

EXPLORING HEALTHCARE SYSTEMS DESIGN RESEARCH AND PRACTICE: OUTCOMES OF AN INTERNATIONAL MEETING

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ABSTRACT

Current healthcare delivery challenges are multi-faceted, requiring multiple perspectives to be addressed using a systems approach. However, a significant amount of healthcare systems design research work is carried out within single disciplines or at best a few disciplines working together. There appears to be little deliberate attempt to draw together a wide range of disciplines committed to working together to overcome differences and tackle some of the complex challenges in healthcare delivery. In this paper, we report on the initial outcomes of such an international initiative that, in the form of a workshop held at the University of Cambridge, brought together researchers and practitioners from a wide range of disciplines to explore the foundations of a community for Healthcare Systems Design Research and Practice.

Keywords: Systems Engineering (SE), Design process, Multi- / Cross- / Trans-disciplinary processes, Healthcare Systems Design Research

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Cite this article: Komashie, A., Lame, G., Patou, F., Ciccone, N., Maier, A., Clarkson, P.J. (2019) 'Exploring Healthcare Systems Design Research and Practice: Outcomes of an International Meeting', in *Proceedings of the 22nd International Conference on Engineering Design (ICED19)*, Delft, The Netherlands, 5-8 August 2019. DOI:10.1017/dsi.2019.100

1 INTRODUCTION

Healthcare is, arguably, one of the most fundamental human needs (Adhanom, 2017). The need for improvements in healthcare delivery is not new. For centuries, better interventions, better medications and better diagnostics have been the answer to the quest for improvement in healthcare (Bhatt, 2010). Improvements in these aspects of healthcare, together with rapid advances in technology have, indeed, brought about significant transformation in how care is organised and delivered.

Over the past two decades, however, there has been a growing recognition that improvements in such elements as interventions, medications, and diagnostics, are not enough to ensure that patients receive care that is consistently safe and of good quality. A considerable number of high profile publications have suggested that a systems approach to healthcare delivery is needed (Kohn *et al.*, 2000, Institute of Medicine, 2001, World Health Organization, 2000, National Academy of Engineering and Institute of Medicine, 2005, Clarkson *et al.*, 2017). In most cases, the calls for a systems approach to healthcare improvement appear to be driven by a common theme – the failure of existing systems (Ham *et al.*, 2016). From examples in engineering (Honour, 2014, Beasley, 2017), it may be argued that significant gains in quality of care, reduction of cost and improvements in efficiency are possible in healthcare if a systems approach is well understood and effectively applied to current healthcare challenges. A systems approach in this context is intended in a broad sense – from a systems approach to smart technology and value-effective healthcare solutions (Patou and Maier, 2017) to a systems approach to health and care design and continuous improvement (Clarkson *et al.*, 2017).

A systems design approach to healthcare improvement is conceptually appealing and the success stories in engineering makes it attractive to healthcare practitioners. However, there is uncertainty about how to realise this approach in practice within the healthcare domain. There is also the question of how such an approach relates to the dominant methodologies in quality improvement, clinical research and evaluation currently in existence in healthcare. Furthermore, there is considerable diversity between researchers and practitioners who employ a systems design approach within different disciplines with interest in healthcare.

We argue that these challenges can be addressed most effectively if the disciplines with an interest in applying a systems design approach to healthcare systems design and delivery work together. This will involve clarifying what a systems design approach essentially entails and developing the tools to support healthcare practitioners to put it into practice. This need to work together was the motivation for the multi-disciplinary meeting on healthcare systems design research we report in this paper.

We organised a workshop that brought together people from the design research community, as well as several other disciplines interested in improving health and healthcare delivery through better systems design and management. The objective was to explore different perspectives on healthcare systems design from various streams of systems design research.

In the paper, we present a summary of the outcomes of this first international meeting on healthcare systems design research co-organised by the Engineering Design Centre, The Healthcare Improvement Studies Institute (THIS Institute), University of Cambridge, and Engineering Systems, Technical University of Denmark. The meeting was held at the University of Cambridge in November 2018. We explored the foundations of a community of diverse researchers and practitioners aiming to work together to tackle some of the most pressing healthcare challenges in the world. We identify some key themes that need addressing if healthcare systems design research is to make deeper impact on health and healthcare delivery. We briefly reflect on the implications of the outcomes for the design community as a discipline that has the potential to make significant contributions to this endeavour.

