

Design-Based Research: Introducing an innovative research methodology to infection prevention and control

Gwyneth L. Meyers, PhD;¹ Michele Jacobsen, PhD;² Elizabeth Henderson, PhD³

¹ Senior Clinical Practice Coordinator, Infection Prevention and Control, Alberta Health Services, Calgary, AB, Canada

² Professor and Vice Dean, Werklund School of Education, University of Calgary, Calgary, AB, Canada

³ Professor Emeritus, Department of Community Health Sciences, University of Calgary, Calgary, AB, Canada

Corresponding author:

Gwyneth L. Meyers

Infection Prevention and Control, Alberta Health Services

Room 3683A, Peter Lougheed Centre

3500 26 Ave. N.E.

Calgary, AB T1Y 6J4

Canada

Tel.: 403-943-4157

Email: gwyneth.meyers@ahs.ca

ABSTRACT

Background: With the rise in the Patient Safety Movement, increased attention is drawn to the efficacy and design of healthcare worker education and how that education is researched. Several challenges with current research methodologies used in research on education have been identified in the literature. The need for alternate research methods is recognized. This second paper in a series of four examines the application of Design-Based Research (DBR) to the design, implementation, and evaluation of innovative educational practices in complex practice settings.

Methods: This paper describes how an iterative, multiphase DBR framework was implemented to study Infection Control Professionals (ICP) educational practice and evaluate the design and development of an ICP professional development experience to build expertise and change educational practices in the Alberta Health Services (AHS) Infection Prevention and Control (IPAC) program. The efficacy of DBR as an alternative methodology was examined by summarizing the outputs, outcomes, and impacts of study activities and how the defining characteristics of DBR were manifest in the study.

Results: Numerous practical and theoretical study outputs and local outcomes resulted in more active and engaged teaching and learning by ICP participants. These outputs and local outcomes impacted the AHS IPAC program, resulting in ongoing ICP educational practice and professional development. The defining characteristics of DBR were effective in systematically designing and engineering change that was relevant and sustainable in the complex context of IPAC practice in the healthcare workplace.

Discussion: DBR contributed substantively to the understanding and building of educational expertise and practice in the AHS IPAC program. DBR is well-suited for use beyond the study of educational teaching and learning environments. Although a complex time- and resource-intensive methodological approach, DBR offers a new philosophical research perspective for studying change and interventions in complex contexts.

KEYWORDS

Infection prevention and control; education; Design-Based Research

INTRODUCTION

The focus of this paper, the second in a series of four dealing with infection prevention and control (IPAC) educational practice and research, is on the application of Design-Based Research (DBR), a change-oriented research methodology from the Learning Sciences to build IPAC educational practice [1, 2].

The emergence of the Patient Safety Movement has resulted in increased research on the effectiveness of healthcare worker

(HCW) education, resulting in a shift away from the provision of knowledge to creating practice change by targeting HCW beliefs, attitudes, values, norms, and behaviours [3, 4]. Research challenges related to sampling, validity, reliability, and a lack of evidence for cause-and-effect relationships have been identified, limiting the credibility of this existing research on the efficacy of educational interventions [5-8]. These problems are consistently identified in traditional reductionist research

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frameworks because of their focus on prediction and control [5, 7, 8]. Creating experimental conditions to study education in healthcare settings is challenging. Contextual, social, and cognitive determinants create variability in HCWs' application of knowledge in practice [4, 5, 9]. Isolating and controlling for all of the complex interactions of such factors is not possible. There is a pressing need for different methodological approaches to studying educational practice in healthcare [4, 7, 10].

These challenges also exist in IPAC educational research [8, 11-15]. A critical review of these challenges, provided in the first paper in this series, resulted in a call for change in our IPAC educational research and practice and to open ourselves to new advances in teaching and learning to effect behaviour change in HCWs' IPAC practice [16].

