) see these issues as arising due to the time pressure and interruptions that professionals face, and recommend standardizing procedures through a checklist.

While we anticipate that organizational handover will involve many instances of such hand-offs between professionals, as these aggregate, we also expect that there will be significant differences between the rapid and local nature of hand-offs in the operational environment of the hospital emergency room and the organizational handovers that our empirical work explores. In our context, delivery professionals with a future orientation hand over to professionals concerned with ongoing operations. Handover unfolds across longer temporal discontinuities and broader organizational structures at the end of a project when a product or built infrastructure goes into operation.

Research setting and methods

Research setting

The setting for this study is the completion of venues and infrastructure on the Olympic Park, on a 2.5-square kilometre site in the east of London developed for the London 2012 Olympic and Paralympic Games. Explanatory documentation (operation and maintenance (O&M) manuals, models, drawings) was developed by the delivery team and made available to operators on the completion of construction. The Games operators used this information to plan logistics and to make any alterations necessary for hosting the Olympic Games, including the opening ceremony. They relied on complete and accurate information about venues and other facilities ahead of the Games in order to test and modify them for the athletes. The delivery team had to deliver to short, fixed timescales ahead of the testing and commissioning for the Games, yet it also had the long-term responsibility for creating physical infrastructure that would continue to be inhabited and modified after the Olympics left, in a legacy of buildings and infrastructure.

In a complex project such as the London 2012 Olympics, there is a significant challenge of systems integration (Davies and Mackenzie, 2014). The construction programme had a £9.3bn budget, including a £1.2bn contingency fund. It involved 20 Tier-1 contractors and their supply chains; and over 400 worksites (NCE, 2011). Delivery involved tight timescales as all the facilities in the Park had to be fully operational by a fixed end date. The Olympic Delivery Authority (ODA) was responsible for the programme and worked with its delivery partner, a consortium of CH2M Hill, Laing O'Rourke and Mace (CLM). Completed assets and digital information were then handed over to the London Organising Committee of the Olympic Games and Paralympic Games (LOCOG), which operated and maintained the Olympic Park during the Games.

There was, unusually, a second handover to clients on this programme, as after the Olympic Games, venues were handed over to legacy owners. During the period studied, it was expected that any changes made by LOCOG in preparation for the Games, or during the Games, would be agreed with the ODA, documented

Table 1 Main data sources analysed in research on handover from projects to operators

Study of London 2012 Olympics handover practices	
Research project meetings	3 hours meetings with two or more of the key stakeholders in ODA; with 2-hour set-up meeting; 2-hour meetings discussing emergent findings. 3 hours site training to obtain a pass for the team to access the project offices on site attended by the lead author
Semi-structured interviews	16 semi-structured interviews with 17 project participants involved in handover as identified by ODA in 2011
Secondary data	Internal documents: 267 pages of guidance for project participants on data handover procedures and 21 Power Point slides
Observation of public presentations	3 hours of evening events disseminating findings from the Olympics; taped with audio and PowerPoint slides available for analysis; 1-hour presentation by the ODA chairman; and 4 other presentations of design and digital technologies at the ODA/CLM attended by members of the research team 1-day conference about London 2012 for Further and Higher Education
Long-term ongoing engagement with the field	Lead author spent 3 weeks working with CLM on information management; and conducted additional interviews with key participants in 2007 as part of this work Related study of industry handover practices, with 3-hour workshop with industry participants; 12 interviews with leading clients and supply chain in 2010 Visit by the ODA Construction Director to the University in May 2012. The first two authors attended a meeting with ODA in July 2012 and the first author spent 4 days ODA offices in September and October 2012. A tour of the Aquatics Centre as conducted in November 2012; and the third author revisited the Stadium and Velodrome of the Olympic Park in January 2013

and either reversed or compensated post-Games, as in the tenancy agreement. A further programme of work would then be designed to transform venues and infrastructure for legacy uses before the assets and data were handed over to legacy owners. The expected sequencing of these post-Games handovers changed during the study, though preparations were underway, with legacy owners able to view relevant data.

Data handovers are important, as beyond the Games, the Olympics leaves the host city with a legacy of new buildings and infrastructure. Data from their delivery have the potential to significantly improve decision-making throughout the operational life of such buildings and infrastructure (Eastman *et al.*, 2008; Mcgraw Hill, 2009). Digital data, particularly that organized through BIM, are becoming seen by policy-makers as central to meeting sustainability targets, delivering value to construction clients, and maintaining a competitive industry (Cabinet Office, 2011). It is important to provide the context, rationale and procedures involved in operating buildings and infrastructure. Yet, on many projects, even those involving leading clients and practitioners, the handover of such data into operations is incomplete, with data sets including unchecked or inaccurate information.

Research approach and data collection

The research design focused attention on the handover of digital information from the delivery project to operations and how the data generated in design added value in operations. Within the Olympic programme, we paid particular attention to two major venues, the Velodrome and Stadium, along with the Structures, Bridges and Highways sub-programme. Our fieldwork examined how related digital information changed hands from the delivery project (the project construction teams, CLM, and ODA) to the operators (the Games operator, with planning for an eventual handover to legacy owners). The main data sources in this study are summarized in Table 1.

