Building the science of research management: What can research management learn from education research?

Jun Song Huang, Ph.D.
National Institute of Education,
Nanyang Technological University, Singapore

Wei Loong Hung, Ph.D.
National Institute of Education,
Nanyang Technological University, Singapore

Abstract: *Research management is an emerging field of study and its development is significant to the advancement of research enterprise. Developing the science of research management requires investigating social mechanisms involved in research management. Yet, studies on social mechanisms of research management is lacking in the literature. To address this gap, this paper proposes importing methodologies and theories from other social science disciplines to study the social mechanisms of research management and to build the science of research management. The paper first articulates what constitutes the science of research management, then proposes to appropriate Design-Based Research (DBR), a methodology in education research, for building the science of research management while at the same time strengthening the theory-practice nexus. A study of education research is then presented to illustrate how DBR is used to enact the theory of homophily which is imported from sociology. It reveals an opportunity to use social designs to develop social relationships among teachers from different schools for networked learning. Such a research endeavour also has potential to advance theories of relationship-building in sociology. Inferring from the example as an analogue to what is suggested for research management, the paper advocates a way to reciprocally connect research management as an emerging research field with more established social science disciplines at large and to advance both the theory and practice of research management.*

Keywords: *Science of research management, social mechanisms, Design-Based Research, theory-practice nexus, education research*

Introduction

In the knowledge economy, research plays a critical role in regional and global innovation systems (Cooke, 2004). How to manage research activities effectively is significant to the success of research enterprise. For example, building research collaborations enhances an institute's research capacity and performance of knowledge production (Katz & Martin, 1997). Translating research to practice enhances the role of research as a key driver that propels the advancement of the knowledge economy (Olssen & Peters, 2005).

Research management, as an emerging field of study, is becoming increasingly comprehensive. There are useful descriptive studies, like Hazelkorn's (2005) case study that describes how new institutions develop research. Such studies focus on describing a research phenomenon, classifying its attributes, and defining patterns and relationships (e.g, correlations between certain attributes and outcomes) in research activities. There are also insightful studies that establish and examine causal relationships in research activities. For example, Gao, Zang, Roth and Wang (2017) use a data set covering 156 countries between 1964 and 2010 to empirically examine whether democratization leads to the growth of research innovation.

However, the research management literature has an inadequate focus on understanding social mechanisms (Hedström & Swedberg, 1998) which specify the processes through which causal relationships arise and produce the observed outcomes in research management. For example, Gao, Zang, Roth and Wang's (2017) study does not answer why, how (i.e., in what causal processes) and in what conditions democracy produces or does not produce research innovations. Hedström (2005) argues that the absence of a plausible mechanism linking X and Y gives us a good reason to be suspicious of the relationship between them being a causal one. But studies that examine social mechanisms in research management are still lacking in the research management literature.

In this paper, we regard scientific knowledge on social mechanisms involved in research management as the science of research management (in short, SciRM). Insufficient understanding of SciRM limits our ability to enhance research management practice. This limitation is recognized in Cooke and Hilton's (2015) consensus study on how to enhance research collaborations. Due to the scant literature on social mechanisms involved in research collaboration, Cooke and Hilton have to rely heavily on drawing inferences, for example from the literature of group dynamics in general settings. Cooke and Hilton's approach is similar to what Tight (2014) observes in higher education research which 'imports' theories from another discipline when the 'home-grown' theory is lacking. We recognize importing theories and methodologies from other disciplines as a promising way to build SciRM.

This paper advocates and proposes a way forward to build SciRM. First, we articulate what constitutes SciRM and the significance of developing such knowledge. Second, we make reference to education research and propose that Design-Based Research (DBR) can be appropriated as a methodology for building SciRM. Third, we illustrate a study in education research. In this example, DBR is used as a methodology to import theories from sociology to develop social relationships among teachers for networked learning (i.e., the practice) while at the same time

advance the understanding of social mechanisms in building social relationships (i.e., the theory). The example serves as an analogue to what we advocate for research management, revealing a feasible way to use DBR as a methodology to import theories in social science research for building SciRM.

The science of research management

Research management is a complex social phenomenon. It involves complex processes with constant changes and challenges (Tauginiene, 2009). Hence, the causal mechanisms specified in SciRM are hardly simple, linear and deterministic causal chains, such as those in a mechanical clock. SciRM is not prescriptive knowledge (Van Aken, 2005) or universal truths that are deterministic or can be used to make precise predictions. It is an explanatory tool that is provisional (hence subject to refinement in future) and has significance in guiding the formulation and rationalization of research management decisions. It empowers research management practices by enabling new practices that open up possibilities for certain desirable events to take place. As James (1907) argues, such knowledge is "*instruments, not answers to enigmas, in which we can rest. We don't lie back upon them, we move forward, and, on occasion, make nature over again by their aid*" (p. 46).

