LEARNING TO WORK TOGETHER INTERPROFESSIONALLY

LESLIE CARSTENSEN FLOREN

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INTERACTION, KNOWLEDGE CONSTRUCTION, AND INFORMAL LEARNING IN CLINICAL EDUCATION

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Interprofessioneel Leren Samenwerken – Interactie, Kennisconstructie en Informeel Leren in Klinisch Onderwijs

Leslie Carstensen Floren

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Chapter 1

Introduction

Delivering high-quality healthcare to increasingly complex patient populations requires interprofessional interaction, collaboration, and shared understanding of patient care goals and the plans to achieve them.[1,2] To prepare learners, most health professions education programs define competencies[3] and deliver curricula to support learners' ability to collaborate interprofessionally in practice. However, few programs are designed with consideration of the interactive knowledge-building processes that underpin successful collaborative decision-making and teamwork. This thesis research explores knowledge construction through interpersonal interactions, with a particular emphasis on interprofessional teams. This research aims to provide health professions educators with the tools needed to design and evaluate interventions to support interprofessional learning through collaboration.

This chapter provides an overview of interprofessional clinical education and practice and the role of interaction in interprofessional learning. The chapter begins with definitions of key terms and concepts. Next, historical perspectives as well as current trends in interprofessional clinical education and clinical practice are discussed. Following this, theoretical perspectives relevant to teamwork and interactive knowledge building in multiple clinical education contexts are presented. Then, to identify gaps in the literature, research is reviewed regarding team effectiveness, shared understandings, and learning through interprofessional interaction. Lastly, subsequent thesis chapters are outlined.

DEFINITIONS

Several terms and concepts discussed in this thesis require definition, to promote conceptual clarity.

Interprofessional collaborative practice IPCP refers to an interactive, interpersonal process in which health professionals from multiple disciplines work together to develop shared goals and objectives related to patient care problems. IPCP exists along a continuum of collaborative intensity and is influenced by six elements including: shared team identity, clear roles/goals, interdependence, integration, shared responsibility, and team tasks.[4] In an updated typology of IP practice proposed by Reeves et al. (2018)[5] – includes: *IP teams* with shared team identity, clarity of roles and goals, interdependence, team integration, and shared responsibility; *IP collaboration*, with shared accountability between individuals, some interdependence between individuals, and clarity of roles and goals, but where shared team identity and integration is less critical; *IP coordination*, similar to collaboration, requires some shared accountability between individuals and clarity of roles, tasks, and goals, but even less emphasis is placed on shared team identity, integration, and interdependence than in IP collaborations; and *IP networks*, in which coordination is required, but where the elements of shared team identity, interdependence, integration, clarity of roles and goals, and shared responsibility are less essential to network function. In this conceptualization, teams and teamworking are matched to the clinical purpose, where the level of task complexity, urgency, and predictability should dictate the IP practice structures. Along this continuum, IP teams are needed to handle the most complex, urgent, and unpredictable tasks. IP networks can adequately handle tasks that are non-complex, non-urgent, and predictable.[5]

In the health professions, *interprofessional education* (IPE) is defined as an activity that involves learners from two or more professional backgrounds who are brought together – each with different areas of expertise, professional culture, identity, and perspective – to interact and learn "with, from, and about each other to improve collaboration and quality of care" (CAIPE, 2016).[6] The definition of learners, in this case, is quite broad, encompassing students at the undergraduate level, newly minted professionals who have just entered their practice area, as well as those individuals who may have been practicing in their field for decades. The general purpose of IPE is to prepare HP learners for IP collaborative practice (IPCP).[7,8]

We have adopted Freeth's broad definition of *interprofessional learning* (IPL) as "learning arising from interaction between members (or students) of two or more professions." Learning may occur as a result of structured activities in formal IPE or may happen spontaneously in either educational settings or the clinical workplace.[9] *Collaborative learning* is an educational approach to teaching and learning that involves bringing groups of learners together to solve a problem, complete a task, or create a product.[10]

In this thesis, we will use the term *interprofessional team* to refer broadly to a social structure encompassing two or more members of different professional disciplines working together, in an interdependent manner, towards a shared patient care goal. This includes configurations of IP teams and IP collaborations, per Reeves' definition (2018).[5]

In IPCP, effective teams work together to develop a shared understanding of the goals, objectives, and plan to solve the patient care problem or problems.[1] This shared understanding – also referred to as a *shared mental model* (SMM) – represents the overlapping mental representation of knowledge held by individual team members.[11] A commonly accepted formal definition of a SMM is an "organized understanding or mental representation of knowledge that is shared by team members."[12] The terms *shared mental model*, *SMM,* and *shared understanding* are used interchangeably in this thesis. Importantly, SMMs are developed through team interactions during the process of interactive knowledge construction.[11]

Knowledge construction (KC) has been defined as a collaborative, interactive process by which learners generate new ideas and negotiate an understanding of concepts by connecting new knowledge to their existing knowledge base.[13,14,15] According to Krathwohl (2002),[16] knowledge can be categorized into four types: (1) factual knowledge, (2) conceptual knowledge, (3) procedural knowledge, and (4) metacognitive knowledge. In the context of this thesis research, knowledge that has been constructed is not necessarily newly discovered knowledge (i.e., knowledge that has never been discovered before), but refers to negotiated meaning and knowledge that was socially constructed as learners contributed their own parts to a whole that is new to the learners involved. (Note: the constructs of both SMMs and interactive KC are elaborated upon further in the "Theoretical Perspectives" section of this chapter.)

HISTORICAL PERSPECTIVE AND CURRENT TRENDS IN INTERPROFESSIONAL EDUCATION AND PRACTICE

The earliest mentions of Interprofessional education in the literature can be found in the 1960s and are primarily focused on the opportunity for such education to better understand the perspectives of the other profession and improve "medico-legal" relations.[17] Efforts to provide interprofessional education among health care professionals also began in the '60s. In 1987, the global collaborative thinktank, the Centre for the Advancement of Interprofessional Education (CAIPE), was established in the United Kingdom. The movement gained greater prominence in 1988 with the publication of a report from the World Health Organization (WHO) – *Learning Together to Work Together for Health*[18] – which called for IPE as the means to develop collaboration-ready health professionals and realize improved health care. However, relatively little is known of the early history of IPE initiatives, as few academic publications reported implementation efforts or outcomes.[19]

Since the early 2000s, explosive growth in IPE literature has followed a growing interest in IPE as a mechanism to develop IPCP-capable practitioners who will be equipped to address several healthcare-related issues. One especially critical issue relates to persistent safety problems and a high incidence of preventable medical errors. This issue was brought to light by the publication, in 1999, of a sobering report from the Institute of Medicine (IOM) entitled *To Err is Human. Building a Safer Health System*.[20] This report revealed a staggering number of medical errors leading to disability and death.[20] The 2003 IOM report *Health Professions Education: a Bridge to Quality* proposed five core competencies for all HP training programs that included the ability to work in interdisciplinary teams, to cooperate, collaborate, communicate, and integrate care.[21]

In addition, the confluence of several other factors – an aging population with attendant shifts in care delivery from acute care to management of chronic conditions; increasing complexity of care delivery; growing recognition of health disparities; increased specialization in healthcare professions; and the unsustainable growth of healthcare costs – has driven interest in and appreciation for IPCP and, therefore, the need for IPE to be an integral component of health professions training.[22]

More recently, in 2010, the WHO has published a *Framework for Action on Interprofessional Education and Collaboration*[23] and the international Lancet Commission, led by Frenk et al., published a widely acclaimed paper lamenting the "mismatch of professional competencies to patient population priorities" resulting from health professions training programs with "fragmentary, outdated, and static curricula…"[24] The graduates of these programs, as a result, were "ill-equipped" to meet the health-care needs of patients and populations in the modern world. The Lancet Commission, in outlining their vision for health professions training in the century following the Flexner Report,[25] pointed to the need for IPE to prepare learners to become practitioners able to provide team-based care to meet the healthcare needs of patients and populations in a manner that was both "locally responsive" and "globally connected."[24]

Following on the heels of the WHO report[23] and the Lancet Commission recommendations[24] to bolster IPE efforts, 2011 saw the publication of two additional reports focused on improving IPE and, by extension, IPCP, through the definition of core IP learning and practice competencies.[3,26] These competencies – including IP communication, values and ethics for IP practice, roles and responsibilities, and teams and teamwork – provided defined and observable behavioral objectives.[27,28] These essential IP competencies have been refined over the intervening years.[29] The existence of multiple competency frameworks exist across countries led O'Keefe et al. (2017)[26] to propose a common set of IP competency statements, designed to be assessable, that would apply to graduates from all entry-level health professions training programs.[26] Evaluation of specific competencies related to IP collaboration by defining a dedicated Entrustable Professional Activity for interprofessional collaboration has recently been deemed unviable. However, these authors promote the consideration of competence to work interprofessionally in most, if not all Entrustable Professional Activities.[30]

Though the aims of IPE are generally accepted, and universities have committed to ensuring that their graduates will be able to demonstrate skills in collaboration and teamwork, the current model of IPE faces several challenges. Most IPE initiatives occur at the pre-licensure level, and logistical challenges have been well-documented[26] and continue to be an Achilles' heel for IPE efforts for pre-licensure learners. Thistlethwaite (2014),[3] highlighted that HP learners' exposure to and participation in teamwork experiences in clinical learning environments is highly variable and, to gain teamwork knowledge, skills, and attitudes, learners must be included as health care team members. One key factor in this variability is the variable adoption of IPCP itself, affecting the availability of clinical placements and limiting learners' opportunities for exposure. Students who are expected to meet IPCP competencies but do not see this behavior modeled in clinical practice are, logically, unlikely to place importance on this aspect of their training.[3]

In a recent review of the evidence base related to IPE, several weaknesses in the quality of evidence, including the widespread use of non-validated instruments and self-reports of changes in attitudes and behaviors, were demonstrated. Some studies report improvements in knowledge and skills related to IP collaboration, with a few demonstrating positive changes in individual practitioners' interactions.[31] Though evidence of the effectiveness of IPE initiatives to positively impact healthcare has been growing (e.g., reductions in infection rates, error rates), a paucity of long-term studies that relate IPE to IPCP and patient care remains.[3,31]

Paradis and Whitehead propose an alternative approach to improving IP practice: *education for collaboration* in a recent critique of IPE.[32] These authors urge educators to consider: the method and timing of delivery of such education; whether all efforts to build IP teamwork skills must be interprofessional; the need to reduce logistical complexity, enhance organizational support locally (i.e., from hospitals and universities), and ensure that teamwork education occurs at the pre-licensure level as well as in clinical practice settings; and, the imperative to concomitantly address (and teach learners how to "navigate and transform") significant structural barriers to collaborative care delivery including power imbalances and professional hierarchies.[32] Importantly, improving IP collaboration is at the heart of these recommendations as well as IPE efforts.

In summary, there is a growing imperative to train IP collaborative practice-ready, teamwork-focused health professionals equipped to provide care in the contexts of aging populations, polypharmacy, medication errors, health disparities, and skyrocketing healthcare costs. An effective way to deal with health care complexity and provide patient-centered care that is safer, more efficient and cost-effective is to embrace models of IPCP where all health care providers are practicing at the top of their licenses.[1] To improve team-based care and improve health outcomes, learners must receive training to become effective collaborators capable of engaging in IPCP.[2,4,23]

THEORETICAL PERSPECTIVES

The ability to work together, through collaborative decision-making processes, to identify and achieve a common patient care goal is the ultimate goal of IPE.[33] Social learning theories and theories related to teamwork may be used in concert to inform our understanding of processes involved in collaborative IP learning, contextual influences on learning, and cognitive outcomes. With enhanced understanding, we may more effectively design, guide, assess, and investigate IP learning.

Given the centrality of shared understanding to IP team effectiveness, we first examine team cognition theory as a means of illuminating the components of shared understandings or shared mental models, across team members. Next, to better understand the behavioral mechanisms involved in developing such shared understandings in IPE, we evaluate social constructivist theories relevant to learning through interaction focusing on the construct of interactive knowledge construction. Lastly, since IP clinical education may occur in the context of either structured activities (e.g., clinical simulations, case conferences, or quality improvement projects) or routine activities in the clinical workplace, we examine the influences of these contexts on learning through the sociocultural learning theory of situated cognition and the related framework of workplace learning. **Figure 1** demonstrates the inter-relationships between these theories, frameworks, and constructs.

Figure 1: Theories and Constructs Relevant to Learning Through Interprofessional Interaction in Clinical Education

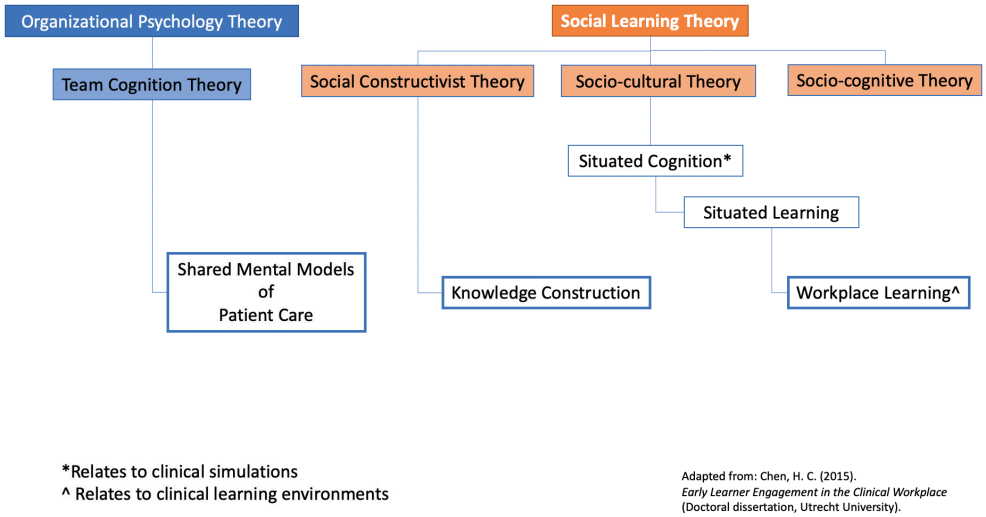

Figure 1 Legend: Blue boxes indicate theories related to organizational psychology. Orange boxes indicate theories related to social learning theory. Heavily outlined boxes indicate theories or constructs explored in this thesis.

Team Cognition and Shared Mental Models

Human teamwork, including IP collaboration and IP teamwork, consists of three interrelated dimensions, including cognitions, skills, and attitudes. Teamwork skills include adaptability, communication, coordination, performance monitoring, and leadership. Team members' attitudes relate to their feelings about the team and include team cohesion, mutual trust, and team orientation.[12]

The cognition dimension of teamwork includes mental representations of knowledge. These cognitive constructs, referred to as mental models, include key elements of the team's relevant environment[34] such as taskwork (i.e., procedures, task goals and objectives, and available resources) and teamwork (i.e., roles, responsibilities, expectations, and capabilities).[12,35] Mental models allow individuals to understand phenomena and make reasoned assumptions.[36] When such cognitive constructs are held in common among individuals, those individuals are said to have a shared mental model. SMMs are considered to be a key coordinating mechanism in high-functioning teams[37] and are associated with higher levels of team effectiveness.[12,37] Though SMMs are not directly observable, they can be measured indirectly and can be used to elucidate aspects of cognition, reasoning, and decision-making behaviors.

Social Constructivist Learning Theory, Social Interaction, and Knowledge Construction

Social constructivism posits that cognition and learning are dependent upon the interaction between the individual and the environment.[38] The individual learner processes new information and integrates it with existing understandings to develop a new cognitive structure or mental representation (i.e., mental model).

The process of building knowledge, or knowledge construction (KC), generally refers to an individual or interactive endeavor that occurs when a learner generates a new idea or a new understanding of "…concepts, phenomena and situations…"[15] through interactions with others and environments.[39,40,41] In the case of interactive, or collaborative, knowledge construction, two or more learners work together in the process of negotiating meaning to actively build new knowledge. [39,40,41] During collaborative KC, both individual and collective knowledge is socially constructed and mediated.[14,42] This social constructivist perspective on learning fits well with the implicit theories guiding the development of many activities in HP education and IPE, specifically.[43,44,45]

Socio-cultural Learning Theories, Clinical Simulations, and Workplace Learning

The central tenet of Vygotsky's sociocultural theory is that learning occurs within a social context and is mediated by that context, including social interactions, culture, and environment.[46]

Situated cognition – a learning theory derived from socio-cultural learning theory – posits that knowing and doing are inextricably linked and that knowledge is situated in activity that is tied to social, cultural, and physical contexts.[47] In HPE, situated cognition has been applied as a framework to describe learning through simulation[48] as well as a pedagogical approach to the design of authentic clinical learning activities.[49] Clinical simulations play an important role in IPE, from activities for pre-registration learners through to interprofessional continuing education for practitioners. Situated cognition, then, helps explain how interactions between the activity, the social actors (i.e., the learners and others within the learning environment), culture, and environment might influence learning in the course of the simulation activity.[49]

IPE in the clinical learning environment may include structured activities, but IP learning during clinical placements occurs largely through daily work practice. With their foundations in Situated Learning theory – where learners are situated in the social context as members of a Community of Practice[50] – Billett's workplace learning theory[51,52] and Eraut's theory of informal workplace learning[53,54] provide two complementary frameworks for understanding IP learning in the clinical workplace.

According to Billett, learning and working are interdependent and the quality of learning is dependent on 1) the affordances for learning – including opportunities for learners to participate in relevant workplace tasks and activities; access to the support and guidance of experts, co-workers, and resources; and the invitational qualities of the workplace – and 2) the learner's engagement with these affordances.[51,52,55,56] In the clinical workplace, learning through participation requires active engagement on the part of the learner, even in the presence of rich workplace affordances.[51]

In contrast to formal learning through structured didactics or trainings, informal learning in the clinical environment occurs through work practice.[57] Eraut's 3*3 typology of informal workplace learning[53,54] delineates three levels of learning intention: implicit (subconscious, reflexive), reactive (near spontaneous, with reflection), and deliberative (intentional, with planned engagement). The learning stimulus may be a past, current, or future (i.e., anticipated or planned) experience. While implicit learning is challenging to capture and substantiate, reactive learning follows from interactions, events, experiences. Deliberative learning follows from initiatives of the learner and clinical educator.

Summary of Theories, Frameworks, and Constructs

IP clinical education may take many forms, including structured IPE, IP clinical simulations, and either structured IPE activities or planned informal IP interactions in the clinical workplace. Informal IP interactions may also occur in the context of day-to-day work in clinical learning environments. In these varied environments, social learning and organizational theories show that the interplay between social interactions (i.e., interactions with other learners, facilitators or clinical educators, practitioners), the activity or task, and the learning environment itself are expected to impact individual and interactive KC processes. In the clinical workplace, learners must not only be afforded opportunities for IP interaction, but they must also actively engage with these opportunities in order for learning to occur. In interactive KC, processes of negotiation and sense-making impact learners' development of new understandings, or mental models, of the task and the team. The development of shared representations depends on whether or not the knowledge constructed for each team member overlaps with other team members' cognitive representations.

TEAM EFFECTIVENESS, SHARED UNDERSTANDINGS, AND LEARNING THROUGH INTERACTION

Team effectiveness and SMMs

Drawing on literature from cognitive psychology and group dynamics, the shared mental model construct was introduced in 1993 to explain team coordination and functioning.[12] SMMs, considered to be one of the key coordinating mechanisms of effective teamwork in high-performance teams[37] allow team members to 1) anticipate and predict each other's needs, 2) identify changes in team or task and make adjustments, and 3) coordinate with each other to complete interdependent tasks.[35] There is clear evidence from the organizational psychology literature that SMMs amongst team members support optimal team functioning, result in improved team processes, and enhance team performance.[35,58,59] Given their importance, several industries, including health care, have introduced training aimed at helping team members develop SMMs,[60] most notably the *Team Strategies and Tools to Enhance Performance and Patient Safety* or TeamSTEPPS™ clinical team training curriculum introduced in 2006.[61]

The topic of SMMs has also progressively gained attention in the healthcare literature since the introduction of TeamSTEPPS™.[60] Authors of two literature reviews focused on the analogous constructs of team[62] and shared mental models[60] suggest that members of health care teams must develop SMMs around taskwork, roles, responsibilities, and attitudes towards safety[62] in order to facilitate teamwork and to promote safe and effective patient care. Since the empirical evidence base related to SMMs in HP trainees in clinical teams is small, further investigation is needed to understand the potential utility of this construct in HPE and IPE.

Learning through interprofessional interaction – knowledge construction across clinical contexts

According to Van den Bossche (2011),[11] "The essence of collaboration is…a process of building and maintaining a shared conception of the problem." Without interaction, collaboration, and collaborative decision-making, there is no IPCP (and there is no "shared conception" or SMMs). Therefore, preparing health professions learners for IPCP requires training opportunities for learners from different professions to interact, engage in collaboration, and build knowledge together to address patient care goals.

Several studies have shown that collaborative activities support learning processes and improve educational outcomes among HP learners from the same profession. Medical students, for example, have been shown to engage in knowledge construction behaviors and develop higher-order thinking skills in the context of problem-based learning environments, collaborating to tackle authentic, complex, and ill-defined problems with many potential solutions.[44,63,64] However, few studies have examined knowledge construction in learners from multiple professions.

Ideally, IP training activities would support learning processes and skill development in a manner similar to the example above by promoting interactivity between learners from different professions as they work together to solve complex clinical issues.[65] But, rather than focus on learning processes, most studies of IP learning interventions have been outcome-focused (i.e., satisfaction with the intervention, changes in attitudes towards IPE and collaborative practice, readiness for IP learning, acquisition of general teamwork and communication skills, or specific content knowledge).[8,31,65,66]

How learners from different health professions interact in the course of IP clinical activities – what processes are involved as they build knowledge together, and what knowledge emerges from these interactions [8,67,68] – remains relatively unexplored. Without assessing the character and quality of the learning process among teammates, we may not appreciate when high-quality learning occurs. For our purposes, we define *high-quality learning,* borrowing from Entwistle & Entwistle (1997),[69] as an active cognitive process in which learners engage in efforts to advance their knowledge and skills by relating ideas, using evidence, and negotiating meaning. Since studies have shown an association between higher quality learning and higher rates of knowledge retention and knowledge transfer to novel situations,[39] investigation of knowledge construction processes in various clinical contexts is warranted.

Knowledge construction frameworks – by providing structure to observe and characterize learning behaviors – might prove useful to illuminate the quality of learners' interactions during IP clinical activities in both clinical simulations and clinical settings. Additionally, since KC is considered to be an essential element of collaborative clinical decision-making,[70] KC frameworks might be used as the basis for formative assessment of team-level KC behaviors during IP clinical activities. They might also provide a mechanism for generating feedback to learner teams so that they may reach higher levels of mental engagement (and learning). After selecting an appropriate framework, the feasibility and utility of these applications will need to be demonstrated.

Lastly, given that much learning in postgraduate medical education happens informally in the workplace,[71-73] we are interested in exploring how IP interactions in various clinical settings contribute to resident physicians' KC. Though we expect that workplace-based, IP interactions likely contribute substantially to residents' learning, little is known about the nature of the contributions that non-physician clinicians' make to residents' KC in the clinical environment.[71] Improved understanding of these interactions on learning would enable a more thoughtful design of resident physicians' training to optimize informal, IP, clinical workplace learning.

OBJECTIVES OF THE THESIS

Considering the complexities of interprofessional collaborative practice and the need to develop shared understanding related to patient care, the constructs of shared mental models (SMMs) and knowledge construction (KC), in conjunction with workplace learning theory, provide a wide lens to examine learning through interprofessional interaction.

To better equip health professions educators to design and evaluate interventions that support interprofessional (IP) learning, we conducted a series of studies related to KC in IP interactions to answer the following questions:

1. How are shared mental models (a potential outcome of interactive KC) conceptualized, developed, and measured in clinical education?
2. Can a model of KC be used to characterize KC behaviors in different IP contexts (e.g., clinical simulation, care planning for real patients)?
3. Can a valid observational tool be developed to assess interactive KC during IP interactions?
4. How do IP interactions support KC and informal clinical workplace learning?

Figure 2 (below) provides a conceptual model for knowledge construction and shared mental model development in the context of interprofessional clinical education.

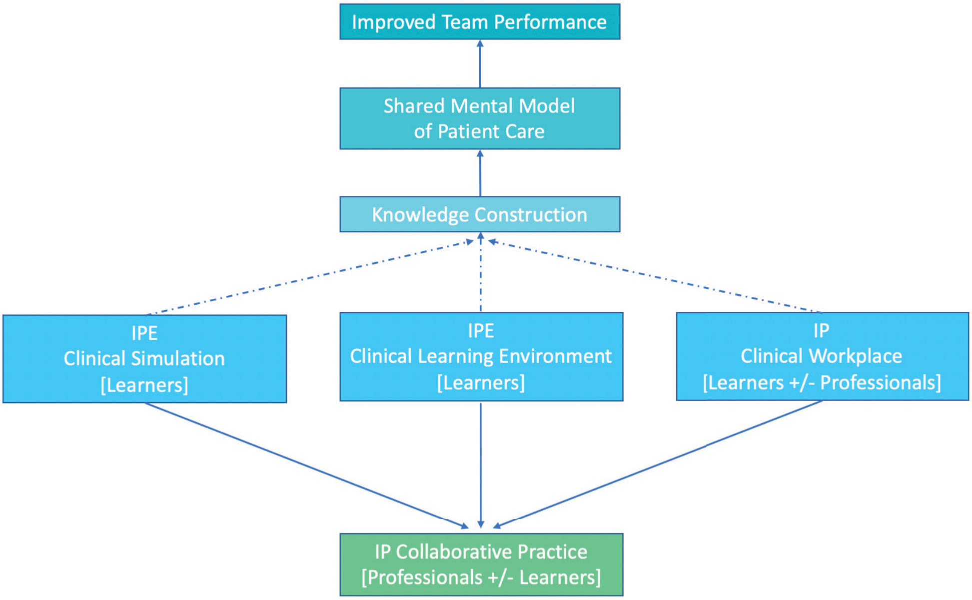

Figure 2 Legend: IP = interprofessional; IPCP= interprofessional collaborative practice; IPE= interprofessional education. Solid arrows represent documented relationships, including: IPE has been shown to support IPCP;[74] SMMs have been shown to improve team performance.[35,58,59,75] Broken arrows represent purported relationships to be investigated.

Chapter 2 presents the results of a scoping review conducted to explore the construct of shared mental models as applied to clinical teamwork and health professions learners, examining definitions, educational interventions, and measurement.

Chapters 3 and 4 address the utility of applying an existing behavioral model of the KC construct – the Interaction Analysis Model (IAM)[39] – to characterize KC behaviors in different IP contexts (e.g., clinical simulation, care planning for real patients).

Chapter 3 describes the development and testing of an app-based, asynchronous, three-phase, IP learning module focused on collaborative medication management of a complex patient. The IAM is used to design dialogue prompts to support KC. In this experimental study, pharmacy-medicine learner pairs (randomized to either high or low guidance prompt condition) interact through the app to develop collaborative care plans for each phase of the case. The impact of the dialogue prompts on both the learners' KC behaviors and the quality of collaborative care plans is evaluated.

Chapter 4 presents a proof-of-concept study that explores the feasibility and utility of applying the IAM in the context of a clinical elective and how it could be used to study KC processes in the IP teams working in clinical environments. We develop a simplified model of interactive KC behaviors– based on the IAM– and, using a content-analytic approach we apply the model to transcripts of observations of three IP teams of learners engaged in patient care during a clinical elective.

Chapter 5 describes the development process, including the collection of validity evidence, for an observational tool to support real-time, formative assessment of interactive KC behaviors in the context of IP interactions between health professions learners.

Chapter 6 presents a cross-sectional, online, survey among medical residents at three institutions, two in the US and one in the Netherlands to explore affordances that residents use for informal IP learning about medications, focusing on their interactions with pharmacists.

Chapter 7 provides an overall summary of key findings in the context of the current literature, the implications of this work for IP education and research, strengths and limitations, as well as future directions for research.

Note: This thesis is comprised of a collection of related articles. Each chapter was written as a stand-alone article and some repetition is expected.

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Chapter 2

Are We on the Same Page? Shared Mental Models to Support Clinical Teamwork Among Health Professions Learners: A Scoping Review

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ABSTRACT

Purpose: To conduct a scoping review to explore the construct of shared mental models (SMMs) in the context of clinical teamwork among health professions learners.

Method: The authors searched the PubMed, ERIC, CINAHL, Scopus, Web of Science, PsychINFO, and EMBASE databases for English-language articles published between 2000 and 2016. Eligible articles mentioned SMMs in relation to clinical teamwork and included health professions learners. Two reviewers screened studies for eligibility and extracted data to determine the depth and breadth of the literature on SMMs. The authors examined definitions of the SMM construct in the context of clinical teams, educational interventions using SMMs, and the measurement of SMMs.

Results: Of the 1,273 articles retrieved, 23 met the inclusion criteria. SMMs were defined in less than two-fifths of the articles (9/23). All articles applied the construct to improvements in hospital-based patient safety, often in high-intensity settings (14/23). Most articles included graduate-level physicians (21/23) within clinical teams (18/23). Interventions designed to foster SMMs (6/23) included teamwork curricula/training and teamwork supportive tools. Measurements of SMMs (7/23) included: qualitative task analyses, a quantitative analysis of speech, a concept mapping, and Likert-type surveys.

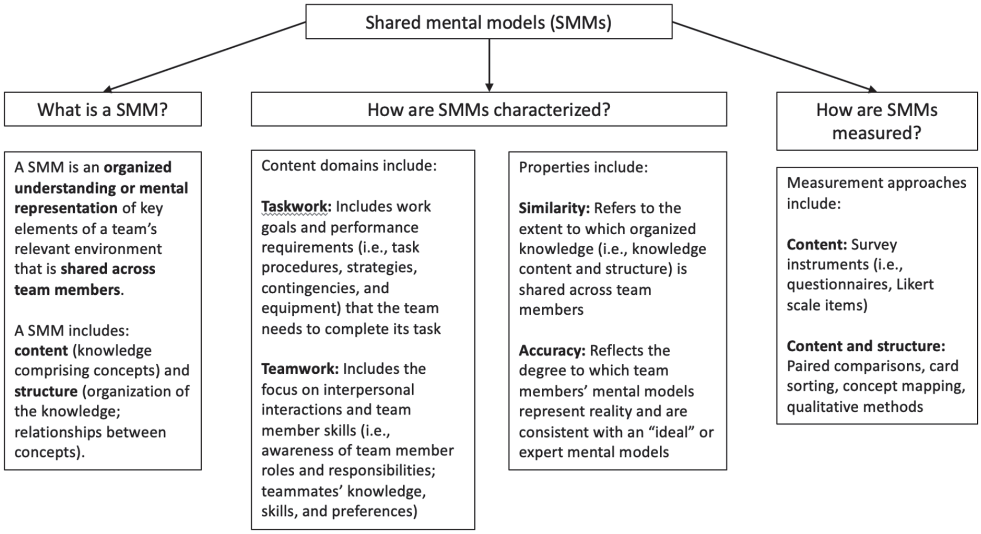
Conclusions: In health professions education, the SMM construct lacks clear definition. Few studies described educational interventions aimed at SMM development, and few attempted to measure the construct. The authors propose an operational definition of SMMs in health care and illustrate how interventions intended to foster SMMs, such as team trainings or planning exercises and communication tools, could be developed, implemented, and assessed.

Team-based practice--where responsibility for the delivery of patient-centered care is distributed across a team of health professionals working collaboratively--is increasingly becoming the norm in health care, yet practitioners and learners on clinical teams often have difficulty "getting on the same page" to provide optimal patient care.[1] Developing a common understanding of both the roles of team members and the structure of the work is called developing a shared mental model (SMM).[2] Several empirical studies, both within and beyond health care, have demonstrated the value of SMMs in supporting teamwork.[1,3] It follows then that health professions learners should be trained to recognize, adapt, and align their mental models with those of their health care team members to create a SMM related to patient care. However, we need to know what a SMM is and how it can be developed and assessed before we can advocate its use in the context of health professions education (HPE). In our study described here, we explored the SMM construct as it relates to clinical teamwork among health professions learners.

In cognitive psychology, mental models are cognitive representations of the environment, including objects, activities, situations, or people.[4,5] These organized knowledge frameworks allow individuals to understand phenomena, develop inferences, and make predictions.[6] When the organized mental representations of individual team members overlap, they are said to have a SMM. SMMs encompass declarative, procedural, and strategic knowledge (i.e., content) as well as the organization of that knowledge (i.e., the knowledge structure or relationships among concepts).[2,7,8] (For a clinical example illustrating this distinction between SMM content and structure, see Appendix 1.) SMMs fall into two interdependent content domains--task-related and team-related mental models.[2,3,5,7,9] Task-related mental models include goals and performance requirements; team-related mental models focus on interpersonal interactions and team member skills.[5,7]

SMMs also have two distinct properties--similarity and accuracy.[7] Similarity is the extent to which team members share organized knowledge. This "sharedness" refers to the degree of overlap among team members' mental models[2] and may range from low to high. Accuracy reflects the degree to which team members' mental models are consistent with reality[10] or what is considered by expert consensus to be the ideal mental model.[3,4] Though multidimensional,[7,11] many simply describe SMMs as a shared understanding among team members or as members being on the same page (see Figure 1).[7,12]

Figure 1: Components, characterization, and measurement approaches to shared mental models (SMMs).



SMMs are considered one of the key coordinating mechanisms of effective teamwork, along with closed loop communication and mutual trust.[9] They support team members' ability to: (1) predict each other's needs; (2) identify changes in the team or task; (3) adjust strategies; and (4) coordinate behavior.[3] Empirical evidence suggests that highly similar and accurate mental models among team members support team functioning, yielding improvements in team processes and performance.[1,3,5,10,13] Empirical studies outside of HPE have also shown that a range of team interventions may effectively facilitate SMM development in teams.[6,7] Given the importance of the SMM construct in the teamwork literature and its relevance to health professions training specifically and health care generally, we believe that the potential utility and impact of SMMs in education warrant a comprehensive review and synthesis of the existing literature.