The main data collection took place during the period when venues and facilities were being completed and handed over, between March and June 2011. We were granted access to the ODA's internal documentation on handover and conducted semi-structured interviews with 17 members[2] of ODA, CLM and with Games operators and owners identified as key players by the ODA. Each interview was scheduled for one hour, but there were variations in length depending on the knowledge and expertise of the participant, with the longest interview lasting more than an hour and a half. All interviews were conducted by two members of the research team and were tape-recorded and then transcribed. Altogether, we gathered 14 hours and 23 minutes of audio recordings and 238 pages of transcript. The interviews were at the programme level (7); with delivery teams for Velodrome (3), Structures, Bridges and Highways (3); Stadium (1); the Games operator and legacy owners (3).

As a research team, we had an "engaged" approach to the field (Van De Ven, 2007), with long-term collaboration with industrial partners and ongoing involvement in industry debates. Ongoing interaction with the setting and wider industry enabled us to discuss preliminary findings with industry partners, checking the robustness of our interpretations. It also enabled us to inform wider work within the industry to develop standard formats and processes and embed them in procurement arrangements in this fast-moving policy and industry context.

Data analysis

First, to gain familiarity with the data set, two researchers coded and analysed instances of handover on individual projects. One researcher examined professional interactions across the programme, and labelled textual expressions in each interview transcript with descriptive phrases. These early descriptive analyses drew categories from the research protocol. Figures and tables were used to condense and display our research data (Miles and Huberman, 1994) for discussion among the research team and with industry participants. Through this work, we then grouped these descriptive phrases into first-order codes, highlighting the time-constrained nature of the work involved.

We did not directly compare and contrast handovers on the Stadium, Velodrome and the Structures Bridges and Highways programme, because the same underlying protocols and systems were used to organize information transfer. Our data were collected as these processes of organizational handing over were ongoing; the handover of the Velodrome was completed, while preparations were underway for the handover of the Stadium (this included refining the protocol), with a range of infrastructure projects at different stages of the handover process.

Our analytical work focused on understanding the practices involved in collating and handing over the digital data, as well as the built infrastructure, from the project delivery teams and delivery client to operators, and how knowledge was coordinated across these boundaries. In interpreting these data, the comparison with the relay race was explored, and the notion of "passing the baton" became helpful in articulating the different aspects of handover. First, we followed Eisenhardt (1989) in iteratively comparing our emerging constructs with the extant literature, drawing on Dyck, Mauws *et al.*'s (2002) categories of sequence, timing, technique and communication in our axial coding to explain the activities in the window of opportunity for handover. Second, having set out our data in this way, we became aware that our data showed the perspectives of the delivery team, who hand over data, more fully than that of operators, who receive this data. We therefore interrogated our data further, to understand what the delivery professionals did to achieve knowledge coordination in the window of opportunity, proposing that projection and probing are used where there was little opportunity to negotiate meaning through parallel working. Thus, we moved from first-order concepts, in the language of the research participants who worked on the Olympic project, to second-order concepts that seek to provide a more theoretical explanation in relation to the analogy. These analyses are discussed in the next two sections.

The analogy with a relay race

The fixed deadline for the delivery of the Olympics makes the pacing of work crucial in ensuring the success of the construction programme. Professionals involved in data handover see a detailed plan of data requirements as necessary on such a tight construction programme:

> You have to really get quick off the blocks doing the Olympics and if there's one lesson learnt […] you need to get a plan off-the-shelf on how you want data structured. You need to know what you want at the end of the project, so you can stipulate at the start of the project. (ODA project director 1)

At the start of the project, the data structure needs to be defined, just as the baton in a relay race needs to be there before the race begins. Although there was substantial work to specify data requirements at the start, the data structure, processes and technologies used for handover on the Olympic programme were not fully in place until late in delivery of the major projects, such as Stadium and Velodrome. Our respondents emphasized the need for more complete planning. We argue that there is also a need for attention to the unfolding practice.

We see passing the baton, not as one moment in time, but as a phase in a race that needs to be well planned, practised and orchestrated. Like passing the baton, data handover involves sequence, timing, technique and communication, as summarized in Table 2. We thus consider data handover as requiring skill in execution as well as planning. In the Olympic programme, there was an opportunity to learn from the experience of organizational handover on the early projects as later projects were still racing to hand over and finish their work.

Sequence

As shown in Figure 3, each handover has two stages. First, there is the collation of data from the project teams during the completion of works, and second, there is its transfer to Games and legacy operators. The operator during the Games is LOCOG and the legacy operators, who take responsibility after the end of the Games, include the Olympic Park Legacy Committee and the Lee Valley Regional Park Authority.

The information collated by the delivery teams, as part of digital delivery, was important in providing explanations of the physical infrastructure handed over. In the second stage of handover, this was transferred by the ODA to Games and legacy operators. Table 2 shows how this sequence involves *ordering handover activities* in which data are recorded and issued, *tracking drawings*, and *progressive build-up of*

Table 2 Handover of digital data in the delivery of built infrastructure as passing the baton