Let us use physical proximity (Katz, 1994) for illustration. Physical proximity refers to the extent to which researchers' office rooms are located close to each other. Physical proximity promotes research collaboration (Katz & Martin, 1997), but the psycho-sociological mechanisms through which physical proximity leads to researchers' social interactions and their trust-building and collaboration is not explicitly examined within the research management literature. SciRM specifies and examines such psycho-sociological mechanisms. Building such scientific understanding not only provides strong explanatory power on *why* research collaboration takes place, but also has potential to inform *how* to enact causal mechanisms related to physical proximity to promote collaborations. For example, such knowledge may inform the design of common spaces in offices, such as Google's '150-feet from food' rule and high-traffic staircases (Alter, 2015), to increase informal interactions among researchers at these common spaces. Such interactions enact related psycho-sociological mechanisms for building trust and research collaborations.

Criteria for the science of research management

If SciRM is provisional, how do we differentiate it from our intuitive causal link? With reference to the philosophy of science (Machamer & Silberstein, 2002), we highlight three key criteria of differentiation, namely clearly specified causal mechanisms, scientific warrant assured by rigorous research methodology, and practice impact through a strong research-practice nexus.

Firstly, SciRM emphasizes understanding causal mechanisms in research management. Salmon (1984), in his book *Scientific explanation and the causal structure of the universe*, highlights that scientific explanation requires causal knowledge. He distinguishes causal process (e.g., ball collision) from pseudo-process (e.g., overlapping of the shadows of balls) and emphasizes the importance of tracing and explaining causal interactions when one causal process intersects with another and produces a modification of its structure. This disposition of causality regards relational structures and change of internal dispositions as the causes of phenomena (Lloyd,

1993). In this view, SciRM, for example the account of human agency in research collaboration, should at least trace to the psychological level explaining how people think and behave and the sociological level explaining how people interact with each other (Coleman, 1988).

The causal mechanisms need to be clearly specified. Clearly and precisely articulated accounts of a mechanism can be subjected to scientific scrutiny and their implications can be assessed more accurately (Glennan, 2002). SciRM does not aim at an exhaustive account of causal details. It seeks to capture the crucial elements of the process by extracting away the irrelevant (or less important) details. It also emphasizes the intellectual virtues of precision and clarity.

Secondly, SciRM is assured by scientific warrant. Scientific knowledge is subject to critical scrutiny (Popper, 1959; Worrall, 2002). This demarcation differentiates SciRM from everyday intuition. For example, the statement "all swans are black" remains a hypothesis if it is not examined through critical, empirical and systematic observation. The hypothesis will be rejected as a scientific statement if one swan is found to be not black. Rigorous research methodology provides scientific warrant, and the rigor of a methodology is generally earmarked by its trustworthiness (Guba & Lincoln, 1989). For a methodology to be trustworthy, Kelly (2004) suggests that it should have argumentative grammar, and a coherent and explicit chain of reasoning on using a set of procedures of the methodology (Shavelson, Phillips, Towne, & Feuer, 2003). For example, the argumentative grammar of randomized control trials includes the justification of small sample analysis, statistical reasoning and randomization procedures. Violating the chains of reasoning underpinning a methodology is often a key reason for rejecting the rigour of a research study (Kelly, 2004). Hence, rigorous research methodology is necessary to assure the scientific warrant of SciRM.

Thirdly, SciRM does not just render explanations to a phenomenon, it also has significance in enacting desired changes in practice. As research management is an applied field, building SciRM is necessary only when it is for impacting the practice. For example, to understand why researchers collaborate, Katz and Martin (1997) categorized six main factors, such as the reduction in research funding, increasing specialization of science, the need for intellectual companionship, and other factors. While informative, many such causal explanations have limited power to be used to intervene and enhance research collaboration. For example, the increased specialization of science means that researchers are on a lone journey probing the frontiers of knowledge. Their needs of intellectual companionship could be satisfied through research collaboration. But it does not make sense for research management practitioners to make researchers feel lonelier in order to promote more collaboration.