2 METHODS

On 29 and 30 November 2018, we held a one-and-a-half day workshop at the Engineering Design Centre at the University of Cambridge (Cambridge, UK) with the following objectives:

1. To identify the unique contributions that systems design research can make in achieving sustainable improvements in health and care delivery systems internationally.
2. To lay the foundations for a community of research and practice dedicated to healthcare systems design across disciplinary boundaries.

As part of the introduction session, participants were asked to respond to the question “what are the three or five key questions that define your current research or interest?” Participants wrote on large A5 size post it notes which were collected afterwards. This exercise resulted in more than 100 questions. It was interesting to find that despite the considerable diversity in the room, there was a strong convergence in our common goal as revealed by the word picture shown in figure 1 above.

3.2 Working together - lessons learnt

Most of the activities during the meeting took place around six tables each with a group of five or six participants. Groups were pre-defined in order to distribute disciplinary backgrounds and participants from various countries as evenly as possible. This also meant that most participants were working outside their comfort zones – with people they do not know, who may have backgrounds very different from theirs. Based on the same principles, the groups were reshuffled for the activities on the second day.

The first day included a two-hour session where small groups worked on fictitious case studies of challenges in healthcare delivery, organised around a set of personas. One set was on the challenges of an ageing population and its impact on primary and secondary care, the other related to hospital outpatient care. Groups were asked to work together to devise a research proposal to address these challenges. As organisers of this meeting, a general reflection on the experience and the outputs lead us to three lessons about working together in this way:

1. *It will be necessary to work together but it will be difficult* – One thing that was sufficiently clear to all of us by the end was that our diversity is both a strength and a weakness. The activities on day one were focused on two patient personae – one of an old person with complex health needs and the second of a cancer patient accessing an outpatient chemotherapy unit. These cases were selected to help us appreciate some of the limitations of working within individual disciplines. The potential for impact is likely to be much higher if we were able to unify our disciplines. From the experiences around the tables, there was a general sense that working together was difficult in some cases.
2. *The difficulties in working together are sometimes due to perceived differences* – During a discussion session after one of the activities, one table reflected on the experience working together to develop a research project to address the needs of an old person with complex health issues. The substance of the reflection was that, though there were strong disagreements at the start on how to go about the task, at least some members realised at the end that, once they began to understand each other better, they actually had more in common than initially perceived.
3. *Language is important, but the goal is to understand one another* – Part of the challenges about working together may be attributed to the fact that each discipline spoke a different “language”. In the situation, it may seem as though we need to speak each other’s language. But as demonstrated on one of the tables mentioned above, being willing to engage and persevering leads to a mutual understanding without needing to speak another “language” - we need to be able to simultaneously translate rather than define a common language. This would lead to richer conversations with enhanced understanding of each other’s views.

3.3 State-of-the-art

The organisers gave a 30-minute presentation around the impact of systems design research on healthcare. The talk started with an overview of systems approaches in practice in healthcare. We gave a brief overview of the many initiatives from policy-makers to support systems thinking in healthcare in the past 20 years, both through reports and statements, e.g. ([Institute of Medicine, 2001](#), [National Academy of Engineering and Institute of Medicine, 2005](#), [Clarkson et al., 2017](#)), and through funding programmes implementing systems techniques. It was argued that a limited set of techniques, mostly imported from industrial operations management (e.g. Lean, root cause analysis, process reengineering) have been particularly explored, while other streams (design thinking, human factors) have lagged behind.

The talk then looked at the situation in research. We showed that the number of publications around systems methods in healthcare seems to increase almost exponentially. However, very few describe implementations of techniques and interventions in routine operations, and it is therefore difficult to evaluate the impact of these interventions. This has been explored in the operational research community, e.g. (Brailsford and Vissers, 2011, van Lent *et al.*, 2012).