Aspect of the baton pass	Evidence from the London Olympics
Sequence	• Ordering of handover activities: so you will need to understand how it moves through the sequence of going from […] drawings issued for tender, drawings issued for construction, as-built drawings that go back into the system and they are given to logistics for their use or whatever and you need to understand that process.[…] you need to understand that loop. It is not straight-forward. (ODA projects director 3) • Tracking of drawings: making sure that we absolutely understand how that drawing is progressed throughout its life, making sure that we can audit and assess whether those drawings are on the system in those revisions and also understand where the drawings are in their life-cycle […] on drawings alone we have a meeting each week in the run up to completion to understand where we are. (CLM systems information manager) • Progressive build-up of information: There is a perception […] in the industry that documents are something you think about in the last 6 months but some of this stuff actually starts right back from the design. […]All our processes here were about progressive build-up of documentation as opposed to […] where you get 90% in the last 10% of time. (CLM processes manager)
Timing	• Delivering high-quality data while competing against a tight deadline: so problems-wise, I think it's the time-scale. It's very much, it's a rush at the end and a lot of mistakes can be made. We can't accept things that aren't correct, so we look as if we are delaying the project, but we are not. We are obviously trying to help it. (CLM document checker) • Addressing issues of data bypassing the system: The update has already gone through the bypass system before the next one comes in and then somebody says, "Hold on a minute, we just had that, that's not the same as this." So you've got to be very careful that your backlog doesn't tempt people to email or even hard-copy bypass systems, a risk involved there. (CLM team leader)
Passing Techniques	• Ensuring traceability: we've got traceability on who's changed what, when and why, and all over the team, what's been done. So that's one of my key jobs moving forward, is making sure now we've got a good document, it's still a good document when we hand it on to the legacy owners of the buildings. (ODA facilities manager) • Getting agreement: "So it's basically a pass the parcel until everyone has agreed and everyone is happy and then they'll go and construct" (CLM document checker) • Compliance with prescribed process: challenges of actually getting the Tier-1s to comply with that, so we set up guidance notes on how to compile an O&M manual and some of them came in and were not structured in that way. So there was lots of to-ing and fro-ing to actually get them to comply so that it's all consistent. (ODA coordinator)
Communication	• Heedful interrelating and adjustment: "we had weekly workshops where we physically got the laptop with the O&M manual and […]made sure those comments were in the revised version of the maintenance files and then we submitted the final versions over." (CLM team leader 1) • Communication through team meetings, emails: "most of my life is meetings and emails. I spend most of my whole time in meetings or reading emails" (ODA projects director 3) • Shared trust: "Unless you're really on top of it, once the data is no longer trusted people stop using it and then it just is a waste, completely falls away" (ODA grounds works and services manager)

information. In each handover, a set of meetings with project teams was organized ahead of the transfer to operators to focus attention on the need to complete handover documentation as well as physical infrastructure. Protocols were seen as important for keeping an ordered process. Drawings were tracked to understand how they progressed in the lifetime of the delivery project and to ensure that the latest revision was used. This progressive build-up is important, as some of the data that are required at handover, such as the building energy logbook, require input from the conceptual designers, who may not be involved in construction stages. While the process of data handover may be a focus in last six months of the project, the progressive build-up of information should start in the design stage. Our research participants argued that data were being developed too near the end (like a J) as opposed to the desired S curve in which data are developed earlier. Thus, while the practitioners involved emphasized the need for full codification of operational data requirements at the start of the project, our findings show that judgements about how to develop appropriate data and how to accomplish its handover were made throughout project delivery. There was a need to reorganize data as new systems were introduced, with later projects, such as Eaton Manor (the competitor training pools) and Basketball benefiting from more developed submission and approval processes at an early stage. To return to our analogy, it is as though the baton is still being manufactured after the race has commenced.

Timing

As shown in Table 2, achieving the appropriate timing involves operators *obtaining information before the end of the delivery programme*, the project team *delivering it while competing against tight deadlines* and managers *addressing issues of data bypassing the system.* There

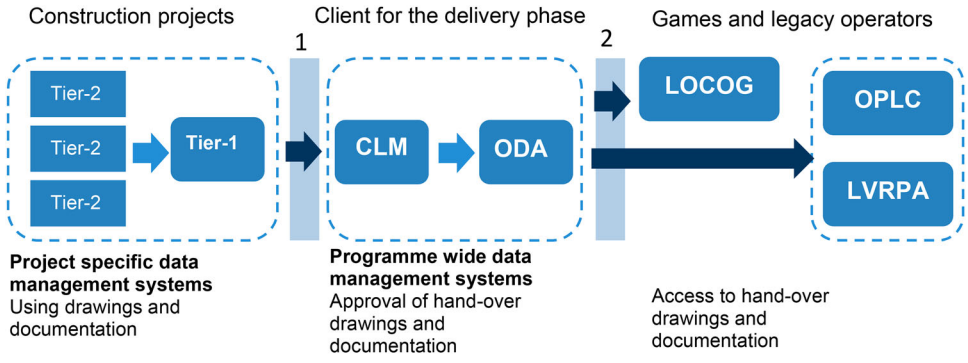

Figure 3 Two stages in each instance of handover to operators in the Olympics programme

was a need for high-quality data to be available to Games operators at construction completion. As one CLM manager indicated, "For many, many years we have always operated under contracts that have said 'You have to deliver this information' but it's about the timing of that delivery." There was an attempt to get the operators, for both the Games and legacy, ready to receive the data from the programme before handover. In the same way that runners try to make optimal use of the track by having the outgoing runners start running before receiving the baton, the ODA facilities management (FM) team was involved in developing the handover information requirements for Velodrome, going through the documentation before the project closed. This is a partial solution, however, as the ODA FM team is organizationally part of the delivery team and will disband after handover. It does provide the delivery team with contact to professionals in the same epistemic group, as the owners and operators that will take over the physical infrastructure and associated data.