In this regard, we advocate that SciRM emphasizes both "why" and "how to", which is akin to Bennis' (1966) advocacy of theory of *change* and theory of *changing* in organizational change. Theory of *change* explains why organizational change takes place (i.e., mechanisms through which an organization changes, for example, why and how people adapt in the process of change). Theory of *changing* seeks to understand how to change an organization (how to design an intervention, for example organization re-structuring, to enact people's adaptation so as to lead to desired organizational *change*). Building scientific knowledge on why things happen (akin to theory of *change*) and how to design an intervention to make things happen (akin to theory of *changing*)

is significant to the research-practice nexus (Tucker & Lowe, 2014) and should be maintained in research management.

Maintaining a strong research-practice nexus is best achieved from the onset of building SciRM, rather than after the building of SciRM. Tucker and Lowe (2014) caution about the gap between research and practice. While research work traditionally develops scientific knowledge first and then seeks to translate research findings into practice, this research-to-practice translation is, though useful (Woolf, 2008), often challenging and problematic (Glasgow & Emmons, 2007). In response, Baumbusch et al. (2008) suggest a collaborative model of knowledge translation between research and practice, rather than *from* research to practice. They argue that the action to mend the research-practice gap is for research to simultaneously achieve the academic aim of rigorous theory building while at the same time addressing the need in practice.

In summary, SciRM is distinctive knowledge in the research management literature. It seeks to establish explanatory power by understanding clearly specified causal mechanisms. It differs from everyday intuition because it is critically scrutinized with rigorous methodology. It also encompasses both the deep theoretical understanding of *why* (i.e., causal mechanisms) and the knowledge of *how* to (i.e., design of research management interventions to enact causal mechanisms) with a strong research-practice nexus.

Highlighting the significance of building SciRM in the research management literature by no means undermines the importance of other types of studies on research management. Carlile and Christensen (2004) posit that advancing a field of study starts from a descriptive stage which involves observing a phenomenon, classifing attributes, and defining relationships between attributes and outcomes. Eventually, the research field evolves into a normative stage which shifts from correlations to causality involved in a phenomenon. While developing practice-based knowledge, descriptive knowledge and evaluative knowledge remains important in the research management literature, we argue that building SciRM is a necessary complement as the field of study progresses.

What can research management learn from education research?

To build SciRM, we need to manage methodological challenges. The methodology to build SciRM needs to be capable of investigating causal mechanisms in research management, ensuring scientific warrant, and strengthening the research-practice nexus from the onset.

Since the research management literature is at an emerging stage, importing theories and methodologies from another discipline can be a promising way forward. For this purpose, we turn to education research, an applied discipline with which we have relative familiarity.

Traditional methodologies in education research have limitations in addressing the methodological challenges in building SciRM. For example, qualitative methodologies, such as grounded theory (Charmaz, 2000), and quantitative methodologies, such as experimental studies (Christensen, 2007), have methodological rigor and argumentative grammar. However, the theory-to-practice nexus is not sufficiently dealt with from the onset of the research process. Often, the practice

impact has to be addressed through separate processes, like research translation and dissemination. Burkhardt and Schoenfeld (2003) find that such processes are often not effective in impacting practice. Their review of six effective models in education recognizes that Design-Based Research "represents a much-needed melding of research and practice" (p. 4).

Design-Based Research

Design-Based Research, in short DBR, seeks to build learning theories and, at the same time, improve the practice of teaching and learning (TDBR Collective, 2003). It focuses on designing a learning environment (e.g., learning tasks, resources, collaboration structure, etc.) that better enables learning. The design is informed by existing cognitive-psychological, socio-cognitive and socio-cultural theories of human learning. The research findings contribute to the advancement of these theories and the design frameworks that enact these theories.

Ann Brown (1992) introduced design science in the educational research community. She discusses analytic science such as anthropology, which seeks to understand how a phenomenon can be explained, and design science, which aims to determine how designed artefacts, such as designed learning environments, affect teaching and learning. The distinction between analytic and design science recognizes that theories of learning (e.g., learning mechanisms) are often quite different from design frameworks for learning (e.g., how to design learning activities that enact the learning mechanisms). Both are critically needed in research and practice.

In DBR, an education researcher is engaged in an iterative process of design, implementation and evaluation of learning activities in real classroom contexts (Sandoval & Bell, 2004). As the design of the learning environment is critical in DBR, researchers often work in collaboration with practitioners, such as teachers, in order to bring the practice expertise and knowledge into producing and analyzing the design. The initial design of learning activities is informed by existing learning theories from the literature. Through the iterative and collaborative process, researchers and practitioners develop new learning and design conjectures which may be tested in future iterations. Hence, DBR contributes to the advancement of learning theories (i.e., the science of learning) and, at the same time, to the improvement of teaching and learning practices (Plomp, 2007). The advancement of learning theories is used to inform the next iterative design of learning activities, which lead to further advancement of learning theories and improvement of practice.