Finally, we presented the results of a recent systematic review (in preparation for publication) which explored the effectiveness of a systems approaches in improving healthcare delivery. The review identified 21 papers, most of which were uncontrolled before-and-after studies. Preliminary results of a meta-analysis involving seven eligible studies support the idea that a systems approach has a positive impact on healthcare delivery. However, the review posed a number of questions on how to define a systems approach and how to evaluate its impact. The adequacy of the meta-analytic approach for measuring the impact of systems approaches was also challenged.

This last part of the presentation triggered an animated debate. First, it was argued that the **definition of systems approaches** requires great care, because many communities claim the word “systems”, but “systems approaches” cannot be reduced to, for instance, systems engineering.

The second theme in the discussion was the notion of **impact and its measurement**. The discussion first tackled the **type of outcomes to assess**. Some participants argued that the best way to assess the impact of systems approaches is by looking at learning among project stakeholders. This could be done, for instance, by assessing if some information that was implicit in the group was made explicit in the intervention. However, others argued that learning should ultimately result in improved outcomes, which should be measured as well. Another approach could be to look at what “appears” after a systems intervention: if something is new in the group, then it is reasonable to explore if it was triggered by the intervention. It was also proposed that we should not focus on a limited set of outcomes, but instead try to take a systemic perspective when defining our outcomes. A broader range of outcomes should be defined for each project, some of which could be removed from patient outcomes.

After discussing outcomes, some participants noted that **study designs** are also a crucial issue. New designs are emerging, like adaptive controlled trials, which could be better suited to our evolving interventions than traditional methods. Mixed-methods, combining qualitative and quantitative evaluation, were also attractive. It was also noted that although the “pharmaceutical” model of evaluation is dominant in healthcare, other groups doing research in this area are developing different approaches to evaluating interventions aimed at improving healthcare. In general, participants were very critical of meta-analysis as a way to evaluate systems approaches, some suggesting that it would be applying reductionist principles to systemic thinking. However, it could also sit within a bigger evaluation framework and contribute as one element of a richer, multi-method approach.

On another level, the group challenged the idea that there would be a one-best-way to evaluate systems approaches. It was argued that we have **very different audiences** in different countries and communities, some of which do not expect the type of evidence present in evidence-based medicine. There was a sense of agreement that as a community, there is a lot more work to be done on how we define and evidence the effectiveness of a systems approach to healthcare.

3.4 SWOT analysis on making an impact

The second day started with a SWOT analysis of how the people present in the room could work as a community to improve healthcare systems. The focus was on practical impact rather than traditional academic output. Table 1 shows a synthesis of the results. Similar answers were grouped under overarching themes.

Diversity was a much-discussed theme, appearing twelve times as a weakness. As a strength, diversity allows the community to approach a problem for different angles, using different methods and ways of communicating. However, it also means that we come from different disciplinary backgrounds and we do not always understand each other and work with different metrics and objectives in mind. We also come from different countries, each with its own specific healthcare system.

Table 1: Results of SWOT analysis.

<p>Strengths (49 answers)</p> <ul style="list-style-type: none"> • Common passion and sense of purpose • Diversity of skills, tools and approaches • Track-record and experience in other sectors • Complexity-oriented community • Willingness to work together and to work with others in a multidisciplinary way • Combination of technological and human perspectives 	<p>Weaknesses (45 answers)</p> <ul style="list-style-type: none"> • Fragmentation, geographic and disciplinary • Miscommunication and preconceptions between different groups in the community • No agreement on ‘the system’ we work on • Funding difficulties • Lack of evidence to support our claims • Lack of recognition as a community (journals, etc.)
<p>Opportunities (44 answers)</p> <ul style="list-style-type: none"> • Take action and show impact, together • Leverage technology to improve or transform healthcare delivery • Healthcare systems design research is timely and needed • Specific topics could be easier to engage with, e.g. public health or the UN development goals on health • Develop training • Share success stories 	<p>Threats (42 answers)</p> <ul style="list-style-type: none"> • Complex political landscape, vested interests • Diversity of needs and constraints to account for from one country to the other • Keeping a momentum as a community can be hard • Funding is in the hand of a few funders and is not oriented towards what we do • Competition for funding and for the attention of clinicians • Engaging with time-stretched managers