With the various timescales and timings to be managed, the structured process associated with handover intensified up to the handover itself, with an initial meeting of all project stakeholders between four weeks and six months before completion (depending on asset size and complexity) to identify and agree all requirements. There was an understanding that rushing this process might result in mistakes. The document checkers involved in accepting information from the supply chain tried not to accept inaccurate information. This sometimes caused frustrations for project teams delayed by the checking process. On these occasions, timing was disrupted when professionals bypassed the system of checking data accuracy to seemingly speed up their own work; however, this resulted in documents of the same name having different updates of information and introduced risk. On the Velodrome project, there was a pressing need to have information ready for preparation for the Games, and at times, when that data were not ready, people made attempts to bypass the system which resulted in version control problems.

Technique

As shown in Table 2, this involved *ensuring traceability*, *getting agreement* and *compliance with the prescribed process*. When documents were passed from the project teams to CLM, document controllers checked that these incoming submissions had the right drawing blocks and revision numbers. They transmitted drawings to the appropriate engineers and managers for approval. This submission and approval process took just a few minutes per drawing, but in one submission, there could be hundreds of drawings. Each required checks on the quality of submitted data, so that issues could be resolved without affecting the project schedule for the completion of work. Who made changes to the documents was recorded to maintain their quality for use by legacy owners. Once documents were approved and the editable drawings were submitted by the designer, another team within CLM had the responsibility to check that the drawings and documents had exactly the same information. Through this process, agreement was reached that drawings were accurate and could be used for ongoing decisions.

However, there were cases in which guidance notes for O&M manuals were not followed. The ODA FM team, which has been in place since 2009, developed guidance for the documentation structure and use in operations, with details for the O&M manual, building energy log, drawings, asset schedule, training and witnessing for the buildings. They adopted industry standards where possible, liaising with the project teams. Tier-1 contractors did not deliver according to the guidance, and it was necessary to introduce an iterative process, with the ODA checking and helping to develop the Tier-1 contractors' work on O&M manuals.

There were also cases where translation of data caused compliance issues. Contractors preferred to work with their own software, rather than unfamiliar software introduced by the ODA and CLM. Hence, they translated data to be compliant with the ODA's output requirements and this sometimes resulted in errors.

> They were doing all their work in [software industry standard], because that's the software they use as a company and at the end of the job having to convert it (to project standard). And in converting it errors have appeared. (CLM team leader 1)

On some projects, the data management system that the Tier-1 contractor used with their supply chain was poorly connected to the ODA and CLM:

> Sometimes there's an electronic disconnect between, say, one side of the fence and the other side of the fence because firewalls and access to the data doesn't exist. So sometimes you have to jump the hurdle. (CLM team leader 2)

An electronic management system was used by the document controllers, with the engineers noting their comments in the system and sending the document back to the document controllers who coded it to update its status. While this was not always straightforwardly achieved, compliance with the prescribed handover processes of the ODA facilitated high performance in the timely delivery of data at the end of the project.

Communication

The requirement for complete information at construction completion is communicated to those involved in project delivery through meetings between CLM and the contractor, sub-contractors and design consultants in each project team. Table 2 shows how communication involves *heedful interactions and adjustments, team meetings and email* (as well as interactions through the digital systems) and *shared trust*. On one of the projects in the programme, the team had weekly workshops through which the email correspondence on comments was conducted and dealt with in the digital system. Communication through team meetings and emails was one way to use the system but also to coordinate the data in a more relational, interactive way. This more relational approach to coordination highlights the value of aligning motivation and understandings to achieve shared deliverables. The successful use of the data was dependent on *shared trust*. If the handover data developed in project delivery was not trusted in operations, all the steps leading to delivery were pointless – and the baton was dropped.

Coordinating knowledge in the handover between the project and operations

As we studied the handover process, set out in Figure 3 and Table 2, we used our data to examine the practices involved in handover from the perspective of the delivery professional. We observed that substantial creativity and problem-solving is involved in coordinating knowledge for handover. Our data suggest that, within such time-constrained windows of opportunity for handover, delivery professionals both *project* the nature of future work across different timescales and *probe* how meanings will be received, as illustrated in Figure 4. They also seek to extend the temporal windows that provide opportunities for negotiating meaning between groups. In developing this understanding, we explored the power and limitations of the metaphor of the relay race to extend it and provide a more nuanced account of how handover is enacted in the organizational context. The following sub-sections describe this, using our empirical data.

Projection

In our case, the delivery team *project* the work of operators in the use of the venues and infrastructure in the Games, transformation after the Games and then legacy. Projections differentiate the future over different timescales, and are analogous to the view of the incoming runner in the relay race, and their sensemaking about what they see, when entering the acceleration zone, as indicated in Figure 4. This work of projection: (1) draws on industry standards as stable referents; (2) seeks understanding of the nature of that future work as a basis for decision-making; and (3) makes judgements about what information will be needed in future knowledge practices.