There are two key critiques to DBR as a research methodology. Firstly, Kelly (2004) critiques that design research lacks an argumentative grammar. He asserts that DBR is committed to the joint pursuit of practical improvement and theoretical refinement, but does not contain logic that supports reasoning about its data, for example, the link of designed learning activity, the process of learning and the observed learning outcomes. Secondly, Phillips and Dolle (2006) critique that design research cannot meet one of its basic commitments: the simultaneous evaluation of designs and testing of theory. The joint design and theoretical ideas embodied in the same intervention makes it difficult to test them simultaneously.

As a response to the critiques to DBR, Sandoval (2014) proposes the conjecture mapping approach which emphasizes investigating and uncovering causal effects in each design iteration. In the following, we discuss conjecture mapping as an important and necessary complement to

DBR as a methodology.

Conjecture mapping

According to Sandoval (2014), researchers conducting DBR need to specify two sets of conjectures; *design conjecture* and *theoretical conjecture*.

Design conjecture refers to how a designed learning activity (such as the learning material, the sequence of lessons and how students work together) enacts desired learning processes. *Theoretical conjecture* refers to how the occurrence of the learning processes leads to desired learning outcomes. For example, when students are given a problem to solve before they are taught the knowledge that is needed to solve the problem, they will struggle on the problem-solving task. This creates a condition for them to activate their prior knowledge (Loibl, Roll, & Rummel, 2016). The activation of prior knowledge leads to their differentiation of prior knowledge and noticing of their knowledge gaps. When students notice their knowledge gap, they will better attend to subsequent instruction, better encode the target knowledge and, hence, experience better learning outcomes (Loibl et al., 2016). In this example, the design is 'problem solving first and instruction later'. The first design conjecture is that the 'problem solving first' design leads to students' prior knowledge activation in the problem-solving phase. The cognitive process is that prior knowledge activation leads to knowledge differentiation and noticing knowledge gaps (i.e., the first theoretical conjecture). This leads to the second design conjecture: when the instruction is provided later, students who notice their knowledge gaps will better attend to their knowledge gap in the instruction. This leads to the second theoretical conjecture; students attending to their knowledge gaps in the instruction will encode the target knowledge well.

The two sets of design and theoretical conjectures make distinctions between how a design functions and how those functions lead to learning outcomes. Together, they capture the hypothesized learning trajectory afforded by the designed activities. They help researchers focus on design elements that are theoretically salient and contribute to theoretical advancement. When the two sets of conjectures are clearly specified and rigorously examined, the development of *theoretical conjecture* leads to the advancement of learning theories, and the development of *design conjecture* contributes to practice impact.

Sandoval (2014) argues that making distinctions between design and theoretical conjectures and clearly specifying them for investigation provide argumentative grammar that articulates the causal attributes of the data (e.g., design, learning process and outcome). The research question is not about *whether* a design works, but *how* and *why* it works. Linking the data of design enactment and learning processes allows design evaluation (e.g., how the design enacted hypothesized learning processes). Linking the data of learning processes and outcomes allows theory evaluation (e.g., how the enacted learning processes lead to learning outcomes). This allows the conjecture mapping approach to address the critique of being able to simultaneously evaluate design and develop theory.

In summary, DBR with conjecture mapping, hereafter simply referred to as DBR, is a rigorous methodology to investigate causal mechanisms in education research and is capable of strengthening the research-practice nexus. It embodies the following characteristics. Firstly, it

involves iterative design and implementation of interventions that seek to address complex real-world problems. Secondly, it works in the authentic real-world context and in partnership with practitioners. Thirdly, the design of intervention is theory-driven: the initial design is informed by the existing theories and, through iterative design, it seeks to advance both the theory (by developing and testing theoretical conjectures) and design framework that enacts the theories (by developing design conjectures).

Appropriating DBR for building the SciRM

There is a good match between what DBR can offer and what is needed in building SciRM. DBR has potential to be appropriated to address the methodological challenges faced by the research management field. It also has potential to both understand the social mechanisms involved in research management, and the design framework to enact these mechanisms, strengthening the research-practice nexus.

Appropriating DBR allows importing social and psychological theories to bootstrap the building of SciRM. The journey of DBR starts with the design of the first iteration which is informed by the existing literature. To investigate the social mechanisms involved in research management, the journey does not have to start from scratch. The research management field is connected to established disciplines, such innovation management, management, psychology and sociology. The rich and deep understanding of causal mechanisms in these related disciplines can be borrowed to inform the design of the first iteration. For example, research is an innovation endeavour and managing research is analogous to managing innovations. Findings on innovation management, such as the mechanisms of managing radical innovations (McDermott & O'Connor, 2002) may bootstrap the building of SciRM.