Considering that our goal was to explore the SMM construct as it relates to clinical teamwork in the context of HPE in a comprehensive and inclusive manner and that we discovered few empirical studies of SMMs in health professions learners in our initial PubMed search, we felt that a scoping review was the appropriate approach for our study. Colquhoun and colleagues defined a scoping review as a "[form of] knowledge synthesis that addresses an exploratory research question aimed at mapping key concepts, types of evidence, and gaps in research related to a defined area or field by systematically searching, selecting and synthesizing existing knowledge."[14] The scoping review methodology supports less restrictive inclusion criteria than the systematic review methodology and also allows for the inclusion of information from disparate sources.[14,15]

There are four primary purposes for conducting a scoping review, including: (1) to examine the extent, range, and nature of research activity in a given area; (2) to determine the value of undertaking a full systematic review; (3) to summarize and disseminate research findings; and (4) to identify gaps in the existing body of literature.[14,15] The primary objective of this scoping review was to conduct a broad investigation of the SMM construct as it relates to clinical teamwork in the context of HPE, to identify gaps in the current literature, and to disseminate these findings to the HPE community.

METHOD

Following the five required steps outlined in Levac and colleagues' refined methodological framework for scoping reviews,[15] we: (1) identified the research questions; (2) identified relevant studies; (3) selected studies to be included in the review; (4) charted the data; and (5) collated, summarized, and reported the results.[15] While we did provide our local educational research community with opportunities to critique the study design and to review an early draft of this article, we did not feel that this engagement rose to the level of a stakeholder consultation (the optional sixth step). The methods we used in each step are detailed below.

Identifying the initial research questions

The initial step of the scoping review process is to develop research questions to guide the review.[15] We generated research questions that would allow for a broad exploration of the SMM construct in the context of clinical teamwork in HPE, including definition, application, interventions, and measurement approaches. We refined our questions during several research team meetings and finalized them as:

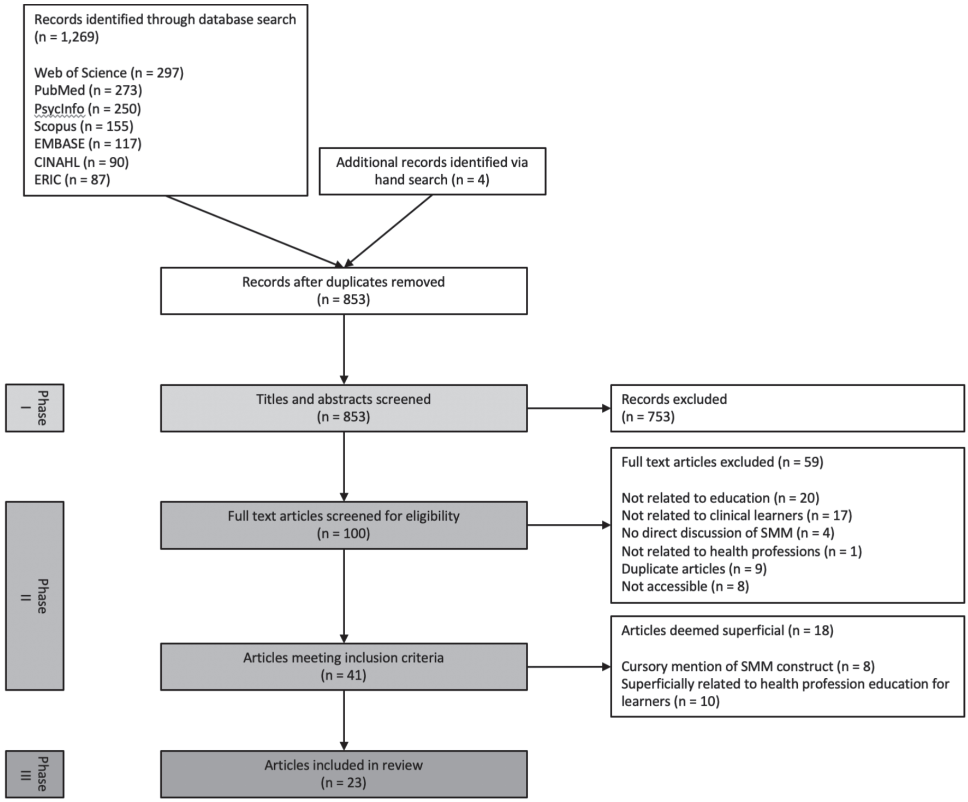
1. How has the SMM construct been defined and applied in relation to clinical teamwork involving health professions learners?
2. What educational interventions are used to develop health professions learners' SMMs related to clinical teamwork? What impact do these interventions have on SMM development and related outcomes?
3. How are SMMs measured in clinical teams with health professions learners and what are the findings?

Identifying relevant studies

Following an initial pilot search of PubMed, using the search terms "shared mental model" OR "shared mental models," to identify synonyms and to locate the entry of this construct into the HPE literature, our reference librarian (E.W.) generated specific search terms, which encompassed the SMM construct (e.g., "shared mental model" and "shared mental models"). And, since we were most interested in trainees (rather than established clinical practitioners), keywords relating to undergraduate and graduate health professions learners were also included (e.g., "clinical training" and "nursing education OR pharmacy education OR medical education OR dental education"). After reaching consensus with the team regarding the search terms, the librarian (E.W.) developed a database-specific search strategy intended to identify the relevant literature from a broad array of English-language, academic, and grey literature sources.

Using this approach, we conducted two separate searches of the CINAHL, EMBASE, ERIC, Scopus, Web of Science, PubMed, and PsycINFO databases (see Figure 2). The initial PubMed pilot search retrieved references related to the SMM construct as it applies to teamwork and simulation. This first comprehensive literature search, conducted in December 2015 by our reference librarian (E.W.), spanned January 2000 through December 2015. As data analysis proceeded from January to April 2016, we discovered new search terms that could potentially both expand and refine the search. And, since the scoping review methodology supports an iterative approach to searching the literature as new ideas or search terms are generated during the review process, a second search (conducted by E.W. and L.C.F.) was conducted in May 2016. This search included an expanded list of search terms that were encountered in those articles reviewed following the first search (e.g., additional terms related to the SMM construct including: "team mental model(s)," "taskwork" and "teamwork"; more specific terms related to trainees such as "resident(s)," "internship and residency," "fellow(s)," and "fellowship"; and terms that attempt to capture "interdisciplinary" and "interprofessional" teams). We (L.C.F. and D.D.) also searched the reference lists of all included articles by hand to identify additional articles for review.

Figure 2: Literature search and article selection process in a scoping review of the literature on shared mental models (SMMs) to support clinical teamwork among health professions learners, 2000-2016.



Selecting studies for review

Two authors (L.C.F. and D.D.) independently reviewed all titles and abstracts for eligibility using a screening tool that allowed for direct comparison of each reviewer's recommended action (i.e., include in the primary analysis, include as a background paper, or exclude) and rationale for eligibility (e.g., mentioned a SMM or team mental model [TMM] in the context of HPE and included learner categories). After this initial screening, we read the full texts of the articles deemed eligible for inclusion. Eligible articles included: empirical and descriptive studies, conceptual papers, letters or communications, commentaries, perspectives, meta-analyses, systematic reviews, abstracts, and poster presentations. Inclusion criteria were developed by the team based on our guiding research questions and required that articles: (1) use the term shared mental model(s) or team mental model(s); (2) pertain to undergraduate- (i.e., medical, pharmacy, nursing, physical therapy students, etc.) and/or graduate-level (i.e., residents, fellows) health professions learners; and (3) take place in a real or simulated clinical setting. We excluded articles not in English and those not related to clinical teamwork or clinical training. Additionally, during the full data extraction, we found that several of the articles that had initially met our inclusion criteria treated the construct of SMMs or TMMs in a cursory manner (n = 8) or contained only a brief mention of the education of undergraduate- or graduate-level health professions trainees (n = 8). We deemed these articles "superficial" and excluded them from the review (see Figure 2). Any disagreements regarding article inclusion were resolved through discussion (L.C.F. and D.D.).

Charting the data

Two authors (L.C.F. and D.D.) developed a data collection form to collect all the information necessary to answer our research questions. Data categories included: author, year of publication, study design (descriptive, experimental, qualitative, quantitative), educational setting, learner characteristics, focus of article, description of intervention (if applicable), SMM definition, SMM content and properties, application of the SMM construct, SMM measurement methods, and key outcomes/findings. We (L.C.F. and D.D.) piloted the data collection form by each extracting data independently from five articles. The high degree of consistency between our extracted data sets supported the utility of the collection form. Our research team identified a few pieces of missing information, so we added article type (program, empirical, conceptual, opinion/position, summary), specific study aims, and target group (i.e., study population) to the form. Using the refined collection form, one author (L.C.F.) revisited the first five articles to extract data relevant to the newly added categories, then extracted data from the remaining 18 articles. Another author (D.D.) then reviewed all of the extracted data for accuracy and completeness. Discrepancies were resolved through discussion. Two authors (L.C.F. and B.C.O.) reviewed all extracted data independently, discussed the findings, and ensured that the extracted data would help us best answer our research questions.

Collating, summarizing, and reporting findings

One author (L.C.F.) reviewed then analyzed the extracted data using both narrative and numerical description. The narrative summaries, combined with the numerical analysis, were intended to highlight the most relevant findings related to each of our three main research questions, including: (1) the proportion of studies that defined the

SMM construct, how SMMs were characterized in each definition (i.e., shared knowledge, knowledge organization, SMM properties, etc.), and the nature of the application of the SMM construct in HPE (i.e., clinical setting, learner characteristics, etc.); (2) the categories of interventions related to SMM development in HPE (i.e., teamwork curricula, team training, or teamwork supportive tools); and (3) approaches to measuring SMMs taken by researchers in the context of HPE. After several in-depth discussions among the research team, we finalized the data summaries.

RESULTS

Our database and reference list searches retrieved a total of 1,273 records (see Figure 2) and, after removing duplicates, 853 records remained. We screened all titles and abstracts and excluded 753 records based on our eligibility criteria. The full texts of 100 articles were read and, in the end, 23 articles met our inclusion criteria and were included in our review (see Tables 1 and 2, as well as Appendix 2 for the data associated with our research questions).

We address each research question in turn in the sections that follow: (1) definition, (2) interventions, and (3) measurement.

How has the SMM construct been defined and applied in relation to clinical teamwork involving health professions learners?

Less than two-fifths of the articles (9/23) explicitly defined the SMM (or TMM) construct (see Table 1).[16-24] All definitions characterized a SMM as a cognitive construct encompassing knowledge shared across team members.[16-24] Definitions characterized mental models as "shared,"[17,18,22] "common,"[21,24] or "overlapping"[23] among team members. One referenced mental model similarity.[19] Another implied that mental models "held by members" are shared, but the language was not explicit.[20] Two-thirds of all definitions (6/9) referenced knowledge structure,[16,18-20,22,23] either explicitly[19,20] or by mentioning "organized"[16] knowledge or cognitive "representation(s)."[18,22,23] Four definitions differentiated between the content domains of task- and team-related knowledge.[20-23]

Table 1: Definition and Dimensions of Shared Mental Models (SMMs) and Team Mental Models (TMMs), According to a Scoping Review of the Literature, 2000-2016

First author (year)	SMM/TMM definition	Dimensions[a]					
		Individual representation	Organized knowledge	SMM properties		SMM content domains	
				Similarity (shared knowledge)	Accuracy[b]	Task-related knowledge	Team-related knowledge
Burtscher (2011)[16]	A TMM is defined as "the organized understanding of relevant knowledge that is shared across team members."	–	+	+	–	+/–	+/–
Janss (2012)[17]	A SMM is defined as a "shared understanding."	–	+/–	+	–	–	–
Mamykina (2014)[18]	A SMM is defined as a "shared cognitive [representation]."	–	+	+	–	–	–
Mamykina (2016)[22]	A SMM is defined as a "shared cognitive [representation] of task requirements, procedures and role responsibilities."	–	+	+	–	+	+
McComb (2015)[19]	A SMM is defined as an "individually held knowledge [structure] that [helps] team members function collaboratively in their environments and [is] comprised of content, similarity, accuracy and dynamics."	+	+	+	+	+/–	+/–
Nakarada-Kordic (2016)[23]	A SMM is described as an "[overlapping]" "internal representation of reality" held by each member of the team regarding the "situation and the plan, and of when and by whom various tasks should be done."	+	+	+	+/–	+	+

		Dimensions[a]					
First author (year)	SMM/TMM definition	Individual representation	Organized knowledge	SMM properties		SMM content domains	
				Similarity (shared knowledge)	Accuracy[b]	Task-related knowledge	Team-related knowledge
O'Connor (2016)[24]	A SMM is defined as a "common understanding about required task(s) and/or patient care."	–	+/–	+	–	+	+/–
Tourgeman-Bashkin (2010)[21]	A SMM is described as a tool "that [provides] team members with a common understanding of who is responsible for which tasks and what the information requirements for each task are."	–	+/–	+	–	+	+
Xie (2015)[20]	A SMM is described as a "knowledge structure held by members of a team that enables them to form accurate explanations and expectations for the task, and in turn, to coordinate their actions and adapt their behavior to demands of task and other team members."	+	+	+/–	+	+	+

[a] **+** indicates that the dimension is included in the definition or description of SMM/TMM.
+/– indicates ambiguity in the language, so it is open for interpretation whether or not the definition or description of SMM/TMM includes the dimension.
– indicates that the dimension is not mentioned in the definition or description of SMM/TMM.
[b] The authors do not consider the SMM property of accuracy to be a key component of the definition of SMM, since team members may hold mental models that overlap to a high degree but are completely inaccurate.

All articles discussed SMMs in the context of hospital-based care, most often in interprofessional teams (14/23) and high-intensity settings (i.e., surgery, trauma) (14/23).[16-23,25-30] Most articles included graduate-level physicians (21/23)[16-36] within clinical teams (18/23).[16-23,25-34] Three articles involved undergraduate-level medical students.[29,33,37] Non-physician learners included junior nurses,[36] nursing and physical therapy students,[37,38] and other unspecified health professions learners.[33]

Most articles discussed SMMs as an outcome (e.g., of team interaction, team training, or curricular interventions) (12/23).[17,18,20,22,23,26,28,30,34,36-38] Others discussed SMMs as a prerequisite for effective teamwork or performance (5/23)[16,19,24,29,31] or as both an outcome and prerequisite (5/23).[21,25,27,33,35]

What educational interventions related to SMMs are described and what impact do they have?

Interventions designed to foster SMMs (6/23) included teamwork curricula/training[28,35,37] and teamwork supportive tools[20,30,24] (see Table 2). Most interventions focused on taskwork such as resuscitation,[28] developing treatment plans,[30] crisis care,[34] and rounding.[20] Others focused on teamwork skills[35] and team-based behaviors.[37] Interventions occurred in both simulated clinical settings and with in-situ clinical teams involving graduate- (5/6)[20,28,30,34,35] and undergraduate-level learners (1/6).[37] Most interventions focused on the clinical team[20,28,30,34] rather than on the individual learners directly.[35,37]

Table 2: Educational Interventions to Develop Shared Mental Models (SMMs) to Support Clinical Teamwork among Health Professions Learners, According to a Scoping Review of the Literature, 2000-2016

First, author (year)	Article type (design)[a]	Aims	Study population (n)	Intervention type/ description	Application of the SMM construct[b]	Methods/Measurements	Key findings/ outcomes related to SMMs[c]
Carbo (2011)[35]	Program (curriculum) and empirical (quantitative)	To develop and investigate the effects of a team training curriculum on attitudes and knowledge related to patient safety	Internal medicine residents from two urban teaching hospitals (n = 50); respondents completed both pre- and post-intervention surveys (n = 33)	Teamwork curricula/ training: Hour-long, case-based, interactive team training curriculum focused on four key teamwork skills and patient safety. Curriculum based on the CRM principles: assertiveness, effective briefings, callback/verification, situational awareness and SMMs; in aggregate, they are called the ABC's of teamwork.	SMM as design principle: SMMs used as an organizing principle guiding the team training curriculum SMM awareness as expected outcome: During interactive discussion, faculty emphasized the importance of briefings as a means of producing a SMM	Pre-/post-test design Measurements: Pre-/post-intervention multiple choice question-based knowledge and attitudes survey Quantitative analysis method not specified	Findings related to SMMs: Findings do not make a clear connection to SMMs, instead they focus on the aggregated ABC's of teamwork After training, residents' knowledge of aggregated teamwork skills nearly doubled SMMs were not directly measured
Garbee (2013)[37]	Program (curriculum) and empirical (quantitative)	To evaluate efficacy and retention of teaching team-based com-petencies to interprofessional student teams using high-fi-delity patient simulation	Interprofessional teams for fall 2009 training (n = 35 students); training was repeated in spring 2010 (n = 25 students); teams consisted of medical (n = 2), nursing (n = 2), nurse anesthesia (n = 2), and physical therapy (n = 1-2) students	Teamwork curricula/ training: During each training session, student teams participated in two simulated inpatient cases (ICU-based) and post-case debriefs.	Focus on teamwork: The SMM is considered a team competency SMM as design principle: SMMs were the focus of post-case, structured debriefing SMM as expected outcome: The SMM is characterized	Pre-/post-test design; data collected for fall and spring sessions from trained observers and participants SMM measurement: Individual and team performance rated by participants and observers using: the Teamwork Assessment Scale, a Likert-style survey to measure overall teamwork (includes a team-based behaviors scale and overall teamwork scale	Findings related to SMMs: SMM subscale scores, as rated by both participants and trained observers (using paired samples t tests), improved significantly from simulation scenario one to two in both fall and spring simulation sessions Significant increases in mean participant

First, author (year)	Article type (design)[a]	Aims	Study population (n)	Intervention type/ description	Application of the SMM construct[b]	Methods/Measurements	Key findings/ outcomes related to SMMs[c]
			from a health sciences training center		as one of nine "key team-based competencies"	with subscales for SMM [3 items] and communication [3 items]) A separate communication and teamwork skills assessment tool was also used	and observer SMM scores between fall simulation one and spring simulation two showed an overall training gain
Hicks (2008)[28]	Empirical (mixed-methods)	To develop and administer a needs assessment survey to measure attitudes towards CRM-based training among emergency medicine clinicians	Interprofessional, emergency medicine clinicians from two academic teaching hospitals, including: emergency medicine staff physicians (n = 35), nurses (n = 19), and emergency medicine residents (n = 30)	Teamwork curricula/ training: Propose CRM-based emergency medicine training with an interdisciplinary focus to improve emergency medicine resuscitation team performance	SMM as expected outcome: Recommend team training to improve communication, collaboration, and increase SMM of resuscitation processes across team	Web-based, 22-item survey developed and administered to measure the attitudes toward CRM behaviors in team resuscitation Descriptive statistics were calculated and a two-tailed Fischer's exact test was used to examine associations Survey data to be used to develop an interdisciplinary, CRM curriculum	Findings related to SMMs: Results demonstrated clinicians' consensus regarding the importance of core CRM principles in emergency department resuscitation (i.e., effective communication, team leadership, resource use, problem solving, and situational awareness, but not specifically SMMs)
Leykum (2014)[30]	Program (communication tool)	To describe the development and plans for pilot testing of a structured communication tool to improve inpatient rounds	Inpatient physician teams including medical attendings and residents	Teamwork supportive tool: Introduced the PRISm-structured communication tool (i.e., Physician Relationships, Improvising, and Sensemaking); the tool consists of pre- and post-.	SMM as expected outcome: The PRISm tool may support development of a SMM of treatment plans	Measurement (planned): Proposed assessment of PRISm usage and physician team outcomes will occur via observations, field notes, surveys, and attending feedback	No research findings were presented

First, author (year)	Article type (design)[a]	Aims	Study population (n)	Intervention type/ description	Application of the SMM construct[b]	Methods/Measurements	Key findings/ outcomes related to SMMs[c]
Wu (2011)[34]	Conceptual (design process)	To describe the early design process of an interactive cognitive aid for anesthesia crisis care teams	Interprofessional, anesthesia crisis care teams in a simulation center; teams included simulation staff (n = 3-4), anesthesia residents (n = 2)	round briefings and structured discussions. The authors propose use of the PRISm tool Teamwork supportive tool: The authors propose the design of a coordinated, interactive system comprised of a large screen display (projecting checklist, vitals) with tablets for data input. Six crisis care scenarios were conducted with the simulation center staff; resident anesthesiologists observed.	SMM as design principle: Authors use the SMM construct as a design principle for their proposed cognitive aid. They highlight the utility of the display to prompt team dialogue and promote development of a SMM. SMM as expected outcome: The SMM of the crisis activities across team members	Measurement: Gaze analysis of separate training videos allowed quantification of demands on attention and time	Findings related to SMMs: Findings do not make a clear connection to SMMs
Xie (2015)[20]	Empirical (mixed-methods)	To promote human factors engineering principles, including participatory ergonomics, in the redesign of FCR and to implement a FCR checklist to	Interprofessional, inpatient care teams, including a hematology/ oncology and hospitalist service, at a children's hospital; the intervention implementation team included:	Teamwork supportive tool: The FCR process was redesigned and a checklist was developed to support rounds; FCR checklist use was implemented.	SMM as design principle: Authors used a SMM as a design principle for the development of the content of the FCR checklist SMM as expected outcome: The intent of the FCR checklist	The participatory ergonomics approach (where workers are encouraged to engage in the design of workplace interventions) included gathering multiple stakeholder groups to form an IIT The IIT designed an intervention to improve family engagement in FCR	Findings related to SMMs: Findings do not make a clear connection to SMMs

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First, author (year)	Article type (design)[a]	Aims	Study population (n)	Intervention type/ description	Application of the SMM construct[b]	Methods/Measurements	Key findings/ outcomes related to SMMs[c]
		promote a SMM	researchers (n = 5), a parent representative, nurse managers (n = 2), nurses (n = 2), attending physicians (n = 2), senior medical residents (n = 2)		was to develop a SMM of the rounds process among team members, patients, and families	Observational, interview, and survey data were used to design an intervention including a FCR checklist that was piloted and evaluated via observations	

Abbreviations: CRM indicates Crew Resource Management; ICU, intensive care unit; FCR, family-centered rounds; IIT, intervention implemental team.

[a] Article categories included: (1) Program: An educational program, curriculum, or tool is described. No data or analysis is included. (2) Empirical: A quantitative, qualitative, or mixed-methods research study is described. Data and analysis are included. (3) Conceptual: A framework or model related to the concept of a SMM is provided. (4) Opinion/Position: Thoughts about SMMs in the context of clinical learning are shared. No research or program development is presented. (5) Summary: A review of the existing literature or research is described. (6) Other: Abstracts or poster presentations are described.[22,23]

[b] Though the term team mental model is specific to shared/overlapping mental models amongst team members, the term shared mental models is the most frequently used in the health professions literature. Therefore, the terminology used in each article is reflected in the table.

c For key findings related to SMMs as well as other key findings from the included articles, see Appendix 2.

Teamwork curricula/training programs. Carbo et al. described a case-based, team training curriculum intended to develop residents' teamwork skills, including their SMMs; they found that learners' knowledge of key teamwork skills nearly doubled, increasing from 35% pre-training to 67% post-training.[35] Hicks et al. proposed a simulation-based, emergency department team training program based on the Crew Resource Management principles to develop SMMs for resuscitation processes.[28] Garbee et al. discussed a case-based, simulation curriculum with post-case debriefing to support SMM development in health professions undergraduates.[37] Participant and observer SMM subscale scores increased significantly post-intervention.

Teamwork supportive tools. Wu et al. described an interactive, large screen display and tablet, which promoted crisis care team dialogue to support the development of SMMs.[34] Leykum et al. reported on their design, implementation, and planned evaluations of a structured communication tool to improve pre- and post-round briefings.[30] Xie et al. developed a checklist to support a SMM of family-centered rounds; though highly utilized, it was applied inconsistently, prompting further team training on checklist items.[20] The impact of these tools on SMM development was not directly measured.

How are SMMs measured in clinical teams with health professions learners and what are the findings?

Researchers measured SMMs qualitatively[25] and quantitatively[16,18,19,22,23,25,37] (7/23). Three studies focused on taskwork, including anesthesia induction,[16] intensive care unit (ICU) handoffs,[18] and pediatric intensive care unit (PICU) patient care.[25] Two focused on teamwork, including medicine team members' roles and responsibilities[19] and general ICU teamwork.[37] Two others quantified the degree of similarity among team members' mental model content and structure[16,18]; one also measured SMM accuracy.[16]

Qualitative methods. Custer et al. organized verbal fragments from interviews into themes to elucidate SMM content related to complex PICU patients.[25] SMMs facilitated longitudinal care across handoffs, but variable interpretations of a patient's condition negatively impacted SMM development.[25]

Quantitative methods. McComb et al. developed a seven-point, Likert-type survey to investigate the similarity of nurses' and physicians' mental models related to roles and responsibilities on general medicine wards.[19] Participants rated the professional they believed to be responsible for a specific role (i.e., diagnosis, administering medicines, etc.). Practitioners' mental models were significantly different for 14 of 22 roles. Garbee et al. used a three-item, Likert-type SMM subscale within an overall teamwork scale to measure team-level performance.[37] The authors reported significant improvements in SMM subscale scores post-simulation and debrief as rated by both participants and observers. Burtscher et al. employed concept mapping to investigate the TMM of anesthesia induction. Residents and nurses arranged 30 task-related concept cards (e.g., ventilate patient, hand intubation set, etc.) by sequence and role to create individual maps. Maps were compared (1) within each team to assess TMM similarity and (2) with maps produced by experts to assess TMM accuracy. When TMM accuracy was high, TMM similarity was positively related to performance.[16] Similarly, Nakarada-Kordic et al. developed a computer-based card sorting tool to measure SMMs in operating room teams that were comprised of three sub-teams (surgery, anesthesia, and nursing).[23] Before each of two simulated laparotomies, team members sorted 20 key tasks by sequence and sub-team responsibility. For more than half the tasks, the authors found mental model similarity across team members for task sequence but poor agreement for sub-team responsibility. Mamykina et al. analyzed speech fragments from ICU team members during handoffs to generate a Shared Mental Model Index (SSMi), which represented the weighted proportion of overlapping statements.[18] Work rounds supported the alignment of individuals' mental models around patient care. In another study, Mamykina et al. analyzed critical care ICU teams' verbal handoffs.[22] They reported higher SMMi scores for statements related to patient presentation and those reflecting past events, as well as an association between SMMi score and a team coherence measure.

DISCUSSION

We conducted this scoping review to explore the construct of SMMs as it is applied to clinical teamwork and health professions learners. Few articles explicitly defined the SMM construct, interventions to foster SMMs were rare, and few studies measured SMMs. Based on these findings and our review of the literature outside HPE, we offer the following recommendations to enhance education and research related to SMMs: (1) carefully define the SMM construct to promote consistent application; (2) improve both the design and evaluation of interventions that support SMMs; and (3) measure key aspects of SMMs in clinical teams with health professions learners. We also discuss challenges related to SMM definitions, interventions, and measurement as well as additional considerations related to SMMs in the context of clinical teamwork.

Defining the SMM construct

Several authors described the lack of clarity in the definition of a SMM.[6,7] McComb and Simpson noted that, in health care, authors generally provide superficial definitions of SMMs and often fail to articulate the dimension of the SMM under study, making it difficult to apply the construct consistently in practice and research.[11] Our review corroborated these findings.

A clear, detailed definition allows researchers and educators to accurately characterize the SMM construct. We suggest that such a definition include three key components, based on definitions proposed by Canon-Bowers and collagues,[2] Mathieu and collagues,[3] and Klimoski and Mohammed.[6] First, capturing knowledge content (concepts) as well as structure (relationships among concepts) in the definition differentiates the SMM from other common team cognition constructs (i.e., group learning, situation awareness, and strategic consensus)[7] and acknowledges the centrality of knowledge structure to the SMM construct.[7] Second, specifying that mental model "sharedness" connotes commonality in cognitive representations adds precision to the definition.[6] Third, characterizing the SMM as an individually held knowledge structure that teammates have in common highlights that measurement of this team-level construct requires aggregation of data across individuals.

To clarify the meaning of the SMM construct in the context of health care and to promote its consistent use and application across HPE, we developed an operational definition, adding common characteristics of the definitions we identified in our review[16-24] and situating the construct in the context of teamwork among health care professionals. From this synthesis, we propose the following definition of a mental model that is shared among health care team members:

> A shared mental model is an individually held, organized, cognitive representation of task-related knowledge and/or team-related knowledge that is held in common among health care providers who must interact as a team in pursuit of common objectives for patient care.

Two content domains characterize SMMs--task- and team-related knowledge. Task-related knowledge encompasses task goals, procedures, strategies, and relevant equipment. Team-related knowledge includes role interdependencies, responsibilities, and communication patterns as well as team members' knowledge, skills, attitudes, and preferences. To address the two dimensions of a SMM--concepts and knowledge organization--we included the term *organized* to refer to knowledge structure or the relationships among concepts. Considering the two properties of a SMM--similarity and accuracy--it is important to recognize that the term *common* in our proposed definition signifies a degree of similarity that will vary in intensity from team to team, ranging from low to high. We excluded the term *accuracy* because team members may have highly similar mental models that are accurate, inaccurate (i.e., the SMM neither reflects the true state of the world nor overlaps with an expert's mental model), or indeterminate (i.e., the situation or task is ambiguous or uncertain).

Throughout the review process, we debated several challenging elements of the SMM construct. We pondered how to characterize the relationship between task-related knowledge and team-related knowledge in health care teams. For example, is it possible to have team-related knowledge without task-related knowledge? Since the team and its task are inextricably connected (i.e., the health care team gathers to do a job related to patient care not just to socialize), we struggled with the conventional separation of the task- and team-related knowledge content domains.[7] Since this separation of the SMM content domains is prevalent in the broader literature, as is the understanding that team members hold multiple SMMs simultaneously[7] (e.g., task requirements and responsibilities), we aligned our definition with common uses of this construct to both gain conceptual clarity and promote standardized use across HPE.

We also debated the SMM properties of similarity and accuracy. For example, we discussed instances where team members' mental models might have minimal overlap. While this overlap might technically generate a SMM, little is known about the ideal level of similarity in the clinical context, and the question remains,[22] "What are the functional consequences of a barely existent SMM?" We also discussed whether or not to include accuracy in our definition. Though similarity and accuracy of team members' mental models is desirable,[3] for a SMM to exist, mental models only need to be shared. There is no requirement that they reflect reality or align with an expert's mental model. A team with an inaccurate SMM of clinical task priorities might actively pursue secondary goals, negatively affecting team performance[5] and patient care. Therefore, we excluded the term *accuracy* from our definition, allowing for the real possibility that team members might have highly similar but inaccurate SMMs. Another reason to exclude accuracy was that, absent an expert mental model, it is impossible to determine SMM accuracy.

Ultimately, our proposed definition aims to provide a coherent conceptual framework for the SMM construct and to guide health professions educators and researchers in the practical application of SMMs in health care teams rather than to serve as an absolute truth.[39]

Applying the SMM construct

A SMM can function as both a dependent and independent variable in education. Educational interventions may support SMM development, and a team's SMMs can impact learning and performance. We found SMMs that were described as expected outcomes of interventions as well as prerequisites for improved team performance. We suspect this dual use contributes to what Mohammed and colleagues characterized as "a fair amount of conceptual confusion surrounding [SMMs]" in research and practical application.[7] While both uses are acceptable, achieving conceptual clarity requires researchers and practitioners to explicitly define how they are using the term.

The prevalence of high-intensity health care teams described in the articles we reviewed is consistent with the broader SMM literature, where the construct has been applied frequently to teams in high-risk environments, such as cockpits and military combat.[2,5,40,41] This focus reveals an important gap in the literature since most health care occurs in lower-intensity, outpatient settings.[42] Though clinical teams practicing in lower intensity settings (e.g., ambulatory care) would not be expected to encounter the same emergent situations as those teams in higher intensity settings (e.g., the ICU), where the need for immediate coordination is generally great,[25,31] they do face unique communication and organizational challenges as members of complex, "virtual," distributed health care teams that provide care in an asynchronous fashion.[43,44] Whether or not accurate SMMs among these health care team members--with respect to their collective task (i.e., goals of care for a specific patient), their respective roles and responsibilities related to that patient's care, or their attitudes towards patient safety--would benefit team performance and improve patient care and safety warrants further study.[12]

Designing educational interventions to facilitate SMM development

Although the broader literature offers a wide range of interventions that facilitate SMM development (i.e., team training, planning, leadership, and reflexivity),[6,7] we found few interventions focused on clinical teamwork among health professions learners.

Despite the complexity of operationalizing and measuring SMMs in teams, educators might use the SMM construct to design interventions to improve team performance outcomes or enhance knowledge of teamwork principles. We offer a few examples of such interventions used within and beyond health care that could be adapted for use in clinical, team-oriented education.

Team training has been studied extensively across fields; it may support either the pursuit of general teamwork outcomes or the development of SMMs[7,45] and includes: computer-based training to develop general teamwork competencies; team interaction training, where teams are trained to coordinate their actions; and cross-training, where team members learn about the tasks, roles, and responsibilities of other team members.[7] Computer-based training has improved team knowledge, communication, and skills,[45] and increased both the similarity and accuracy of team mental models.[13] Team-interaction training and cross-training have led to improvements in team outcomes[46] and promoted SMM development.[41] Team-interaction training during an inpatient rotation, for example, might include a case-based curriculum focused on effective team communication. Cross-training in HPE might provide learners with opportunities to shadow other team members and to see teamwork from various perspectives, such as a medical resident shadowing a nurse during nursing rounds.