Responding to this call to action, a DBR study was conducted in the Alberta Health Services (AHS) IPAC program that focused on building Infection Control Professional (ICP) educational expertise. This study involved the design, development, implementation, and evaluation of an innovative professional development experience in education for a group of ICPs that was situated in the context of a community of learning (CoL) located in the ICPs' workplace practice [2]. This paper describes the DBR methodology employed and

exemplifies how this research approach can be used to study educational interventions in complex healthcare settings. Study findings regarding ICP educational practice and the educational professional development change intervention will be reported in subsequent papers.

Design-Based Research

DBR is an innovative, change-oriented research methodology developed by educational researchers to bridge the theory-to-practice gap and balance scientific rigor with relevance [17-19]. The methodology assists researchers in identifying multiple interacting variables and enables a systems-based understanding of the events being studied, making it a beneficial approach to investigating and facilitating change in complex environments like education and healthcare.

Several defining features describe DBR, including: interventionist, theoretically-oriented, grounded, iterative, contextual, flexible, collaborative, and integrative [20, 21]. DBR is considered to be interventionist because researchers intentionally engineer transformation by developing solutions to sponsor change and influence practice [18, 20]. To guide this engineered change, theory is put to work in the research process to solve practical problems throughout the study [18, 20, 22]. DBR is theoretically-oriented because theory not only frames the

FIGURE 1: The research framework based on a generic DBR model [20].