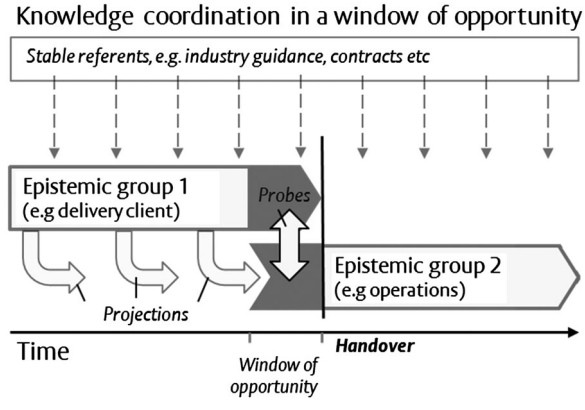

Figure 4 Use of projections and probes in the time-constrained window of opportunity for knowledge coordination before organizational handover

First, the project managers and programme close-out teams highlighted the role of industry standards in providing stable referents for understanding practices across this boundary. Because of the lack of certainty, projections of future work have to rely on sources that can be mobilized in the present:

> If you are designing something then you need to have the people who operate it finally involved otherwise you might build something that isn't suitable for purpose but most of our standards for highways, bridges, structures etc. come from external sources and they are not driven … Well they are driven for the final use as we get input from the Highway Authorities, Local Boroughs and organizations on the structural requirement for bridges and loading requirements. […] We are a short-term organization so we have to pass the asset onto others. (CLM processes manager)

As this interviewee articulated the challenge of getting the people who will later operate the particular facility involved, he first emphasized the limitations associated with lack of operator involvement and reliance on standards, so that "you might build something that isn't suitable". He then decided that external standards *are* a satisfactory proxy for the inputs of operators "well, they are driven for the final use as we get input", as the final owners that will eventually take responsibility will be the kinds of organizations involved in developing these standards. These stable referents are available at the time of the delivery team's work and hence provide a basis for understanding the nature of future work in operations. As the future is changing and imperfectly understood, industry-wide standards and protocols are important in framing the development of documentation for handover. They are external points of reference that can be returned to in operations to provide additional context and explain the rationale behind a particular documentation structure or the organization of the information that is handed over.

Second, professionals with operations experience were enrolled by the delivery client, ODA, to help articulate the future work of operations as a basis for present decision-making. The ODA FM team did not involve people who would be involved in the future operation of the venues and facilities, who were only appointed and involved within the window of opportunity associated with the time-minus process. Instead, it was an internal team with FM expertise. This team developed guidance for the documentation structure for use in operations, with details for the O&M manual, building energy log, drawings, and asset schedule; as well as for handover processes such as training and witnessing for the buildings. The team played an assurance role, and was involved in reading and commenting on documentation, as one team member explained:

> I get an O&M manual for a lift, say, […] I'll write a schedule of improvements I'd like making, or where I think information's missing, or […] not quite correct. (ODA facilities manager)

Rather than being engaged in the work of operating buildings and facilities, this ODA team used knowledge of having been engaged in related activities to inform the work of the delivery teams. It encouraged them to adopt industry standards where possible, reviewing their documentation and visiting the projects to give delivery teams opportunities to ask questions ahead of handover:

> We held various workshops with the teams to understand how they're planning on structuring the documents and saying actually we think it may be beneficial […] doing it this way, and this is why. […] Sitting down across the table from people, talking to them, having workshops … every venue is different; you can't apply the same general practices, so the guidance is generic and the workshop is where you talk through specific examples for each of the venues. (ODA facilities manager)

This member of the ODA FM team was particularly pleased that technical authors, with FM experience, had been employed in many of the delivery teams to help prepare documentation for use in operations. Such recruitment of people with operations experience into the ODA, and into project delivery teams, was an attempt to make knowledge of the nature of future operations available in the present, as the delivery teams prepared to hand over and disengage.

Third, there are judgements made about what information will be needed. Not all documentation generated in delivery is relevant to operations. Projection of the future knowledge work of operations is important in aligning practices, for example, in:

> determining what information needs to go through to operations. If you imagine there are hundreds of thousands of drawings […] it's also filtering out which information, right down your supply chain, is passed on up to the designer [who] makes the final record. A typical example would be: you've got a partition installer who does some fabrication drawings. […] Those are required as a record of what happened but not as a record to go forward for operations. (CLM information manager)

Such work took place across both the stages of handover described in the last section, involving suppliers, CLM and ODA in reflexively imagining future information needed to operate the built infrastructure. This included filtering the data not only to include the relevant explanatory information but also to remove information that was only needed as a record of the delivery programme.

CLM sought to project the future use of the information that it was collating in the data management system, and how the changes in those data would be controlled, both in the handover process itself, and beyond that in operations:

> … there are several different stakeholders who will change that record […] trying to get a very controlled mechanism for controlling alterations to the record. It's got to be very, very timely because things are happening consecutively or simultaneously […] moving forward into operation space [the challenge is the] controlling of accurate information because part of the problem is also the unknown. (CLM information manager)

The unknowability of the future is projected in this process, and the judgements that are made seek to provide solutions that allow for information to be updated in response, to enable continuity and the accumulation of knowledge into operations.

Probes

This involves direct and immediate interaction between the delivery team that is disengaging, and the operators that are engaging to initiate their work, within the window of opportunity in which these groups overlap. Such a window does not often exist at all in the construction industry, but was created in this project to enable this activity:

> What tends to happen in the industry is you build it, you finish it and you hand it over to someone to manage and there is very little transition. With a pull-back transition 3–6 months before completion, so that the FM teams are getting themselves fully mobilized so at the point of completion of that asset, they know what they have got and they know how they are going to manage it. (CLM processes manager)

In our case, this direct probing activity between the groups involved in delivery and operations was through (1) *involvement of operation teams in handover* and (2) *early granting of access* for Games and legacy users to access the information in the ODA knowledge base.