Other opportunities to use SMMs include during team huddles--to develop team goal setting, coordination, and communication skills[47]--and during team coaching, team performance monitoring, and group and individual reflections. For example, a group reflection exercise, implemented in July as new residents arrive, could allow new residents to reflect on their individual and shared expectations related to team functioning and processes in their new surroundings. Alternatively, an SMM-focused intervention might serve as a team diagnostic tool to encourage team members to explore how the lack of a SMM might have contributed to a near miss during a patient encounter.

Measuring SMMs

The complexity of assessing and representing cognition at the individual and group levels has been characterized as a “thorn in the side” of this field of research.[48] Several factors contribute to the complexity of measuring SMMs and to the limited empirical progress in SMM research.[48] The SMM construct lacks a common definition[4] and is inherently complex with two content domains (task- and team-related knowledge), two dimensions (concepts and organization), and two properties (similarity and accuracy).

Since SMMs are “organized knowledge structures,”[2] their measurement requires that the content of each individual team member’s mental model be elicited and the structure of their knowledge elucidated.[48] Then individual mental models must be evaluated and aggregated to determine the degree of similarity or “sharedness.” Accuracy may be determined by comparison to an ideal mental model (if one exists) that is derived by aggregating mental models from subject matter experts.[3,7]

Though the challenges with measuring SMMs are well documented,[7] the literature suggests that they are not insurmountable.[4,8,48] The four main measurement techniques described in the literature include: paired comparisons, card sorting, concept mapping, and qualitative analysis.[7,8] To choose a method to measure a SMM, the purpose and setting of the investigation must be considered.[7]

We considered the limitations of measuring SMMs, from instrument development to application. Most instruments are context-dependent and lack generalizability.[49] Logistical difficulties in administering these instruments include the substantial time needed for completion, the difficulty of completing in-situ team SMM measurements, and the analytic expertise required to analyze the data. In light of these challenges, SMM measurement may not be feasible for many educators and may limit the practical application of SMMs as a diagnostic tool to assess team performance in the workplace or learning environment.[49] Alternatively, direct measurement of SMMs may not be necessary if the outcomes expected, such as team processes (e.g., coordination, communication) or measures of team effectiveness (e.g., performance metrics), can be determined.[15,49] However, without direct measurement of mental model similarity and accuracy, it would be impossible to tie any team performance improvements directly to SMM development.

Further considerations

Our analysis revealed that the complexity of the SMM construct, in combination with the myriad measurement issues identified in the articles we reviewed, may limit the wide applicability of this construct in HPE. In addition, we believe that, while some researchers have discussed the benefits of distinctive perspectives,[2] the general emphasis in the literature on team members' mental model "convergence"[50] may lead to a biased view in favor of greatly overlapping mental models. And, the overt promotion of SMMs in clinical teams, without the creation of a safe team atmosphere where alternate issues or solutions to problems are welcomed and expected, may have unintended negative consequences such as promoting "groupthink."[51] Groupthink may prevent the potentially productive divergence of opinion,[44] result in lower quality team decision-making,[52] or instantiate the status quo that is in need of change. For these reasons, some researchers feel that members of a team must be given the opportunity to bring their diverse knowledge and perspectives forward for the team's consideration[50] and that mental model complementarity (i.e., where team members' mental models are related to one another in a complementary fashion) might be as important as mental model similarity among team members in improving team performance.[22,50]

Limitations

First, since *shared* and *mental model(s)* were defining keywords in our literature search, articles that applied the SMM construct but did not contain these terms were not captured. And, though our search included databases that capture grey literature sources (EMBASE, Scopus, PsycINFO, and Web of Science), our search of the grey literature was limited and we may have missed relevant information. Next, our review was based on a small set of articles that met our inclusion criteria, which speaks to the limited number of publications in the field and perhaps to the limited utility of the SMM construct in HPE. However, the included articles accurately reflected the published literature focused on SMMs to support clinical teamwork in health professions learners.

CONCLUSIONS

Through this scoping review, we explored how the SMM construct has been applied to clinical teamwork involving health professions learners. The gaps we identified in this review revealed opportunities for refinements and further research. We recommend that, if health professions educators and researchers choose to use the SMM construct, they should (1) consistently apply a clear definition of the SMM construct; (2) design and evaluate interventions to support SMM development in a variety of clinical environments; and (3) practice methodological rigor in measuring SMM content, structure, similarity, and accuracy. Following these recommendations can expand our understanding of the ways in which SMMs can empower team members, including health professions learners, to get on the same page and more effectively collaborate to deliver optimal team-based clinical care.

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Appendix 1: An illustration of the distinction between SMM content and structure.

Consider the following clinical example focused on the task of patient falls prevention:

Mr. Smith, an 88 year-old male resident of a skilled nursing facility, has a history of multiple falls in the past month and fell again yesterday as he attempted to get out of bed and walk to the bathroom. All members of his care team (i.e., his daytime floor nurse, charge nurse, physical therapist and geriatrician) are focused on the goal of preventing further falls and agree that Mr. Smith now needs a walker to minimize the risk of further falls. However, a disagreement in the implementation of that strategy arises. The floor nurse, who is new to the team, suggests that the walker be placed in Mr. Smith's room, but out of sight behind the curtain so that it is accessible to her, but does not encourage him to get out of bed. The physical therapist, geriatrician and charge nurse recommend instead that the walker be placed at the bedside.

In this example, the content of each team member's taskwork mental model regarding a falls prevention strategy for Mr. Smith is similar (e.g., to help **prevent falls**, an **assistive device** is now needed and a **walker** is preferred). However, the organization of that knowledge, specifically the association between the need for a walker and the rationale for optimal placement of the walker in Mr. Smith's room, differs between the clinicians.

With further team discussion, the individual team members' organized mental representations of the proper use and placement of the walker for Mr. Smith come into alignment. The team comes to a shared understanding that the walker must be placed at bedside to prevent falls – they have developed a SMM around a fall prevention strategy.

Appendix 2: Overview of all included studies (n=23)

Author	Article Type [Design]*	Aims	Study Population [n]	Intervention Type/ Description	Application of Shared Mental Model (SMM) Construct^	Methods / SMM Measurement	Key Findings/ Outcomes
Burtscher (2011)[16]	Empirical [Mixed-methods]	To investigate how team mental model (TMM) properties interact with monitoring behaviors to predict team performance in simulated anesthesia induction, including "non-routine" events	IP anesthesia teams [n=31] [(comprised of an anesthesia resident and an anesthesia nurse) from a hospital	N/A	<u>Focus on Taskwork:</u> - Anesthesia induction <u>TMM characterized as Prerequisite for Effective Teamwork</u>	<u>TMM Measurement:</u> -**Concept mapping technique** used to measure similarity and accuracy of team members' TMM of the task of anesthesia induction Similarity measured by comparing individual maps Accuracy measured by comparing participants' maps with 2 subject matter experts' maps. Individual accuracy ratings averaged to create a team level measure. <u>Other Measurements:</u> - Monitoring behaviors (i.e., observing activities/ performance of other team members) assessed based on observations - Team performance assessed via checklist	<u>Findings related to TMMs:</u> - TMM similarity moderated relationship between team monitoring behaviors and performance - TMM similarity and accuracy interacted to predict performance - Increased monitoring behaviors, in absence of similar TMM, negatively affected performance

Author	Article Type [Design]*	Aims	Study Population [n]	Intervention Type/ Description	Application of Shared Mental Model (SMM) Construct^	Methods / SMM Measurement	Key Findings/ Outcomes
Carbo (2011)[35]	Program [Curriculum] + Empirical [Quantitative]	To develop and investigate the effect of a team training curriculum on attitudes and knowledge related to patient safety	IM residents from 2 urban teaching hospitals [n=50]; respondents completing both pre- and post-intervention survey [n=33]	Teamwork Curricula/ Training - Hour-long, case-based, interactive team training curriculum focused on 4 key teamwork skills and patient safety. Curriculum based on Crew Resource Management (CRM) principles which include: assertiveness, effective briefings, callback/ verification, situational awareness and SMMs; in aggregate, called the "ABC'S" of teamwork	SMM as Design Principle: - SMMs used as an organizing principle guiding the team training curriculum SMM Awareness as Expected Outcome: - During interactive discussion, faculty emphasized importance of briefings as means of producing a SMM	- Pre-post-test design Measurements: - Pre-post intervention, multiple choice question-based knowledge and attitudes survey - Quantitative analysis method not specified	Findings related to SMMs: - Findings do not make a clear connection to SMMs, instead focus on the aggregated "ABC'S" of teamwork - After training, resident's knowledge of aggregated teamwork skills nearly doubled, but SMMs were not directly measured
Custer (2012) [25]	Empirical [Qualitative]	To understand expert and team cognition of complex patients in Pediatric ICU (PICU)	IP PICU team from a children's hospital, including attending physicians [n=9]; NPs [n=2]; bedside nurses [n=4]; pediatric critical care fellows [n=3]	N/A	Focus on Taskwork: - Care of complex PICU patients SMM characterized as Pre-requisite for Effective Teamwork and Expected Outcome of working together	SMM Measurement: - **Cognitive task analysis** based on thematic analysis of verbal fragments from semi-structured interviews	Findings related to SMMs: - 11 themes and 4 categories were identified: formation of patient-related MMs; and causes, results and recognition/ management of inadequate MMs

Author	Article Type [Design]*	Aims	Study Population [n]	Intervention Type/ Description	Application of Shared Mental Model (SMM) Construct^	Methods / SMM Measurement	Key Findings/ Outcomes
							- Critical care teams tried to create SMMs of their patients - An "Inadequately developed or inadequately shared mental model" of patient care was a major barrier to team cognition in PICU; what constituted an "inadequately shared mental model" was not explicitly defined
Dickerson (2016) [29]	Empirical [Mixed-methods]	To determine if direct, in-person communication between radiologists and acute care surgeons alters surgical decision making	IP clinical teams from a large academic medical center included: attending physician(s) from acute care surgery [n=1] and abdominal radiology [n=1-3]; chief surgical resident [n=1]; abdominal radiology fellows [n=1-2]; acute care surgery residents [n=2-4]; radiology residents [n=1-2]; acute care surgery PAs [n=1-2]; medical students [n=1-3] Patients were reviewed [n=100] during multidisciplinary meetings [n=21]	N/A	Focus on Teamwork: - Team communications and collaboration	- Comprehensive imaging review was performed for cases selected by surgeons - Semi-weekly, ~60 minute-long, rounds between radiologists and acute care surgeons focused on promoting targeted, in person collaboration - RADPEER interradiologist concordance scores were assigned to all reviewed examinations. -Impression and plan of the attending surgeon were recorded before and after each in-person review	Findings related to SMMs: - Promotion of a SMM between acute care surgical team and abdominal radiologists cited as primary mechanism driving substantial and frequent changes in patient management -SMM facilitates exchange of complex information related to patient management within the multidisciplinary team

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Author	Article Type [Design]*	Aims	Study Population [n]	Intervention Type/ Description	Application of Shared Mental Model (SMM) Construct^	Methods / SMM Measurement	Key Findings/ Outcomes
Duthie (2014)[26]	Empirical [Qualitative]	To present a case analysis of cognitive under-specification (CU) in 2 instances of unintended communication outcomes	IP, inpatient clinical teams from 2 large academic medical centers, included medical residents	N/A	Focus on Teamwork: - Team communications SMM as Expected Outcome: - Prevention of SMM development may result from incomplete communications between providers where a knowledge gap is bridged with mismatching information	- Applied Reason's human error theory and Dekker's theory of human incident investigation to case analyses of CU errors	Findings related to SMMs: - Contributing factors to CU include: workload, interruptions, inexperience, and lack of a SMM
Garbee (2013)[37]	Program [Curriculum] + Empirical [Quantitative]	To evaluate efficacy and retention of teaching team-based competencies to interprofessional (IP) student teams using high-fidelity patient simulation	IP teams for Fall 2009 training [n=35 students]; training was repeated in Spring 2010 [n=25 students] Teams consisted of medical [n=2], nursing [n=2], nurse anesthesia [n=2] and physical therapy [n=1-2] students from a health sciences training center	Teamwork Curricula/ Training During each training session, student teams participated in two simulated inpatient cases (ICU-based) and debrief post-case	Focus on Teamwork: - SMM is characterized by authors as a team competency SMM as Design Principle: - SMMs were focus of post-case, structured debriefing SMM as Expected Outcome: - SMM is characterized as one of nine "key team-based competencies"	- Pre-post-test design; data collected for Fall and Spring sessions from trained observers and participants SMM Measurement: - Individual and team performance rated by participants and observers using: **Teamwork Assessment Scale [TAS], a Likert-style survey** to measure overall teamwork (includes team based behaviors scale and overall teamwork scale (with **subscales for SMM [3-items**] and communication [3 items])	Findings related to SMMs: - SMM subscale scores, as rated by both participants and trained observers (using paired samples t-tests) improved significantly from simulation scenario one to two in both Fall and Spring simulation sessions - Significant increases in mean participant and observer SMM scores between Fall simulation one and Spring simulation two showed an overall training gain

Author	Article Type [Design]*	Aims	Study Population [n]	Intervention Type/ Description	Application of Shared Mental Model (SMM) Construct^	Methods / SMM Measurement	Key Findings/ Outcomes
						- Separate Communication and Teamwork Skills (CATS) assessment tool was also used	
Gonzalo (2014)[27]	Empirical [Mixed-methods]	To measure provider differences in perception of quality and safety issues during "off hours" in medicine units	IP, "off hours care team" in an Inpatient medicine unit in an academic medical center including: attending physicians [n= 25], housestaff (residents, medical interns) [n=71 completed survey; n= 5 for debriefings], nurses [n=64]	N/A	Focus on Taskwork: - Off-hours care delivery SMM as Pre-requisite for Effective Teamwork and Expected Outcome: - Development of a SMM related to quality and safety issues in off-hours care delivery may facilitate quality improvement	- Thematic analysis of housestaff debriefs enabled development of Likert survey to measure provider perceptions of quality and safety issues during "off hours" Measurement: - Survey measured average ratings compared, significant differences between groups reported	Findings related to SMMs: - Team members lacked a SMM of off-hours care delivery - ED transfers and timeliness of consults contributed to poorly developed SMM
Hicks (2008)[28]	Empirical [Mixed-methods	To develop and administer a needs assessment survey to measure attitudes towards CRM-based training amongst Emergency Medicine (EM) clinicians	IP, EM clinicians from two academic teaching hospitals including: EM staff physicians [n= 35], nurses [n=19], and EM residents [n=30]	Teamwork Curricula/ Training - Propose CRM-based EM training with interdisciplinary focus to improve EM resuscitation team performance	SMM as Expected Outcome: - Propose CRM-based EM training with interdisciplinary focus; recommended team training to improve communication, collaboration and increase SMM of resuscitation processes across team	- Web-based, 22-item survey developed and administered to measure the attitudes importance of CRM behaviors in team resuscitation; descriptive statistics were calculated and a two-tailed Fischer's exact test was used to examine associations - Survey data to be used to develop an interdisciplinary, CRM curriculum	Findings related to SMMs: - Findings do not make a clear connection to SMMs, but survey results demonstrated clinicians' consensus regarding importance of core CRM principles in emergency department resuscitation (i.e., effective communication, team leadership, resource

Author	Article Type [Design]*	Aims	Study Population [n]	Intervention Type/ Description	Application of Shared Mental Model (SMM) Construct^	Methods / SMM Measurement	Key Findings/ Outcomes
							utilization, problem solving and situational awareness, but not specifically SMMs) <u>Other key findings:</u> - Nurses rated communication as a barrier to teamwork more often than physicians and residents
Janss (2012) [17]	Summary + Conceptual [Framework for medical action team dynamics]	To review social psychology and organizational behavior literature to develop framework for understanding team dynamics in ad hoc medical action teams	IP, ad hoc Medical action teams (e.g., trauma, OR, etc.) including Junior medical residents	N/A	<u>SMM as Expected Outcome:</u> - Checklists (one for preop briefing focused on task/ procedures; one focused on team member characteristics) could support SMM development	N/A	<u>Findings related to SMMs:</u> - Findings do not make a clear connection to SMMs <u>Other key findings:</u> - Power and conflict strongly influence team behaviors and dynamics
Leykum (2014)[30]	Program [Communication tool]	To describe the development and pilot test plans for a structured communication tool to improve inpatient rounds	Inpatient physician teams including medical attendings and medical residents	<u>Teamwork Supportive Tool:</u> - Introduced PRISm (Physician Relationships, Improvement and Sensemaking) structured communication tool (pre- and post-round briefings, structured discussions)	<u>SMM as Expected Outcome:</u> - PRISm tool may support development of SMM of treatment plans - SMM may extend beyond physician team to other providers, patients, caregivers	<u>Measurement (planned):</u> - Proposed assessment of PRISm usage and physician team outcomes will occur via observations, field notes, surveys, and attending feedback	- No research findings were presented

Author	Article Type [Design]*	Aims	Study Population [n]	Intervention Type/ Description	Application of Shared Mental Model (SMM) Construct^	Methods / SMM Measurement	Key Findings/ Outcomes
				- Authors propose use of "PRISm" tool and outline plans to implement the PRISm intervention on 8 inpatient medical and surgical teams			
Mamykina (2014)[18]	Summary [Book chapter with literature review] + Empirical [Mixed-methods]	To investigate and measure development of SMMs in critical care setting	IP, critical care ICU teams at a large urban medical center were observed and in-depth interviews were conducted w/ a nurse, medical residents [n=2], and a medical fellow	N/A	Focus on Taskwork: - SMM construct applied to ICU handoffs SMM as Expected Outcome: - Rounds expected to align team members' MM around taskwork	SMM Measurement: - **Qualitative analysis of transcripts from interviews, observations, audio recordings** of handoffs - **SMM Index** (numeric value between 0-1 signifying extent of overlap across team members) was assigned to segments of conversation - SMMs during handoffs measured by focusing on handoffs related to a single patient over 3 days	Findings related to SMMs: - Rounds support alignment of team member MMs around taskwork (i.e., patient care in ICU) and handoffs facilitate information integration, supporting coherent SMM development with respect to patient care - Disruptions in SMM continuity can be attributed to transitions of care Other key findings: - Nurses, residents and fellows' focus on patient encounters in different timescales, where nurses may focus on minute-to minute care, while fellows may focus on the patient's entire hospitalization

Author	Article Type [Design]*	Aims	Study Population [n]	Intervention Type/ Description	Application of Shared Mental Model (SMM) Construct^	Methods / SMM Measurement	Key Findings/ Outcomes
Mamykina (2016) [22]	Empirical [Mixed-methods]	To examine a mixed-methods approach for analyzing handoff from the perspective of patient care teams	IP, CTICU teams at a large urban medical center were observed and recorded during handoffs; teams included: an attending, a fellow, a resident, a PA or NP and a bedside nurse	N/A	Focus on Taskwork: - SMM construct applied to CTICU handoffs in an overlap analysis	SMM Measurement: **- Qualitative analysis of transcripts from recorded observations** of verbal handoffs - Patterns related to temporal frame and clinical content were identified using categorical cluster analysis - **SMM Index** (numeric value between 0-1 signifying extent of overlap across team members' statements) was assigned to segments of conversation	Findings related to SMMs: - SMM Index calculations showed higher degree of overlap for statements concerned with patient presentation and statements referring to the past - Team coherence was positively associated with SMM Index Other key findings: -Temporal focus of handoff often determined by role of clinician handing off
McComb (2015) [19]	Empirical [Quantitative]	To develop and administer a survey to examine SMMs and mutual trust among nurses and physicians working in GM units	IP, GM clinical team members from an urban teaching medical center; participants included: nurses [n=37] and doctors [n=42] {Note: medical residents were "majority of respondents"}	N/A	Focus on Teamwork: - SMMs, mutual trust viewed as coordinating mechanisms facilitating teamwork and impacting patient safety - Focus of survey is to analyze SMMs of nurses and physicians related to professional roles and responsibilities SMM as Pre-requisite for Effective Teamwork	SMM Measurement: -**SMM/Mutual Trust questionnaire**, a 7 point Likert scale survey, was developed and administered - Respondents indicated which professional they felt was responsible for each role, rated perceptions of cross-discipline interactions - Statistical comparison of ratings followed	Findings related to SMMs: - In 14 out of 22 mental models regarding role responsibilities, nurses and physicians report significant differences in perception; no significant differences were noted for the remaining 8 mental models

Author	Article Type [Design]*	Aims	Study Population [n]	Intervention Type/ Description	Application of Shared Mental Model (SMM) Construct^	Methods / SMM Measurement	Key Findings/ Outcomes
Nakarada-Kordic (2016) [23]	Empirical [Quantitative]	To explore the similarity of MMs of task sequence and responsibility for task within multidisciplinary OR teams using surgical simulations	IP, OR clinical team members from two teaching hospitals; [n=20, 6-person teams] where each team included: a consultant and junior surgeon (surgical subteam); a consultant anesthetist or senior anesthetic fellow (anesthetic subteam); two nurses (nursing subteam) {Note: team members had worked together previously in their ORs}	N/A	Focus on Taskwork: - SMM construct applied to OR task sequence Focus on Teamwork: - SMM construct applied to task responsibilities of OR subteams	SMM Measurement: - Using a **computer-based card-sorting tool ("Momento"),** individuals sorted 20 key tasks by sequence and by subteam responsibility for task prior to commencing each simulation (card sorts and simulations were completed for two laparotomy-related scenarios) - Similarity of SMMs measured by pairwise comparisons of scores within each OR teams and subteam; mean similarity scores were calculated for each task - Accuracy not measured	Findings related to SMMs: - For laparotomy simulations, OR team members' MMs were similar with respect to task sequence - Poor agreement b/w OR team members' MMs related to subteam responsibility was observed for half of the tasks
O'Connor (2016) [24]	Empirical [Mixed-methods]	To collect and analyze examples of poor teamwork between junior doctors (interns) and nurses working in GM units; identify the failures in teamwork that contributed to poor teamwork;	First year interns [n=28] and nurses [n=8] working in the inpatient setting from two teaching hospitals; [n=33] scenarios were coded	N/A	Focus on Teamwork: - Lack of SMM associated with high-risk Teamwork failures SMM as Pre-requisite for Effective Teamwork	- Critical Incident Technique interviews were conducted, focusing on a recent challenging incident where interns and nurses had failed to work effectively as a team - Interview transcripts coded by aspects of poor teamwork (poor quality of collaboration; lack of coordination; lack of SMMs; poor	Findings related to SMMs: - Lack of SMM and poor communication between interns and nurses were significantly associated with high-levels of potential risk to patients, relative to medium risk scenarios Other key findings: - The majority of

Author	Article Type [Design]*	Aims	Study Population [n]	Intervention Type/ Description	Application of Shared Mental Model (SMM) Construct^	Methods / SMM Measurement	Key Findings/ Outcomes
		ascertain if specific types of teamwork failures are associated with higher levels of risk to patients				communication; poor leadership) as well as potential risk to patients	teamwork failures were related to "poor quality of collaboration" (63.6%); and "lack of coordination" and "poor leadership" were also common causes of teamwork failure (48.5% and 42.4%, respectively)
Reader (2009)[31]	Summary + Conceptual [Framework for ICU team performance]	To review the literature on relationship between teamwork and patient outcomes in ICU settings and to develop ICU team performance framework	IP ICU teams; Residents and Fellows mentioned as part of the ICU team	N/A	SMM as Pre-requisite for Effective Teamwork: - SMMs discussed as an integral part of team coordination processes, where plans are "cross-checked" to ensure SMM development around task	- Literature search followed by extraction of data related to teamwork behaviors associated with patient or staff-related outcomes	Findings related to SMMs: - Findings do not make a clear connection to SMMs Other key findings: - Authors propose model of ICU performance focusing on inputs (team, task, leader), processes (team communication, leadership, coordination, decision making) and outcomes (patient, team outcomes)
Senette (2013)[38]	Empirical [Mixed methods]	To investigate use of simulation as a teaching and learning strategy to support handoff communication and teamwork	IP teams [n=4-5 students/ team] of nursing students [n=13] and paramedic students [n=13] from two community campuses	N/A	Focus on Taskwork and Teamwork: -Simulations to support handoffs and team communications	- Quasi-experimental, 2-group, post-test design Measurements: - Attitude Toward \ Collaboration Survey measured collaborative learning attitudes	Findings related to SMMs: - Divergent MMs related to patient status were identified as a theme in qualitative analysis

Author	Article Type [Design]*	Aims	Study Population [n]	Intervention Type/ Description	Application of Shared Mental Model (SMM) Construct^	Methods / SMM Measurement	Key Findings/ Outcomes
						, intent to collaborate, preferred teamwork and communication strategies - Qualitative content analysis of open-ended questions used to assess perceived benefits, challenges of this IP simulation	Other key findings: - High degree of satisfaction regarding simulation, strong intention to use collaborative strategies in practice; striking differences in some preferences for teamwork and collaboration were revealed (e.g., nursing students preferred SBAR >10:1 over paramedic students)
Thomas (2006)[32]	Empirical [Quantitative]	To measure frequency of team behaviors during delivery room care and explore relationship between behaviors and care quality	IP, neonatal resuscitation teams in a large, urban teaching hospital; teams included at least 2 providers (generally, Pediatric medical residents and neonatal nurses); in high risk resuscitations, faculty, pediatric fellows, respiratory therapists joined [n=132 videos, 118 unique teams]	N/A		Measurements: - Using videos of neonatal resuscitations, raters assessed frequency of 10 teamwork behaviors, compliance with neonatal resuscitation guidelines and quality of care	Findings related to SMMs: - Findings do not make a clear connection to SMMs Other key findings: - Teamwork behaviors generally related to neonatal resuscitation guidelines and quality of care - Leadership was observed < 20% of the time

Author	Article Type [Design]*	Aims	Study Population [n]	Intervention Type/ Description	Application of Shared Mental Model (SMM) Construct^	Methods / SMM Measurement	Key Findings/ Outcomes
Tourgeman-Bashkin (2010)[21]	Empirical [Qualitative]	To examine how ICU clinicians evaluate potential severity of Almost Adverse Events (AAEs)	IP, critical care teams from both a Neonatal ICU (NICU) and PICU in a large medical center; NICU teams included nurses, senior physicians; PICU teams included nurses, senior physicians; a pediatric critical care fellow and pediatric resident	N/A	SMM as Pre-requisite for Effective Teamwork and Expected Outcome: - Sharing of relevant information amongst clinicians can help promote SMM development and lead to more efficient team communications, improved performance	- Both ICUs were observed for 500 hrs. Measurements: - AAEs [n=114] rated independently and anonymously by 5 staff (senior nurses and physicians) using 3 point severity scale	- Low levels of rater agreement observed between clinicians in both ICUs - Agreement significantly greater among nurses than physicians
Weller (2014)[33]	Summary + Program [7-point plan for effective teams]	To describe features of effective teams, discuss evidence of information sharing amongst team members, categorize IP teamwork and communication challenges and to propose a plan for effective health care team communication	IP, hospital-based teams; Medical students, medical residents and junior doctors; learners from other health professions were referred to in general terms	N/A	SMM as Pre-requisite for Effective Teamwork and Expected Outcome: - SMMs posited to be critical for effective teamwork - Sharing information is a "fundamental requirement" for developing SMM - Structured briefings and verbalizations (observations and decision-making processes) promote SMM development amongst team members	N/A	- Team information sharing can be promoted by: teaching effective communication strategies, training teams together, using simulations in training, defining an inclusive team, creating a democratic team ethos, using protocols to support teamwork and developing a supportive culture

Author	Article Type [Design]*	Aims	Study Population [n]	Intervention Type/ Description	Application of Shared Mental Model (SMM) Construct^	Methods / SMM Measurement	Key Findings/ Outcomes
Weller (2011)[36]	Empirical [Qualitative]	To understand the nature of interactions, activities and issues facing new graduates from medicine and nursing in order to inform and improve IP collaboration interventions	Junior doctors [n= 13] and junior nurses [n=12](both recent graduates) who had hospital-based work experience	N/A	SMM as Expected Outcome: -Sharing patient information is a way to build SMMs and shared priorities are viewed as evidence of SMMs regarding the clinical situation - SMMs between clinicians may be supported through formal processes of information sharing and IP education focused on experience, capabilities and knowledge of multiple health professionals	- Interviews were conducted focused on exploration of IP work experiences Measurements: - Data were coded thematically using a framework of healthcare team function including: collaboration quality, SMMs, team coordination and communication environment	Findings related to SMMs: -Findings do not make a clear connection to SMMs Other key findings: - Mutual respect was evident, but organizational structures were seen to limit establishment of professional relationships - Information sharing and agreement regarding goals were keys to good decision-making; could be hindered by environment, differing professional perspectives - Participants saw themselves as having complementary, non-competitive roles
Wu (2011)[34]	Conceptual [Design process]	To describe the early design process of an interactive cognitive aid for anesthesia crisis care teams	IP, anesthesia crisis care team in a simulation center in a large urban teaching hospital; teams included simulation staff [n=3-4], anesthesia residents [n=2]	Teamwork Supportive Tool: Authors propose design of a coordinated, interactive system comprised of	SMM as Design Principle: - Authors use SMM construct as a design principle for their proposed cognitive aid	Measurement: - Gaze analysis of separate training videos allowed quantification of demands on attention, time	Findings related to SMMs: - Findings do not make a clear connection to SMMs

Author	Article Type [Design]*	Aims	Study Population [n]	Intervention Type/ Description	Application of Shared Mental Model (SMM) Construct^	Methods / SMM Measurement	Key Findings/ Outcomes
				large screen display (projecting checklist, vitals) with tablet for data input -Six crisis care scenarios were conducted with simulation center staff; resident anesthesiologists observed	- Highlight utility of display to prompt team dialogue and promote development of a SMM SMM as Expected Outcome: - SMM of the crisis across team members		Other key findings: - Delays/failures of information transfer, patterns of attention and checklist use were noted
Xie (2015)[20]	Empirical [Mixed-methods]	To promote Human Factors Engineering principles, including Participatory ergonomics in redesign of family centered rounds (FCR) and implement FCR checklist to promote	IP, inpatient care teams, including a heme/onc and hospitalist service, at a large children's hospital; intervention implementation team included: Researcher [n=5], a parent representative, nurse managers [n=2], nurses [n=2], attending physicians [n=2], senior medical residents [n=2]	Teamwork Supportive Tool: FCR process was redesigned and a checklist was developed to support rounds; FCR checklist use was implemented	SMM as Design Principle: - Authors used SMM as a design principle for development of the content of FCR checklist SMM as Expected Outcome: - Intent of FCR checklist is to develop SMM of rounds process among team members, patients and families	- Participatory ergonomics approach (where workers are encouraged to engage in design of workplace interventions) included gathering of multiple stakeholder groups to form intervention implementation team (IIT) - IIT designed intervention to improve family engagement in FCR - Observational, interview and survey data used to design an intervention including a FCR checklist that was piloted and evaluated via observations	Findings related to SMMs: - Findings do not make a clear connection to SMMs Other key findings: - Survey data demonstrated consistently high satisfaction with IIT process and FCR checklist trainings were well-received - Observations of FCR checklist usage demonstrated very high, but inconsistent usage of some items, prompting addition of a "tips" section

* Article categories included: 1) Program —An educational program, curriculum or tool is described. No data or analysis is included; 2) Empirical —A quantitative, qualitative or mixed-methods research study is described. Data and analysis are included; 3) Conceptual —A framework or model related to the concept of SMM is provided; 4) Opinion/position —Thoughts about SMMs in the context of clinical learning. No research or program development is presented; 5) Summary —Review of existing literature or research; 6) Other —Abstracts, poster presentation.[22,23]

^ Though the term "team mental model" is specific to shared/overlapping mental models amongst team members, "shared mental models" is the term that is most frequently used in the HP literature. Therefore, the terminology used in each paper is reflected in the tables.

Chapter 3

A Mobile Learning Module to Support Interprofessional Knowledge Construction in the Health Professions

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ABSTRACT:

Objective. To develop and evaluate a mobile learning module to support knowledge construction between medical and pharmacy students through structured dialogue prompts.

Methods. Rheumatologists and pharmacists collaboratively developed a two-week, case-based, asynchronous interprofessional learning module that was delivered via a mobile app and focused on collaborative medication management of a complex case involving a patient with systemic lupus erythematosus. The clinical case evolved over three phases: diagnosis, initial treatment, and medication-related complications. Dialogue prompts were incorporated in each phase as a mechanism to support knowledge construction among learners. Pharmacy and medical student pairs were randomized to receive either high guidance or low guidance prompts for collaborative learning. The student pairs worked together, asynchronously, online, to develop three collaborative care plans. The authors evaluated dialogue prompts within the learning module to support knowledge construction including analysis of text-based dialogue, coded for knowledge construction phases; the accuracy and completeness of the three collaborative care plans; and quantitative and qualitative participant feedback.

Results. Sixteen pairs of medical and pharmacy students (n=32) participated. Pairs who received high guidance engaged in all phases of knowledge construction more often than pairs who received low guidance. Guidance phase did not differentially impact collaborative care plan scores. Ninety-eight percent of students agreed or strongly agreed that the module improved their clinical reasoning, interprofessional communication, and knowledge of systemic lupus erythematosus.

Conclusion. The knowledge construction framework can guide the design and evaluation of educational interventions such as a mobile learning module to support knowledge construction among health professionals.

Keywords: knowledge construction; interprofessional education; pharmacy; medicine; asynchronous learning

INTRODUCTION

Studies of physician-pharmacist collaborative care models have shown improvements in medication management for medically complex patients, such as those with hypertension, pediatric asthma, and diabetes.[1-3] Preparing health professions students to provide such care requires training opportunities within small collaborative teams.[4,5] Yet, implementing these training opportunities is challenging because of logistical problems associated with scheduling students across health professions educational programs.[6-8] By allowing asynchronous interactions between students, use of mobile learning modules might overcome many of these logistical barriers and, with appropriate levels of scaffolding, effectively support collaborative learning.