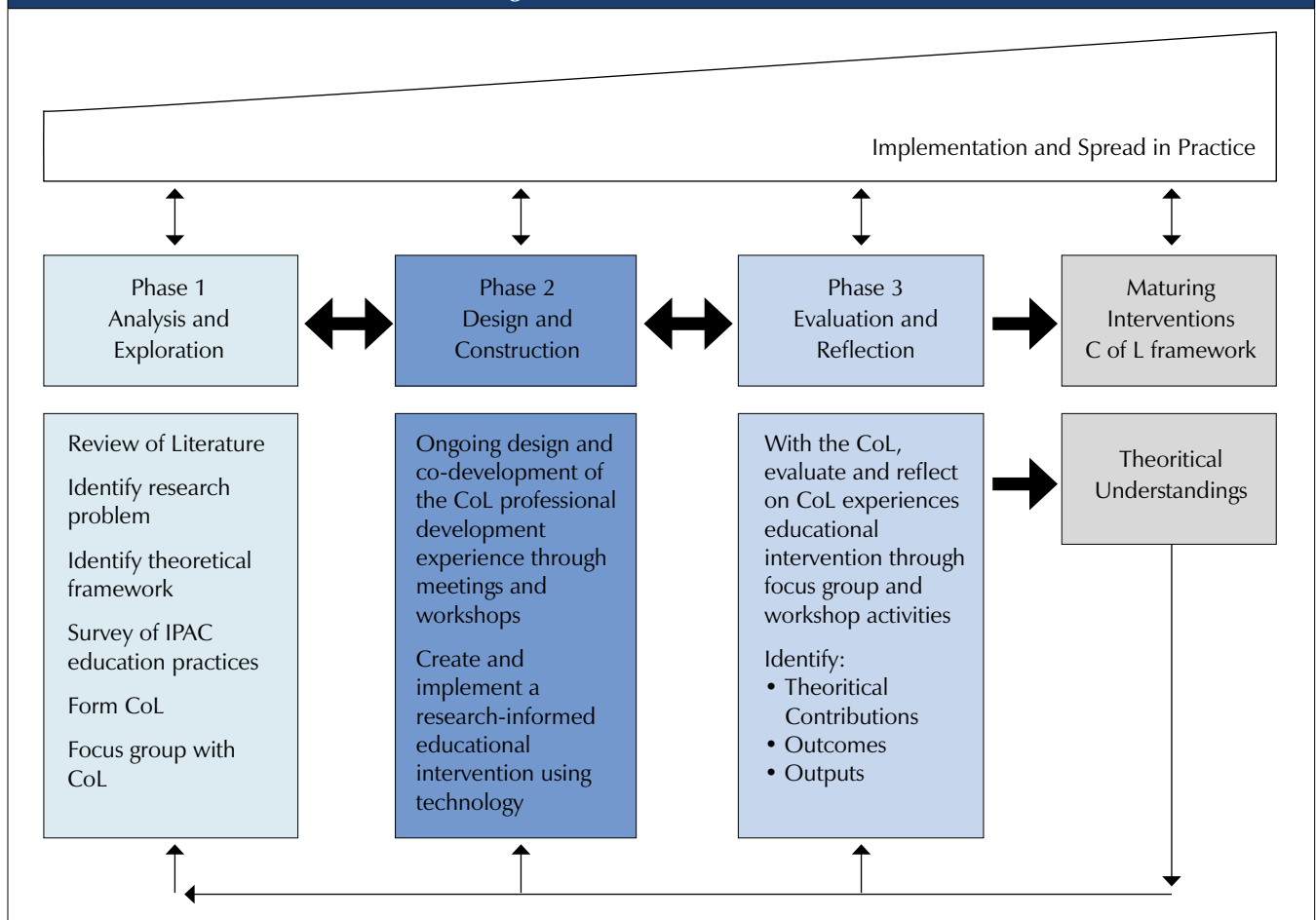
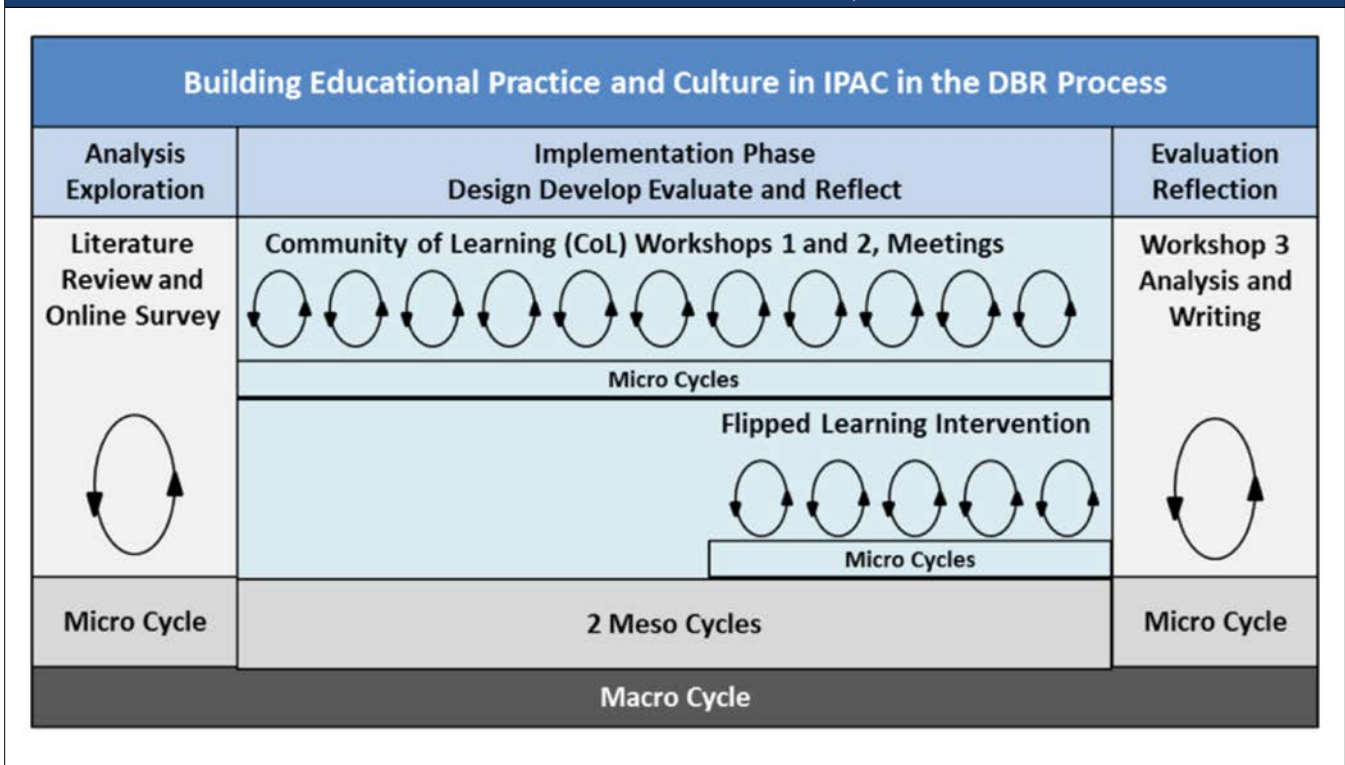