First, during the weeks before handover, the FM teams that will take over responsibility for each of the venues and facilities are trained in preparation for their work. For example, in describing the training of the Velodrome operations team, the delivery partner said:

> In terms of the actual facilities of the building and FM, we gave them training, we had two weeks of everyday training on every system, that includes things like […] Building Management System, light control, control for monitors, PCs, around there, so all that training is provided to the FM providers. (CLM delivery leader)

At the same time, they are given access to the information that has been collated in order to capture knowledge about the venues and facilities and explain the context, rationale and procedures.

Second, the operators are also given access to the information by the ODA, with not only the Games operator, but also the known legacy operators given direct access to the information relevant to handover in the ODA knowledge base.

> Operators involved 12 weeks up to handover: operations management tends to come in at T minus 12 […] and the systems are used to inform him from that point onwards […] He has his say then from T-12 up to the handover […] into how the template of the O&M manuals […] and what he wants to see on the as-built drawings. (CLM team leader)

There was an understanding that this early access to data was important but the interaction between the ODA and operators highlighted different perspectives on what information was useful for the knowledge work involved in operations. As one legacy owner explained:

> As an operator, I think it's still the case that, frankly, we're not saying that we only utilise paper systems but actually, as an operator, that usually is the simplest way in actual fact. To just simplify things down to one side of A4, you might use that on a computer screen rather than an actual piece of paper but simple systems are what you need to operate. You can end up with huge documents, huge files of which you only use one line or something like that, you can't function like that. (Legacy owner)

In the midst of handover practices, there were concerns that the formats of data in the data management system were not those used regularly in their ongoing operations. There were also issues accessing the relevant data. As the ODA is a public body and the data were protectively marked, this major legacy user had few computers through which they could access the data during this stage, at which the delivery teams disengaged.

Extending the window of opportunity

Within handover, where possible, practitioners use strategies to turn sequential coordination activities into parallel ones, extending the edges of the window of opportunity. Organizational structures were used to create continuity, through people with operations experience located within the ODA, and through collaboration between the ODA and LOCOG to procure specialist operations expertise in the commissioning phase. Handover of documentation was not easy, because of the different organizational structures and digital systems:

> In an idealised world […] those two companies would sit on the same document management platform and

> the sharing of information between the two would therefore be a lot easier. (LOCOG manager)

One strategy that was used to extend the window of opportunity for knowledge coordination was for a contractor that had been involved in project delivery to take on responsibility during the Games, working for the Games operator, LOCOG. For example, on the Velodrome project:

> the building contractor is now separately contracted to provide the FM services … […] but the people would have been very different, so we've not suddenly got somebody who worked on the job but we have got somebody within their FM team, so at least there is knowledge transfer within the company. (ODA organizer)

Such involvement of the same organization in project delivery and operation is not unproblematic, as the construction delivery and FM professionals are in different divisions of large firms. It creates the potential, however, for checks to be made and knowledge to be transferred in the future, as those involved in operations are located within the same corporate structure as those involved in delivery.

The legacy owner of the Velodrome articulated their aspiration to draw on the experience and knowledge of the project team by employing the same specialist mechanical and electrical (M&E) contractor that had worked on the delivery of the project as part of the FM team:

> I know that the M&E contractor for the Velodrome has been contracted to work as part of the FM team in this interim period by the ODA […]. I suspect we will take those people on when it's handed back to us some time in 2013, but that's so far away at this point that we haven't made those decisions. (Legacy owner)

This owner indicated that they would do the basic operation directly, but the involvement of specialists who understood the facility was seen as key to its maintenance. The benefit of this specialist role becoming mobilized in both delivery and operations activities is to transfer knowledge across these groups. There is uncertainty in this decision, as the legacy owner indicates, because of the temporal distance from the interview, conducted in 2011, and the focus on the London Olympics before the conversion of the facilities for legacy use.

Discussion and conclusions

In shifting focus from knowledge coordination between groups in ongoing activity, to knowledge coordination between temporally separated groups, this study provides new theoretical insights, raises new questions and opens up new phenomena for study. It also makes a practical contribution to those involved in the handover from projects to operations in the close-out phase of complex projects. The analogy of passing the baton in a relay race illuminates the temporal nature of the knowledge coordination involved in organizational handover.

Just as the baton is often dropped in the relay race, in handover, knowledge transfer is by no means certain. Yet, this temporally constrained form of knowledge coordination was, in the case of the London Olympics, the focus of significant attention, with the handing over of both the physical venues and infrastructures, and an associated set of digital data. Using the analogy with a relay race, we articulate the sequence, timing, technique and communication involved. We also show how, to address the difficulties of such knowledge coordination, practitioners both *project* the nature of the future work of operations and *probe* how meanings will be interpreted within time-constrained windows of opportunity. Practitioners also sought opportunities to extend the window of opportunity in which to negotiate and check meaning. Unlike a baton of limited shape and mass, the information that is handed over between groups is shaped in the process of delivery.