While the concept of mobile learning is still emerging and the debate regarding its definition continues, Crompton proposed a broad definition of mobile learning as "learning across multiple contexts, through social and content interactions, using personal devices."[9,10] The process of knowledge construction, derived from social constructivist theory, is a goal of collaborative learning activities and practice. Knowledge construction occurs when two or more learners work together to actively build new knowledge or meaning.[11-13]

According to Gunawardena's knowledge construction framework, social construction of knowledge progresses across five phases that reflect increasingly collaborative interaction among participants.[11] Mental engagement increases with each successive phase, from phase I which is "sharing/comparing," to phase V, which is reaching "agreement/applying newly constructed meaning" (Table 1). Higher phases of knowledge construction behaviors, associated with moderate to high levels of mental engagement, may result in "substantial restructuring of knowledge" and deeper, higher quality learning.[14]

Table 1. Phase of Interactive Knowledge Construction (KC) Assessed in a Study in Which Medical and Pharmacy Students Tested a Mobile Learning Module Designed to Encourage Interprofessional Collaboration

TERM	DEFINITION	EXAMPLE
Phase I "Sharing / Comparing"	"Sharing and comparing" information Students make statements of observation/ opinion/ability; share information or intended actions with colleague; solicit information from/ask a question of colleague, but no dialogue ensues.	Trainee puts forward his/her clinical recommendations to their partner, but no discussion ensues; or, engages in peer teaching. Example: PH makes a recommendation to MD, *"I would like to strongly recommend to switch (our patient's) combined oral contraceptive to a progestin-only pill due to her PMH of migraines."* [Pair 1, RE: CCP1]
Phase II "Exploring Dissonance"	"Exploration of dissonance" among ideas, concepts, statements Students identifying and discuss areas of disagreement; Students ask/answer questions to clarify source/extent of disagreement.	Trainee puts forward his/her clinical recommendations to their trainee colleague, but the other trainee disagrees. Example: MD, responding to PH, suggests an alternate medication to what PH initially recommended– *"...(the patient) can probably use acetaminophen for pain and constitutional symptoms, instead of ibuprofen, to avoid the interaction between NSAIDS and prednisone."* [Pair 4]
Phase III "Co-constructing"	"Negotiation of meaning/co-construction of knowledge" Students negotiate or clarify terms; identify areas of agreement or overlap among conflicting concepts; Students propose and negotiate new statements embodying compromise, co-construction.	Trainees negotiate clinical recommendations, augmenting the CCP. Example: MD, builds on PH's counseling recommendations (for both plaquenil and prednisone), suggesting an augmentation of the care plan –*"The only other thing I would mention (to the patient) is that prednisone works by suppressing the body's immune response... (making) it an effective tool for SLE, but also (putting) her at risk for infections."* [Pair 11, RE: CCP2]
Phase IV "Testing/ Modification"	"Evaluation and modification of new schemas" resulting from the co-construction Students evaluate proposed synthesis (i.e., the co-constructed knowledge, plan) against "received fact" as shared by the other participants.	Trainees talk with one another about how their co-constructed plan compares to existing clinical guidelines. Example: PH evaluates one aspect of their co-constructed plan by putting in the context of his past experience. He wrote, *"When trying to rule out medication-related conditions, my experience has taught me to change one thing at a time to best determine the cause of the AE as well as properly documenting this incidence so as to prevent future AEs."* [Pair 5]
Phase V "Reaching Agreement / Application"	"Agreement statement(s)/ applications of newly constructed meaning" Students summarize agreement(s) related to co-constructed knowledge of plan; Students apply of new knowledge.	Trainees explicitly agree on conclusions and recommendations to include in their CCP. Example: PH explicitly agrees w/ the shared plan, writing, *"Great - thanks for your insight! It definitely looks like we are on the same page, and it's cool to see how you think of the case from the medical student perspective."* [Pair 9]

CCP=collaborative care plan; KC=knowledge construction; MD=medical student; NSAID=non-steroidal anti-inflammatory drug; Pair=student pair; PH=pharmacy student; PMH= past medical history.

NOTE: Definitions of KC levels and general examples of evidence/observable behaviors related to each level of interactive KC were adapted Gunawardena et al. (1997). For our study, KC refers to how trainees construct knowledge (i.e., how they generate knowledge and meaning from the interaction between their experiences and ideas). We focused on KC behaviors that were observed in the dialogue that each pair generated while they interacted, engaging with one another to work through this rheumatology case.

The organization and structure of learning environments impacts knowledge construction behaviors in online collaborative groups.[12,15] Learner collaboration that results in deep learning, especially at the intersection of interprofessional education and the virtual learning environment, requires that educators provide some degree of scaffolding to guide the interaction between learners and support knowledge construction.[16] Providing structured guidance to prompt communication between learners, also known as *dialogue scaffolding*, may support collaborative knowledge construction.[14,16,17] However, little is known about how to design online curricula to include dialogue scaffolding that promotes collaborative construction of knowledge among health professions students.

We report on the development, pilot implementation, and evaluation of an asynchronous, medication-focused, mobile learning module containing structured dialogue prompts aiming to support knowledge construction behaviors among medical and pharmacy students. Our evaluation focuses on answering a specific question: How effective are structured dialogue prompts (based on Gunawardena's knowledge construction framework) at stimulating higher-phase knowledge construction behaviors and positively impacting learning outcomes?

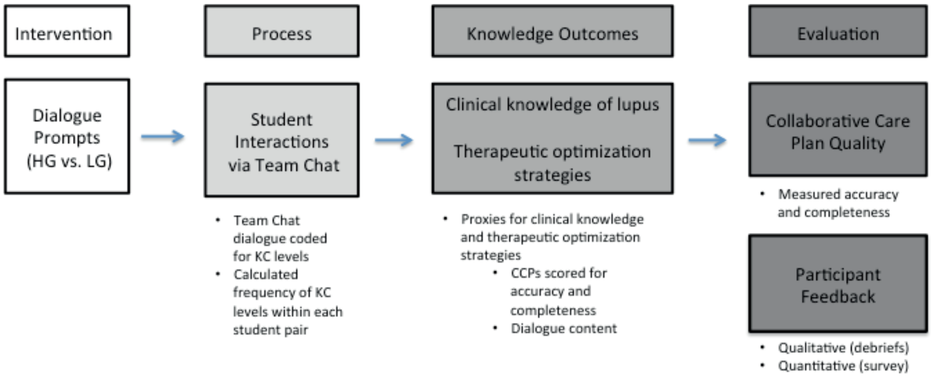
METHODS

To address the logistical challenges that often hamper the implementation of interprofessional training opportunities, we created a learning module that was delivered via the PIVOT med (Practice Improvement using Virtual Online Training) mobile app (HoloDox, LLC, Palo Alto, CA) for asynchronous, online collaboration between medical and pharmacy students.[6-8] Through the mobile app, students can access clinical case information at their convenience, exchange messages with their interprofessional partner, and build knowledge together.

This pilot interventional study was conducted from January through July 2018 and consisted of three parts: developing the module (January-March), including the case and dialogue prompts; implementing the module (March); and conducting a limited efficacy evaluation of the module. This evaluation focused on two outcomes: impact of the dialogue prompts on knowledge construction behaviors and the quality of the collaborative care plan as measured by scores for accuracy and completeness; and student feedback on the prompts (March-July). The University of California, San Francisco Committee on Human Research approved this study.

The PIVOT study design, including the intervention, process, knowledge outcomes, and evaluation is presented in Figure 1.

Figure 1: PIVOT Pilot Study Framework

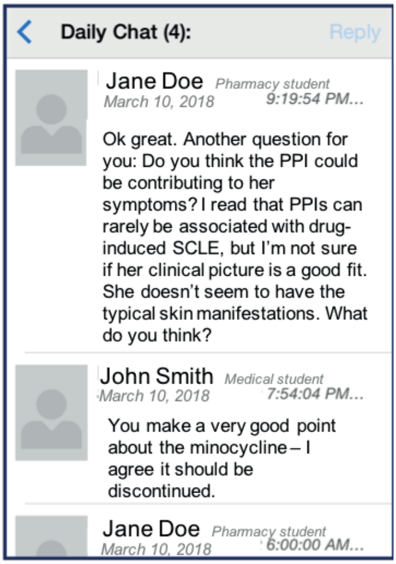


The PIVOT med mobile app is an educational tool developed to support health professions student engagement (Figure 2) through simulation of real-world patient scenarios. The first learning module delivered via PIVOT med was piloted at UCSF in 2016 to support second-year medical students' development of diagnostic reasoning skills through analysis of a complex case of systemic lupus erythematosus.[18] Based on its success and a desire to increase interprofessional learning experiences for undergraduate students, we revised the case and the learning module structure to support knowledge construction among pharmacy and medical students.

Figure 2: PIVOT app interface: Home screen

The PIVOT med app allows students to work together asynchronously, communicating only through the app, to manage a complex and evolving clinical case. Students received clinical case data, including the patient's medical history, physical examination findings, laboratory results, and multimedia content including a video interview with the patient and radiographic images. Student pairs communicated through instant messaging (referred to as "team chats") (Figure 3), and the app captured user entered data (i.e., answers to questions/assignments, including care plans) as well as text exchanges (i.e., the team chat dialogue), and supported distribution of survey questions.

Figure 3: PIVOT app interface: "Team Chat" instant messaging



To enhance collaborative learning, authenticity and clinical relevance for the students, two physicians and two pharmacists revised the case used in the original pilot to focus on increasingly complex medication management issues that would benefit from a collaborative approach between the referring physician and a pharmacist consultant.

The module was designed for medical and pharmacy student pairs to work together on a virtual, interactive case of a 44-year-old woman presenting with fatigue, joint pain, and low-grade fever. In the revised case, the patient's clinical course evolved over two weeks, with new case details revealed in three separate phases: the patient is diagnosed with systemic lupus erythematosus (phase 1), starts treatment (phase 2), and develops treatment complications (phase 3). Students used the PIVOT med app to review clinical case data, communicate with their partner via team chat and work together to formulate three separate collaborative care plans, one for each phase. The learning objectives and structure of the module were designed to support students as they constructed knowledge in the following domains: clinical knowledge of systemic lupus erythematosus and development of optimal therapeutic strategies.

To support the process of student interactions and knowledge construction in our mobile-learning module and to explore the impact of dialogue scaffolding both on students' knowledge construction behaviors and their performance on the collaborative care plans, we used Gunawardena's knowledge construction framework to design "high guidance" and "low guidance" dialogue prompts.[11] Matching sets of structured dialogue prompts, one high guidance and one low guidance, were created for each phase of the clinical case with the aim of facilitating creation and subsequent application of new knowledge between medical and pharmacy students (see Appendix 1 for an example). We expected student pairs who received high guidance prompts to engage in higher phases of knowledge construction behaviors than pairs receiving low guidance prompts. Each set of dialogue prompts and associated collaborative care plans focused on medications and therapeutic strategies, as this is where, in practice, we would expect the most prevalent interactions between pharmacists and physicians.

To improve construct validity, we piloted the dialogue prompts with two medical and two pharmacy students not participating in the study and then revised these to maximize clarity and minimize wordiness. As shown in Appendix 1, the high guidance and low guidance prompts contained overlapping language and instructed students to "collaborate" with their colleagues to address the clinical questions that were posed. The high guidance prompts were designed to encourage collaboration on clinical questions via higher levels of interaction and knowledge construction behaviors. Students under the high guidance condition were generally instructed to: share individual professional opinions based on specific questions posed for each phase of the case (i.e., achieve phase I knowledge construction); explore differences of professional opinion (i.e., achieve phase II knowledge construction); articulate the clinical rationale for proposed recommendations (i.e., achieve phase III knowledge construction); discuss how past experiences informed their thinking (i.e., achieve phase IV knowledge construction); and, formulate a mutually agreeable plan (i.e., achieve phase V knowledge construction).

Implementation included student recruitment and orientation to the module, preparation for launch of the module, and technological support throughout the two-week pilot. The 16 third-year medical students were completing their clinical clerkship and the module was a component of the curriculum. They were free to opt out of the study, but all consented to participate. The pharmacy students were in their third year (n=8) or fourth year (n=8) of the curriculum. The students were randomly assigned to medicine-pharmacy pairs, and pairs were randomly assigned to either the low guidance or high guidance condition, with third- and fourth-year pharmacy students evenly distributed between low guidance and high guidance groups. Orientation sessions were conducted to introduce the learning module, learning objectives, and expectations regarding participation in the study. Students were not informed about the study question regarding high guidance and low guidance prompts and their impact on knowledge construction until after the study.

In preparation for launch of the module, we worked extensively with the software development team to create a detailed calendar of events that specified the date and time when the app would release information and or send notifications (including high guidance and low guidance prompts) to student pairs. Faculty members and the software development team supported students during the pilot phase, mainly addressing technological issues (e.g., trouble logging into the system, difficulty uploading collaborative care plans).

The evaluation of the PIVOT med module included analyses of: text-based dialogue coded for knowledge construction phases; the accuracy and completeness of each pairs' collaborative care plans; and quantitative and qualitative participant feedback.

For the pilot study, we collected data to evaluate the impact of the level of guidance provided (i.e., either high guidance or low guidance dialogue prompts) on both the frequency and phase of knowledge construction behaviors manifested in team chat dialogue (i.e., text-based dialogue) within student pairs. We applied directed content analysis to all team chat data throughout the two-week curriculum.[19] Using knowledge construction phases as codes, two investigators (LCF and JM) evaluated each sentence in the team chat dialogue and independently applied knowledge construction codes to each sentence. We segmented team chat dialogue to correspond with discussion of each plan (i.e., collaborative care plans 1, 2, and 3) and tabulated knowledge construction behaviors for each collaborative care plan. Both investigators reviewed independently coded data and resolved discrepancies through discussion. We calculated descriptive statistics to compare the effect of the level of guidance on the frequencies of specific knowledge construction behaviors observed during the team chat dialogue. We computed the 95% CI values for the difference in the mean frequencies of knowledge construction behaviors between the two groups (i.e., high guidance vs low guidance). Cohen's d effect size values were calculated as the difference in the two groups' means divided by the average of their standard deviations to demonstrate the magnitude of the difference in the frequencies of knowledge construction behaviors between the two groups (i.e., high guidance vs low guidance).

The collaborative care plans served as a proxy for clinical knowledge attained, and student pairs were free to determine the structure of their submitted plans. The clinician-investigators developed rubrics to assess the accuracy and completeness of collaborative care plans 1, 2, and 3 (a rubric for each distinct phase of the case) using a three-point scale (1=below expectations, 2=meets expectations, and 3=exceeds expectations) [see Supplemental Table 1 for an example].[20] All of the collaborative care plans (n=48) were stripped of information regarding the associated guidance level, and then randomly assigned to two of three clinician-investigators on our research team for scoring. Each collaborative care plan was scored independently according to the rubrics. Discrepancies were discussed among the raters who then came to agreement on the students' final score based on the rubric. If not, a third rater with a different clinical background was consulted. We calculated descriptive statistics to compare the quality of collaborative care plans (i.e., accuracy and completeness) in high guidance and low guidance pairs. We computed the 95% CI values for the difference in the mean collaborative care plan scores for accuracy and completeness between the two groups (i.e., high guidance vs low guidance). Cohen's d effect size values were calculated (i.e., the difference in the two groups' means divided by the average of their standard deviations) to demonstrate the magnitude of the difference in the collaborative care plans scores between the two groups (i.e., high guidance vs low guidance).

The medical and pharmacy student participants were encouraged to attend one of two post-study debrief sessions. In these sessions, one of the faculty members (LCF) described the different types of prompts students received and asked for feedback on their experience with either low guidance or high guidance prompts. Additionally, all participants were encouraged to complete an online survey that assessed their perceptions of the intervention and solicited their ideas for improvement. Using an open coding approach, we analyzed student feedback for satisfaction with the experience and perceptions of the guidance prompts.[21]

RESULTS

All 16 interprofessional pairs completed the curriculum and submitted three collaborative care plans. Overall, medical and pharmacy student pairs that received high guidance prompts interacted with greater frequency (i.e., higher mean frequencies of knowledge construction behaviors) at all knowledge construction phases than pairs that received low guidance prompts (Table 2).

Table 2. Mean (SD) Frequencies of Knowledge Construction Behaviors in High Guidance Pairs (N=16) vs. Low Guidance Pairs (N=16)

	High Guidance Pairs	Low Guidance Pairs	
	Mean (SD)	**Mean (SD)**	**[95% CI]{Cohen's d}^**
Phase I: "Sharing / Comparing"	12.0 (3.4)	9.8 (3.7)	[-7.2, 2.7] {0.62}
Phase II: "Exploring Dissonance"	1.9 (2.2)	1.1 (0.8)	[-2.7, 1.2] {0.48}
Phase III: "Co-constructing"	6.9 (3.1)	6.4 (3.7)	[-5.6, 4.4] {0.15}
Phase IV: "Testing/Modification"	1 (1.1)	0.38 (0.7)	[-1.5, 0.26] {0.66}
Phase V: "Reaching Agreement/Application"	5.3 (2.2)	3.0 (2.4)	[-5.5, 0.96] {1.00}

^Significance was not tested, due to small sample size and expectation of insufficient power.

Though the extent of interactivity was greater in all groups that received a higher level of guidance, comparing the frequencies of interactive behaviors underscores the similarity in behavior patterns in both high guidance and low guidance groups. Sharing and comparing (phase I) accounted for 44% and 47% of all interactions in the high guidance and low guidance pairs, respectively. Most of these behaviors involved students providing clinical recommendations to or soliciting input from their partner. Across pairs, exploring dissonance (phase II interactions) occurred infrequently (in 7% of interactions occurring between pairs who received a high level of guidance and in 5% between pairs who received a low level of guidance). Co-construction (phase III) accounted for 26% and 31% of the interactions between students in the student pairs receiving high guidance and low guidance, respectively. Phase III behaviors were usually associated with sequential additions by partners that resulted in plan augmentation. We rarely observed pairs in either the high guidance or the low guidance groups testing their co-constructed knowledge (phase IV interactions; 4% and 2%, respectively). Reaching agreement and application (phase V interaction) occurred in 18% of the interactions among pairs that received high guidance and 15% of the pairs that received low guidance and included instances where consensus was reached on co-constructed knowledge, or when pairs explicitly agreed upon patient assessments. There was no statistically significant difference in the means at any phase of knowledge construction (Table 2). The effect sizes of the differences between the high guidance and low guidance pairs (where effect size cutoffs of *d*= 0.2, 0.5 and 0.8 are considered to be small, medium, and large, respectively) were medium to large for knowledge construction phases I, IV, V (Table 2).[22] See Table 1 for knowledge construction definitions and for specific examples of each knowledge construction phase taken from the team chat dialogue.

Guidance level (i.e., high or low) did not impact any of the care plan scores in terms of their accuracy and completeness (Table 3). Across all groups, there was much heterogeneity in collaborative care plan scores (as reflected by the wide standard deviations as shown in Table 3). Given that the 95% CI values for collaborative care plan scores all contained zero, we did not have sufficient evidence to conclude that there was a difference in the collaborative care plan means on the basis of either accuracy or completeness. From our data, the effect sizes of the differences in collaborative care plan accuracy and completeness between high guidance and low guidance pairs were low, with the exception of collaborative care plan 3 accuracy scores where there was a medium effect size.[22]

Table 3. Collaborative Care Plan (CCP) Accuracy and Completeness Scores in High Guidance Pairs (N=16) vs. Low Guidance Pairs (N=16)

	High Guidance	Low Guidance		High Guidance	Low Guidance	
	Mean (SD)	Mean (SD)	[95% CI] {Cohen's d}^	Mean (SD)	Mean (SD)	[95% CI] {Cohen's d}^
	Accuracy			Completeness		
CCP 1*	1.8 (0.9)	1.5 (0.7)	[-1.2, 0.72] {0.36}	2.0 (0.5)	1.8 (0.7)	[-0.99, 0.49] {0.32}
CCP 2*	2.4 (0.9)	2.3 (0.7)	[-1.3, 1.0] {0.12}	2.3 (0.7)	2.3 (0.7)	[-0.89, 0.89] {0}
CCP 3*	2.0 (0.7)	1.6 (0.7)	[-1.4, 0.62] {0.53}	2.0 (0.9)	1.8 (0.5)	[-1.2, 0.72] {0.27}

* Each CCP was assessed for both accuracy and completeness using a 3-point scale [i.e., 1 ("below expectations"); 2 ("meets expectations"); and 3 ("exceeds expectations")]. The maximum score is 3 for Accuracy and 3 for Completeness.

^Significance was not tested, due to small sample size and expectation of insufficient power.

All participants completed the survey (n=32). Because of scheduling differences, all of the medical students (n=16) but only three pharmacy students attended debrief session 1, while only pharmacy students (n=11) attended debrief session 2.

Survey data indicated that 98% of students agreed or strongly agreed that the module was an effective way to improve their knowledge about SLE, practice clinical reasoning, and improve their ability to communicate with colleagues from medicine or pharmacy. In the debrief sessions, technological issues with the PIVOT med app, including intermittency of the notifications function and difficulty with the text-editing interface, were mentioned as challenges.

While student feedback from the survey and debriefs helped us to better understand their learning experience during the pilot, their responses regarding the impact of both the high guidance and low guidance prompts on their own learning was mixed, and students expressed a variety of views, both positive and negative. Reflecting positively on the experience, one medical student felt the low guidance prompts allowed for a more realistic exchange of ideas and information, noting, "…I think it really allowed for me to think about, 'Okay what's actually important about this patient,' and practice communicating in that way…I think the openness (i.e., minimal structure) allowed for a lot of discussion."

Responses to the high guidance prompts were mixed. One pharmacy student appreciated that the high guidance prompt directed her and her partner to discuss differences of opinion (i.e., to support phase II knowledge construction). However, one medical student suggested that this was unlikely to be effective because, as students, "…we tend to be polite and nice…especially when it's not a real patient's wellbeing." Two medical students and one pharmacy student stated that the prompts were initially helpful but eventually became "redundant." Another medical student explained that, at "…the beginning I thought it was more thorough going through each step, but then it started to seem a bit repetitive…" One pharmacy student stated that she felt that the prompts helped structure her own thinking and responses, but logistical constraints made answering each question "too challenging." Another pharmacy student said that she "didn't really use" the high guidance prompts at all.

Two pharmacy students from pairs that received low guidance stated that they would have come to a consensus with their medical colleagues independently of any prompting because they are trained "…in a holistic way… we are (the patient's) healthcare providers, so we should be on a common ground when treating a patient….there's just a natural tendency to (ask one another), 'What do we think? What is the best plan?'"

DISCUSSION

Informed by the knowledge construction framework, we designed and piloted a case-based, mobile learning module to enhance interaction between medical and pharmacy students and, ultimately, support higher-phase knowledge construction.[11] This module, delivered via the PIVOT med app, allowed medical and pharmacy students to learn about the clinical manifestations and treatment of systemic lupus erythematosus and to practice interprofessional collaboration, communication, and clinical reasoning. The results of the knowledge construction coding of the team chats suggest that the high-guidance prompts provided dialogue scaffolds that enhanced student interaction and supported higher-phase knowledge construction behaviors more than the low-guidance prompts did. However, the feedback we received from the students suggested that the influence of the prompts is less clear. While both the high-guidance and low-guidance prompts helped focus some students' thinking, several students expressed that repeated exposure to the detailed, high-guidance prompts during the module was unnecessary.

The pattern of student pairs' knowledge construction behaviors generally corresponds with the findings from studies conducted in online learning environments, but with one key exception. While the majority of interactions between our student pairs were at phase I, as observed in other investigations, we found that both our high-guidance and low-guidance prompts were associated with a relatively high frequency of phase V interactions, accounting for approximately 20% of all interactions.[11,23,24] In other studies, phase V interactions only accounted for 0.4%, 1.9%, and 3% of total interactions.[11,24,25,26] Our study included complex clinical problems with no defined solution as the primary driver of learner interactivity in the PIVOT med module.[26] For this type of ill-structured problem-solving, the high-guidance *and* low-guidance prompts may have effectively supported phase V interactions to a greater extent than found in previously published studies and encouraged students to negotiate ideas, co-construct knowledge, and come to agreement to create each collaborative care plan.[26,27] Alternately, the activity itself may have required more phase V behaviors than activities in other studies, or phase V interaction behavior may be enmeshed in health professional culture, where members are normed to seek agreement on the care plan in a timely manner by virtue of their training. If so, this raises a key question: would further interventions to support higher-phase knowledge construction translate into learning benefits?

We also considered whether "over scripting" the guidance prompts might dampen the impact of the high-guidance condition.[16,28] In other words, a prompt that is too detailed or too prescriptive, may actually limit the level of knowledge construction by constraining students' creativity and open discussion. Based on the feedback from the debrief sessions, some students felt the high-guidance prompts were excessive. If the prompts had been less scripted, we might have seen greater differences in knowledge construction between students who received the high-guidance prompts vs. those who received the low-guidance prompts. From van Aalst's work, we know that enhanced learning outcomes have been observed in the settings of collaborative knowledge construction where student interactions have been scaffolded or guided.[14] However, when more guidance than is needed is provided to students, students may disengage in ways that have negative effects. As we heard in the debrief sessions, some students felt that the excessive detail and repetition were unnecessary. Another concern is that some students might become dependent on the high level of guidance. In either case, too much guidance can be detrimental to students' motivation and construction of new knowledge.[29,30,31] Further investigation into the role of structured guidance is warranted.

Our findings showed no difference in students' knowledge outcomes based on the quality of the collaborative care plans. While this result may indicate that our intervention (i.e., structured dialogue prompts) did not produce substantial enough difference in knowledge construction behaviors to yield different outcomes, it may also reflect the unintended consequences of choosing to provide students with only minimal guidance about the content and structure of the collaborative care plan. We decided that an overly prescriptive collaborative care plan structure could constrain the students' knowledge construction and limit the variability in responses, so we did not require a specific structure/organization for the collaborative care plans. This decision resulted in considerable heterogeneity in the structure and level of detail within the plans (e.g., some pairs had richly detailed discussions about their care plans during their team chat, but submitted only a few brief bullet points for their final collaborative care plan). In retrospect, if we had required students to use a general structure for the collaborative care plans (i.e., asking for student pairs to include at least their patient assessment and plan in each care plan), then we would have been able to more evenly apply the rubrics in assessing the accuracy and completeness of the care plans. This would have allowed an "apples to apples" comparison without eliminating performance variation. These findings raise questions similar to those discussed in relation to the optimal amount of scripting in dialogue prompts. That is, the level of scripting must be considered not only in the design of the dialogue prompts, but also in the design of instructions provided to students regarding their work products.

To scaffold higher-phase knowledge construction and promote deeper learning in the setting of collaborative learning environments, some form of student guidance is necessary.[32] Educators can reduce the risk of over-scripting by periodically checking on the dialogue and actively promoting productive dialogue through guidance tailored to the needs of the students.[16,26,27,32,33] Given that individualization of guidance is of paramount importance to foster deep, high-quality learning, we expect that scaffolded dialogue, combined with customized facilitation by an instructor, will effectively support achievement of higher-phase knowledge construction.[30,31]

There are many potential uses for PIVOT med and similar mobile learning modules to support knowledge construction for other disease states, patient populations, and interprofessional contexts. Future work to make logistical and technical refinements to the platform and to calibrate dialogue prompts with desired phases of knowledge construction behavior and outcomes will be important.

Limitations of this study include technological glitches with the mobile app that negatively impacted the interactions of some student pairs. The limited availability of students from both the medical and pharmacy programs resulted in the study being underpowered and prevented us from performing a full statistical evaluation of the results. Also, our inclusion of more senior learners rather than first- and second-year students, may have blunted the impact of the high guidance prompts on knowledge construction behaviors. Additionally, given that the debrief sessions were essentially uni-professional (i.e., mostly medical students in the first session and only pharmacy students in the second), we were unable to gather feedback and insights from the interprofessional student pairs themselves.

In this pilot, we focused on the effectiveness of structured dialogue prompts to support high-level knowledge construction behaviors and their impact on primary learning outcomes (in our case, the accuracy and completeness of the collaborative care plans). We believe that the differences observed between the high guidance and low guidance pairs show potentially promising trends that warrant further investigation with a larger group of students. Though we chose not to apply an objective assessment of students' knowledge of systemic lupus erythematosus, pre- and post-intervention in the current investigation, future studies of similar interventions should consider including a more robust evaluation of learning effects.

CONCLUSION

This study represents the successful development and implementation of a case-based, mobile-learning module using the PIVOT med app and evaluation of structured dialogue prompts to support knowledge construction in student pairs. While technological issues with the app hampered interactions for some student pairs, the module supported interprofessional collaboration as student learned about the clinical manifestations and treatment of systemic lupus erythematosus and allowed us to explore knowledge construction behaviors of pharmacy and medical student pairs as they worked together to solve complex medication-focused problems in the virtual training environment. Our pilot shows that health professions educators may use the knowledge construction framework to both design and evaluate educational interventions for asynchronous learning. It also highlights opportunities for further investigation into the ways that we design interprofessional interventions and implement tailored guidance to most effectively support high-level knowledge construction in our trainees as they learn to work together to deliver high quality, collaborative clinical care.

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Appendix 1: PIVOT High and Low Guidance Prompts for Collaborative Care Plan 1

	HIGH GUIDANCE PROMPTS	LOW GUIDANCE PROMPTS
Collaborative Care Plan #1 Phase 1-Released Day 5	**Pharmacy students -- please first review your medicine colleague's response to yesterday's medication question.^** **Medical students -- please first review your pharmacy colleague's Pharmacy Consult Note.** **Then, using the "Team Chat" function [go to the Menu, then select: Messages > Team Chat], please collaborate with your colleague to decide whether or not to recommend any medication changes for Virginia.** [NOTE: As you work through the next set of questions, we encourage you to ask clarifying questions of one another, as needed, to make sure you're on the same page.] FIRST: SHARE YOUR INDIVIDUAL PROFESSIONAL OPINIONS WITH ONE ANOTHER* - What are the possible relationships between Virginia's medications and her symptoms? - What changes, if any, would you make to Virginia's medication regimen and why (i.e., what were the major considerations that led to this recommendation)? NEXT: WORK TOGETHER TO COMPOSE A MUTUALLY AGREEABLE PLAN THAT OUTLINES YOUR JOINT RECOMMENDATIONS FOR VIRGINIA 1. Explore differences of opinion that you may have with one another** 2. Prioritize and articulate the clinical rationale for your joint recommendations*** 3. Discuss if/how your past experiences (i.e., examples of past cases you've worked on or learned about) inform your thinking about this case**** 4. Formulate a mutually agreeable plan for the patient. ********* **Please submit your final collaborative care plan in the "Response" box.**	**Pharmacy students -- please first review your medicine colleague's response to yesterday's medication question. ^** **Medical students -- please first review your pharmacy colleague's Pharmacy Consult Note.** **Then, using the "Team Chat" function [go to the Menu, then select: Messages > Team Chat], collaborate with your colleague to decide whether or not to recommend any medication changes for Virginia.** **Please submit your final collaborative care plan in the "Response" box.**

^ NOTE: The previous day's medication question was: *"Do you think any of Virginia's medications could be contributing to her current symptoms? Would you recommend any changes to her medication regimen?"*

NOTE: The high guidance dialogue prompts were intended to promote *phase I, **phase II, ***phase III, ****phase IV and *****phase V KC.

SUPPLEMENTAL MATERIAL – CHAPTER 3

Supplemental Table 1: Collaborative Care Plan Rubric

Collaborative Care Plan #1:			
	1 (Below Expectations)	**2 (Meets Expectations)**	**3 (Exceeds Expectations)**
Accuracy	- Plan fails to mention the possibility of drug-induced lupus (DILE) - Plan contains incorrect/inaccurate clinical information - Plan does not include adequate explanation/ justification for treatment recommendations (e.g., recommends stopping minocycline but does not explain why)	- Plan includes at least cursory discussion of the possibility of DILE - Plan recognizes that minocycline AND/OR pantoprazole can be associated with DILE, AND recommends stopping the medication(s) for this reason	In addition to the key clinical recommendation re: DILE the plan *also* includes additional reasonable recommendation(s) such as: - DC both minocycline and pantoprazole - Alternative therapies to replace minocycline and/or to replace pantoprazole (+ 1 of the following:) - DC/limitation of ibuprofen given her history of peptic ulcer disease - DC OCP given concern for possible hypercoagulable state - Additional testing that could be useful (e.g., anti-histone antibodies, hemoglobin/ hematocrit, creatinine) - Plan includes a particularly detailed and/or outstanding discussion of DILE
Completeness	- Plan does not discuss how medications may be contributing to patient's symptoms - Plan does not include specific recommendations for changes to the med regimen	- Plan includes discussion of which medications might be contributing to patient's chief complaints and why - Plan includes specific recommendations for changes to patient's med regimen	- Plan includes a particularly thorough/exhaustive review of patients' med list and how each might contribute to her symptoms - Plan contains thorough proposal for medication changes (ex: detailed justifications for discontinuing medications; suggestive alternative therapies) - Well organized

Chapter 4

An Interaction Analysis Model to Study Knowledge Construction in Interprofessional Education: Proof-of-Concept

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ABSTRACT

A goal of interprofessional clinical learning experiences is to facilitate learning through co-construction of knowledge in support of patient care. Yet, little is known about knowledge construction processes among health professions students working together to care for patients. Understanding knowledge construction processes can guide health professions educators in the design of interventions to support knowledge construction and high quality learning in clinical placements. In this paper we describe findings from a proof of concept study that explores the feasibility and utility of using Gunawardena's Interaction Analysis Model (IAM) to evaluate health professions students' knowledge construction processes in clinical placements. The IAM has been used to study knowledge construction processes in computer supported collaborative learning environments, but not in interprofessional education. The IAM describes five phases of knowledge construction – sharing/comparing; exploring dissonance; co-constructing meaning; testing; coming to agreement/applying co-constructed knowledge – each representing a progressively higher-level learning process. Application of the IAM to learner dialogue proved labor-intensive but feasible and useful as a research tool to characterize learners' knowledge construction behaviors. Our findings suggest that the IAM warrants further study and may offer a framework to guide the design of clinical placements and analysis of interprofessional learning behaviors.