FIGURE 2: The research framework in the context of micro, meso, and macro cycles.



research process; theory and practice actively work together to both enhance practice and build theory. DBR is considered grounded because it is dually embedded in both real-life practice and theoretical frameworks. This enables the research to address process dynamics within both the study design and interventions, attending to how and why adjustments are made during the study.

This dual grounding guides an iterative development process, not just an evaluation of a set intervention. Through iterative cycles, data is re-examined and reflected upon and new designs are created and implemented [23]. In this way, not only is an intervention refined, but the theoretical framework upon which the design is based is extended, leading to a better understanding of how and why any intervention does or does not work.

Because DBR is grounded in practice, it is described as contextual, ensuring that solutions are responsive to complex issues of local practice. In this way, DBR is considered socially responsive because it puts the concerns and problems of practitioners at the forefront of the research and development process [21, 24]. DBR also involves researcher-practitioner collaborative partnerships that provide expert advice based on experience and practice wisdom, which help shape the research and the many decisions taken throughout the process [20, 21]. This approach allows for flexibility and responsiveness to emerging issues while maintaining a research focus as the study evolves.

Finally, DBR is considered integrative, drawing from a variety of research approaches and systematically using both qualitative

and quantitative methodologies [21]. The combined use of mixed methods allows problems to be studied from diverse perspectives. The combination of methods and data collected from multiple sources increases the objectivity, validity, and applicability of the research.

MATERIALS AND METHODS

This section describes the DBR methodology used in the context of an IPAC healthcare setting. The purpose of the study was to respond to identified gaps in IPAC educational expertise and research methodology by employing DBR to deliberately engineer change using a systematically and intentionally designed educational professional development experience for ICPs. The study had three goals: 1) to develop ICP pedagogical expertise in ICP educational practices through participation in a learning community and the co-development of a research-informed education intervention focused on improving HCW IPAC practice; 2) to contribute to pedagogical and theoretical understandings of IPAC educational practices; and 3) to introduce DBR from educational research to a healthcare setting to explore its efficacy as an alternate research methodology with which to research IPAC education.

Implementation of the DBR process

A framework, illustrated in Figure 1, guided the study. It involved three core phases that informed each other iteratively.

The various activities involved in the study are listed under each phase. Movement through each of these phases facilitated the design and development of an intervention that

contributed to the professional development experience and to the theoretical understanding of IPC educational practice. Study activities also interacted with the ICPs' ongoing practice from the beginning and increased in implementation and spread beyond study participants as the study progressed. Figure 2 illustrates how the DBR process occurred through multiple iterative cycles within the context of these three study phases in greater detail.

The iterative cycles took the form of micro, meso, and macro cycles. Overall, this study encompassed the first of potentially several macro cycles in the DBR research process. The first macro cycle incorporated all three phases of the study in the design and development of the ICP professional development intervention experience. A second study would involve a second macro cycle in which the professional development experience would be repeated, modified, and refined. Within the first macro cycle reported here, there were several micro cycles that repeated exploration, implementation, and evaluation of activities in the ICP professional development experience. These micro cycles are grouped into two meso cycles iterating within the larger macro cycle.

Phase 1 of the study involved analysis and exploration of the research problem and theoretical framework as informed by the literature and researchers' experiences working in IPAC. An online questionnaire (N = 48 participants) was administered to obtain a deeper understanding of the identified research problem in the context of local AHS IPAC educational practices and culture. After the survey was conducted, a CoL was formed with the eight ICPs who consented to participate in a collaborative professional development experience over the course of this study. One characteristic of DBR is close collaboration with practitioners; thus, one of the CoL's first activities was to create a focus group comprising ICPs to verify and build on survey findings to co-develop a deeper understanding of IPAC educational culture and the nature of the ICPs' educational issues and concerns. The focus group interview was part of the study's first micro cycle.