Our explanation differs from and extends current theorizing about the coordination of knowledge work. First, it examines organizational handing over. Unlike the medical hand-offs described in previous work (Solet *et al.*, 2005; Catchpole *et al.*, 2007; Mostaghimi and Crotty, 2011), our focus is on a larger process, in which groups disengage and engage without retaining ongoing relationships. Such a situation is common at the end of projects, where infrastructure becomes operational. In our setting, handover is not a single event, but involves cascading learning across many instances of handover within a programme, as physical artefacts, together with the digital information that explains their function and use, are handed over from delivery teams to operators. While our findings concur with previous research that sees both standardized processes and face-to-face interaction between professionals as important to knowledge transfer, they show the difficulties of bringing temporally separated groups into contact with one another, and the kinds of projections and probes that are used to understand future work.

Second, our explanation is concerned with the engagement with and imagination of possible futures across different timescales. Although one of our interviewees, engaged in handover, argues that "You need to know what you want at the end of the project, so you can stipulate at the start of the project", it is the failure to completely specify these requirements that leads to a

substantial knowledge coordination between project delivery teams and operators in the final stages of the programme. Here, our explanation differs from that of Pitsis *et al.* (2003), who build on a study of the Sydney Olympics to argue that delivery professionals have a "future perfect strategy" in which the planned act bears the temporal character of the past. We do not see the future being treated as past, but rather as uncertain, only partially comprehended and difficult to bring into focus. Within this practice of handing over, judgements are made. We see knowledge coordination in the window of opportunity as a creative act, projecting and probing futures and drawing on the stable referents that represent, however partially, the views of future operators, as well as those that allow for intrinsic coordination (Christensen, 2012), as representations produced by the delivery team continue to be used and worked on over time by operators.

This research has practical implications for those involved in the handover from projects to operations. It illustrates the unfolding practices associated with handover, through which professionals need to collate reliable digital asset information during the project, hand over this information to owners and operators, and work with them as they take over responsibilities for management of this information. Integrated data management systems create new interdependencies between the knowledge work of different groups over time. Such organizational handover is vital to achieving the ambitions of performance improvement through BIM, as set out, for example, in the UK government's BIM agenda. Challenges include obtaining high-quality information from the supply chain towards the end of construction, collating and checking information before teams disband, controlling changes to requirements and information, extracting data to owner-operator systems, establishing practices for managing change while maintaining the "single source of truth", and understanding (evolving/shifting) requirements for operations. Such challenges can be addressed through extending the window of opportunity for knowledge coordination, projecting the nature of the future work of operations; and probing how meanings will be interpreted.

This work raises new theoretical questions. For example, we examined work practices that are analogous to the incoming runner entering the acceleration zone and about to pass the baton: here, we had strong data on which to build new theoretical understanding. We had more limited data on how knowledge that has been handed over becomes mobilized in the everyday practices of operators. There is a need for further research on these activities, which could be seen as analogous to the outgoing runner picking up the baton and running with it. We understand from previous work (Scarbrough *et al.*, 2004; Newell *et al.* 2006) that such knowledge transfer is unlikely to be complete. However, given the significant resources that are mobilized to hand over knowledge, more needs to be understood about how knowledge is taken up as one group disengages and hands over to another. By establishing what is transferred, such work could also examine the effectiveness of strategies to project and probe, and to extend the window of opportunity for handover.

How are failures avoided and managed in the organizational handing over? In hand-offs within professions, occasionally, established protocols were sometimes productively broken in order to deal with a medical emergency (Faraj and Xiao, 2006). A team would have to accept the risk of breaking such protocol, but could only do this with the agreement of a senior member. While we have examples of professionals bypassing the digital system to finish their tasks on time, we know insufficient about what a good or bad breach of protocol might look like in our context.

Finally, more work is needed to develop practical advice to those involved in the hand-over from projects into operations. Thus, in shifting focus from knowledge coordination between groups in ongoing activity, to knowledge coordination between temporally separated groups, this study provides new insights, raising new questions and opening up new phenomena for study.

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Notes

1. This estimate is taken from Reuters, http://uk.reuters.com/article/2012/08/07/uk-oly-ratings-day-idUKBRE8760V820120807 (accessed 19 April 2013), within the UK, 51.9m (90% of the UK population) were estimated to have watched at least 15 minutes of coverage, see http://www.bbc.co.uk/mediacentre/latestnews/2012/olympic-viewing-figs.html (accessed 19 April 2013).
2. Two interviewees came to one interview.

References

Boisot, M. (2011) Generating knowledge in a connected world: the case of the ATLAS experiment at CERN. *Management Learning*, 42(4), 447–57.

Boyadjian, A., and Bootsma, R. J. (1999) Timing in relay running. *Perceptual and Motor Skills*, 88, 1223–30.

Cabinet Office. (2011) *Government Construction Strategy*, Cabinet Office, London.

Carlile, P.R. (2004) Transferring, translating and transforming: an integrative relational approach to sharing and assessing knowledge across boundaries. *Organization Science*, 15(5), 555–68.

Catchpole, K.R., De Leval, M.R., McEwan, A., Pigott, N., Elliott, M.J., McQuillan, A., … Goldman, A.J. (2007) Patient handover from surgery to intensive care: using formula 1 pit-stop and aviation models to improve safety and quality. *Pediatric Anasthesia*, 17(5), 470–78.