Appropriating DBR to build SciRM requires close collaboration between research management scholars and practitioners. The scholarly and professional communities of research management possess at least two key strengths to appropriate DBR.

First, the research management profession has existing scholarly capacity to pursue SciRM. For example, the Journal of Research Administration (JRA) is a premier peer-reviewed academic journal in the field of research administration and management. A review of the manuscripts published by JRA in the past ten years shows that about 36% of the 149 manuscripts were authored or co-authored by research management practitioners. Some of the most recent issues (i.e., Vol. 46.2, Vol. 45.2 and Vol. 45.1) have 50%, 83% and 50% respectively of the manuscripts authored by practitioners. Anecdotal evidence on the membership of the research management societies also suggests that more and more research management practitioners are now holding PhD degrees. These practitioners understand research management practice, have solid understanding of research methodologies, and have completed rigorous research training. They are capable of building and advancing SciRM.

Second, the research management profession is further benefiting from its closeness to research enterprise. Research management practitioners support research enterprise and they work closely with researchers in various disciplines. This makes it possible and convenient for research management practitioners to gain access to knowledge and skills that researchers possess.

Benefiting from this closeness, Pongpirul and Srisasalux (2007) note that research management practitioners develop academic capacities, such as knowledge of research methodology, ability to review and map existing knowledge, research program evaluation skills, etc. Research management practitioners could leverage their close relationship with the research enterprise and intentionally develop further capacities for building SciRM.

In addition to capacities, there is also a need to understand how to appropriate DBR and import theories from other disciplines to build SciRM. In the following, we present a concrete example of how an education study imports social theories to building social relationships among teachers. Although in the education research context, the example is analogous to the research endeavor we advocate for research management.

An education research example that imports social theories

This example arises from one of our research projects on teacher learning. More specifically, we present an example focusing on how DBR is adopted to borrow social theories and design activities of a Networked Learning Community (NLC) (Jackson & Temperley, 2007) to build social relationships among teachers from different schools. It simultaneously advances theoretical understanding on the social mechanisms related to relationship building and designs frameworks that enact such mechanisms.

Contextual background

The example arises from our study on NLC in Singapore. A NLC involves a network of schools working together in intentional ways to enhance teacher professional learning (Jackson & Temperley, 2007). It connects the within-school professional learning communities and eventually leads to within-school and between-school learning communities that are networked. Hence, building laterality (i.e., peer-level social relations) among teachers from different schools is critical to the success of NLCs.

The NLC presented in this paper is championed by Master Teachers from the Academy of Singapore Teachers of Singapore's Ministry of Education. The Master Teachers are experienced expert teachers who are the leading teaching practitioners in Singapore. They operate across schools to help develop the teaching workforce through mentoring and demonstrating good teaching practices. To fulfil this role, Master Teachers develop NLCs as a professional development platform for teachers from different schools to come together to deepen the knowledge base of the profession (Academy of Singapore Teachers, 2012).

In this example, we present a NLC event which took place in June 2016 for science teachers. More specifically, we focus on one session of an outdoor learning trail of this NLC event. In this one-and-a-half-hour activity which took place in a national park, teachers from different schools were to gain first-hand experience of an outdoor learning inquiry designed by the Master Teachers. The teachers were first assigned to respective tables for briefing in a seminar room. Subsequently, teachers from each table were led by a Master Teacher to experience the outdoor learning trail. Upon returning to the seminar room, teachers in each table worked together to reflect upon their

experience. This was followed by a consolidation given to all the participants. The intention of the NLC event was for the teachers to adopt the outdoor learning trail for student learning in their respective schools. While the main purpose of this NLC activity was for teacher learning, it provided a platform for teachers to build lateral relationships with their peers from other schools and thus, through them, to connect professional learning communities in the respective schools.

In this example, we illustrate how DBR, with its origination in research on learning, is appropriated for building laterality among teachers for networked learning. By importing theories from sociology to design for social interactions and to build laterality among teachers, it enables the advancement of social mechanisms of building social relationships.

The design: Group membership assignment

The participants of this NLC activity were mostly first time participants who did not have prior social relationships with each other. The design elements for relationship building included group membership assignment, lunch arrangement (i.e., no lunch was catered, hence, teachers needed to self-organize lunch partners for lunch at nearby coffee shops), "illegal" group adventure (i.e., the group excitedly ventured into a prohibited spot to take group photos and was stopped by the park guards for entering the area 'illegally'), etc.