In Phase 2, survey and focus group interview results were combined with information from the literature and further consultation with the IPAC program to inform the ongoing design and development of the CoL professional development collaborative learning experience. The CoL experience underwent several iterative micro cycles involving design, implementation, and evaluation phases as the professional development intervention unfolded, resulting in one meso cycle within the study. Embedded within the CoL professional development experience was the ICPs' involvement in the co-creation of a research-informed educational intervention employing a Flipped Learning design that they themselves could use to teach HCWs. This co-design process formed a second meso cycle through another series of micro iterative cycles in the design, implementation, and evaluation of the intervention. The overall goal of iterative cycles was to produce a sustainable, practical, and effective professional development experience and educational product for the AHS IPAC program.

Phase 3 of this study included the implementation of an additional micro cycle that involved the evaluation of and reflection on the overall design, implementation, and research processes used in the creation of the CoL professional development experience and the educational intervention to develop a deeper understanding of the processes, the design principles used, and their effects. Evaluation and reflections were useful not only for the enhancement of the CoL and the educational intervention, but also for understanding the learning environments in which the interventions were developed and implemented.

Data collection and analysis

Data collection occurred over a period of 19 months from April 2014 to March 2016. Table 1 summarizes the various data sources and the collection and analysis methods that were used in the various study phases. In DBR, data collection processes can be complex, with large amounts of data collected from multiple data sources using a variety of collection methods.

TABLE 1: A summary of the data source and the collection and analysis methods.

Data Sources	Sample	Method/Tool	Method of Analysis
Phase 1 Online survey	Convenience sample: N = 48	Online questionnaire using Survey Select	Descriptive statistics and qualitative analysis
Phases 1 and 3 Focus group interviews	Convenience sample: N = 8 CoL participants	Question guides and digital recordings	Qualitative analysis
Phase 1, 2, and 3 Short questionnaires	Convenience sample: N = 8 CoL participants	One-page questionnaire, paper-based	Qualitative analysis
Phases 1, 2, and 3 Field observations	Subset from CoL N = 3	Observation tool, paper-based	Qualitative analysis
Phases 1, 2, and 3 Study documents and products	N/A	N/A	Content analysis
Phases 1, 2, and 3 Researcher journals	N = 1 researcher	Online journals; QSR NVivo Memos	Qualitative analysis

TABLE 2: A summary of the study outputs, outcomes, and impacts.

Outputs	Outcomes	Measurable Impacts
<p>Practical</p> <ul style="list-style-type: none"> • Documents (e.g., teaching guide toolkit) • Online teaching and learning resources for ICPs • Development of online teaching module for HCWs • An IPAC professional development model and program • Summary report to AHS IPAC leadership with recommendations for IPAC education development • Installation and utilization of a software platform to design e-learning <p>Theoretical</p> <ul style="list-style-type: none"> • Descriptive local theory regarding IPC educational practice • Descriptive, explanatory, and predictive mid-range theory regarding IPC educational professional development 	<p>Practical</p> <ul style="list-style-type: none"> • ICPs: Increased pedagogical expertise; more active teaching and less reliance on PowerPoint • Researcher: Increased educational and research expertise • Increased visibility of education within the AHS IPAC program • Increased AHS IPAC leadership engagement with IPAC education • Increased skill and facility to use software to design e-learning in AHS IPAC program • Ongoing educational professional development in teaching and learning for all interested AHS ICPs through a Community of Practice <p>Theoretical</p> <p>Better understanding of:</p> <ul style="list-style-type: none"> • Existing ICP educational practices and challenges • Strategies needed to facilitate ICP educational practice (e.g., development of IPAC identity as educator, pedagogical knowledge, and lexicon) • AHS system issues limiting effective IPAC education 	<p>Measurable Impacts</p> <ul style="list-style-type: none"> • AHS IPAC leadership approved purchase of additional e-learning software licences (seven IPAC staff now designing with e-learning design software) • AHS IPAC leadership requested the development of two additional online modules: an Ebola (Viral Haemorrhagic Fever) PPE module and a general IPAC PPE module • Two education sessions were provided to AHS IPAC staff: one on adult learning to hand hygiene reviewers and one on collaborative and game-based learning to senior staff • An IPAC Education Community of Practice has been operating for two years. ICP attendance ranges from 25 to 30 people • Within the first six months of posting and without promotion, 1,898 HCWs accessed the online module created as part of the study (1,156 completions, 256 withdrawals, and 486 still active)