INTRODUCTION

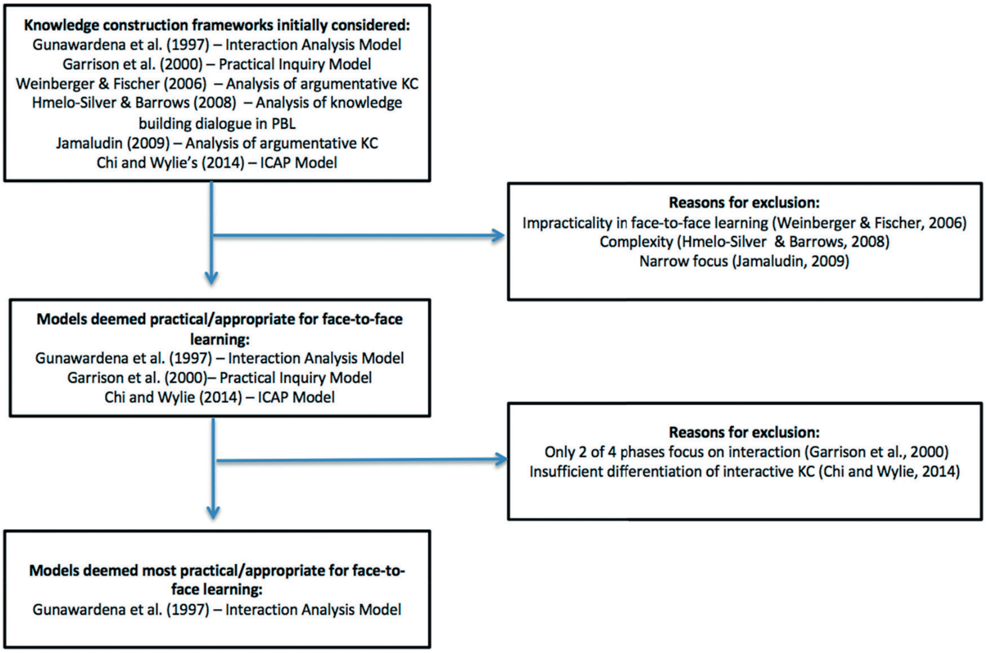
In interprofessional education (IPE), learners from diverse professional backgrounds are brought together – each with different content expertise and cultural perspectives – to learn with, about, and from one another (Collaborative, 2016). In clinical settings, these experiences aim to engage students in patient care activities that benefit from collaboration across professions. Students are expected to learn during these activities by sharing and integrating knowledge related to critical aspects of clinical practice such as patient care, professional roles, and teamwork (Floren et al., 2018). Yet, little is known about how learners from different health professions actually interact during these activities, what processes are involved as learners build knowledge, and what knowledge emerges during these interactions (Hinyard et al., 2019; Reeves et al., 2017; Rogers et al., 2017). Knowledge construction frameworks provide structure to observe and characterize learning behaviors and might be useful in illuminating the quality of learners' interactions during interprofessional activities.

Frameworks for the Analysis of Knowledge Construction

Knowledge construction has been conceptualized as a collaborative, interactive process by which learners develop and negotiate understanding of concepts by connecting new knowledge to their existing knowledge base (Bransford et al., 2000; De Wever et al., 2008; Van Aalst, 2009). During this learning process, both individual and collective knowledge is socially constructed and mediated (Bandura, 1971; De Wever et al., 2008; Ertmer & Newby, 1993; Rimor & Rosen, 2010). This perspective on learning fits well with the theories guiding many health professions education and IPE activities (Hean et al., 2012; Hmelo-Silver & Eberbach, 2012; Taylor & Hamdy, 2013). The process of knowledge construction can be assessed quantitatively (Lestari et al., 2019) or with qualitative methodologies such as interaction analysis to characterize learning behaviors (Chi & Wylie, 2014; Garrison et al., 2001; Gunawardena et al., 1997; Hmelo-Silver, 2003).

To evaluate the quality of interprofessional collaboration in health professions education, we considered several knowledge construction frameworks for their appropriateness in the context of clinical learning environments (See Figure 1). Among the existing knowledge construction frameworks, some appeared either limited in focus (e.g., Jamaludin et al.'s use [2009] of Toulmin's argument pattern [1958] as a framework to evaluate argumentative knowledge construction), overly complex (e.g., Hmelo-Silver and Barrows' ([2008), approach to analyzing knowledge building dialogue in problem-based learning environments or impractical for evaluating face-to-face learning (e.g., Weinberger and Fischer's [2006] process-focused model of argumentative knowledge construction). The three promising knowledge construction frameworks – not overly complex and practical for application to face-to-face learning –were Chi and Wylie's ICAP model (2014), Garrison et al.'s Practical Inquiry Model (2001), and Gunawardena et al.'s Interaction Analysis Model (1997).

Figure 1. Evaluation of knowledge construction frameworks.



Abbreviations: [KC] knowledge construction; [PBL] problem-based learning

The ICAP model describes a progression of knowledge construction in which an individual learner moves from Passive ("P") to Active ("A") to Constructive ("C") to Interactive ("I") levels of knowledge construction. This framework is supported by a substantial theoretical and research underpinning (Chi & Wylie, 2014) and is a convincing model that explains how understanding of content matter deepens when learners move through the four phases. However, our search was focused on a model that could capture knowledge construction in a variety of interprofessional interactions in the context of a clinical placement. Chi and Wylie's model acknowledges the importance of interaction as an advanced learning activity, but elaborates co-construction through interaction only as the last phase of the model. Given our interest in knowledge construction during highly interactive interprofessional learning activities, we decided that the ICAP model would not provide sufficient differentiation to comprehensively describe a wide variety of interactive learning behaviors.

Garrison et al.'s Practical Inquiry Model (2001) delineates four phases of critical thinking to reveal group sociocognitive processes – a triggering event, exploration, integration, and generation of the resolution of a dilemma or problem. This model was created to assess and guide dialogic writing for the purpose of creating cognitive presence in a community of inquiry in asynchronous computer conferencing (Garrison et al., 2001). Cognitive presence, a central tenet in their theory, is the extent to which participants in any particular configuration of community of inquiry are able to construct meaning through sustained communication, which aligns with our purpose. The Practical Inquiry Model, like the ICAP, is highly cited and influential. A reason, however, to discard this as a preferred model for our purpose is that two of the phases in the model (exploration and integration) are located in what the authors call a 'private world' of reflection, and only the triggering event and the final resolution phase happen in a 'shared world' of discourse (Garrison et al., 2001).

Finally, Gunawardena et al.'s Interaction Analysis Model (IAM) focuses on learner interactions and describes a progression of knowledge construction through five distinct phases with corresponding increases in mental engagement (Gunawardena et al., 1997). As our model of choice, we will expand on this model more deeply.

The Interaction Analysis Model of Knowledge Construction: Theory and Methodology

Gunawardena et al. (1997) viewed knowledge construction as a process of negotiating meaning through social interaction (Gunawardena et al., 1997), based on a social constructivist perspective on learning. Building on the work of Henri (1992), Garrison et al. (1992) and Newman et al. (1995; Newman et al., 1996), Gunawardena et al. (1997) conducted an interaction analysis using content analytic techniques to evaluate knowledge construction in the context of an international, online debate. The authors (Gunawardena et al., 1997) identified five distinct phases of mental engagement, each associated with overt, observable learning behaviors (termed "operations"), and progressively higher levels of learning. In contrast with the ICAP and the Practical Inquiry models, Gunawardena's IAM for examining the social construction of knowledge includes five phases that can all be observed in social interactions: I – Sharing/Comparing of information; II- The discovery and exploration of dissonance or inconsistency among ideas, concepts or statements; III- Negotiation of meaning/Co-construction of knowledge; IV – Testing and modification of proposed synthesis or co-construction; V- Agreement statement(s)/Applications of newly constructed meaning (See Table 1).

Table 1: Gunawardena's Interaction Analysis Model

Phase of knowledge construction	Operations included
Phase I: Sharing/Comparing of information	A. A statement of observation or opinion B. A statement of agreement from one or more other participants C. Corroborating examples provided by one or more participants D. Asking and answering questions to clarify details of statements E. Definition, description, or identification of a problem
Phase II: The discovery and exploration of dissonance or inconsistency among ideas, concepts or statements	A. Identifying and stating areas of disagreement B. Asking and answering questions to clarify the source and extent of disagreement C. Restating the participant's position, and possibly advancing arguments or considerations in its support by references to the participant's experience, literature, formal data collected, or proposal of relevant metaphor or analogy to illustrate point of view
Phase III: Negotiation of meaning/Co-construction of knowledge	A. Negotiation and clarification of the meaning of terms B. Negotiation of the relative weight to be assigned to types of argument C. Identification of areas of agreement or overlap among conflicting concepts D. Proposal and negotiation of new statements embodying compromise, co-construction E. Proposal of integrating or accommodating metaphors or analogies
Phase IV: Testing and modification of proposed synthesis or co-construction	A. Testing the proposed synthesis against "received fact" as shared by the participants and/or their culture B. Testing against existing cognitive schema C. Testing against personal experience D. Testing against formal data collected E. Testing against contradictory testimony in the literature
Phase V: Agreement statement(s)/ Applications of newly constructed meaning	A. Summarization of agreement(s) B. Applications of new knowledge C. Metacognitive statements by the participants illustrating their understanding that their knowledge or ways of thinking (cognitive schema) have changed as a result of the conference interactions

Note. Adapted from "Analysis of a global online debate and the development of an interaction analysis model for examining social construction of knowledge in computer conferencing," by C.N. Gunawardena, C.A. Lowe, and T. Anderson, 1997, *Journal of educational computing research*, *17*(4), p. 414 [Figure 2: Interaction Analysis Model for examining social construction of knowledge in computer conferencing] (https://doi.org/10.2190/7MQV-X9UJ-C7Q3-NRAG). Copyright 1997 by Baywood Publishing Co., Inc. Reprinted by Permission of SAGE Publications, Inc.

Importantly, the five successive phases of knowledge construction describe the entire process of negotiation of meaning that occurs when there are substantial areas of dissonance among learners requiring resolution. However, all five phases do not need to occur over the course of a group's interactions, they may occur in either sequential or non-sequential order (e.g., learners may move directly from Phase I to Phase III without exploring dissonance [Phase II] if none occurs), and different phases may be present at the same time (i.e., two or more phases and multiple operations may be included in the same online message or unit of dialogue; Lu & Jeng, 2006).

Gunawardena et al. (1997) suggested that lower mental functions are associated with lower phases of knowledge construction (Phases I and II) and higher mental functions are associated with higher phases of knowledge construction (Phases III, IV, and V). Higher-quality learning experiences engage learners in multiple phases of knowledge construction, supporting their negotiation of meaning (Gunawardena et al., 1997). Yeh and Lo (2005) reported that learners reaching higher phases of knowledge construction demonstrated higher rates of knowledge retention and transfer to novel situations (i.e., effective application of knowledge outside original learning context). Given these positive associations between knowledge construction and learning quality, the IAM (Gunawardena et al., 1997) offers an appealing approach to studying learning during IPE. Focusing on learners' social interactions as the primary mechanism for knowledge construction, the IAM offers specific, directly observable behavioral markers that operationalize the construction of knowledge, and provides a hierarchical analysis tool to characterize learner interactions.

The most important limitation of Gunawardena's model is that, like Garrison et al.'s model, it was created for asynchronous online interactions (Lucas et al., 2014) and computer supported collaborative learning environments, but not for live interactions, nor interprofessional interactions in the context of the clinical learning environment. However, we believe the model is applicable to analyze interprofessional clinical learning interactions. Gunawardena et al. suggested in 1997 that some types of online dialogue are akin to face-to-face interactions and appropriate for evaluation using IAM (Gunawardena et al., 1997), and a few researchers have examined face-to-face interactions, albeit only in primary school settings (Bao et al., 2016; Cheng et al., 2019; Socratous & Ionnanou, 2018; Zhou & Yang, 2017). Although the IAM has not been applied to face-to-face learning in health professions education, these studies suggest the model's potential use to analyze interactive learning in clinical placements.

We decided to explore the application of the IAM to clinical IPE in a proof of concept study. Proof of concept research aims to demonstrate the feasibility of an idea, concept or physical model and to argue for its continued development in settings beyond those in which it was established (Feng et al., 2019; Kendig, 2016). We defined feasibility as translated to the questions: Can the IAM be applied to observations of learners engaged in face-to-face interactions in an interprofessional clinical activity? Can researchers identify each of the five knowledge construction phases in the learner dialogues? Is the time and resource investment reasonable? We defined utility as translated to the questions: Can the model serve as a research tool to characterize learners' knowledge construction behaviors in an interprofessional clinical placement? Is the model potentially transportable to new contexts (Kendig, 2016)? We explored these questions in a proof of concept study.

METHODS

To determine the feasibility and utility of Gunawardena et al.'s (1997) IAM to clinical IPE, we observed health professions learners engaged in patient care during a geriatrics clinical placement and used the IAM to analyze their interactions. The institutional review boards at the University of California, San Francisco and the San Francisco Veterans Affairs Medical Center approved this study and all learners consented to participate.

Context of the Learning Activity

A 2-week clinical placement was used to examine the IAM. This full-time course addressed multiple geriatric and interprofessional competencies relevant to medicine, pharmacy, and physical therapy. Three distinct groups containing three learners each (i.e., nine learners total) – a medical student (MS, fourth-year), a pharmacy learner (PS, fourth-year student or PGY1 resident), and a physical therapy student (PTS, second or third-year) – engaged in information gathering, assessment, and care planning for a nursing home patient who had experienced a recent fall. To develop competency in the evaluation of patient functional status/fall risk, each week, teams were instructed to work together for 3–4 hours to identify the circumstances contributing to a specific patient's fall, interview and examine the patient, and generate recommendations (a team Falls Note) to share with staff at the nursing home.

Data Collection and Unit of Analysis

One researcher LCF collected data through direct observation of three teams (Teams 1, 2, and 3) and through individual interviews with student members of each of the teams (nine students in total). This researcher, serving as a non-participant observer with minimal interactions with the students, took field notes during three phases of the patient work-up: the pre-interview workup, the patient interview and examination, and the construction of the Falls Note. She extensively annotated field notes to create a synthesized text of the students' verbal and non-verbal interactions.

We chose as the unit of analysis an occurrence of interactive behavior with individual utterances and a dialogue focused on a single topic (such as a discussion of musculoskeletal exam findings or medication reconciliation).

Initial Application and Modification of the IAM

Initially, we developed a codebook based on Gunawardena et al.'s (1997) IAM, as originally conceived (i.e., including five separate knowledge construction phases each containing three to five operations [Gunawardena et al., 1997]) (Table 1). Two researchers (LCF and BOB) used Dedoose™ analytic software Version 8.0.31 (SocioCultural Research Consultants, LLC, Manhattan Beach, CA) to conduct a directed qualitative content analysis (Hsieh & Shannon, 2005). Using predetermined codes, they independently coded a subset of learner dialogue in the field note transcripts based on the original model, but this proved somewhat unwieldy given the number of operations. Following other researchers (De Wever et al., 2009; Hew & Cheung, 2011; Lu & Jeng, 2006), we revised the codebook according to only the five primary phases of knowledge construction (Table 1, left column). We used the descriptions of the operations in Gunawardena's original IAM to construct definitions and generated associated examples from our own data (see Table 2 for definitions and exemplars of each phase of knowledge construction behavior). This yielded a simplified IAM framework for observing knowledge construction in action that was both manageable, in terms of application of the final codes to the field notes, and sufficiently fine-grained for our research purposes while maintaining fidelity to the original IAM.

Table 2: Gunawardena's Interaction Analysis Model as applied to this study: Definitions and examples

Term	Definition	Example from our application
Phase I: "Sharing or Comparing"	Sharing or Comparing information Learners make statements of observation / opinion/ability; share information (facts and relevant content knowledge) or intended actions with teammates; solicit information from/ask a question of teammate, but no dialogue ensues	Team member puts forward their clinical recommendations to the team, but does not engage in discussion with teammates; Trainee "thinks aloud," making thinking visible or engages in peer teaching.
Phase II: "Exploring Dissonance or Divergence"	The discovery and exploration of dissonance or inconsistency among ideas, concepts or statements Learners identify and discuss areas of disagreement with existing notions or divergence of ideas; Learners ask and answer questions to clarify source and extent of disagreement	Trainee puts forward their clinical recommendations to the team, but another teammate says, in response, "I think that you and I have a different way of looking at this issue."
Phase III: "Negotiating or Co-constructing"	Negotiation of meaning or Co-construction of knowledge Learners negotiate or clarify terms; identify areas of agreement or overlap among conflicting concepts; Learners resolve differences and arrive at mutual understanding; Learners propose and negotiate new statements embodying compromise, co-construction	Trainees work together at the whiteboard, negotiating and prioritizing the patient's problem list; One trainee asks another, "Can we come to an agreement on the primary contributor to the fall?"
Phase IV: "Evaluating, Modifying or Verifying"	Testing and modification of proposed synthesis or co-construction Learners evaluate proposed synthesis (i.e., the co-constructed knowledge, plan) against "received fact" as shared by the other participants	Trainees talk with one another about how the patient's gait disturbance doesn't "seem that bad" compared to what they've seen before, but that all the evidence points to gait as the main problem for this patient.
Phase V: "Reaching agreement or Application"	Agreement statement(s) or Applications of newly constructed meaning Learners summarize agreement(s) related to co-constructed knowledge, plan; Learners apply newly constructed knowledge	Trainees explicitly agree on the conclusions and recommendations to include in their Falls Note; PT says to MD, "Even though we initially disagreed on the primary contributor to the fall, I think that, after examining him, we agree that his gait disturbance is the main problem."

Because the IAM focuses solely on cognitive processes, we also included two broad codes– facilitators and barriers to knowledge construction. These sought to capture some of the environmental, situational and social impacts on knowledge construction.

Both coders (LCF and BOB) were involved in developing the simplified IAM code book. They independently coded learner dialogue from four of six field note transcripts based on the simplified IAM, then compared coding. Differences in coding and interpretation were resolved through discussion. One coder (LCF) independently coded the remaining two transcripts.

Analysis of the Feasibility and Utility of the Simplified IAM

To determine the feasibility of applying the simplified IAM, we evaluated the ability of coders to apply the simplified IAM to transcripts of observations of learners engaged in face-to-face interactions and dialogue and find each knowledge construction phase in the learner dialogue. In addition, we evaluated the time intensity of data collection and analysis.

To explore the utility of the simplified IAM, we evaluated the functionality of the model as research tool to characterize learners' knowledge construction behaviors in the context of an interprofessional clinical placement. We did not empirically explore the potential of the model to be applied in new contexts but will elaborate on these options in the discussion section.

RESULTS

Feasibility

Data collection proved feasible but time intensive, requiring the researcher (LCF) to be present for the duration of the learner interaction. Next, producing the transcripts and annotating the observational data was especially time-intensive, as was the coding and reconciliation process. No other resources were used. Generally, there was consistent agreement between the two coders. Their differences occurred more frequently in the beginning of the coding process and lessened as the researchers became more familiar with the construct and exemplar behaviors. Both coders were able to observe all five phases of knowledge construction (See Table 2 as well as Supplemental Table 1 for exemplars).

Utility

To assess utility, we set out to explore whether the model could function as a research tool for identifying knowledge construction phases as defined by Gunawardena. We found that applying the simplified IAM to learner dialogue enabled us to characterize the learners' knowledge construction behaviors as they worked together during their interprofessional clinical placement and identify variations in the frequency of these behaviors within and across teams. Two researchers were able to independently apply the simplified IAM to learner dialogue captured in transcripts of observations and to characterize knowledge construction behaviors in all three teams of learners. We did not study the application of the simplified IAM in other contexts.

DISCUSSION

We set out to identify a research model to analyze knowledge construction in interprofessional teams of learners participating in a clinical placement. We found several knowledge construction frameworks with potential to be transformed into an observational tool for this purpose and chose Gunawardena's IAM (Gunawardena et al., 1997). After initially applying the original five phase model (including 21 operations) to characterize learner interactions, we simplified to a general five phase model for practical purposes (Table 2). We then studied the feasibility and utility of this model in a limited proof of concept study. What did we learn from this study?

The feasibility of the simplified IAM proved to be satisfactory, but labor intensive. The model was feasible for research purposes – coders could apply it to observations of learner interactions during an interprofessional clinical activity and all phases of knowledge construction were identifiable. Qualitative research is generally labor intensive, and researchers may anticipate that application of the model to observational data would require considerable effort and time.

The utility as of the model as a research tool to characterize knowledge construction behaviors in the context of an interprofessional clinical placement was established. Focusing on the five primary categories of the IAM enabled us to analyze lengthy activities and complex interactions occurring outside the context of asynchronous communication and computer supported collaborative learning environments for which the model was originally designed.

We faced important methodological issues related to data collection and preparation as well as the definition of the unit of analysis. The IAM has been applied almost exclusively in online settings, where the online dialogue is fully captured and available for analysis (Gunawardena et al., 1997; Schellens & Valcke, 2005, 2006). In the clinical context in which our study occurred, learner interactions occurred in real-time. Audio and video recording of learner interactions were considered, but raised patient privacy concerns, so we relied on detailed field notes, rather than verbatim transcripts, to capture verbal and non-verbal communication. We found that the data collection and preparation (i.e., having one observer take detailed field notes, transcribe and then extensively annotate them) was labor-intensive and time consuming. For future applications of the model in clinical learning environments, we would encourage collection of audio or video recordings of dialogue rather than relying solely on field notes. This would serve two purposes: the recordings could be transcribed verbatim as a way to eliminate omissions in the dialogue and could be independently reviewed to limit potential observer bias.

Additionally, we needed to choose the unit of analysis. In the context of asynchronous online discussions, each discrete message posting can be considered to embody individual participants' cognitive activity and contribution to collective construction of knowledge. These discrete messages can be considered single units of analysis to be evaluated for the knowledge construction phase(s) (Gunawardena et al., 1997). In our application of the IAM to field notes, the unit of analysis was harder to define because the dialogue during face-to-face, real time learning activities could not be divided into discrete messages. After reviewing and testing different options (e.g., by speaker, by tasks, by time, by content), we defined the unit of analysis as an occurrence of observed behaviors, individual utterances, and interactive dialogue focused on a single topic (such as a discussion of musculoskeletal exam findings or medication reconciliation). Once we chose the unit of analysis, we found that parsing the dialogue into separate units was a straightforward process.

We also needed to revisit the concept of knowledge construction to enable applying the model. According to Gunawardena et al. (1997), the five successive knowledge construction phases do not always occur during a threaded interaction and phases may occur out of sequence, or they may be present simultaneously. We found that all five knowledge construction phases indeed rarely occurred during discussion of a single topic, and we found some interdependencies between knowledge construction phases (De Wever et al., 2008). For example, Phase III (negotiating meaning or co-constructing knowledge) did not occur without some Phase I (sharing or comparing information) behaviors upon which the co-constructive process was based. Similarly, Phase IV behaviors (evaluation and modification of new schemas) and Phase V behaviors (coming to agreement on the co-constructed knowledge) required engagement in the co-constructive process in Phase III. In fact, when Phase IV behaviors did occur, they appeared as an extension of Phase

III behaviors (i.e., the learners' process of evaluating their co-constructed knowledge and modification of these new schema followed from their process of negotiating meaning). Understanding patterns of knowledge construction behaviors and expected interdependencies allowed us to perform a form of quality control on our coding.

In addition to supporting the interaction analysis focused on knowledge construction phases, our field note approach allowed us to record barriers and enablers of learner interactions (e.g., disengagement from the learning activity and collaborative communications, respectively) related to social dynamics at the team and individual learner level as well as environmental factors (Anderson & Kanuka, 1998; Lu & Jeng, 2006; Lucas et al., 2014) in a way that audio recording or online dialogue exchanges would not offer, and video recording would support only in a limited way.

Although the simplified IAM allowed us to analyze complex, face-to-face interactions in the clinical learning environment and characterize all phases of knowledge construction behaviors, this study was limited by several factors. First, a single observer (LCF) collected the field notes, and there were no recordings made of the student interactions, so the data could not be verified. Also, this same observer annotated the field notes, and this may have introduced bias into the data. We were unable to corroborate the contents of the field notes with a second observer, and some observer bias may be reflected in the data.

Future Directions

Although we have established a first proof of concept for the simplified IAM as a research tool, this is only one step in model development. Next steps should include application in other learner populations and contexts and the collection of validity evidence related to these applications. Studying learners in various stages in professional development may shed light on usefulness of the model to describe longitudinal developments in quality of interactions and knowledge construction. Researchers might also use the model to compare knowledge construction behaviors in different learning activities to determine which yield higher-level thinking or may design studies to investigate how observed knowledge construction behaviors correspond to actual knowledge production. Development of an IAM-based observational tool for clinical educators' assessment of learning and feedback would require tool development and validation followed by teacher training.

We applied the model to characterize learners' interactions during an interprofessional clinical placement as we believe that these learners – because of their different backgrounds and level of clinical autonomy – could fruitfully construct knowledge as they worked together on a patient case. However, any interactive setting of peer-assisted learning should be analyzable with the IAM, as well as near-peer learning and teaching interactions (ten Cate & Durning, 2007). For that matter, even teacher-student interactions may be suitable for analysis with the IAM. Studies using the IAM may potentially yield important information to improve education.

The IAM, if presented as a succinct tool for clinical teachers (such as a rubric or behavioral checklist based on the model), could support teachers in observation and feedback to learners. Student-run interprofessional learning wards (Oosterom et al., 2019) employ supervising clinician observers who must evaluate interprofessional interactions, and such a tool might support their feedback provision. For example, faculty could observe the interaction of the team of learners as they perform the end-of-day handover on an interprofessional training ward, applying the tool to evaluate the level of knowledge construction that the learners were engaging in. The faculty would then provide feedback to the learners based upon their assessment of the learners' interactive knowledge construction. For example, faculty could actively encourage exploration of dissonance between learners (Phase II), guide learners to build upon one another's ideas (Phase III), or explicitly come to a consensus decision (Phase V). By providing explicit examples of desired learning behaviors, faculty could encourage the learners to achieve higher-level engagement.

CONCLUSION

Based on our criteria for feasibility and utility, we found evidence in a test case to suggest the viability of further application and study of the IAM. Applying the model and labeling the phases of knowledge construction allowed us to characterize learning behaviors exhibited in the course of clinical care. We have demonstrated that the model can function as a research tool if supported with sufficient and realistic expectations around time intensity. Expected caveats of these applications include requiring observer/researcher training and time for data collection and analysis. The model might, theoretically, be applied in other contexts. Given that the simplified IAM consists of only five phases, each with distinct behavioral anchors that are observable in the clinical environment, trained clinical educators could use an IAM-based tool to observe and evaluate the learners' knowledge construction behaviors and level of engagement in the moment, then provide feedback to promote a higher-level interaction and enhance learning. Though requiring development, validity testing and faculty training, we believe that the simplified IAM may be useful for the evaluation of interprofessional team learning processes in real-time.

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SUPPLEMENTAL MATERIAL – CHAPTER 4

Supplemental Table 1: Phases of Knowledge Construction – Examples from observations and interviews of Teams 1, 2 and 3

	Team 1	Team 2	Team 3
Phase I "Sharing or Comparing"	- PT frequently engages both MD and PH teaching about physical therapy. PT describes how to assign grading of muscle strength; makes thinking visible by explaining to them what he/she is looking for from their perspective as a PT. [Observation – Interview/Exam] - "…A few times I think I offered teaching about things because I had the sense that my teammates didn't know that much about it so I have to do 30 seconds on (a) topic… " [Interview – MD-1]	- Most interactions were Level I and occurred when a teammate engaged in one-way, stated an opinion to a teammate or, posed open-ended questions - PT asks teammates, "do you guys know what modified independent means?" PT points out pertinent information about their patient to his/her teammates and says, "so, these are his transfers and where he's had his issues." MD, trying to learn some of the specific PT acronyms, asks PT, "so what does 'CGA' stand for versus standby assist?" PT teaches teammates about the different kinds of assistance, including Contact Guard Assist. [Observation – Pre-interview workup]	- MD asks PH, "Do (certain) meds that cause orthostasis cause drop in bp? or are there any autonomic effects?" PH responds to her in elevator, providing peer teaching to MD. [Observation – Pre-interview workup]
Phase II "Exploring Dissonance or Divergence"	- MD and PH discussed their divergent approaches to the process of medication reconciliation. [Observation – Note preparation] - "When we were doing the medication reconciliation, you saw what happened where I was looking at the medications first and then the med student was looking	-MD suggests beginning to write Falls note *before* patient interview. PT suggests gathering more information and says, "I think we should get an idea of what happened. We can go see him, then write the note. Don't you think? Or, whatever you guys think." PT is initially assertive, suggesting that rather than writing a note without seeing the patient first (as MD seems to want to do, based on their	- PH notices potential deconditioning in the note, PT responds, "…but his strength seemed fine." MD challenges PT's assessment. [Observation – Note preparation]

	Team 1	Team 2	Team 3
	at their problems first. It's interesting to see that based on your training. You would both come to the same conclusion, but there's a different order in which you would do it. I thought that was really interesting." [Interview – PH-1]	behaviors), they go see the patient, then write the note based on what they find. [Observation – Pre-interview workup]	
Phase III "Negotiating or Co-constructing"	- MD appears very focused on the Falls note template. It seems like they are going it alone. MD is typing and talking under his/her breath. MD says, "falls are (both) witnessed and unwitnessed, appear to be mechanical in nature…" PT chimes in, "Major contributing factors include improper use of assistive device, generalized weakness, balance impairment…" PT and MD continue co-constructing the note and the narrative of the fall [and the vast majority of the recommendations]. [Observation – Note preparation] - "When we put together the plan, PT likes to write on the whiteboard, so while PT's scribing we're all discussing all the problems." [Interview – MD-1]	- PT says to the team, "so, with my…(investigation) of this fall, (I can see why) they gave the prn (trazadone)." Then PT asks PH ,"….(the timing of the trazodone dose and norco – both increase risk for falls) would make a difference, right?" [PT is pursuing a really important line of thinking about the potential correlation between med administration and the fall. PT is actively engaged and trying to co-construct meaning with PH. PH discovers that an extra 25 mg dose was given and suggests that, given the timing of the dose, this could have contributed to the fall. PT is obviously really interested [and very engaged], and is asking PH lots of questions about the timing of the dose and the peak effects. [Observation – Pre-interview]	- PH teaches what two different medications are for and carefully goes through his/her thought process and concerns - aloud- as well as answering PT's specific questions. MD-3 and PT ask PH about the drugs and their dosages. PT asks, "is that normal? What makes it orthostatic?" PH answer PT's specific questions and says, "what you'll be concerned with is syncope…." [Observation – Note preparation]
Phase IV "Evaluating, Modifying or Verifying"			-A few instances of confirming newly gained knowledge ((e.g., After having just learned to calculate the Morse fall scale from PT-3, PH-3 exclaims to

	Team 1	Team 2	Team 3
			teammates, "so (he's) high risk (for falls)!" But, because PT-3 had previously assessed the patient as being at lower fall risk, he then asks the team, "I'm wondering why he got such a high score…" His question prompts the team members to independently re-calculate the Morse-scale and then verify their results with one another. [Observation – Note preparation]
Phase V "Reaching agreement or Application"	- PT, speaking to MD, says about the team's co-constructed Falls note, "what you have is great. That's what we are trying to show." PT is encouraging as well as inclusive. [Observation – Note preparation]	- PH now begins [to get engaged with the others after having been really passive]. Reading from the note about the functional assessment, PH begins to focus on the patient's glasses (as a possible contributor to the fall)….MD agrees with PH. [Observation – Note preparation]	- Continuing from the Level IV example above, after the trainees each independently re-calculated the Morse scale scores, they cross-checked their scores to ensure accuracy and then came to agreement on the final Morse-scale number. [Observation – Note preparation]

*Observations were split into three separate time periods for analysis relative to the team interview of the patient– the pre- interview and exam preparation; during the patient interview and exam; and, during the "Falls Note" preparation (i.e., Pre- interview, Exam/Interview, Note Preparation, respectively).

ABBREVIATIONS: bp [blood pressure]; CGA [Contact Guard Assist]; EMR [Electronic Medical Record]; MD [Medical learner]; PH [Pharmacy learner]; prn [as needed]; PT [Physical therapy learner]

Chapter 5

Preliminary Evidence for a Tool to Observe the Construction of Knowledge in Interprofessional Teams (TOCK– IP)

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ABSTRACT

Collaborative knowledge construction (KC) is an important process in interprofessional learning and a logical assessment target. A tool supporting the formative evaluation of KC behaviors ideally would be: 1) applicable to interprofessional teams of learners in clinical contexts; 2) informed by contemporary learning frameworks; 3) feasible and useful. No existing assessment tool meets these criteria. This paper describes the development and preliminary validity evidence for a Tool for Observing Construction of Knowledge in Interprofessional teams (TOCK-IP). Following literature review and needs assessment, the TOCK-IP was drafted based upon Gunawardena's five-phase KC model. Educational expert review established content validity. Response process and internal structure validity, feasibility, and utility were assessed through step-wise evaluation. Faculty raters applied the tool to four videos of simulated interactions between health professions learners. Faculty ratings were compared to expert consensus ratings. Thematic analysis of post-rating survey and debrief allowed assessment of feasibility and utility. Across videos, faculty raters' agreement was fair (n=25; Fleiss' kappa= 0.40, <0.001). Excellent agreement (95%) was found for raters' scores compared to consensus rating. Faculty supported tool feasibility and utility. The TOCK-IP meets the three criteria for evaluating team-level KC and offers a progression roadmap to help learners move toward collaborative learning.