3.5 Challenges in healthcare systems

We spent considerable time exploring some of the important healthcare issues in the various countries from participants’ perspectives. This was first discussed in smaller groups of three or four before a plenary discussion involving all participants. The groups were given the question “What are the 3 or 5 healthcare systems needs in your country and what can we as a group do about them? *Think about clinical, organisational, economic, technological, social, public health ... challenges.*”

The results of the smaller group discussions revealed several major challenges. A full analysis of these here will not be possible due to space limitations, the most common were the challenges of older persons with complex needs, difficulties with research funding, technical and ethical issues with technology, staff workload, and the growing interest in moving care out of hospitals into the community.

The plenary discussion picked up on the issue of staff workload which turned out to be recognised in most of the countries represented. The discussion that ensued revealed the complexity of the issue, identifying it as not being unique to healthcare but a problem for society as a whole. This point reflected a broader question on the definition of “healthcare systems”: where do they stop? Are we only looking at patients and health services, or at a much broader system? Despite these questions, it was felt that Healthcare Systems Design Research as a community may be able to contribute to the solution through the deployment of various modelling techniques to provide insight into the long-term effects of the problem within healthcare. This area shows the need for multiple disciplines from organisational science, psychology, design and systems.

4 DISCUSSION

Researchers within the engineering design community have in recent years begun to highlight the opportunities that exist for design and systems engineering to engage with healthcare delivery research and practice (Patou and Maier, 2017, Lamé, 2018, Komashie *et al.*, 2017). The event reported here is in one sense a culmination of these efforts. The involvement of several other disciplines provides useful insight in several ways.

4.1 Impact

The question of generating and measuring impact was pervasive through the workshop. Systems approaches do not fit well in the classic “pharmaceutical” model of evaluation. However, we do not have a formalised alternative at this stage. We are not alone in struggling to deal with the recurring question — “what’s the evidence?” Operational researchers have recently expressed similar challenges (Brailsford and Klein, 2015). The issue is here, and we cannot escape it.

One way to tackle this issue could be to review and better apprehend possible approaches to evaluation and definitions of what counts as evidence in various fields of healthcare. Indeed, behind the apparent dominance of randomised clinical trials meta-analyses and the so-called “hierarchy of evidence”, the debate on what counts as evidence and how it needs to be generated is sometimes heated (Zuiderent-Jerak *et al.*, 2012, Greenhalgh *et al.*, 2014). A diversity of approaches exist to evaluate impact in healthcare (Petticrew *et al.*, 2013), and getting a better understanding of these approaches would help us in defining which ones are suitable for evaluating systems design methods and interventions. Evaluation scientists have long since recognised the need for a variety of approaches, beyond quantitative, experimental studies (Patton, 2018). We could collaborate with and learn from them to build our own approach to evaluation.

A second argument that was made during the workshop is that we work with different stakeholders, who expect different types of evidence. Brailsford and Klein (2015) distinguish between historicist, empiricist and rationalist evidence. Walshe (2009) discusses experiential, empirical and theoretical evidence. A finer understanding of which stakeholders expect what type of evidence would help us to better align our work with these expectations, or to engage in an informed dialogue if we think that these demands cannot apply to systems approaches in the same way that they apply to clinical interventions.

4.2 Diversity

The discussions showed a broader range of perspectives than the organisers had anticipated. Diversity manifested itself in different ways:

- Coming from different disciplinary backgrounds and research traditions means we have different research objects and objectives, e.g. with some people focusing primarily on existing processes and organisations when others took a technological angle.
- The workshop also illustrated variations in language and definitions. Words like “modelling” or “system design” sometimes triggered intense *conceptual* debates, until people realised that they were talking about similar *practices*. This shows that preconceptions exist between groups and could be a barrier to collaborations if we do not tackle them and remain entrenched in paradigmatic debates.

This situation creates issues. First, it is difficult to create an overview of our current situation as a community, if we do not call the same things by the same name. Second, preconceptions and different expectations can hinder collaborations.