A DBR approach embraces the concept of triangulation – that is, the combination of information from mixed methods to cross-check results for consistency, enhance the confidence in research findings, and reduce possible bias from the use of a single method [25]. In this study, a combination of an online survey questionnaire, focus group interviews, short questionnaires, field observations of ICP educational practices, researcher journals, researcher and researcher assistant notes, and documents and educational products created during the study were used as sources of data. As data was collected, it was cleaned and entered into Microsoft Excel® and QSR Nvivo10® for analysis. QSR NVivo 10 is a computer program that supports the qualitative analysis process [26].

Descriptive statistics and Chi-Square tests were used to analyze several of the online survey questions. All other data were analyzed using an iterative, systematic thematic analysis [27]. This study was approved by the University of Calgary's Conjoint Health Research Ethics Board.

RESULTS

DBR outputs, outcomes, and impacts

The theoretical and practical contributions of DBR studies can be identified in terms of the study's outputs, outcomes, and impacts. Outputs are the practical and tangible products that directly result from the study activities, including emergent theoretical

understandings. Outcomes are substantive changes that occurred following the designed interventions and resulting impacts are the measurable changes that occurred. Table 2 lists the study's numerous and beneficial outputs, outcomes, and impacts.

It was found that both the theoretical and practical outputs and outcomes of the study led to more active and engaged teaching and learning by ICPs and provided the foundation for continuous, ongoing development and change within the AHS IPAC program beyond the study.

Manifestation of the DBR characteristics in this study

The efficacy and utility of the DBR methodology can also be assessed by examining how its defining characteristics were realized in a study. Table 3 summarizes the results of such an examination.

The value of the theoretical, interventionist, collaborative, and flexible aspects of the study for IPAC practice bears mentioning in greater detail. The knowledge produced by DBR has been described as principled, practical knowledge (i.e., the “know-how” is combined with the “know-why”) [28]. Such knowledge provides practical guidance that bridges and links theory and practice. DBR is collaboratively situated in practice; therefore, the theory developed is linked specifically to the interventional design and local context, yielding local theory [20]. Local theory provides an explanation of real-life

TABLE 3: Examining the characteristics of DBR as realized in the present study.

Characteristics of DBR	Realization in the Present Study
Interventionist [18, 20]	<ul style="list-style-type: none"> • Created a change in participating ICPs' educational understanding and practice in terms of teaching and learning • Facilitated the development of more effective and professionally rewarding educational practices by ICPs • Produced a research-informed solution to build on IPAC educational practices and culture • Influenced AHS IPAC educational activities generally
Theoretically oriented [18, 20]	<ul style="list-style-type: none"> • Literature was used to identify theoretical, methodological, and conceptual problems • The research design was informed by constructivist theories of situated, collaborative, and blended learning and were used to systematically guide iterative design of the CoL and educational intervention • Findings contributed to theoretical understanding of teaching in IPAC. This was used to inform the professional development experience of the ICPs in the CoL
Contextual [21, 22]	<ul style="list-style-type: none"> • Was situated in the ongoing real-life practice of IPAC and the complex healthcare environment
Grounded [21]	<ul style="list-style-type: none"> • Research was anchored in both constructivist theoretical principles and embedded in authentic IPAC practice
Flexible [21]	<ul style="list-style-type: none"> • The design was responsive to the complexity of ICP professional practice demands as well as emerging issues that impacted the study and ICP practice (i.e., the Ebola epidemic)
Iterative [20, 21]	<ul style="list-style-type: none"> • The design of the interventions was repeatedly informed by ongoing research and emerging issues • The research focus went beyond the evaluation of an intervention to explore learning processes and develop design principles that informed the ICPs' professional development experience
Collaborative and Interactive [20, 21]	<ul style="list-style-type: none"> • The research was done in partnership with IPAC leadership, ICPs, and the researcher
Integrative [21]	<ul style="list-style-type: none"> • The research used the concept of triangulation: data from multiple sources and different data collection methods