Keywords: observational assessment, knowledge construction, interprofessional education, interactions, collaborative learning

INTRODUCTION

This past decade has seen a surge of publications in support for interprofessional collaborative healthcare practice (IPCP) and growing commitment of universities to graduate health professions learners with skills in teamwork and collaboration (O'Keefe et al., 2017; Ong et al., 2019). In parallel, there has been increasing interest in providing opportunities for interprofessional education (IPE) (World Health Organization, 2010; O'Keefe, et al., 2017) and the creation of assessable interprofessional (IP) learning and practice competencies (Thistlethwaite et al., 2014; O'Keefe et al., 2017). However, assessment of these competencies has lagged behind the worldwide enthusiasm for IPE itself (Ong et al., 2019; J. Rivera, personal communication, July 24, 2020; Rogers et al., 2017). To address the assessment gap in IPE, and to further the goal of preparing IPCP-ready clinicians, focused work on the assessment of learners' IP teamwork and collaboration is warranted (Rogers et al., 2017).

Recognizing the important role that assessment plays in conveying the significance of IP learning to all stakeholders and as a method for promoting learning, a core group of international IPE leaders developed a consensus statement on the assessment of IP learning outcomes (Rogers et al., 2017). This group asserts that both formative and summative assessments should be included in any programmatic approach to IPE and, further, that "formative assessment of skills-based activities and complex tasks such as teamwork should involve frequent observation with constructive and timely feedback" (p. 350). They recommend assessment of seven key domains, including: professional communication, role understanding, IP values, coordination and collaborative decision-making, reflexivity, and teamwork. Competencies focused on collaborative interactions are especially prominent in the domains of professional communication, coordination and collaborative decision-making, and teamwork. Assessment of teamwork and collaborative practice should focus on the contributions of both the whole team and individual learners, requires a combination of assessments, and should be undertaken through observation of learners as they interact and work together in teams on clinically relevant tasks, during simulation or in the workplace (Rogers et al., 2017).

Learners in the context of IPE are expected to interact with one another to share their understandings, negotiate meaning together, and integrate knowledge related to key aspects of clinical practice (Floren et al., 2018). This interactive process, where learners work together to actively build new knowledge (Gunawardena et al., 1997; De Wever et al., 2010; Chi & Wylie, 2014) – known as knowledge construction – is increasingly recognized as an important determinant of the quality of collaborative learning (Gunawardena et al., 1997; Floren et al., 2020) and an essential aspect of shared clinical decision-making (Quinlan, 2009). Given that collaborative decision-making is a key IP competency domain (Rogers et al., 2017), knowledge construction is an important assessment target.

In this article, we describe the development of a novel observational assessment tool – "Tool for Observing Construction of Knowledge in Interprofessional teams" (TOCK-IP) – and present preliminary evidence of validity, feasibility, and utility. The TOCK-IP is designed to guide clinical educators' observations and formative assessment of discrete, constructive learning behaviors and to support greater consistency and quality of feedback to learners (Frank et al., 2010).

METHODS

To assess interactive KC behaviors in the context of clinical IPE, we developed and collected evidence of validity, feasibility and utility for our tool in two stages as described below. Using Messick's unified validity framework (Messick, 1989; Cook & Beckman, 2006), we collected validity evidence for content, response process, and internal structure.

Stage I: Tool development and expert review (content validity)

Literature review

Following established guidelines for designing formative and observational assessments (Downing and Yudkowsky, 2009; McGaghie et al., 2009), we first conducted a literature review using the following search terms: *assessment, collaboration, communication, education, health professions, instrument, interprofessional, interprofessional competencies, knowledge construction, learning behavior, non-technical skills, observational, review, teamwork, tool, workplace-based assessment.* This review revealed a wide variety of observation tools that assess team behaviors and performance across a variety of domains (such as communication and collaboration); (Havyer et al., 2016; Shrader et al., 2017; Higham et al., 2019) identified two tools that assess individual's contributions to team knowledge construction (Curran, et al., 2011; and Thistlethwaite et al., 2016), but no tools that measure interactive KC at the whole-team level.

Needs assessment

To assess the need for an observational assessment tool focused on team learning behaviors and potential applications, one investigator (LCF) conducted informal interviews with educators experienced in IPE (n= 5 MDs; and n=4 PharmDs). All educators affirmed the need for such an instrument.

Initial draft of the tool

Given the lack of an existing assessment tool and positive feedback from the needs assessment, we proceeded to develop a draft observational assessment tool (TOCK-IP). We based the initial draft on Gunawardena's Interaction Analysis Model (IAM) (Gunawardena et al., 1997; Floren et al., 2020) – an existing theoretical model of interactive KC that delineates phases of cognitive engagement. The first section of the tool was divided into five behavioral modes, corresponding directly to the IAM's five knowledge construction phases (Gunawardena et al., 1997; Floren et al., 2020) that describe successively higher levels of cognitive engagement: Mode 1 – Sharing or comparing; Mode 2 – Exploring divergence or disagreement; Mode 3 – Negotiating or Co-constructing knowledge; Mode 4 – Modifying, verifying, or evaluating/ testing; and, Mode 5 – Reaching agreement or application. Since tools anchored by discrete, observable learning behaviors, can reduce subjectivity and improve tool reliability and validity (Rosen et al., 2008), we developed 3-4 corresponding behavioral subcategories for each mode. Check boxes allowed observers to note whether a behavioral mode or corresponding subcategory was present or absent and space was provided for rater comments. The second section contained a holistic rating scale (i.e., whether the team's level of KC was low, medium, or high) as well as feedback prompts for raters (i.e., observed team behaviors to continue and those that may need improvement).Iterative modifications were made to the tool based on input from five HPE educator-researchers with a deep understanding of KC and the IAM (including all study authors).

Expert review

As a next step in building the content validity argument, additional expert input was provided by two educational researchers experienced in advanced measurement. The originator of the IAM reviewed the tool and provided feedback regarding clarification of Mode 4 behavioral descriptors (C.N. Gunawardena, personal communication, December 14, 2020).

Stage II: Collection of additional validity evidence, feasibility and utility

Response process validity

To evaluate the ability of faculty to apply the tool to rate learner team interactions, we created four videos that simulated interactions between learners developing an IP team care plan. Videos feature the full range of knowledge construction behavioral modes in typical combinations. Three videos utilized existing faculty development videos, based on real student team interactions (UCSF IRB 16-19440). Four researchers (including ALP and LCF), all involved in IPE, and with experience in applying the IAM to learner dialogue, independently rated all videos using TOCK-IP. Group review and discussion produced: 1) expert consensus ratings for each video, indicating the presence of absence of each behavioral mode and behavioral subcategories, as well as the holistic rating; and 2) modifications of behavioral mode and subcategory descriptors.

We wrote a one-page Backgrounder to provide an overview of the KC construct and to articulate the purpose of the tool as well as a rater instruction sheet (Please see Appendices A and B, respectively).

To refine the tool and gather feedback on response process, internal structure, feasibility, and utility, we invited faculty to participate in one of three evaluation steps (i.e., the think-aloud, Pilot #1, or Pilot #2). From February – April of 2021, we recruited health professions faculty with experience in IPE, including faculty from anatomy, medicine, nursing, pharmacy, and physical therapy from University of California San Francisco (UCSF), University of Minnesota (UMN) as well as Oregon Health and Sciences University (OHSU).

To examine response process validity (Padilla & Benitez, 2014), two researchers (LCF and ALP) conducted cognitive interviews (Charter et al., 2003) with three faculty who precept learners on IP clinical teams. Raters were instructed to think aloud as they rated each video. A pre-pilot test (i.e., Pilot #1) was conducted with four clinical faculty. For Pilot #2, twenty-five faculty members from UCSF, UMN and OHSU were recruited.

Faculty raters in each evaluation phase were first asked to: 1) independently review the Backgrounder and rater instruction sheet; then 2) view and apply the TOCK-IP to rate the videos. For each video, faculty raters used the TOCK-IP to: 1) determine the presence or absence of each behavioral mode and subcategory; 2) provide a holistic rating; and 3) complete a ten-item survey focused on tool clarity, utility and potential to improve learning.

To collect additional evidence of response process and to assess tool feasibility and utility, each rater completed a post-rating, semi-structured interview with investigators (LCF, ALP, or both) focused on utility of the backgrounder, rater instructions, feasibility and utility of the tool, review of raters' scores relative to expert scores, problems and questions that arose during the rating process, and suggested improvements. Debriefs were recorded, transcribed and used to triangulate the narrative comments on the raters' TOCK-IP forms to document consistency.

Internal structure validity

Inter-rater reliability among Pilot #2 raters, was calculated for each video and across all videos using Fleiss' Kappa (Landis & Koch, 1977; Gwet, 2014), accounting for agreement relating to: 1) the presence or absence of each behavioral mode and associated behavioral subcategories, and 2) the holistic rating. Fleiss' Kappa indicates the probability of agreement between raters that is above chance levels (i.e., 0.50) and is appropriate for assessing reliability among more than two raters when the response variable is nominal and binary (i.e., presence or absence of a behavior).

The percent agreement between the faculty raters' scores and the expert consensus score was calculated for the primary behavioral modes across all four videos.

Lastly, a repeated measures general linear model was created to examine differences in agreement between raters' scores from UCSF and UMN (Tabachnick et al., 2007). The institution (i.e., either UCSF or UMN) was entered as the fixed independent variable. Percent agreement across all behavioral modes and associated subcategories was entered as a single outcome variable.

Statistical analyses were performed using SPSS v. 27 (SPSS, Armonk, NY, USA: IBM Corp.).

Feasibility and utility

To assess feasibility and utility, we used thematic analysis (Braun & Clarke, 2008) to analyze Pilot #2 raters' post-rating debrief transcripts. Feasibility and utility were operationalized as: 1) ability of faculty to apply the tool to learner videos without training (feasibility, 2021), and 2) faculty perceptions that the tool and its application could be useful in the context of HPE (utility, 2021), respectively. Themes, developed inductively (by LCF and ALP), included: positive aspects of the tool; areas for improvement; feasibility; utility; and potential applications. Half of all transcripts were double coded (by LCF and ALP) and disputes were reconciled through discussion. Qualitative findings were summarized in narrative form.

Reflexivity

ALP and LCF are both practicing clinical pharmacists, clinical educators, and educational researchers with a keen interest in IPE and an assumption that IP collaborative care is good healthcare. Our personal interst in this topic – especially the potential of IPE to promote pharmacists' inclusion in IP collaborstive teams in furtherance of improved patient care – could have positively biased our interpretation of the faculty debriefs. DMI and OtC are experienced educational researchers, the former from the US and the latter from the Netherlands.

Ethical Considerations

The Institutional Review Boards of UCSF (#19-29344) and UMN (#STUDY00011400) approved the study.

RESULTS

Stage I: Tool development and expert review (content validity)

The results of this stage included the initial version of the TOCK-IP as well as supporting documents (i.e., the Backgrounder and rater instructions) that were iteratively modified prior to Stage II (see Figure 1, Appendices A and B, respectively).

Stage II – Collection of additional validity evidence, and feasibility and utility data

Participants

A convenience sample of thirty-two faculty participants ((UCSF (n=18); UMN (n=13); OHSU (n=1)) participated in the study. All faculty participants had experience with interprofessional education (See Table 1 for participant demographics).

Table 1: Participant demographics

	Respondents		
	Think-alouds (Total n = 3)	**Pilot 1 (Total n = 4)**	**Pilot 2 (Total n = 25)**
Female	3	3	21
Academic Rank		17	7
No rank	-	-	1
Assistant Professor	2	-	6
Associate Professor	-	1	10
Full Professor	1	3	8
Profession			
Basic science ^	-	-	1
Dentistry	-	-	1
Medicine	-	2	5
Nursing	1	1	6
Pharmacy	2	1	10
Physical Therapy	-	-	2

^Anatomy faculty

Response process validity

Based on rater feedback from the think-alouds, Pilot #1, and Pilot #2 (including survey results and post-rating debriefs) and after research team discussion (ALP, DI, LCF, and OtC), we made iterative refinements to the Backgrounder, rater instructions, and TOCK-IP. Most significantly, after Pilot #1, when faculty raters struggled to distinguish Modes 3 and 4, we decided to combine behavioral anchors from these modes into a single behavioral Mode 3 (i.e., Building new knowledge together). This modification was reviewed with the originator of the KC model who supported the decision (C.N. Gunawardena, personal communication, May 3, 2021). After Pilot #2, where faculty reported difficulty with applying the holistic rating and questioned its utility, we eliminated the holistic rating. The final version of the TOCK-IP is provided in Figure 1.

Figure 1: Tool for Observing the Construction of Knowledge in Interprofessional Teams (TOCK-IP)

Learner Team:	**Date:**
Observer:	**Location:**
Prior to rating, please review the *Rater Instructions* and knowledge construction *Backgrounder.* During your observation, check *Observed Team Interactions* between team members as they occur the first time. If you observe a learning behavior frequently, you may note this in the *Observations* field below each mode. If a mode is not observed, tick the *Not Observed* box. After your observation, provide specific feedback to the learner team based on the behaviors of the team as a whole in the *Team Feedback* section.	
Knowledge Construction Modes	**Observed Team Interactions**
1. Sharing, comparing □ Not Observed	□ Making statements of observation or opinion □ Defining, describing, or identifying a problem □ Sharing information or intended actions □ Soliciting information from or asking questions to clarify details of statements
Observations:	
2. Exploring divergence, disagreement □ Not Observed	□ Identifying and discussing divergence of ideas, concepts, or statements □ Exploring areas of disagreement or differing perspectives □ Clarifying the source and extent of divergence disagreement
Observations:	
3. Building new knowledge together □ Not Observed	□ Identifying areas of agreement □ Building upon or modifying each other's ideas □ Evaluating, testing ideas or verifying joint understanding □ Resolving differences and creating a compromise to arrive at mutual understanding
Observations:	
4. Reaching agreement, applying/ acting on new knowledge □ Not Observed	□ Reaching agreement on jointly constructed knowledge and recommendations □ Applying jointly constructed knowledge □ Taking action to implement team recommendations
Observations:	
Team Feedback	
What learning behaviors should the team continue?	**What learning behaviors could the team improve upon?**

Internal structure validity

Inter-rater agreement for the presence or absence of behavioral modes and associated subcategories were sufficiently above chance and ranged from slight (i.e., Fleiss' kappa = 0.01-0.20) to fair (i.e., Fleiss' kappa = 0.21-0.40) for each video separately. For video 4, though there was total agreement across raters on the main behavioral modes, there was greater variability in the raters' observations of the behavioral subcategories. This resulted in the "slight" agreement when modes and subcategories were combined. Agreement was "fair" overall across videos (Landis & Koch, 1977) (See Table 2). The Fleiss' kappa for overall agreement for the holistic rating (i.e., Low, Medium, and High levels of KC) across all videos was "fair" (Fleiss' kappa = 0.26, $p < 0.001$).

Table 2: Inter-rater reliability estimates for KC modes and associated subcategories

Video	Fleiss' kappa	p
1	0.35	<0.001
2	0.21	<0.001
3	0.38	<0.001
4	0.12	<0.001
Overall	0.40	<0.001

Within the sample, there was a 95% agreement rate between the raters' scores and the expert consensus score across all videos and modes, which meets the 0.05 threshold for statistical significance.

The test of between raters' effects showed no significant difference in overall agreement between institutions ($F(1, 25)=0.62$, $p=.44$, $R^2=0.03$).

Feasibility and Utility

The thematic analysis of Pilot #2 raters' post-rating debriefs demonstrated that faculty raters found that application of the TOCK-IP was feasible. Raters were able to identify the four distinct knowledge construction modes as applied to learners interacting in the videos, even in the absence of training. Nearly all raters reported that TOCK-IP application required multiple views of the videos but grew progressively easier. Most faculty struggled to apply the holistic rating to the videos and a high degree of variability in raters' approaches were noted. Raters, almost universally, recommended the development of a brief training module that would allow raters to practice applying the tool and to calibrate their ratings with peers and experts, including more examples that demonstrate differences between behavioral modes, especially Modes 3 and 4.

In terms of the utility of the TOCK-IP, all faculty reported that they could either use the tool in their own teaching (including courses and clinical precepting) or they could imagine potential applications where the tool would be useful. The majority suggested that the tool could be applied and used for formative evaluation and for generating feedback in multiple settings and learner groups, including: all learner levels; inter- and intra-professional teams; and clinical as well as non-clinical settings. Many raters remarked that the constructive feedback prompts (i.e., team behaviors to continue and areas for improvement) were essential elements of the tool's utility and could provide an opportunity to provide feedback to the team regarding problematic, non-KC related behaviors. None of our faculty raters use tools in their clinical precepting, small group activities, or OSCEs that are focused on KC behaviors; and nearly all faculty recognized that the TOCK-IP fills a gap in the assessment of team-based learning behaviors.

The qualitative analysis also revealed that the majority of faculty had incorporated the language from the IAM framework (i.e., sharing and comparing, exploring divergence, knowledge construction, and coming to agreement) in their narrative feedback to learner teams, survey responses as well as in the debrief sessions.

DISCUSSION

We designed and developed a study to support validity evidence for a novel, theory-based observational tool – the TOCK-IP – to support the formative assessment of knowledge construction behaviors in the context of clinical IPE and IPCP. The tool content, based on Gunawardena's model of knowledge construction (Gunawardena et al. 1997), includes well-delineated learning behavior modes and associated subcategories. Response process evidence was obtained through a rigorous, multi-step faculty evaluation process. Evidence for reliability includes fair agreement overall across faculty raters and videos. A high degree of agreement was observed between faculty and the expert consensus ratings. All faculty raters endorsed the tool's utility and found the application feasible, though development of rater training was a universal recommendation. Preliminary validity and reliability evidence supports the use of this tool by educators in the formative assessment of learner teams' interactive knowledge construction behaviors (Messick, 1989; Downing & Yudkowsky, 2003; Cook & Beckman, 2006).

The TOCK-IP focuses on knowledge construction behaviors at the whole-team level, rather than at the individual level as in the iTOFT (Thistlethwaite et al., 2016) and the ICAR (Curran et al., 2011). Another contrast to these instruments is that the TOCK-IP is focused on the single domain of interactive, collaborative learning whereas the iTOFT and ICAR are intended to support the assessment of multiple teamwork behaviors. While the iTOFT includes behavioral descriptors related to the learner's contribution to team knowledge construction (e.g., shares information, builds on another's ideas), these constructive behaviors are often combined with several other non-constructive behaviors (e.g., student is polite). Combined descriptors may make assessment of those processes purely related to knowledge construction more difficult. The TOCK-IP, in contrast, focuses solely on discrete, observable, team-level constructive behaviors and avoids potential response bias from double-barreled descriptors (Wetzel, et al. 2016). Though the ICAR, unlike in the iTOFT, includes relatively discrete descriptors related to the learner's contribution to team knowledge construction (e.g., integrates information and perspectives, shares information with other providers), it is a complex rubric including six domains of teamwork behaviors that raters assign a grade of either not observable, or a subjective rating ranging from minimal to mastery. With the removal of the subjective holistic rating question from the final TOCK-IP, we have further simplified the single-domain tool and avoided this potential source of response bias (Moore, 2018).

As evidenced by the literature review and faculty feedback from our study, the TOCK-IP fills a recognized gap in assessment strategies for IPE. As highlighted by the 2019 National Academies of Practice State of the Science whitepaper (National Academies of Science, 2019), assessment of collaborative behavior and collective decision-making competencies in the context of clinical performance is a critical goal. With its focus on specific, observable, delineated team knowledge construction behaviors, the TOCK-IP is intended to focus the learners' attention on collaborative learning and collective decision-making. Given this focus, the TOCK-IP would not be appropriate as a stand-alone assessment but may comprise one element in the combination of IP competency assessments as recommended by Rogers et al. (2017). As an example, the TOCK-IP might be included as a component of a workplace-based assessment portfolio (Chan et al., 2020). This tool offers faculty a progression roadmap to help learners move past parallel play (Olson et al., 2020), toward collaborative learning, and equips both learners and educators with a common framework and common language.

Limitations

This study has several limitations. The pilot study applying the tool to four videos was conducted with faculty members who had previously taught in IPE and may not be representative of faculty who have not done so. However, this is also a strength of the study since this is the faculty group that the form is designed to assist. The pilot was also conducted in a simulated setting, which may not be like real team meetings in the workplace. Alternatively, this created an opportunity for all raters to observe the same interactions so that we could study the reliability of the observations and congruence with expert observers.

Future research

Next steps in the instrument development process will include: 1) the development of a rater training module to enhance rater consistency (Downing & Yudowsky, 2009); 2) the evaluation of faculty as they apply the tool and provide targeted feedback to learners in actual clinical settings; and 3) an investigation of learner perceptions and impact. Such real-world application will provide an opportunity to generate evidence of external validity as well as an important opportunity to assess the impact of the feedback on learners' subsequent interactional behaviors and would begin to address consequential validity of the instrument.

CONCLUSION

The TOCK-IP is a novel, theory-based, observational tool for the formative assessment of interactive knowledge construction behaviors at the whole team level. Faculty raters found the tool feasible to use and advocated for its use in observing and giving feedback on collaborative knowledge construction in multiple settings and learner groups. Preliminary validity evidence is promising, and reliability data support the tool's internal consistency. Based on our findings, further application of TOCK-IP is warranted.

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Declaration of interest

The authors report no known conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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Appendix A: TOCK-IP Backgrounder

Backgrounder –
Tool for Observing the Construction of Knowledge in Interprofessional Teams (TOCK-IP)

What –

The TOCK-IP is an observational tool designed to help educators identify and document **team-based knowledge construction** (building knowledge together) behaviors in learner teams during interprofessional activities and to provide a structure for communicating feedback to learners using a consistent framework and process.

Why –
This tool, by defining and categorizing specific aspects of collaborative, interactive learning behaviors, was designed to be useful for educators to formatively assess the quality of **team-based knowledge construction** at the whole-team level and support structured feedback to learner teams, providing both learners and educators with examples of common language to promote consistent feedback.

How –
Team-based knowledge construction is defined by 4 distinct phases of mental engagement, each associated with observable learning behaviors and progressively higher levels of learning. These four phases or "modes" can all be observed in social interactions: 1. Sharing/Comparing of information; 2. Exploring divergence, disagreement; 3. Building new knowledge together; 4. Reaching Agreement, applying/acting on new knowledge (See "Theory Box" at the end of this document for description of the research supporting this approach).

Examples –
Here are three brief dialogue exchanges within an interprofessional team of learners – from pharmacy, medicine, and physical therapy (PT) – as they construct a clinical note for a patient who has experienced a recent fall. The **team-based knowledge construction** modes have been coded to provide an example and to emphasize that this is not necessarily a sequential process nor is it necessary for every mode to occur.

Exchange #1

> *The pharmacy student says "Since we weren't able to get him out of bed during our exam this morning, I'd recommend that we (include in the note that we) need to reassess whether or not the patient can or can't get up by himself*. [Mode 1-Describing a problem; Stating opinion]

The PT student enthusiastically agrees, saying, "lack of assistance and the lack of access to help, was, I think likely a major contributing factor (to his fall)" [Mode 3-Buidling on each other's ideas]

The medical student says to her teammates, "I totally agree. Let's plan to reassess him tomorrow." [Mode 4-Reaching agreement on jointly constructed knowledge and recommendations]

Exchange #2

The PT student teaches his teammates about the components of the Morse Fall scale. [Mode 1-Sharing information]

The pharmacy student takes this new information, calculates their patient's score, then says, "so (he's) high risk (for falls)!" and PT says, "Yes, and I'm wondering why we get such a high score…?" [Mode 3-Buidling on each other's ideas]

The medical student says, "I got the same score!" [Mode 1-Sharing information; Mode 3-Verifying jointly constructed knowledge]

Exchange #3

The PT student says to her teammates, "It's really important that we emphasize (in our note) that patient's risk for falls at home are mostly due to his left-sided weakness." [Mode 1- Stating opinion]

The medical student disagrees, stating, "I don't know, I actually think that the most important risk factor for him is his heavy alcohol consumption combined with the opiates he's taking for pain." [Mode 2- Identifying and discussing divergence of ideas]

PT replies, "Yeah, you're right, I forgot about his meds interacting with the alcohol." [Mode 3-Indentifying areas of agreement]

The pharmacy student states, "It seems like both of these (risks) might be of equal importance as we consider his transition back to home." [Mode 3-Buidling on each other's ideas]

The PT and MD students nod in agreement and PT says, "Yes, let's definitely make sure that these (risks) are emphasized equally in the note so that home nursing is aware of these key issues!" [Mode 4-Reaching agreement and on jointly constructed knowledge; Implementing team recommendations]

Theory Box

Knowledge construction – a collaborative, interactive process by which learners within a group develop new understandings or knowledge of concepts by connecting new knowledge to their existing knowledge base – is a common goal of collaborative learning activities. During this learning process, both individual and collective knowledge is socially constructed and mediated (De Wever et al., 2008; Hmelo-Silver & Eberbach, 2012). The new understanding or knowledge that emerges from this process exceeds that which could have been developed by the individual.

In interprofessional clinical learning environments, knowledge – including not only facts and concepts but also information about group processes – can be shared by team members and built through collaborative interactions. Gunawardena et al. (1997) view knowledge construction as a collaborative process of negotiating meaning through social interaction.

Gunawardena et al. suggest that lower mental functions are associated with lower phases or modes of knowledge construction (i.e., Modes 1 and 2) and higher mental functions are associated with higher modes (i.e., Modes 3 and 4). All modes do not need to occur over the course of a group's interactions, they may occur in either sequential or non-sequential order (e.g., learners may move directly from Mode 1 to Mode 3 without exploring divergence of ideas [Mode 2] if none occurs), and different modes may be present at the same time. *[Note that our tool is based on a modification of Gunawardena's original five phase model.]*

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Appendix B: TOCK-IP rater instruction sheet

RATER INSTRUCTIONS: The TOCK-IP is intended to support the formative assessment of the learner team's knowledge construction behaviors – in a holistic fashion– as they interact together during a clinical learning encounter. Please consider the four modes of knowledge construction and their associated behaviors (see below for Definitions and Examples) as you observe the learners interacting.

During your observation, check *Observed Team Interactions* between team members as they occur the first time.

If a mode is observed, tick the *Observed* box and if not observed, tick the *Not Observed* box. It is not necessary to count each behavior. However, if you observe a learning behavior frequently, you may note this in the *Observations* field below each mode. Include noteworthy observations in the *Observations* section associated with the mode. These notes may help you to construct team feedback.

Immediately after the learning encounter, provide specific feedback to the learner team: Please include at least two specific points of feedback for the learner team in each box (i.e., positive behaviors to continue, areas to improve).

Modes of Knowledge Construction – Definitions In each phase or mode, individual learners in the team are:	**Exemplar Behaviors**
1. Sharing, comparing - Making statements of observation or opinion - Defining, describing, or identifying a problem - Sharing information (facts, relevant content knowledge, processes) or intended actions with teammates - Soliciting information; questioning a teammate to clarify details of statements or terminology *[Note: **Mode 1 is required as a precursor** of higher Modes]*	A team member puts forward their clinical recommendations to the team but does not engage in discussion or defense of these recommendations. One trainee says, "I think we should write up the patient interview before we tackle the physical exam." An individual trainee "thinks aloud," making thinking visible or engages in peer teaching.

2. Exploring divergence, disagreement - Identifying & discussing divergence of ideas, concepts or statements - Identifying & discussing disagreement with existing notions - Asking & answering questions to clarify source and extent of divergence of ideas/perspectives or disagreement *[Note: **Mode 2 is not required** as a precursor of higher Modes]*	Trainee puts forward their clinical recommendations to the team, but another teammate says, in response, "I think that you and I have a different way of looking at this issue." One trainee says to another, "Given the patient's fall risk, I have some concerns about your proposal to increase the pain meds."
3. Building new knowledge together, co-constructing - Identifying areas of agreement/ overlap among conflicting concepts - Building on each other's ideas or modifying ideas developed together - Evaluating, testing ideas or verifying joint understanding - Resolving differences and creating a compromise to arrive at mutual understanding *[Note: **Mode 3** must be **preceded by Mode 1**]*	Trainees work together at the whiteboard, negotiating and prioritizing the patient's problem list, collaborating and building on one another's ideas. A trainee asks another, "Based on physical findings and med review, do we think that over-sedation led to the fall?" One team member repeats or re-states a collaboratively-generated clinical recommendation for their patient. One trainee brings to light that their group-generated care plan was based on an outdated clinical guideline. Team re-evaluates the plan based on the new guidance.

4. Reaching agreement, applying/ acting on new knowledge - Reaching agreement on jointly constructed knowledge and recommendations - Applying jointly constructed knowledge - Taking action to implement team recommendations *[Note: **Mode 4** must be **preceded by Mode 3**]*	Trainees come to consensus and express explicit agreement on collaboratively generated clinical plan. PT says to MD, “Even though we initially disagreed on the primary contributor to the fall, I think that, after examining him, we agree that his gait disturbance is the main issue.”
Floren, L.C., Ten Cate, O., Irby, D. M., & O’Brien, B. C. (2020). An interaction analysis model to study knowledge construction in interprofessional education: proof of concept. *Journal of interprofessional care*, 1-8. [[*Note.* Adapted from “Analysis of a global online debate and the development of an interaction analysis model for examining social construction of knowledge in computer conferencing,” by C.N. Gunawardena, C.A. Lowe, and T. Anderson, 1997, *Journal of educational computing research*, *17*(4), p. 414. Copyright 1997 by Baywood Publishing Co., Inc.]].	

Chapter 6

Medical Residents' Informal Learning From Pharmacists in the Clinical Workplace: Affordances and Engagement

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ABSTRACT

Objective. This study sought to investigate the affordances residents use for informal learning about medications, their interactions with pharmacists, including variations by context and training year, and patterns of resident-pharmacist engagement.

Methods. We conducted a cross-sectional, online, 25-item survey study, including closed-format and open-response questions among current resident physicians (PGY1-6, from a variety of residency programs n=803) from the University of California San Francisco, the University of Minnesota, and the University Medical Center Utrecht.

Results. Responses from 173 residents in both countries revealed that these physician trainees were afforded opportunities to engage in a wide variety of pharmacotherapy-related activities but engaged differently with social and environmental resources for support. US residents utilized pharmacists and Up-To-Date, whereas Dutch residents preferentially utilized the online formulary and EHR-embedded medication resources. US residents interacted with and learned from pharmacists significantly more than Dutch residents. Pharmacists provided residents with a wide range of useful information, much of which is integrated into the Dutch EHR.

Conclusion. This study demonstrated that increasing opportunities for interprofessional interactions between medical residents and pharmacists and with on-line resources has the potential to positively impact the quality of residents' informal workplace learning.

INTRODUCTION

Most learning in postgraduate medical education happens informally in the clinical workspace. Such learning takes place in the context of everyday work activities, is generally unstructured, often tacit, and may be unplanned or intentional.[1-5] Despite considerable interest in residents' informal learning processes, gaps exist in our understanding of pharmacists' contributions to residents' learning in the clinical environment, especially beyond the early training years. Workplace-based interactions between residents and pharmacists, though relatively underexplored,[4] likely contribute substantially to learning.

Informal learning in the health professions is primarily experiential, occurring as trainees participate in clinical care. [6,7] According to Billett's workplace learning theory, learning and working are interdependent and the quality of learning is dependent on: 1) the affordances for learning – including opportunities for learners to participate in relevant workplace tasks and activities as well as access to the support and guidance of experts, co-workers, and resources; and 2) the learner's engagement with these affordances. [8-11] Informal learning in the clinical workplace is an important contributor to residents' competency development.[4,12]

Western medicine approaches rely heavily on pharmacotherapy with 66% of US adults and 66% of the Dutch population using prescription medications.[13,14] Resident physicians are expected to develop the knowledge-base and skillset required to plan, implement, and monitor pharmacotherapy-based treatments (i.e., Accreditation Council for Graduate Medical Education Core Competencies, CanMEDS Physician Competency Framework). Such learning occurs through formal and informal experiences with pharmacists, other physicians, and interaction with online medical information resources. Unfortunately, this learning process is not always sufficient, as evidenced by some practicing physicians' inadequate drug knowledge and inexperience, which contribute to preventable medication errors, a significant source of morbidity and mortality worldwide.[15] To examine how residents learn pharmacotherapy, we investigated the extent and impact of informal resident-pharmacist interactions in the clinical workplace.

This study aims to answer the following questions: What affordances do residents use for informal learning about medications? How frequently do residents informally interact with pharmacists? Do informal interactions vary as residents advance in training or by institutional or international contexts? How do residents and pharmacists engage with one another in the clinical workplace? And, how do residents perceive the impact of interactions with pharmacists on their learning?

METHODS

We conducted a cross-sectional, online, twenty-five-item survey study among residents at three institutions – two in the US and one in the Netherlands. The Institutional Review Boards of UCSF (#20-31758; Ref. #288894), UMN (#STUDY00010438), and the Netherlands Association of Medical Education Ethics Review Board (NERB Dossier #2020.6.4) approved the study.

Participants and contexts

We conducted this study among resident physicians of medical and surgical training programs at the University of California San Francisco (UCSF), the University of Minnesota (UMN), and the University Medical Center Utrecht (UMCU) in the Netherlands. While US residency training begins after a four-year undergraduate program, Dutch medical trainees complete six undergraduate years, then usually work for up to 3.5 years – often assisting in health care jobs, including prescribing medication – before starting residency.[16]

Survey development

Following established guidelines,[17] we conducted a literature search but found no existing survey related to informal, interprofessional workplace learning. Using Billett's workplace learning theory, focused on affordances and learner engagement constructs,[8-11] we drafted questionnaire items and gathered feedback from three physicians and two pharmacists with training in health professions education research. For expert validation, five panelists – medicine or pharmacy faculty members, from the United States, United Kingdom, the Netherlands, and Canada; and chosen for their expertise in workplace learning theory, interprofessional education, and pharmacology education – critically reviewed the draft survey to ensure that the constructs of interest were well-represented. Guided by panelist input, we modified the initial draft, producing an online survey including twenty-one closed-response and four open-response questions.