However, should we manage to integrate our contributions, it seems clear that we would be stronger and be better able to support patients and caregivers. Indeed, when working in groups of five or six on case study vignettes, some groups concluded that although individually none of them could tackle the entire issue, they were confident that by putting together the strengths of the people around the table they would be able to solve the problem. Combining problem solving tools and methods, theories, and research methodologies could allow us to be ambitious in tackling complex problems through innovative approaches.

Previous studies on interdisciplinary research in healthcare suggest that these issues are best tackled at an interpersonal level in research projects (Nair *et al.*, 2008). However, these results on specific projects do not say much on what happens at the higher level of a research community. One interesting example that we could build upon is that of sustainability science, which has established a space of its own. Sustainability science brings a different perspective to the specific issue of practical and social interest, sustainability (Kastenhofer *et al.*, 2011, Popa *et al.*, 2015). There are clear similarities with our situation. Our common interest in addressing crucial practical, social and political issues in healthcare systems and health more generally brings us together, but we come from different research perspectives. We could try to learn from sustainability science and see how collaborations emerge in

this field and how a common identity was forged. This is not something we are unfamiliar with, as design research itself is a diverse field (McMahon, 2012).

In practice, a first step towards better collaboration and a common identity could be through gathering case studies and project stories, to understand better what we all do, what are the similarities, and where are the complementarities. Getting down to the level of research *practices* would help overcome language issues and preconceptions and set a common basis on what we *do* as healthcare systems design researchers.

4.3 Defining “healthcare” and “healthcare systems”

Coming from different research traditions and each with our own personal interests, participants all had a definition, albeit implicit, of what was “in” the research topic of healthcare and healthcare systems. During plenary discussions, questions arose very quickly, for instance:

- Is “healthcare” only about sick people and their caregivers?
- Are we focusing on patients, or on the healthcare delivery system? In other words, are we patient-centred or services-centred?
- Are we looking at “healthcare” or “health”?

We noted that even apparently bounded problems of organising hospital care can easily be ‘complexified’ by extending the scope to explore the impact of diseases and care processes on patients’ families and social life. A discussion on the occupational health of caregivers also suggested that many issues in healthcare systems are present in other areas of society, e.g. the performance focus of ‘new public management’. It is not clear at this stage whether we need to clarify the definition of this research object. Here again, sharing case studies and project stories would help mapping what we currently do as a community.

4.4 Opportunities for the design research community

Engineering design has a particularly disciplined approach to problem solving. The community has excelled in not only the design and delivery of products, but also systems. Although the wicked problems common in healthcare systems may not be the same as in engineering, we will argue that there is a lot that engineering design can contribute. In any case, the learning from this first Healthcare Systems Design Research meeting reported in this paper shows that part of the key to effectively responding to the healthcare delivery challenges of our time is being able to work together from a diverse range of disciplines. There is no reason engineering design should be missing from this. By presenting this paper, we also hope to stimulate further discussion within the design community as to how we engage with healthcare systems design, and as an opportunity to raise the profile of healthcare improvement research within our own community.

As a multi-disciplinary community of healthcare systems design researchers and practitioners from across Europe, we can also imagine the opportunity to do joint projects and publications and facilitate the movement of people – PhD students, visiting academics and collaborating practitioners – between institutions. If well executed, this could be a positive outcome of the healthcare systems of many countries in Europe.

4.5 Limitations

Two limitations of this report are worth noting. First, the event was limited to academics, researchers and practitioners from Europe. Though there was one participant from Canada, it must be noted that the geographical focus being Europe may influence what we report.

Secondly, participation in the event was by invitation only. We first went through the proceedings of the DESIGN 2018 conference and invited anyone who presented anything that was healthcare related. The authors then used existing contacts from previous attempts to build a collaboration between the Design Society and the Operational Research (OR) Society. A few invitees also invited colleagues to whom they felt the event might be of interest.