Chrisman, N. (1999) *Trading Zones or Boundary Objects: Understanding Incomplete Translations of Technical Expertise*. Paper presented at the Social Studies of Science Annual Meeting, London.

Christensen, L. R. (2012) *Coordinative Practices in the Building Process*, Springer, London.

Cook, S.D.N. and Brown, J. S. (1999) Bridging Epistemologies: the generative dance between organizational knowledge and organizational knowing. *Organization Science*, 10(4), 381–400.

Davies, A. and Mackenzie, I. (2014) Project complexity and systems integration: Constructing the London 2012 Olympics and Paralympics Games. *International Journal of Project Management*, 32(5), 773–90.

Dossick, C.S. and Neff, G. (2011) Messy talk and clean technology: communication, problem-solving and collaboration using building information modelling. *Engineering Project Organization Journal*, 1, 83–93.

Dyck, B., Mauws, M., Starke, F.A. and Mischke, G. A. (2002) Passing the baton: the importance of sequence, timing, technique and communication in executive succession. *Journal of Business Venturing*, 17, 143–62.

Eastman, C., Teicholz, P., Sacks, R. and Liston, K. (2008) *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors*, John Wiley & Sons Ltd, New Jersey.

Edkins, A., Geraldi, J., Morris, P. and Smith, A. (2013) Exploring the front-end of project management. *Engineering Project Organizational Journal*, 3, 71–85.

Eisenhardt, K.M. (1989) Building theories from case study research. *Academy of Management Review*, 14(4), 532–50.

Ewenstein, B. and Whyte, J. (2009) Knowledge practices in design: the role of visual representations as "epistemic objects". *Organization Studies*, 30(1), 7–30.

Faraj, S. and Xiao, Y. (2006) Coordination in fast-response organizations. *Management Science*, 52(8), 1155–69.

Kellogg, K.C., Orlikowski, W.J. and Yates, J. (2006) Life in the trading zone: structuring coordination across boundaries in postbureaucratic organizations. *Organization Science*, 17(1), 22–44.

Lervik, J.E., Fahy, K.M. and Easterby-Smith, M. (2010) Temporal dynamics of situated learning in organizations. *Management Learning*, 41(3), 285–301.

Levina, N. and Vaast, E. (2005) The emergence of boundary spanning competence in practice: implications for the implementation and use of information systems. *MIS Quarterly*, 29(2), 335–63.

McGivern, G. and Dopson, S. (2010) Inter-epistemic power and transforming knowledge objects in a biomedical network. *Organization Studies*, 31(12), 1667–86.

McGraw Hill. (2009) *The Business Value of BIM: Getting Building Information Modeling to the Bottom Line*, New York.

Miettinen, R. and Virkkunen, J. (2005) Epistemic objects, artefacts and organizational change. *Organization*, 12(3), 437–56.

Miles, M.B. and Huberman, A.M. (1994) *Qualitative Data Analysis: An Expanded Sourcebook of New Methods*, Sage, Thousand Oaks, CA.

Mostaghimi, A. and Crotty, B.H. (2011) Professionalism in the digital age. *Annuals of Internal Medicine*, 154(8), 560–62.

NCE. (2011) *Major Project Report: Delivering the UK Games*. New Civil Engineer, London.

Newell, S., Bresnen, M., Edelman, L., Scarbrough, H. and Swan, J. (2006) Sharing knowledge across projects: limits to ICT-led project review practices. *Management Learning*, 37(2), 167–85.

Nicolini, D., Mengis, J. and Swan, J. (2012) Understanding the role of objects in cross-disciplinary collaboration. *Organization Science*, 23, 612–29.

Okhuysen, G.A. and Bechky, B.A. (2009) 10 coordination in organizations: an integrative perspective. *Academy of Management Annals*, 3, 463–502.

Pitsis, T.S., Clegg, S.R., Marosszeky, M. and Rura-Pouey, T. (2003) Constructing the Olympic dream: a future perfect strategy of project management. *Organization Science*, 14 (5), 574–90.

Radford, P.F. and Ward-Smith, A.J. (2003) The baton exchange during the 4×100 m relay: a mathematical analysis. *Journal of Sports Sciences*, 21, 493–501.

Sarcevic, A. and Burd, R.S. (2009) *Information Handover in Time-Critical Work*. Paper presented at the ACM 2009 International Conference on Supporting Group Work (GROUP 2009), Florida, Sanibel Island.

Scarbrough, H., Bresnen, M., Edelman, L.F., Laurent, S., Newell, S. and Swan, J. (2004) The processes of project-based learning: an exploratory study. *Management Learning*, 35(4), 491–506.

Solet, D.J., Norvell, J.M., Rutan, G.H. and Frankel, R.M. (2005) Lost in translation: challenges and opportunities in physician-to-physician communication during patient handoffs. *Academic Medicine*, 80(12), 1094–99.

Swart, J., Hooff, B.v.d., and Baalen, P.v. (2011) Connecting worlds. *Management Learning*, 42(4), 371–77.

Van de Ven, A.H. (2007) *Engaged Scholarship: A Guide for Organizational and Social Research*, Oxford University Press, Oxford.

Ward-Smith, A.J., and Radford, P.F. (2002) A mathematical analysis of the 4 × 100 m relay. *Journal of Sports Sciences*, 20(5), 369–81.