Next, five medical residents (n=2 UCSF, n=1 UMN; n=2 UMCU) completed a cognitive interview while answering survey items,[18] with post-interview discussion. We iteratively modified the survey to improve clarity and ensure adequate coverage of workplace learning constructs.

We piloted the survey with three medical residents (n=1, UCSF; n=2 UMN) and one clinical fellow (UMCU) to assess feasibility. Before distribution, we pilot tested the final survey with four residents (n=3 US; n=1, UMCU). The final survey was distributed via Qualtrics (Qualtrics, 2020).

Data collection and analysis

Data were collected in English during the fall of 2020, in the midst of COVID. The target group of respondents included current medical and surgical residents from UCSF, UMN, and UMCU. A link to the survey, including an explanation of the study purpose and informed consent statement, was distributed by email to 803 residents at three medical centers (UCSF, n= 251; UMN, n=117; and UMCU, n=435), which represent a variety of residents at their institutions (e.g., family and internal medicine, pediatrics, general surgery, OB/GYN programs, and smaller specialty programs). To maximize survey responses,[19] residents were sent periodic reminders until survey closure (November 15, 2020).

Most questions related to residents' experiences during the prior three months of training. Quantitative questions included either a Likert-type scale or a nominal response format. For each question, we determined response totals and associated percentages by postgraduate year (PGY) and institution. We performed Chi-square tests, looking for associations between the variable of interest, PGY, and institution. When data from the US institutions were not substantially different, US populations were combined for statistical analysis.

We analyzed open-response questions using directed qualitative content analysis.[20] The first author (LCF) developed a coding system. A second author (i.e., either ALP or IW) checked all response codes. Disputes were reconciled through discussion. Code counts for comparison across groups were performed using R,[21] and qualitative findings were summarized in narrative form.

RESULTS

Participants

Our study population included current resident physicians, PGY1-6, from UCSF, UMN, and UMCU ((n=803; including medical (e.g., internal medicine, peds, psych, etc.), OB/GYN and surgical residents at UCSF (n=251), UMN (n=117) and UMCU (n=435)). Between mid-October and mid-November 2020, 175 residents initiated the survey. After removing two respondents (1 UMCU pathology resident deemed unlikely to regularly interact with pharmacists and 1 UMN resident with unspecified specialty), statistical analyses were conducted on 173 respondents, yielding an overall response rate of 21.5%. This compares well with other online surveys of academics and health professionals[22,23] (See Table 1).

Table 1. Participant Training Year by Institution (n=173)

		Respondents N (%)	
PGY	**UCSF**	**UMN**	**UMCU**
1	14 (32.6)	26 (43.3)	7 (10)
2	17 (39.5)	17 (28.3)	7 (10)
3	11 (25.6)	9 (15)	18 (25.7)
4	-	6 (10)	15 (21.4)
5	1 (2.3)	1 (1.7)	13 (18.6)
6	-	1 (1.7)	10 (14.3)
Total	43	60	70

Abbreviations: PGY = Post-graduate year; UCSF = University of California San Francisco; UMN = University of Minnesota; UMCU = University Medical Center, Utrecht, the Netherlands.

Participating residency programs included:
UCSF: General Surgery and Internal Medicine
UMN: Dermatology, Family Medicine, General Surgery, OB/GYN, and Psychiatry
UMCU: Anesthesiology, Cardiology, Clinical Genetics, Clinical Geriatrics, CT Surgery, Dermatology, ENT, Gastroenterology, General Surgery, Internal Medicine, Medical Microbiology, Nuclear Medicine, Neurosurgery, Neurology, OB/GYN, Ophthalmology, Oral-maxillo-facial surgery, Orthopedics, Pediatrics, Plastics, Psychiatry, Pulmonary and Critical Care, Radiotherapy, Rheumatology, and Urology

During the three months before the survey, resident respondents worked inpatient (85.5%; n= 148 of 173), in ambulatory clinics (45.7%; n = 79), or both settings (32.4%; n = 56).

Affordances residents use for informal learning about medications

Residents reported (n=398 responses; n=251 US; n=147 Netherlands) learning about medications from various resources (See Table 2 for the top-ranked resources used by country and PGY). US residents learned about medications from Up-to-Date (n=66 of 251, 26.3%) and interactions with pharmacists (n=64, 25.5%), followed by senior residents or fellows (n=41, 16.3%). Dutch residents' resource use varied by PGY. Across PGYs, they learned about medications most often from EHR-embedded resources (n = 51 of 147, 34.7%); attendings (n=35, 23.8%) (i.e., PGY1, 3, and 4+ residents); and interactions with pharmacists (n=26, 17.7%).

Table 2. Top-ranked Resources Residents Used to Answer Medication Questions

		Top three resources ranked^					
	PGY	**Senior resident or fellow**	**Attending / staff physician**	**Pharmacist or pharmacy resident**	**Lexicomp or Micromedex (US residents)**	**Up-to-Date**	**Online medication resources (Dutch residents)**
US	**1**	1*		1*	3	2	
	2		3	2		1	
	3		3	2		1	
	4+		2*	1	3	2*	
Dutch	**1**	3*	2	3*			1
	2	2	3*	3*		3*	1
	3		2	3			1
	4+		2	3			1

^Residents chose their top three resources that they turned to most often for their questions about medications. Additional resource options not included in the table were: another peer resident; Google, and original publications. The three most commonly selected options, by country and by PGY, were assigned the ranks of "1," "2," or "3," as determined by the percentage of residents selecting the option in each PGY category (Note: percentages were calculated by dividing the number of residents selecting the option in each PGY category by the total number of residents in each PGY category).

*Rankings marked by an asterisk were split evenly based on the percentage of residents selecting this option.

Frequency of residents' informal interactions with pharmacists

Half of the residents (50.3%; n=87 of 173) indicated that a pharmacist was regularly present as a member of the clinical team in at least one clinical setting, though significantly more often in the US than in the Netherlands ($X^2 = 37.2$, $p = < 0.0001$). Nearly three-quarters of the respondents interacted with inpatient pharmacists at least weekly (n=102 of 139, 73.4%). In ambulatory care, resident-pharmacist interactions were relatively infrequent, with over two-thirds interacting less than once weekly (n=90 of 128, 70.3%).

Variations in residents' interactions with pharmacists

Though UCSF-based residents maintained at least weekly contact across training years, PGY1-2 residents at UMN and PGY1 residents at UMCU engaged in significantly more frequent interactions with inpatient pharmacists than did the more senior residents ($X^2 = 34.0$, $p = < 0.0001$). Dutch residents interacted significantly less often with inpatient pharmacists (i.e., ≤1x/week) than US-based residents ($X^2 = 68.6$, $p = < 0.0001$) (See Table 3).

Table 3. Residents Interacting with Inpatient Pharmacists ≥ Weekly by Institution, Specialty, and PGY

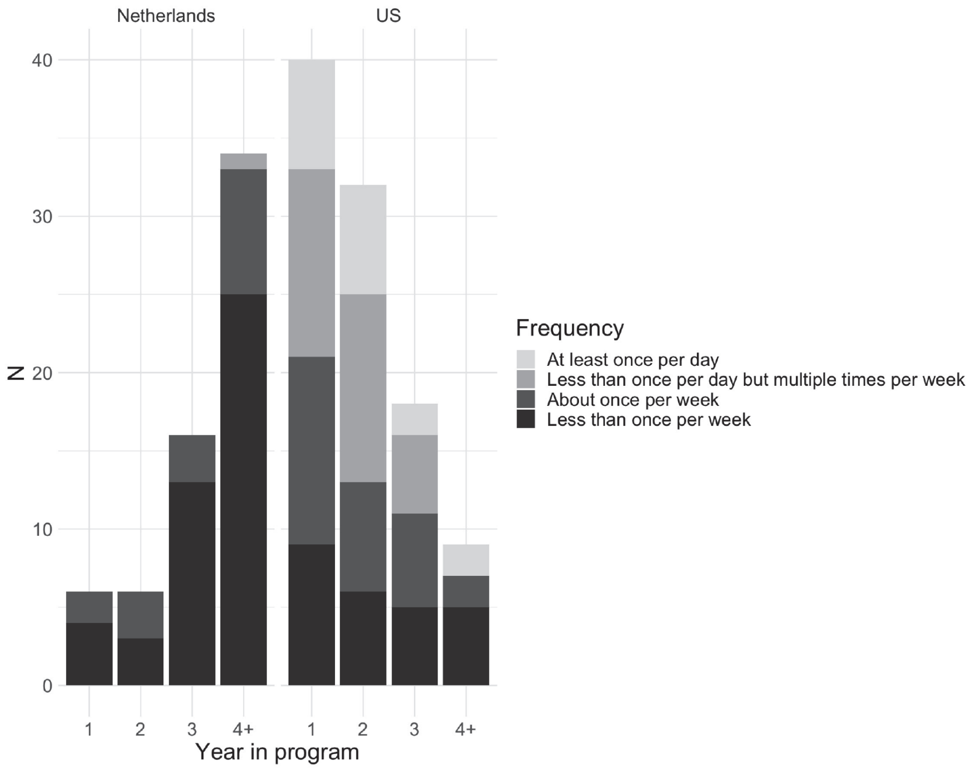
	PGY1	PGY2	PGY3	PGY4+
Institutions Total (n=102 of 139; 73.4%)				
UCSF (n=37 of 38; 97.4%)	92.9% (n=13 of 14)	100% (n=15 of 15)	100% (n=8 of 8)	100% (n=1 of 1)
UMN (n=47 of 53; 88.7%)	96.2% (n=25 of 26)	93.3% (n=14 of 15)	71.4% (n=5 of 7)	60% (n=3 of 5)
UMCU (n=18 of 48; 37.5%)	60% (n=3 of 5)	25% (n=1 of 4)	35.7% (n=5 of 14)	36% (n=9 of 25)

Abbreviations: PGY = Post-graduate year; UCSF = University of California San Francisco; UMN = University of Minnesota; UMCU = University Medical Center, Utrecht, the Netherlands.

Resident and pharmacist engagement

US-based residents, especially PGY1s and PGY2s, contacted pharmacists significantly more often than did Dutch residents (n=161 responses; n=62 Netherlands; n=99 US; $X^2 = 46.6$, $p = < 0.0001$). Nearly half of US residents (47.5%; n=47) contacted pharmacists at least multiple times per week, while 98.4% of Dutch respondents (n=61) reported contacting pharmacists ≤1x/week. From PGY 3-6, while US residents contacted pharmacists progressively less often, Dutch residents' contacts increased ($X^2 = 30$, $p = 0.0004$) (See Figure 1).

Figure 1: Frequency of Residents Contacting Pharmacists by PGY and Country



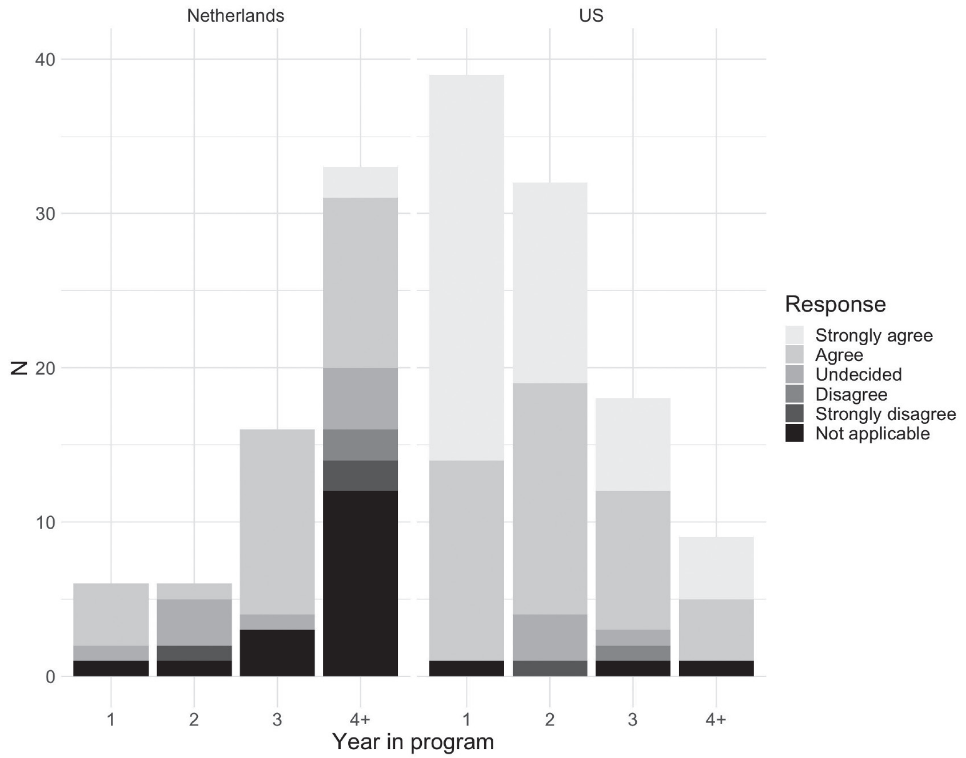
Across PGYs, the most common questions or issues for which US residents contacted a pharmacist were related to dosing (i.e., dose, administration rate, adjustment for organ failure); followed by selecting appropriate medications. Drug side effects and interactions as well as monitoring drug levels and PK issues were also common reasons for all but PGY4+ residents to contact pharmacists. Across training years, Dutch residents' most common questions were related equally to medication dosing, side effects and interactions; followed by drug-level monitoring and PK; and, lastly, drug availability. Eighteen residents (n=13 Netherlands; n=5 US) never contacted a pharmacist.

Pharmacists contacted US residents (n=99) significantly more often than Dutch residents (n=62) (X^2 = 75.1, $p < 0.0001$), from multiple times per week (n=27, 27.3% vs. n=1, 1.5% Netherlands) up to daily (n=17, 17.2% vs. 0% Netherlands) – especially in PGY1 and 2 (X^2 = 38, $p < 0.0001$). Dutch residents reported infrequent contacts from pharmacists (i.e., ≤1X/week; n=54, 87.1%). Pharmacists commonly contacted residents for questions related to medication or prescription errors and dosing; monitoring drug levels or PK issues; medication availability; drug regimen optimization; and medication selection. Twenty-three residents were never contacted (78.3% Netherlands; 21.7% US).

Perceived learning impact of pharmacist interactions

Significantly more US residents (n=89 of 98; 90.1%) strongly agreed or agreed that informal interactions with pharmacists contributed to their learning compared to Dutch residents (n=30 of 61; 49.2%) (X^2 = 52.0, p < 0.0001). US residents' reported learning from pharmacists was significantly associated with earlier training years (i.e., PGY1-3), independent of specialty (X^2 = 47.1, p < 0.0001) (See Figure 2). Most residents, independent of PGY, agreed or strongly agreed (n= 140 of 161, 86.9%) that pharmacists had taken the time to explain things to them.

Figure 2: Informal Interactions with Pharmacists Contributing to Learning by PGY and Country



Common ways that residents learned from pharmacists (n=293 responses; n=208 US; n=85 Netherlands), varied significantly by country (X^2 = 25.3, $p < 0.0001$) but was independent of PGY, included asking questions ((n=119, 40.6%)), caring for patients together ((n=63 (n=55 US and n=8 Netherlands), 21.5%)), and engaging in discussions ((n= 58 (n=44 US and n=14 Netherlands), 19.8%)). US-based PGY1-4 medicine residents frequently mentioned ward rounding – especially in the ICU – as a process by which they had learned from pharmacists. Dutch residents frequently mentioned didactics as a mechanism for learning from pharmacists. As one UMN resident explained:

> "Having a pharmacist on rounds in the ICU is extremely advantageous, and it allows us to get real-life clinical experience with various medications."
>
> [PGY 3, surgery, UMN]

Pharmacists provided a wide range of information that was useful for residents' learning needs. PGY1-2 trainees found information related to selection of new medications, dosing, medication errors, and optimization most useful for their learning. Residents in PGY4+ were more likely than PGY1-2 trainees to have found information about side effects, interactions, monitoring drug levels, and PK issues most useful. An open response question revealed a broad range of positive impacts that informal interactions with pharmacists had on residents' learning including: learning about medications, prescribing, patient care, evidence-based medicine, and drug safety issues.

The majority of resident respondents (n=35 of 39, 89.7% UCSF; n=48 of 60, 80.0% UMN; n=45 of 62, 72.6% UMCU) expressed that they would have liked to have had even more opportunities to learn from pharmacists during their training. Over two-thirds of residents (n=99 of 141; 70.2%) stated that having both easy and regular access to pharmacists (e.g., having opportunities to work with pharmacists on rounds) – could have led them to interact more often with pharmacists. As one resident described:

> "I wish we had a pharmacist on every inpatient team who rounds with us."
>
> [PGY3, medicine, UCSF]

DISCUSSION

Residents in both the US and the Netherlands were afforded opportunities to engage in a wide variety of activities related to pharmacotherapy, but interacted differently with pharmacists, other physicians, and online information resources for guidance and in support of those activities. US residents relied on pharmacists and Up-To-Date for medication-related questions, whereas Dutch residents preferentially relied on the EHR-embedded medication resources. US residents primarily interacted with and learned from pharmacists significantly more frequently than their Dutch counterparts, especially in the early years. Pharmacists provided a wide range of information useful for resident learning, much of which is available online in the Dutch EHR.

To help answer medication-related questions, US-based residents utilized pharmacists as medication information resources more often than Dutch residents. This difference in utilization of pharmacists is likely multi-factorial and impacted by greater accessibility of pharmacists in the US relative to the Netherlands; Dutch residents' pre-training practice experience; as well as the integration of key medication information and decision-support in the Dutch formulary and EHR.

Residents in both countries relied heavily on indirect support provided by online medication information resources. This finding reflects the growing imperative for evidence-based clinical decision making[24] and highlights the Dutch residents' ease of access to on-line formulary and EHR-embedded medication resources (i.e., drug interaction alerts; guideline-driven dose optimization) as an especially important affordance. Our findings parallel those of Chong and colleagues who found that most Australian junior doctors utilized online clinical resources heavily in their daily practice.[25] To support residents' learning, pharmacists might purposefully model how they integrate online resources in their own clinical decision-making processes.

One of the most salient, and to some extent surprising, findings was the difference in reported resident-pharmacist interaction frequency internationally. While most US residents interacted with pharmacists daily or weekly, Dutch residents interacted much less often with pharmacists. In the US, pharmacists were frequently present on the wards and participated in ward rounds, and informal interactions happened naturally. Rounding with pharmacists was an especially impactful affordance for US-based residents in our study, but rarely occurred in the Netherlands. At UMCU, like many teaching hospitals in the Netherlands, pharmacists are available on-call, attend multidisciplinary patient consultations, and provide therapeutic recommendations to physicians via the EHR.

Though Dutch residents highlighted formal didactics from pharmacists as important learning activities, informal, interaction with pharmacists is a less common affordance. We expect that integrating Dutch pharmacists in daily ward rounds would promote interaction and may improve residents' learning.[26,27]

A majority of residents across contexts reported that pharmacists took time to explain things to them and they wanted even more opportunities to learn from pharmacists. This comports with Noble and colleagues' finding that direct instruction and guidance, assistance in decision-making, and feedback from pharmacists were key affordances supporting residents' learning to prescribe.[28] Similarly, Tubb & Loesch reported that internal medicine residents who interacted with pharmacists in acute care rounds "always" wanted a pharmacist team member, appreciated pharmacists' recommendations, and felt that these interactions had improved their drug knowledge.[27] However, a small contingent of residents, mainly from the Netherlands, never contacted a pharmacist. Reasons for lack of engagement with pharmacists may include: lack of opportunity to interact; lack of awareness that pharmacists could be useful learning resources; or a workplace microculture that does not support resident-pharmacist interaction.[29,30] Residents in the current study suggested brief internships, ward rounds, presence in clinic as mechanisms to increase interactions with pharmacists.

While most studies related to pharmacist-physician interactions have focused on junior doctors' prescribing practices,[28,31-33] we characterize how residents across training years engage with pharmacists, formularies and EHRs during pharmacotherapy-related activities and how they value these interactions for learning. We have also provided an international context by exploring the impact of practice differences across countries and how these differences affect affordances. Our study has identified that pharmacists are an affordance for residents' learning in the clinical workplace that, in some cases, is not fully utilized and highlights the need to train current pharmacists as well as pharmacy learners to assume this important role as resident educators. Future research may focus on identifying interventions to enhance access to and utilization of pharmacists to optimally support residents' learning.

The primary limitations of our study were the limited access to some resident populations for recruitment at the US institutions as well as the low response rate at UCSF and UMCU. The low response rate creates the potential for bias (i.e., non-responder and responder bias) and limits the generalizability of our findings. However, we believe that the patterns of behavior reported by residents and our interpretations of them offer useful insights into workplace learning between pharmacists and residents. The reasons for the low response rates are most likely multifactorial and may include resident prioritization of clinical duties during the fall of 2020 with COVID-surges as well as survey fatigue.[34] Since we did not measure residents' pharmacotherapeutic knowledge and skills, any conclusions drawn about the direct effects of resident-pharmacist interactions on learning must be made cautiously.

CONCLUSION

Informal, interprofessional workplace learning occurs from residents' interactions with pharmacists. For some medical residents, pharmacists have been significant contributors to their development of pharmacotherapeutic knowledge. For Dutch residents, though interactions with pharmacists were more limited, the online formulary and EHR-embedded medication resources served as important affordances for their learning about medications. Intentionally designing residents' training to include opportunities for interactions with pharmacists, including pharmacist guidance on utilization of on-line resources for clinical decision-making, could positively impact the quality of residents' informal workplace learning.

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The authors LCF, ALP, IW, DI, and OtC declare that they have no competing interests.

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Chapter 7

Discussion

Preparing for interprofessional (IP) collaborative care, health professions (HP) learners from across the training spectrum must receive training to effectively collaborate with other learners and practitioners from outside of their discipline. Though HP training programs are increasingly incorporating team-oriented learning approaches[1-3] and clinical training experiences for learners,[4-7] the knowledge-building processes that occur through IP interactions, as well as factors that influence informal learning through IP interactions, have been relatively under-explored. As such, educators may not be optimally targeting training efforts to help learners achieve competency in interaction-dependent domains (e.g., collaborative decision-making, teamwork). Equipped with a broad understanding of learning through IP interaction, educators will be better prepared to design, implement, and evaluate interventions to support IP learning. The studies in this thesis focus on learning through interaction in the context of clinical education, grounded in the complementary theoretical perspectives of social constructivism, socio-culturalism, and organizational psychology.

The following summary of our research findings is organized around the four main research questions presented in Chapter 1:

1. How are shared mental models (a potential outcome of interactive knowledge construction) conceptualized, developed, and measured in clinical education?
2. Can a model of knowledge construction (KC) be used to characterize KC behaviors in different IP contexts (e.g., clinical simulation, care planning for real patients)?
3. Can a valid observational tool be developed to assess interactive KC during IP interactions?
4. How do IP interactions support KC and informal clinical workplace learning?

Chapters 2 through 6 addressed each of these research questions. This chapter summarizes key findings related to each research question, discusses the implications and recommendations related to research and practice, reviews the strengths and limitations of the body of work, and presents ideas for future research.

KEY FINDINGS

The conceptual model presented in Chapter 1 (**Figure 2**) has been amended (see **Figure 3** below) to include key findings from the studies conducted for this thesis. The following section will present key findings and high-level conclusions from each study.

Figure 3:

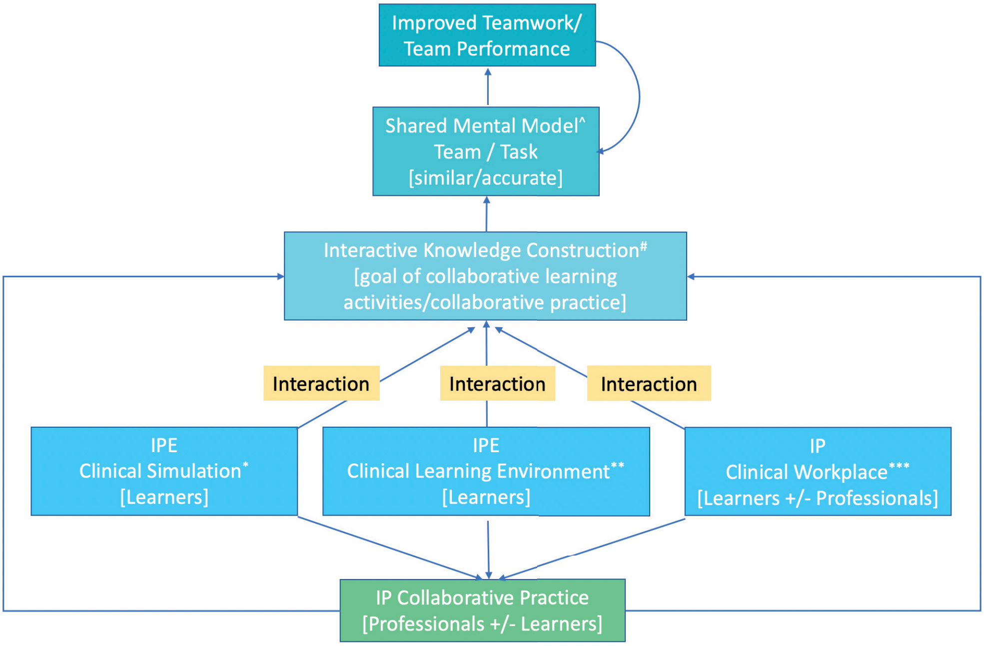

Figure 3 Legend: IAM = Interaction Analysis Model; IP = interprofessional; IPCP= interprofessional collaborative practice; IPE= interprofessional education; KC= knowledge construction. Solid arrows represent documented relationships, including: IPE has been shown to support IPCP;[8] SMMs have been shown to improve team performance.[9-12] KC behaviors documented in IP interactions in clinical simulation (Chapter 3*) and during structured activities in clinical elective (Chapter 4**). KC supportive processes (e.g., IP rounds) documented as a consequence of informal, IP interactions in the workplace, resulting in KC output (e.g., self-reported pharmacotherapeutic knowledge) (Chapter 6***).

^SMMs (Ch. 2): Key Findings
Multidimensional construct

- Cognitive representation including content + structure
- Domains: task + team factors
- Properties: similarity + accuracy
- Both antecedent and outcome of team interaction
- Foster improved teamwork, performance
- Measurement difficulties limit utility in HPE

*Interactive KC Behaviors in Clinical Simulation (Ch. 3): Key Findings

- Supported by dialogue prompts
- May be characterized in asynchronous dialogue using IAM
- Increased engagement, increased learning

**Interactive KC Behaviors in Clinical Elective (Ch. 4): Key Findings

- Simplified, 5-phase IAM supports characterization of KC behaviors during IP interactions in clinical learning environment

#Observational Tool Based on Further Simplified IAM (Ch. 5): Key Findings

- Simplified, 4-phase IAM supports assessment of KC behaviors during IP interactions in simulated clinical encounters

***Interactive KC in Clinical Workplace (Ch. 6): Key Findings

- Opportunities for IP interaction support informal learning
- Learner engagement required

Shared Mental Models in Clinical Education

Given the relationship between developing shared understandings with teammates and team performance,[9-11,13,14] we explored the shared mental model (SMM) construct as a potential educational target for improving teamwork in HP learners. In Chapter 2, we present the results of a scoping review in which we analyzed the use and application of the SMM construct as applied to clinical teamwork involving HP learners. We found that the SMM construct – complex and multidimensional – lacked a clear definition in the context of HP education. Both educational interventions to support SMMs and attempts to measure the construct were rare. Interventions included teamwork curricula, trainings, and teamwork supportive tools.

To bring conceptual clarity to the HPE and research communities and to HP learners, we proposed a precise definition of SMMs in the context of clinical practice. Based on its complexity, coupled with challenges inherent in measuring cognitive representations such as SMMs, we determined that the SMM construct may be of limited use to the HPE and research communities. These limitations led us to explore other theoretical frameworks for describing, supporting, and evaluating learning through interaction.

Use of the Interaction Analysis Model to Characterize and Support Knowledge Construction in Clinical Education

After a thorough investigation of various models of interactive learning behaviors, we selected KC as a more suitable framework to guide and analyze learning through IP interaction and collaboration. Our investigations build on Gunawardena's KC framework, the Interaction Analysis Model (IAM).[15] The original IAM consists of five primary phases of KC each representing a progressively higher-level learning process and increased mental engagement. Each primary phase is associated with three to five subphases (See Chapter 4, Table 1).[15]

Application of IAM to Characterize and Support Knowledge Construction in Interprofessional Clinical Simulation

Since the IAM had been shown to enable characterization of learning behaviors observed through dialogic interaction in asynchronous learning environments,[15] we decided first to investigate this construct in a similar context – an asynchronous, IP learning module. In Chapter 3, we present the results of an experimental study to investigate how learners within IP teams construct knowledge as they worked together virtually and asynchronously to develop collaborative care plans. We applied the five primary IAM phases (Phase 1 – sharing and comparing; Phase 2– exploration of dissonance; Phase 3 – knowledge co-construction; Phase 4 – knowledge verification or testing; Phase 5 – summarization/ agreement; See Chapter 3, Table 1) to design dialogue scaffolds (i.e., both "high guidance (HG)" and "low guidance (LG)" prompts based on the IAM) and then to evaluate qualitatively the learning behaviors evident in the participants' dialogue. We found that HG pairs engaged in all levels of KC more often than LG pairs. However, guidance level did not differentially impact care plan scores. Our evaluation suggested that HG prompts supported interactive IP KC as learners collaborated on authentic, medication-focused problems. This study showed that HP educators might utilize the IAM to design and evaluate educational interventions to support KC in asynchronous learning contexts.

Application of IAM to Characterize Knowledge Construction in an Interprofessional Clinical Elective

Chapter 4 presents the results of our proof of concept study to determine the feasibility and utility of applying the IAM to evaluate learners' KC behaviors in the context of an IP clinical elective. We initially attempted to apply the original IAM (including all phases and subphases) and found it unwieldy. We next applied a simplified, five-phase IAM to analyze qualitatively transcripts of learner dialogue. This model enabled us to characterize all five primary phases of KC in these IP learner teams as they interacted during the clinical learning experience. KC was most frequently observed at the lowest level of interactivity, Phase 1 (sharing and comparing), but rarely at Phase 2 (exploration of dissonance). Phase 3 (knowledge co-construction) behaviors were often observed when learners were planning for patient interviews/exams or planning their collaborative care notes. While Phase 4 (knowledge verification or testing) behaviors were rarely observed, Phase 5 (summarization/ agreement) interactions were observed as team members explicitly agreed upon the team priorities for the patient and patient assessments.

Through the studies in Chapters 3 and 4, we demonstrated that the simplified, five-phase IAM was useful as a research tool to characterize learners' KC behaviors and generate valuable insights about the quality of these IP interactions for learning and collaboration. Qualitative analysis was feasible, though labor-intensive. We determined that an observational tool, based on the simplified IAM, would be more practical in the context of IPE. The decision to develop an observational tool is discussed in greater detail in the "Implications for Practice and Research" section.

Development of an Observational Tool to Assess Interactive Knowledge Construction

Chapter 5 describes the development of and preliminary validity evidence for a Tool for Observing Construction of Knowledge in Interprofessional teams (TOCK-IP). We developed a novel, theory-based observational tool to support the formative assessment of learner teams' interactive KC behaviors in the context of IP, clinical collaboration. The initial draft of the tool, based on Gunawardena's IAM,[15] was divided into five behavioral modes, corresponding directly to the IAM's five knowledge construction phases. Pre-pilot testing revealed that faculty had difficulty distinguishing behavioral Phases 3 (knowledge co-construction) and 4 (knowledge verification or testing) and we decided to simplify the tool by combining behavioral anchors and creating a single behavioral phase (called Mode 3, building new knowledge together). This modification was reviewed with the originator of the IAM who supported the decision (C.N. Gunawardena, personal communication, May 3, 2021). Faculty raters applied the simplified tool to four videos of simulated interactions between HP learners, found the tool feasible to use, and advocated for its use in observing and giving feedback on interactive KC in multiple settings and learner groups. Evidence for reliability includes fair agreement overall across faculty raters and videos. Preliminary validity evidence is encouraging, with excellent agreement (95%) for faculty raters' scores compared to an expert consensus rating. Our findings support the application of the tool for the formative assessment of team-level, interactive KC behaviors in the context of IP interaction. Our results suggest that educators may use the tool to guide learners toward collaborative learning. Based on our findings, we recommended the development of a rater training module and further application and validation of the TOCK-IP in clinical settings.

Role of Interprofessional Interaction in Supporting Knowledge Construction and Informal Learning in the Clinical Workplace

Given our interest in expanding what is known about learning through IP interaction across the training spectrum, Chapter 6 investigated learning through informal, IP interactions between resident physicians and pharmacists in clinical workplaces in the United States and in the Netherlands. We explored the affordances for residents' learning about pharmacotherapy, focusing on interactions with pharmacists and learner engagement with these affordances. This study revealed that interactions with pharmacists in the workplace – afforded frequently to US-based residents, but infrequently to the Dutch – overwhelmingly determined residents' sense and appreciation of IP learning. IP rounding with pharmacists was an impactful affordance for US residents' learning. Though all residents relied on online medication information resources, the online formulary and EHR-embedded medication resources were especially important affordances for Dutch residents' learning about medications. The most common barrier to residents' informal learning from pharmacists observed in our study was the lack of opportunity to interact. This study highlights the importance of IP interaction as an affordance that supports residents' KC in the clinical environment. Increasing opportunities for IP interactions between medical residents and pharmacists may positively impact the quality of residents' informal workplace learning.