5 CONCLUSIONS AND NEXT STEPS

This workshop showed that there is **considerable interest** from researchers and practitioners from a wide range of disciplines in several countries across Europe, to look at ways to use systems design approaches to improve healthcare delivery. This is in line with a **strong demand and growing need**

from healthcare practitioners and policy-makers, confronted with major challenges that require systemic thinking and a combination of process, organisational and technological design. There is a **common commitment** from all the disciplines involved to design and improve healthcare delivery systems. However, there is **significant diversity** of perspectives on how a systems design approach is realised in practice. There is currently a **lack of clarity** on the state-of-the-art on these approaches, and it is hard to **evidence impact**. **The identification of diversity both as a strength and as a weakness was felt in a real way during the one and a half days of interactions. These factors made the idea of the foundations of a community of Healthcare Systems Design Research that spans several disciplines appealing to participants and there was a strong sense of needing to work together.**

The Design Society has a role to play in this movement. Today, healthcare represents a very small part of all the research presented at Design Society conferences. This paper suggests that there is a potential contribution the design discipline can make to improve and transform healthcare using systems design, and for the Design Society to support and enable this.

Several options were identified for next steps. The most important to participants were the need to develop better understanding of the various disciplines and their healthcare systems research directions, work towards tangible academic outputs and explore opportunities for cross-disciplinary and cross-country research collaborations. These are part of the objectives of the follow-up meeting planned for the 29th and 30th of April 2019 at Denmark Technical University, Copenhagen. Further work will also involve the development of a rigorous approach to analysing the outputs from subsequent events in order to provide more generalizable insights from the outputs that emerge.

REFERENCES

- Adhanom, T. (2017), *Health is a fundamental human right*. World Health Organization, Geneva. Available at: <https://www.who.int/mediacentre/news/statements/fundamental-human-right/en/> (Accessed: 2 April 2019).
- Beasley, R. (2017), "Realizing the value of systems engineering", *INCOSE International Symposium*, Vol. 27 No. 1, pp. 1100–1113, <http://doi.org/10.1002/j.2334-5837.2017.00415.x>
- Bhatt, A. (2010), "Evolution of clinical research: A history before and beyond James Lind", *Perspectives in Clinical Research*, Vol. 1 No. 1, pp. 6–10
- Brailsford, S. C. and Klein, J. H. (2015), *The value of modelling and simulation in healthcare. A review of the evidence and some possible ways forward.*, The Cumberland initiative., London Available at: http://cumberland-initiative.org/wp-content/uploads/2015/07/the_value_report_web.pdf (Accessed: 3 August 2018).
- Brailsford, S. C. and Vissers, J. (2011), "OR in healthcare: A European perspective", *European Journal of Operational Research*, Vol. 212 No. 2, pp. 223–234, <http://doi.org/10.1016/j.ejor.2010.10.026>
- Clarkson, P. J., Bogle, D., Dean, J., Tooley, M., Trewby, J., Vaughan, L., Adams, E., Dudgeon, P., Platt, N. and Shelton, P. (2017), *Engineering Better Care*, Royal Academy of Engineering, Academy of Medical Sciences & Royal College of Physicians, London. Available at: <http://www.raeng.org.uk/publications/reports/engineering-better-care> (Accessed: 21 Nov 2017).
- Greenhalgh, T., Howick, J. and Maskrey, N. (2014), "Evidence based medicine: a movement in crisis?", *BMJ*, Vol. 348, <http://doi.org/10.1136/bmj.g3725>
- Ham, C., Berwick, D. M. and Dixon, J. (2016), *Improving quality in the English NHS: a strategy for action*. King's Fund.
- Honour, E. C. (2014), "Understanding the Value of Systems Engineering", *INCOSE International Symposium*, Vol. 14 No. 1, pp. 1207–1222, <http://doi.org/10.1002/j.2334-5837.2004.tb00567.x>
- Institute of Medicine (2001), *Crossing the quality chasm: a new health system for the 21st century*. National Academy Press, Washington, D.C.
- Kastenhofer, K., Bechtold, U. and Wilfing, H. (2011), "Sustaining sustainability science: The role of established inter-disciplines", *Ecological Economics*, Vol. 70 No. 4, pp. 835–843, <http://doi.org/10.1016/j.ecolecon.2010.12.008>
- Kohn, L. T., Corrigan, J. and Donaldson, M. S. (2000), *To err is human: building a safer health system*. National Academy Press, Washington, D.C.
- Komashie, A., Ray, S., Kar Ray, M. and Clarkson, P. J. "Designing mental health delivery systems: Where do we start?". *ICED17: 21st International Conference on Engineering Design*, The Design Society, Vancouver, BC, pp. 399–408.
- Lamé, G. "Position paper: on design research engaging with healthcare systems". *15th International Design Conference - DESIGN2018*, The Design Society, Dubrovnik, Croatia. <http://doi.org/10.21278/IDC.2018.0164>