In the following, we focus on one particular design element, the assignment of group membership for each table. Before the start of the outdoor learning trail, the Master Teachers paired the participants in groups and each group was assigned to a table. Every group comprised 4-5 participating teachers led by a Master Teacher (or equivalent).

One group embodied a "2+1+1" group membership design: besides the Master Teacher, the group included two teachers from School A, one teacher from School B and one from School C. The two teachers from School A were colleagues and knew each other well. The teachers from School B and School C met each other for the first time at this NLC event. They did not know the two teachers from School A either.

Design conjecture and theoretical conjecture

We first specify the design conjecture related to the "2+1+1" membership design. The two teachers from School A had more shared identities (i.e., colleagues from the same school) and common knowledge and interests. The teachers from Schools B and C did not know each other, nor did they know the teachers from School A. They have fewer shared identities, or shared understanding of their common knowledge and interests. In the "2+1+1" membership design, every member needed to face a large percentage of strangers. For the teachers from School A, 50% of the group members (i.e., teachers from Schools B and C) were strangers. For the teacher from School B, 75% of the group members (i.e., the two teachers from School A and the teacher from School C) were strangers. The same was true for the teacher from School C. This design influences the two teachers from School A to feel similar to each other, and the teachers from Schools B and C to feel similar to each other.

The theoretical conjecture homophily (Kadushin, 2011), borrowed from sociology, suggests

that "birds of a feather flock together". Individuals enjoy the comfort of interacting with others who are similar (e.g., shared identity). Communication is also more effective between people who are homophilous, for example, when they share common meanings, beliefs, and mutual understandings. Homophily produces homophilous group members over time as well. People in the same social group tend to become homophilous over time (Kadushin, 2011). This is often referred to as "similarity breeds connections" (McPherson, Smith-Lovin, & Cook, 2001). Hence, members of the same network create group tastes and preference, and inspire conformity in thought and action (Burt, 2003).

Putting the design and theoretical conjectures together in the "2+1+1" group membership design, the homophily between the two teachers from School A causes them to feel comfortable staying close to each other and naturally nudges them into a cluster. As interactions among teachers transpire during the outdoor learning trail, the homophily between the teachers from Schools B and C builds up, predominantly because they shared the same identity of 'being left out', and they eventually form another cluster. Because the two clusters (i.e, the two teachers from School A as one cluster and the teachers from Schools B and C as the other cluster) had equal size in membership, they progressively evolved into one homophilous group as a result of other design conjectures mentioned earlier, such as "illegal" group adventure, lunch arrangement, etc.

Process and outcome: Evidence of relationship building

The laterality among teachers in the group developed in a similar way as what the design and theoretical conjectures projected. During the outdoor learning trail, although the Master Teacher focused primarily on teacher learning, rather than the growth of laterality, the "2+1+1" membership design enabled the lateral relationships to emerge when the four teachers followed the Master Teacher to explore and experience the outdoor learning trail.

As per the conjecture, when the outdoor learning trail first started, the two teachers from School A clustered together. The two teachers from Schools B and C were as random in their interactions between each other as with the two teachers from School A. Figure 1 shows the initial dynamics in the group. The two teachers from School A walked together. The teacher from School B walked behind, and the teacher from School C walked in the front, closely following the Master Teacher.

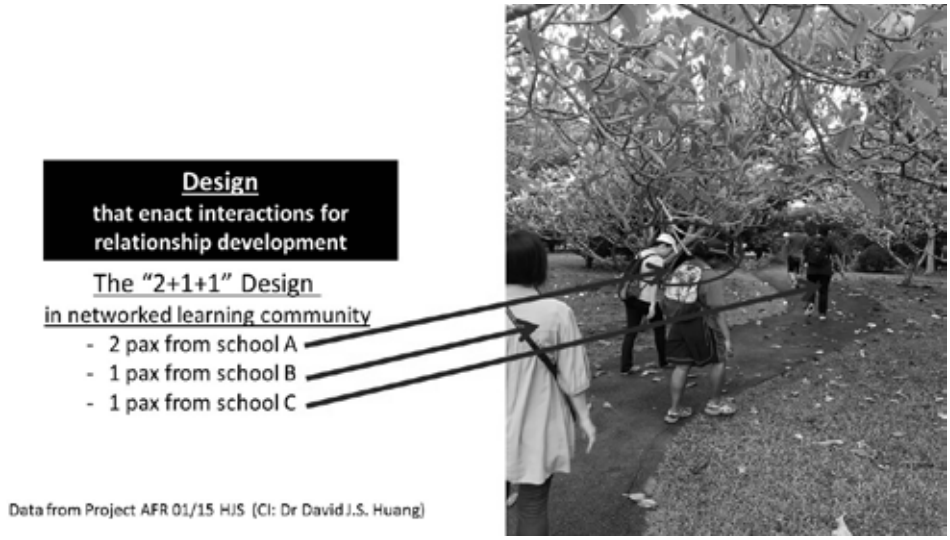

Figure 1. The initial interactions of the group.