phenomenon – in this case, representing the complexity of IPAC educational practice and how to develop and advance ICP educational knowledge, practice, and expertise.

The interventionist and collaborative aspects of the methodology were important because these facilitated active engagement with ICPs, impacted their teaching practice in real time, and also afforded increased visibility and buy-in from AHS IPAC leadership who were in positions of influence to support and encourage change. Such collaborative engagement contributed to the outputs and outcomes of the study.

The flexibility of the DBR process was both important and invaluable in CoL design and evaluation. Dynamic, real-life environments can be complex and emergent; however, unpredictability is a hallmark of an IPAC professional's work life. A lived example of unpredictability became evident with the emergence of an Ebola epidemic during the study. The AHS Ebola response preparations resulted in increased demands and a change in focus in the daily work of the ICPs, including those of the first author, during the study. The DBR methodology's flexible nature allowed the research team to leverage the living laboratory that was the Ebola epidemic. The ICPs' teaching and learning experiences while developing and implementing large-scale, just-in-time education for Ebola were incorporated into the CoL professional development experience. Field observations confirmed that some of the ICPs began to

implement teaching strategies they had learned in the CoL into their Ebola education.

Limitations

DBR is a complex research methodology that can be time-intensive and resource-intensive. DBR depends on collaborative partnerships with practitioners throughout the research process and does not always yield immediate results. While initial macro cycles of the DBR process can produce data and theory that are both valuable and relevant to local practice, it takes time to influence sustainable change. DBR is a long-term process that requires a series of macro cycles to upscale local theory and achieve relevant higher-level theory as interventions and design principles mature and emerging theories are synthesized to become generalizable theories for broader contexts and populations. One of the specific limitations of the present study is that, as a first macro cycle in the DBR approach, the findings contribute primarily to local practice and theory. Additional cycles are called for to refine the emerging theory and educational professional development framework for the broader ICP population and for ICP educational practices in general. The unique nature of the AHS organization must be considered, as healthcare is a provincial responsibility and organizational policies and procedures vary from province to province and the IPAC programs within them. It will be

important to explore IPAC educational practices in other IPAC programs across Canada to scale up this current study's findings.

DISCUSSION

The merits of the DBR methodology to research interventional designs to change learning environments are well documented [18, 20, 29]. Investments in this complex methodology have proven worth it. In the present study, DBR contributed to significant understanding and development of ICP educational practice in the AHS IPAC program. The emergence of the Patient Safety Movement in healthcare has attracted increased focus on psychosocial behavioural aspects of HCWs to improve and change practice. Randomized and controlled research on psychosocial change interventions and inherently complex HCW behaviours is challenging and fails to yield useful insights for teaching and learning. DBR is an effective and innovative research methodology for studying educational interventions for the purpose of practice change, thus offering a systematic alternative approach to experimental research methods. This study demonstrates a successful use of DBR to design and study teaching and learning in the contextual complexity of healthcare. As a change methodology, DBR is well-suited for inquiry beyond the evaluation of teaching and learning environments. DBR offers a new philosophical research perspective for studying change and innovation in complex contexts.

Adoption of a DBR methodology in healthcare will require a philosophical shift in research agendas. Traditional, reductionist research methods that focus on prediction and control are ill-suited for creating and studying change in complex and authentic learning systems. DBR uniquely balances rigor from research with relevance in the field by drawing continually on both theory and practice throughout the research process to inform the design and implementation of sustainable solutions to practice problems. Adoption of a DBR approach focused on creating change will open the door to new discoveries for IPAC educational research designed to promote IPAC HCW practice change.

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