- McMahon, C. A. (2012), "Reflections on diversity in design research", *Journal of Engineering Design*, Vol. 23 No. 8, pp. 563–576, <http://doi.org/10.1080/09544828.2012.676634>
- Nair, K. M., Dolovich, L., Brazil, K. and Raina, P. (2008), "It's all about relationships: A qualitative study of health researchers' perspectives of conducting interdisciplinary health research", *BMC Health Services Research*, Vol. 8 No. 1, <http://doi.org/10.1186/1472-6963-8-110>
- National Academy of Engineering and Institute of Medicine (2005), *Building a Better Delivery System: a New Engineering/Health Care Partnership*. National Academies Press, Washington.
- Patou, F. and Maier, A. "Engineering value-effective healthcare solutions: A systems design perspective". *ICED17: 21st International Conference on Engineering Design*, The Design Society, Vancouver, BC, pp. 31–41.
- Patton, M. Q. (2018), "Evaluation Science", *American Journal of Evaluation*, Vol. 39 No. 2, pp. 183–200, <http://doi.org/10.1177/1098214018763121>
- Petticrew, M., Rehfuess, E., Noyes, J., Higgins, J. P. T., Mayhew, A., Pantoja, T., Shemilt, I. and Sowden, A. (2013), "Synthesizing evidence on complex interventions: how meta-analytical, qualitative, and mixed-method approaches can contribute", *Journal of Clinical Epidemiology*, Vol. 66 No. 11, pp. 1230–1243, <http://doi.org/10.1016/j.jclinepi.2013.06.005>
- Popa, F., Guillermin, M. and Dedeurwaerdere, T. (2015), "A pragmatist approach to transdisciplinarity in sustainability research: From complex systems theory to reflexive science", *Futures*, Vol. 65, pp. 45–56, <http://doi.org/10.1016/j.futures.2014.02.002>
- Simon, H. A. (1996), *The sciences of the artificial*. 3rd edn. MIT Press, Cambridge, MA; London.
- van Lent, W. A. M., VanBerkel, P. and van Harten, W. H. (2012), "A review on the relation between simulation and improvement in hospitals", *BMC Medical Informatics and Decision Making*, Vol. 12 No. 1, pp. 18, <http://doi.org/10.1186/1472-6947-12-18>
- Walshe, K. (2009), "Pseudoinnovation: the development and spread of healthcare quality improvement methodologies", *International Journal for Quality in Health Care*, Vol. 21 No. 3, pp. 153–159, <http://doi.org/10.1093/intqhc/mzp012>
- World Health Organization (2000), *The world health report 2000: health systems: improving performance: World Health Organization (924156198X)*.
- Zuiderent-Jerak, T., Forland, F. and Macbeth, F. (2012), "Guidelines should reflect all knowledge, not just clinical trials", *BMJ*, Vol. 345, <http://doi.org/10.1136/bmj.e6702>

ACKNOWLEDGMENTS

The authors acknowledge the contributions of the 34 workshop participants. We also thank the communication and engagement team at THIS Institute for their support in organising the event.

FUNDING

The Cambridge Engineering Design Centre and The Healthcare Improvement Studies Institute (THIS Institute) at the University of Cambridge. THIS Institute is supported by the Health Foundation - an independent charity committed to bringing about better health and health care for people in the UK. AK and GL are supported by THIS Institute. AK is also partly supported by the NIHR Collaboration for Leadership in Applied Health Research and Care (CLAHRC) for the East of England.