As the outdoor learning trail unfolded, interactions between the two teachers from Schools B and C increased. Toward the latter part of the outdoor learning trail, the two teachers from School A walked in the front, the teacher from School B walked behind them and the teacher from School C was left far behind as she stopped to tie her shoelace. As she was catching up, the teacher from School B stopped, turned back and said to the teacher from School C: "I missed my partner". Figure 2 below captured the moment of interaction. The behaviour and the utterance by the teacher from School B indicates a growth of a social closeness between her and the teacher from School C.

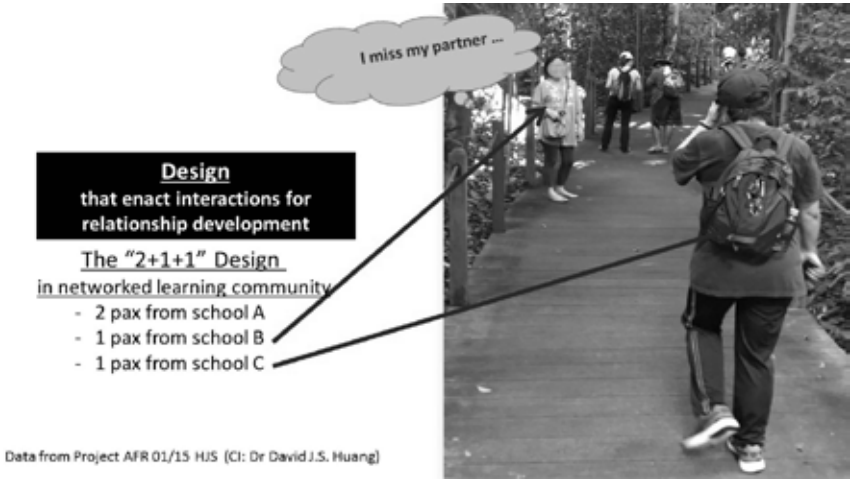

Figure 2. The social closeness built between teachers from Schools B and C.

The example illustrates the first iteration of DBR in which the social design (i.e., the design of environment for social interactions) enacted social theories, such as homophily for teachers to build lateral relationships in a NLC event. The group dynamics observed in the outdoor learning trail, in particular the growth of laterality between the teachers from Schools B and C, is generally consistent with the design and theoretical conjectures.

Possible conjectures for the next DBR iteration

While the "2+1+1" design works in this example, there are competing conjectures that can be investigated in future iterations. For example, what about teachers with different personalities, what about alternative designs, such as a "1+1+1" design, etc.

Take the alternative "1+1+1" design for example, we hypothesize that this design would not be as effective as the "2+1+1" design. This is because in the "1+1+1" design, everyone feels equally 'left out'. There is no initial presence of a strong cluster, for example, the cluster formed by the two teachers from School A in the "2+1+1" design. Without the presence of a strong cluster at the beginning of the activity, the members of the "1+1+1" design would not produce a strong feeling of 'being left out'. This would not effectively enact homophily to foster their interactions for developing laterality.

The hypothesis of the "1+1+1" design may lead to a new conjecture which can be a direction to further investigate the theory of homophily, for example the condition in which homophily takes place, and why and in what condition homophily outweighs other social theories. Investigating alternative design conjectures in the second DBR iteration allows deeper and broader investigation of theoretical and design conjectures in building laterality.

In summary, the example reveals a possibility to adopt DBR and to borrow social theories for building laterality among teachers in NLC. It allows simultaneously building and improving social theories while enhancing the NLC practice. Although the example is in the context of teacher learning, it informs how a similar approach may be adopted to enhance the theory and practice of research collaborations and contributes to the building of SciRM.

Discussion and conclusion

Research management is an emerging field of study. To develop this emerging field, this paper proposes to build the science of research management (SciRM) with two advocates. Firstly, it argues for a need to build SciRM and highlights three key criteria that differentiate SciRM from other types of knowledge: investigating on clearly specified causal mechanisms, assured by rigorous scientific warrant, and contributing to a strong research-practice nexus. Secondly, the paper proposes a way forward to build SciRM. It examines the Design-Based Research (DBR) methodology in education research and suggests adopting DBR to import theories from other disciplines to bootstrap the building of SciRM. An example on networked learning in education research is then presented to illustrate how the design of a social context enacted the homophily theory (imported from sociology) and fostered social interactions among teachers for building lateral relationships. The example, serving as an analogue to what we advocate in the research

management field, reveals a possibility in which DBR can be appropriated to import theories from disciplines, such as psychology and sociology, to bootstrap the building of SciRM.

The paper makes three main contributions to research management. Firstly, it is significant to the advancement of research management as a field of study. Building SciRM is a response to Cooke and Hilton's (2015) consensus study which highlights a lack of theories on research collaborations. It also corresponds to Tight's (2014) observation of importing theories from another discipline when the 'home-grown' theory is lacking in higher education research. Building SciRM should not be regarded as the only research direction or the only productive research direction. Nor should DBR be regarded as the only appropriate methodology to be adopted to build SciRM. What we highlight in this paper is the deficiency in understanding social mechanisms involved in research management. Addressing this deficiency is important and necessary to complement the existing research management literature. Using DBR to import theories from other disciplines to bootstrap the building of 'home-grown' theories in research management is only one useful and promising approach.

Secondly, importing theories from disciplines such as psychology and sociology not only helps to bootstrap the building of SciRM, but also connects studies on research management with social science research at large. This is significant to emerging fields of study such as research management, because it reduces "wheel reinvention and replication" (Tight, 2014, p. 94). For example, in social sciences research, there is a long tradition of research on groups and teams, including studies on group membership (Hogg & Williams, 2000), team communication (Frey, Gouran, & Poole, 1999), team assembly (Guimera, Uzzi, Spiro, & Amaral, 2005) and more. Importing these theories for building SciRM contributes to the further development of these theories as well. This is because when adopting DBR and importing theories to build SciRM, research management becomes a field in which research such as psychological and sociological studies are situated. Such studies not only bootstrap the growth of the research management field in specific, but also reciprocally complement social science research and basic research on psychology and sociology at large.

Thirdly, building SciRM is significant to the research management practice by opening up new possibilities of thinking and doing research management. Research management is an applied field of study with a strong root in practice. The methodology we propose, DBR, contributes to both the theoretical advancement, such as *why*, *how* and *in what causal processes* things happen, and the advancement of design frameworks which answers *in what conditions* causal processes take place. In this sense, SciRM is useful to practice because it informs practitioners how to enact SciRM for their research management needs, such as building research collaborations.

Building SciRM also pushes new structures and capacities in managing research. For practitioners to make use of design frameworks to achieve desired outcomes in research management, they need to have sufficient information for decision-making. For example, analyzing social networks among researchers, such as their grant collaboration and co-authorship, may inform how management enacts the homophily theory among a groups of researchers to foster their collaboration. Such decision-making is only possible if institutions build up their data management structure and analytical capacity (Terenzini, 2013).

To build and appreciate SciRM, the research management community needs to embrace research culture. Traditionally, the professional community focuses on sharing practical knowledge with an aim to apply what is learned to practice. The scientific community, although it also shares knowledge, holds an important role in gatekeeping what is warranted as scientific knowledge. In order to scrutinize the scientific warrant of a piece of knowledge, the scientific community, in comparison to the professional community, tends to be more critical, argumentative and skeptical before accepting the knowledge for sharing. Given the cultural difference between the two communities, building SciRM requires a progressive embracement of criticality as a useful and necessary complement to the existing culture of the research management community.

In conclusion, this paper advocates for building SciRM and suggests adopting DBR as a research methodology to import theories from the broad social science domain to bootstrap the building of SciRM. Such a research direction also reciprocally complements social science research at large. It opens up possibilities of new practices in research management. It is envisaged that, as the research management community pursues this much-needed research direction, and as the reciprocity between research management and social science research progressively enlarges, the research management practice will be more effective in supporting research enterprise. It will also turn research management into a fertile field of study, leading to 'home-grown' theories in research management and contributing to social science research at large.

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Correspondence concerning this article should be addressed to:
Jun Song HUANG (*David*), Ph.D.
Assistant Dean, Research Strategy
National Institute of Education
Nanyang Technological University
1 Nanyang Walk
Singapore, 637616
Email: junsong.huang@nie.edu.sg

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