IMPLICATIONS FOR PRACTICE AND RESEARCH

Our research reveals valuable information about learning through interaction in clinical education. The thesis studies highlight the complexity of the SMM construct and its role in supporting teamwork; chronicle the development of a simplified version of Gunawardena's IAM and demonstrate its utility to support, characterize, and assess KC in various IP clinical education contexts; and affirm the importance of IP interaction in informal learning in the clinical workplace. Next, we discuss the implications of our key findings as they relate to educational research and practice.

Shared Mental Model Construct Utility as a Conceptual Framework in Health Professions Education

Since SMMs are positively related to team performance and are needed for IPCP,[14,16] learners should learn what SMMs are, how they are developed, and their role in supporting teamwork.

To promote consistent usage of the term *shared mental models* and highlight the complexity of this construct for learners, educators may use our definition of SMMs in healthcare (see Chapter 2). This definition of *shared mental models* makes explicit the multidimensional nature of this cognitive construct. There is evidence in the literature that some HP educators have employed our definition.[14,17-19] We hope that greater uptake of this definition in the HPE community will provide HP educators and learners with a common language to discuss the construct and help establish a common understanding, or SMM, of SMMs in the context of clinical teamwork.

Our review (Chapter 2) revealed a lack of consensus regarding SMM measurement approaches and a lack of robust outcome measures for SMMs, which has significantly impeded empirical research related to SMMs in the dynamic health care environment[20] and limits broad applicability of the construct in HPE. However, we recommend that educators use the construct as a conceptual framework to design cognitive tools[21] and experiential learning interventions to support learners' development of SMMs. Additionally, providing opportunities for learners to actively participate in processes such as IP team huddles and post-rounding team debriefs in the clinical workplace are expected to support their SMM development.[22] HP educators may also consider IP team training approaches – such as Liaw et al.'s (2019)[14] recently proposed virtual simulations – to foster SMM development and improve IPCP.

For educators and researchers wishing to evaluate the impact of these interventions, the most straightforward approach would be to measure outcomes that are expected to be influenced by the development of SMMs (e.g., team members' adherence to the processes delineated in a structured communication tool). To measure the SMM construct directly, researchers may consider the survey approach taken by McComb et al. (2014).[23] One limitation of this approach is that it measures only SMM content, and an additional measurement would be needed to capture the underlying SMM structure.

Successful efforts to raise learners' awareness of the critical role of SMMs in teamwork and to provide opportunities for the deliberate practice of SMM development, from the earliest days of their training, should foster early development of teamwork competencies.[23] Training HP learners and practitioners alike to recognize the complexity of SMMs, will better equip them to modify and align their mental models with those of the other members of the care team to develop a SMM related to patient care.

Utility of Simplified Interaction Analysis Model for Characterization, Support, and Assessment of Knowledge Construction Behaviors

Before discussing the implications of applying the IAM in clinical education, we briefly review the sequential modifications of the IAM across the studies presented in Chapters 3, 4, and 5.

In Chapter 3, we found that the five primary phases of the IAM provided a natural and effective scaffold for designing dialogue prompts intended to promote higher-level, interactive KC and allowed us to characterize learning behaviors in text-based dialogue. Since the IAM had not yet been applied to IP learner interactions in real clinical contexts, we initially included all five phases and twenty-one sub-phases of the IAM in our coding scheme in our proof of concept study (Chapter 4).[15] Given the volume of field notes, this scheme was cumbersome and more detailed than necessary. Once again, we modified the coding scheme to include only the five primary phases of KC. This modification yielded a simplified, five-phase IAM framework for observing KC in action that maintained fidelity to the original IAM but was feasible and sufficiently fine-grained for our research purposes. Several other research groups have independently arrived at this same modification in the context of computer-supported collaborative learning,.[24-27]

The simplified, five-phase model had proved useful as a design framework for HPE (Chapter 3) and for a research tool to characterize learners' KC behaviors (Chapters 3 and 4). However, the resource and time intensity of the qualitative data analyses led us to think critically about the utility and applicability of the IAM in the context of HPE. Ultimately, we recommended developing a practical observational tool that could be applied by HP educators to evaluate learner interactions in real-time and provide feedback to the learner team (Chapter 5).

For the IAM-based observational tool (TOCK-IP, Chapter 5), we based the initial draft on Gunawardena's five-phase IAM. During pre-pilot testing, when faculty raters had difficulty distinguishing behaviors in Phases 3 (knowledge co-construction) and 4 (knowledge verification or testing), we considered merging the two phases. We determined that verification and testing behaviors (associated with Phase 4) could be conceptualized as an extension of the co-construction process occurring in Phase 3 (knowledge co-construction). We also considered Lucas' (2014) assertion that the "[the IAM's] higher levels of thinking need to be reconsidered and possibly merged into one unique phase."[28] We concluded that these phases could be combined into a single behavioral mode (Mode 3) described as "building new knowledge together," for behavioral evaluation. With this merging, we created a further simplified, four-phase IAM, and this model formed the basis of the TOCK-IP observational tool (see Chapter 5).

Though further testing and validation are needed, as well as the development of rater training (see "Future Research" section), we expect that the TOCK-IP will support the formative assessment of KC in learner teams in educational settings where collaboration is expected to take place (e.g., team-based learning activities, clinical simulations, and the clinical workplace). The tool should allow educators to assess the levels of team-based KC achieved during a learning activity or, perhaps, longitudinally across several activities in sequence. Educators will be able to provide feedback to the team, highlighting strengths and weaknesses related to specific learning objectives. Such assessment and feedback are critical to promote learning progression,[29] growth, and change.[30] Our tool is not intended as a standalone assessment. Since Rogers et al. (2017)[31] recommended to assess learners at both the individual and team level, we suggest combining TOCK-IP with an individual assessment (such as the I-TOFT).[32] The combined assessment should provide a better indicator of the learner's competency across several IP competency domains.

Also, we envision clinical facilitators using the tool as a behavioral roadmap for learners, encouraging them to explore the range of KC behaviors and to reach higher levels of engagement by sharing their ideas, making their thinking visible; expressing and discussing divergent opinions or counter-arguments; negotiating solutions to clinical problems; and, then summarizing agreements across the group.[28]

Based on our findings reported in Chapter 5, we suggest that the four-phase IAM (as delineated in the TOCK-IP (Chapter 5)) could be used as an educational research tool but must be tested and validated for use in clinical contexts. We expect that coding learner dialogue will remain a labor-intensive endeavor as long as coding is completed by hand. However, based on research from D'Angelo et al. (2020),[33] advances in automated audio transcription, combined with automated coding algorithms, will significantly enhance the efficiency of coding for researchers and may enable coding in real-time.

Opportunities for Interprofessional Interaction Important for Informal Clinical Workplace Learning

Our study comparing workplace affordances and resident engagement with pharmacists within different healthcare systems provides unique insights into how we may promote informal learning in the clinical workplace by enhancing opportunities for IP interaction and KC. For example, educators may intentionally design supportive workplace learning environments to increase residents' opportunities to learn from informal, IP interactions. Affordances designed to increase access to experts may include readily implementable interventions such as arranging for residents to shadow or request clinical consults from non-medical colleagues.[34-36] Educators may also create opportunities for daily interaction such as IP team meetings, huddles, ward rounds,[37] and handoffs to further engage learners in IPCP.[38,39] Casual interactions in commonly shared spaces[34,35] may also provide opportunities for informal workplace learning and engender collegiality among health professionals from different disciplines.[40] Systems-level changes – such as re-evaluating the structure of medical teams to incorporate non-medical colleagues as regular contributors to patient care[41] – may also be warranted.

To promote residents' engagement with opportunities for IP interaction, based on Hager et al. (2018),[42] we recommend that educators start each new clinical rotation by orienting residents to the roles and responsibilities of key non-physician team members. Learner engagement may also be enhanced by purposefully including non-physician clinicians as residents' educational team members. Valuing the roles of IP colleagues in supporting physician trainees' development as competent professionals,[41,43] making these clinicians' roles as educators explicit[41] – as well as preparing them for and including them in resident assessment[43] – may serve as a potent promoter of learner engagement. Early in residency training, coupling interprofessionally-focused clinical rotations with formal educational programs, such as a pharmacist-led effort to reduce medication errors,[44] may support IP learning. Positive formal learning experiences from non-physician colleagues may generate a positive feedback loop where residents seek these clinicians out as resources for informal learning.

Task Conflict – an Opportunity to Reframe Dissonance in Interprofessional Education and Practice

We expect the TOCK-IP, if adopted by HP training programs, to provide HP learners and clinical educators with a common framework of interactive learning behaviors. The framework provides a common language, allowing learners and educators to discuss all phases of interactive KC and recognize the progression of behaviors associated with increased levels of mental engagement and higher-quality learning. Importantly, educators may use the TOCK-IP and four-phase IAM to make explicit connections between the exploration of dissonance (i.e., behavior associated with Phase 2 of the four-phase IAM), higher-level learning, and the positive correlation between task conflict and team performance.[45] Educators may use the TOCK-IP framework to reframe dissonance and task conflict for learners, actively encouraging learners to respectfully contribute dissenting opinions to IP team deliberations –and, potentially, to intra-professional team interactions[46]– rather than treating dissonance as a behavior to be avoided for the sake of team cohesion. Educators must create a psychologically supportive environment for learners to engage in such behaviors without fear of reprisal.[47] Normalization of such behaviors in the context of IPCP may: positively influence IP team dynamics by allowing members to express their opinions (even when going "against the grain"); provide a mechanism to minimize "groupthink" associated with team SMMs;[48] contribute to flattening the hierarchical structure in the local team environment;[49]and promote innovation.[50]

STRENGTHS AND LIMITATIONS

One of the strengths of this thesis lies in our use of well-established theoretical frameworks and constructs from both the learning sciences and organizational psychology to inform our studies. Our interest in improving IP learning as a mechanism to improve IPCP led us to investigate the construct of SMMs which are prominent in the team sciences literature. Our research on interactive KC relied on Gunawardena's IAM,[15] derived from social constructivist learning theory. Finally, the investigation of learning through IP interaction in the clinical workplace drew upon Billett's workplace learning theory,[51-54] derived from sociocultural learning theory. Approaching these investigations from multiple, complementary theoretical angles allowed us to examine the interconnections between these theories and constructs and to build a comprehensive conceptual model of the relationships between IP interactions and KC in the context of IPE (i.e., in simulations, structured clinical activities, and informal interactions in the clinical workplace) and IPCP; the development of SMMs as a potential product of interactive KC; and team performance (See **Figure 3** above).

The power of our conclusions is also enhanced by our application of rigorous methods of investigation following established research practices and guidelines. For example, we utilized Levac's guidance to conduct our scoping study (Chapter 2).[55,56] Developing our IAM-based observational tool (Chapter 5), we followed established guidelines for designing formative and observational assessments[29,30] and used Messick's unified validity framework[57] to guide the collection of validity evidence. Additionally, for the international survey study (Chapter 6), we employed Artino's guidance for the development of survey instruments.[58]

Perhaps the strongest aspect of the thesis research is that, through our sequential investigations (in Chapters 3, 4, and 5), we were able to modify and simplify an existing model of KC, the IAM.[15] Our simplified five-phase model supported the design of learning scaffolds and characterization of interactive KC behaviors in clinical education settings. Our formative assessment tool relies on a further simplified, four-phase IAM. With additional testing (see Future Research section below), the four-phase IAM may prove useful and practical for both IPE and HP research.

The principle limitations of this thesis research flow from the breadth of the investigations and the lack of terminal outcome measurements in most of our studies. Given the paucity of research related to interactive KC in IPE and IPCP, we conducted a broad investigation of learning through IP interaction. Collectively, our investigations focused on the inputs, processes, and outputs of KC; featured different levels of learners, from pre-licensure learners to graduates; and included a variety of different clinical educational environments. The breadth of the thesis research, coupled with the fact that studies in Chapters 3, 4, and 5 were pilot investigations, results in a thesis that could have delved more deeply into any one topic. Instead, the body of work focuses on the basic characteristics of multiple, related aspects of learning through interaction in clinical education. Though broad in scope, this body of work could be viewed positively as boundary-spanning and providing a solid basis for expanding areas of inquiry (see "Future Research" in the next section).

Another important limitation of the body of work is that, except for the study presented in Chapter 3, we did not empirically measure learning outcomes in our studies. For example, we did not measure the quality of the collaborative care plans that the learners developed in Chapter 4. In the international survey study (Chapter 6), we did not compare learning outcomes (i.e., residents' pharmacotherapeutic knowledge and skills) across institutions or international contexts. For that reason, we were unable to draw any conclusions about the direct effects of IP interactions on learning.

FUTURE RESEARCH

This thesis research encompasses several lines of investigation related to learning through IP interaction in clinical education. The findings provide a strong basis for future research related to the role of SMMs in IPE and IPCP; the applicability of our four-phase IAM for design and evaluation of educational interventions; the validity of the TOCK-IP in various clinical contexts; and the mechanisms to support informal, workplace learning through IP interactions.

Our scoping review of SMMs in HPE (Chapter 2) revealed difficulties in measuring SMMs (including instrument development and application) that we expect to substantially limit the number HPE and IPE investigations in which SMMs are directly measured. Alternatively, we suggest that educators may use the SMM construct to design educational interventions to improve team performance outcomes or enhance knowledge of teamwork principles, then evaluate the efficacy of those interventions to achieve specific outcomes.[59]

Additional questions related to SMMs that are of interest in IPE relate to the role of SMMs in IP healthcare teams practicing outside of acute care settings. Most SMM research focuses on teams functioning in high-intensity settings (e.g., trauma teams[11]). However, there has been little research investigating the role of SMMs in supporting team performance in lower-intensity settings, such as ambulatory care.[60] Identifying the SMMs most critical for optimal IP care delivery (including content domain(s) and the requisite degree of similarity) would enable the design of targeted IP team trainings to support team performance in various models of IP care delivery.

Though initial validity evidence for the TOCK-IP is promising, further development and validation of the instrument in clinical contexts is required. Based on unanimous feedback from our faculty raters and to improve rater consistency, the next development phase should include the design and testing of a rater training module.[29] For this initial pilot, we did not explore raters' feedback to the learner teams. However, since targeted feedback is a critical element of the formative assessment instrument, we intend to evaluate faculty as they apply the tool and provide feedback to learner teams in actual clinical settings. Finally, it will be essential to investigate the impact of the assessment on learners' interactional behaviors to evaluate the consequential validity of the tool.

Our research, focused on KC processes, has revealed several potentially fruitful areas for future investigation. Since the four-phase, simplified IAM has not yet been studied in learners in real clinical settings, the next steps should include application of the model in various clinical contexts, with IP teams of various compositions, and the collection of validity evidence related to these applications. We suggest that studying learners in various stages across the continuum of professional development may shed light on the model's utility to describe longitudinal changes in quality of interactions and knowledge construction. In addition, researchers might apply the four-phase IAM to compare learners' KC behaviors in different learning activities to determine which activities are more generative (i.e., which foster learner engagement, yield higher-level thinking) and, ideally, correlate these behaviors with actual knowledge production.

Lastly, our finding that pharmacists were an important affordance for some medical residents' learning in the clinical workplace (Chapter 6) suggests that these health care providers, and perhaps others (e.g., nurses, physical therapists, social workers), are not being fully utilized as clinical educators. This finding highlights the need to prepare both current pharmacists and pharmacy learners to take on this important role as resident educators and there are research questions around how best to accomplish this goal. We suggest that future investigations focus on identifying and evaluating educational interventions to enhance access to and utilization of healthcare team members from outside of medicine to effectively support residents' learning.

CONCLUSIONS

IP teams and IP collaboration are now integral to the delivery of high-quality, safe, and effective healthcare.[61,62] The goal of this thesis was to expand our understanding of learning through IP interaction in clinical education as a means of improving IPCP. To accomplish this goal, we relied on a combination of complementary theoretical frameworks and constructs to describe, support, and evaluate learning through interaction: SMMs, KC, and workplace learning. We discovered that the complexity of the SMM construct, in combination with myriad measurement issues related to the elucidation of these cognitive representations, limits the applicability of this construct in HPE. Searching for other frameworks based on observable interactive learning behaviors (rather than opaque cognitive structures) led us to the construct of KC and the Interaction Analysis Model.[15] Through a series of investigations, we established the relevance of the KC construct in clinical education. We simplified the IAM and found that this framework can be used to support, characterize, and assess interactive KC in the context of both IP clinical simulations and the IP interactions in clinical learning environments. Our investigation of resident learning in the clinical workplace demonstrated that IP interactions with pharmacists are an especially important affordance supporting KC in the clinical workplace. Together, this research has provided clarity around the important teamwork concept of SMMs; it has illuminated IP, constructive learning processes and generated a tool that may be used to assess these processes; and it has revealed that the quality of informal clinical workplace learning may be enhanced by creating more opportunities for IP interactions. Using the insights developed through this work, HP educators will be better equipped to design and evaluate interventions focused on building IP collaboration competencies, and learners will be better prepared for IPCP.

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Summary

The purpose of thesis is to broadly explore learning through interprofessional (IP) interaction in clinical education. The past two decades have witnessed tremendous growth in efforts to provide interprofessional education (IPE) to develop IP practice-ready clinicians. Ideally, training will equip these practitioners to collaborate with one another to care for increasingly complex patients and address a variety of urgent healthcare-related issues. To prepare learners, core IP learning and practice competencies have been defined and most health professions training programs deliver curricula intended to build their learners' collaborative practice knowledge and skills. Although high-quality healthcare delivery requires IP teamwork – including interaction, collaboration, and shared understanding of patient care – few programs design learning interventions with a focus on the interactive knowledge-building processes that underlie successful collaboration and team-based care. This thesis includes a range of investigations related to knowledge construction (KC) in IP interactions. The findings may be used to inform the design, implementation, and evaluation of interventions that support IP learning in a variety of clinical education settings and across the training continuum.

Chapter 1 provides an overview of IP clinical education and IP collaborative practice. The role of social interaction in learning and in the development of shared understandings or shared mental models (SMMs) is also discussed. Definitions of IPE, IP collaborative practice, IP learning, SMMs and KC are provided in an attempt to provide conceptual clarity at the outset of the thesis. Next, to provide context for the thesis research, the origins of IPE and IP clinical practice are discussed and current trends that are fuelling the growth of IPE efforts are highlighted. Given that the primary goal of IPE is to provide learners with the knowledge and training to work collaboratively, make team-based decisions, and identify and achieve patient care goals, complementary theories and frameworks related to team cognition and social learning are presented. A review of the literature regarding team effectiveness, shared understandings, and learning through IP interaction is presented to identify gaps in understanding and unanswered questions. The following research questions form the basis of our inquiry: How are shared mental models conceptualized, developed, and measured in clinical education? Can a model of KC – the Interaction Analysis Model – be used to characterize KC behaviors in different IP contexts? Can an observational tool be developed to assess interactive KC during IP interactions? How do IP interactions support KC and informal clinical workplace learning?

Chapter 2 addresses the research question 'How are shared mental models conceptualized, developed, and measured in clinical education?' To answer this question, the authors conducted a scoping review to explore the SMM construct as applied to clinical teamwork involving HP learners. The literature review revealed that the SMM construct is complex, multidimensional, and lacking a clear definition. The majority of articles included physicians at the graduate level and were focused on clinical teams. Educational interventions to support SMMs and attempts to measure the construct were rare in HPE. The authors proposed an operational definition of SMMs in health care (*an individually held, organized, cognitive representation of task-related knowledge and/or team related knowledge that is held in common among health care providers who must interact as a team in pursuit of common objectives for patient care)*. Though development, implementation, and assessment of interventions intended to foster SMMs are presented, the authors suggest that measurement issues limit the applicability of the construct in HPE.

Chapter 3 addresses the research question 'Can a model of KC – the Interaction Analysis Model (IAM) – be used to characterize KC behaviors in different IP contexts?' and focuses on the application of the IAM to an asynchronous, IP learning module. The authors developed a learning module focused on medication management and designed dialogue prompts to support KC using the five primary phases of the IAM. Pharmacy-medicine learner pairs were randomized to receive either high- or low-KC guidance prompts and their text-based dialogue was coded for KC level using directed content analysis. The impact of the dialogue prompts on learners' KC behaviors and care plan quality were assessed. High-guidance pairs engaged in all levels of KC more often than low-guidance pairs, but the guidance level did not differentially impact care plan quality. Application of the simplified IAM revealed valuable insights about the quality of IP interactions during the asynchronous learning module. This study showed that educators may utilize the simplified IAM framework to both design and evaluate educational interventions for asynchronous learning.

Chapter 4 also addresses the research question 'Can a model of KC – the Interaction Analysis Model (IAM) – be used to characterize KC behaviors in different IP contexts?' In this proof-of-concept study, the authors extend the focus of the IAM application to learners in an IP clinical elective. They explore the feasibility and utility of applying the IAM to transcripts of care planning discussions to evaluate the KC processes of IP learner teams in clinical placements. After initially applying the original five-phase IAM (including all sub-phases) to characterize learner interactions, the authors simplified the model for practical purposes. Application of the five-phase IAM to code learner dialogue was feasible, though labor-intensive, suggesting greater utility as a research tool to characterize learners' knowledge construction behaviors. The authors suggest that the simplified framework may be useful guide the design of clinical placements and as a research tool to analyze IP learning behaviors. For practical application in the context of HPE, the authors recommend the development of an IAM-based observational tool.

Chapter 5 addresses the research question 'Can an observational tool be developed to assess interactive KC during IP interactions?' Following literature review and needs assessment, the authors developed and collected validity evidence for a novel, theory-based observational tool (TOCK-IP) to support the formative assessment of interactive KC behaviors between health professions learners. The initial draft of the tool was based upon Gunawardena's five-phase IAM; however, based on pre-pilot feedback from faculty raters, the tool was further simplified to four-phases. Faculty raters applied the tool to videos of simulated interactions between learners from different professions. Raters were able to identify the four distinct knowledge construction modes even in the absence of training. Evaluation of the tool yielded validity evidence that indicated inter-rater reliability and congruence with expert ratings as well as support for its use in practice. This evidence supports the use of the TOCK-IP by educators in the formative assessment of learner teams' interactive KC behaviors and suggests that further development of the tool is warranted.

Chapter 6 addresses the research question 'How do IP interactions support KC and informal clinical workplace learning?' To answer this question, the authors developed and administered an international, cross-sectional, online survey to medical residents at three institutions – two in the US and one in the Netherlands – to explore how interactions with pharmacists support residents' KC and informal clinical workplace learning. The survey revealed that US-based residents relied on pharmacists and Up-To-Date to answer medication-related questions, whereas Dutch residents preferentially utilized the online formulary and EHR-embedded medication resources. US residents, especially in their early years of training, interacted with and learned from pharmacists significantly more than Dutch residents. Pharmacists provided residents with a wide range of useful information, much of which is integrated into the Dutch EHR. Opportunities to interact with pharmacists in the workplace were afforded frequently to US-based residents, but infrequently to the Dutch. These affordances overwhelmingly determined residents' perceptions of IP learning and the value that they placed on IP learning. This study demonstrated that increasing opportunities for interprofessional interactions between medical residents and pharmacists has the potential to positively impact the quality of residents' informal workplace learning.

Chapter 7 provides a summary of the key findings regarding learning through IP interaction in the context of clinical education. The implications of the thesis research for both IP education and research are presented. Both the strengths and limitations of this body of research are discussed as well as future directions for research. The authors demonstrate the utility of a simplified version of the IAM for support and analysis of learners' KC behaviors and provide validity evidence for a tool based on the IAM that can be used to give learners formative feedback on their IP interactions. In doing so, their work establishes the utility of the KC construct in IP clinical education. The research also highlights the importance of IP interaction in informal clinical workplace leaning. The body of research from this thesis advances our understanding of how to design and evaluate IP interventions to better support the interactive KC processes required for IP collaboration in practice.

Samenvatting

Het doel van dit proefschrift is om leren in het klinisch onderwijs, door middel van interprofessionele (IP) interactie, breed te onderzoeken. De afgelopen twee decennia is er een enorme groei geweest in de inzet van interprofessioneel onderwijs (*interprofessional education* of IPE) om clinici beter op te leiden voor interprofessionele interactie. Idealiter rust dit behandelaars toe om samen te werken voor steeds complexere patiënten met een verscheidenheid aan urgente zorggerelateerde problemen. Om studenten voor te bereiden, zijn kerncompetenties voor leren en oefenen op het gebied van IP gedefinieerd en de meeste trainingsprogramma's voor gezondheidszorgberoepen bieden curricula die bedoeld zijn om de kennis en vaardigheden op het gebied van gezamenlijke praktijkvoering op te bouwen. Hoewel hoogwaardige zorgverlening IP-teamwerk vereist - inclusief interactie, samenwerking en gedeeld begrip van patiëntenzorg - ontwerpen nog maar weinig programma's leerinterventies met een focus op de interactieve kennisopbouw dat ten grondslag ligt aan succesvolle samenwerking en teamgebaseerde zorg. Dit proefschrift omvat een reeks onderzoeken met betrekking tot kennisconstructie (KC) in IP-interacties. De bevindingen kunnen worden gebruikt voor het ontwerpen, implementeren en evalueren van interventies die IP-leren ondersteunen in verschillende klinische onderwijsomgevingen en in het hele opleidingscontinuüm.

Hoofdstuk 1 geeft een overzicht van IP in het klinisch onderwijs en in samenwerking in de zorgpraktijk. De rol van sociale interactie bij het leren en bij de ontwikkeling van gedeelde inzichten of gedeelde mentale modellen (*shared mental models* of SMM's) word besproken. Definities worden gegeven van IPE, IP-*collaborative practice*, IP-leren, SMM's en KC, in een poging om conceptuele duidelijkheid te verschaffen aan het begin van het proefschrift. Vervolgens worden, om context te bieden voor het proefschriftonderzoek, de oorsprong van IPE en IP-klinische praktijk besproken en worden huidige trends die de groei van IPE-inspanningen voeden belicht. Omdat het primaire doel van IPE is om studenten kennis en training te geven in samenwerken, teambeslissingen nemen en doelen voor patiëntenzorg identificeren en bereiken, worden complementaire theorieën en kaders met betrekking tot teamcognitie en sociaal leren zijn gepresenteerd. Een overzicht van de literatuur over teameffectiviteit, gedeelde inzichten en leren door middel van IP-interactie wordt gepresenteerd om hiaten in het begrip en onbeantwoorde onderzoeksvragen te identificeren. De volgende onderzoeksvragen vormen de basis van ons onderzoek: Hoe worden *shared mental models* geconceptualiseerd, ontwikkeld en gemeten in klinisch onderwijs? Kan een model van kennisconstructie (KC) - het *Interaction Analysis Model* - worden gebruikt om KC-gedrag in verschillende IP-contexten te karakteriseren? Kan een observatietool worden ontwikkeld om interactieve kennisconstructie tijdens IP interacties te beoordelen? Hoe ondersteunen IP-interacties KC en informeel klinisch leren op de werkplek?

Hoofdstuk 2 behandelt de onderzoeksvraag 'Hoe worden gedeelde mentale modellen geconceptualiseerd, ontwikkeld en gemeten in het klinisch onderwijs?' Om deze vraag te beantwoorden, hebben de auteurs een scoping review uitgevoerd om het SMM-construct te onderzoeken zoals toegepast bij klinisch teamwerk waarbij studenten uit diverse gezondheidszorgopleiding zijn betrokken. Uit het literatuuronderzoek bleek dat het SMM-construct complex is, multidimensionaal en zonder duidelijke definitie. De meeste artikelen betreffen artsen in vervolgopleidingen en zijn gericht op klinische teams. Educatieve interventies ter ondersteuning van SMM's en pogingen om het construct te meten bleken zeldzaam in gezondheidszorgopleidingen (*health professions education* of HPE. De auteurs stellen een operationele definitie van SMM's in de gezondheidszorg voor (*an individually held, organized, cognitive representation of task-related knowledge and/ or team related knowledge that is held in common among health care providers who must interact as a team in pursuit of common objectives for patient care)*. Hoewel de ontwikkeling, implementatie en beoordeling van interventies die bedoeld zijn om SMM's te bevorderen worden gepresenteerd, suggereren de auteurs dat meetproblemen de toepasbaarheid van het SMM construct in HPE beperken.

Hoofdstuk 3 behandelt de onderzoeksvraag 'Kan het *Interaction Analysis Model* (IAM) worden gebruikt om KC-gedrag in verschillende IP-contexten te karakteriseren?' en richt zich op de toepassing van de IAM op een asynchrone IP-leermodule. De auteurs ontwikkelden een leermodule gericht op medicatiebeheer en ontwierpen dialoogvragen om KC te ondersteunen met behulp van de vijf primaire fasen van het IAM. Studentenparen uit opleidingen farmacie en geneeskunde werden gerandomiseerd om begeleidingshints gericht op ofwel hoge of lage niveau's van kennisconstructie te ontvangen en hun dialoog (in tekstuele vorm) werd gecodeerd voor het KC-niveau met behulp van *directed content analysis*. De impact van de dialoogvragen op het KC-gedrag van de leerlingen en de kwaliteit van het zorgplan werd beoordeeld. Paren met hoog niveau van begeleidingshints waren vaker betrokken bij alle niveaus van KC dan paren met een laag niveau, maar het begeleidingsniveau had geen invloed op de kwaliteit van het zorgplan. Toepassing van een (vereenvoudigd) IAM leverde waardevolle inzichten op over de kwaliteit van IP-interacties tijdens de asynchrone leermodule. Deze studie toonde aan dat docenten het vereenvoudigde IAM-raamwerk kunnen gebruiken om onderwijsinterventies voor asynchroon leren te ontwerpen en te evalueren.

Ook hoofdstuk 4 behandelt de onderzoeksvraag 'kan het Interaction Analysis Model (IAM) worden gebruikt om KC-gedrag in verschillende IP-contexten te karakteriseren?' In deze proof-of-concept-studie breiden de auteurs de focus van de IAM-toepassing uit naar studeten in een IP-klinisch keuzevak. Ze onderzoeken de haalbaarheid en het nut van het toepassen van de IAM op transcripties van zorgplanningdiscussies, om de KC-processen van IP-studententeams in klinische stages te evalueren. Na aanvankelijk de oorspronkelijke IAM met vijf fasen (inclusief alle subfasen) toe te passen om de interacties tussen leerlingen te karakteriseren, hebben de auteurs het model vereenvoudigd voor praktisch gebruik. Toepassing van het vijf-fasen IAM om de dialoog met leerlingen te coderen was haalbaar, hoewel arbeidsintensief, hetgeen suggereert dat het vooral bruikbaar is als onderzoeksinstrument om kennisconstructiegedrag van leerlingen in kaart te brengen. De auteurs suggereren dat het vereenvoudigde raamwerk wel nuttig kan zijn als leidraad bij het ontwerpen van klinische stages met IPE, naast de functie als onderzoeksinstrument om IP-leergedrag te analyseren. Voor praktische toepassing in de context van HPE bevelen de auteurs de ontwikkeling van een IAM-gebaseerd observatie-instrument aan.

Hoofdstuk 5 behandelt de onderzoeksvraag 'Kan een observatie-instrument worden ontwikkeld om interactieve KC tijdens IP-interacties te beoordelen?' Na literatuuronderzoek en *needs analysis*, werd *validity evidence* verzameld voor een nieuw, theoretisch gefundeerd observatie-instrument ("TOCK-IP"), ter ondersteuning van de formatieve beoordeling van interactief KC-gedrag tussen lerenden bij gezondheidszorgberoepen. Het eerste ontwerp van de tool was gebaseerd op Gunawardena's vijf-fasen IAM; op basis van pre-pilot feedback van docenten-beoordelaars werd de tool verder vereenvoudigd tot vier fasen. Docenten-beoordelaars pasten de tool toe bij video's van gesimuleerde interacties tussen leerlingen uit verschillende beroepen. De beoordelaars bleken in staat om de vier verschillende vormen van kennisconstructie in de IAM te identificeren, zelfs zonder training. Evaluatie van de tool leverde validiteitsondersteuning op in de vorm van interbeoordelaarsbetrouwbaarheid en congruentie met expertbeoordelingen, evenals ondersteuning voor het gebruik ervan in de praktijk. Dit onderbouwing ondersteunt het gebruik van de TOCK-IP door docenten bij de formatieve beoordeling van interactief KC-gedrag bij studententeams en suggereert dat verdere ontwikkeling van de tool gerechtvaardigd is.

Hoofdstuk 6 behandelt de onderzoeksvraag 'Hoe ondersteunen IP-interacties KC en informeel leren op de klinische werkplek?" Om deze vraag te beantwoorden, ontwikkelden en voerden de auteurs een internationale, cross-sectionele, online-enquête uit onder AIOS van drie instellingen – twee in de VS en één in Nederland – om te onderzoeken hoe interacties met apothekers AIOS in specialistenopleidingen ondersteunen bij KC en informeel klinisch werkplekleren. Uit het onderzoek bleek dat AIOS in de VS sterk leunden op apothekers en Up-To-Date bij medicatie-gerelateerde vragen, terwijl Nederlandse AIOS bij voorkeur gebruik maakten van het Farmacotherapeutisch Kompas en in EPD ingebedde medicatiebronnen. AIOS in de VS, vooral in hun eerste jaren van opleiding, hadden significant meer interactie met en leerden van apothekers dan Nederlandse AIOS. Apothekers voorzagen AIOS van een brede scala aan nuttige informatie, waarvan in Nederland een groot deel is geïntegreerd in het EPD. De mogelijkheden om op de werkplek met apothekers te overleggen waren veel groter de VS dan in Nederland. Deze voordelen bepaalden sterk de perceptie van AIOS over IP-leren en de waarde die zij daaraan hechtten.

Deze studie toonde aan dat het vergroten van de mogelijkheden voor interprofessionele interactie tussen medische AIOS en apothekers de potentie van een positieve invloed heeft op de kwaliteit van het informele werkplekleren van AIOS.

Hoofdstuk 7 vat de belangrijkste bevindingen over het leren door middel van IP-interactie in de context van klinisch onderwijs samen. De implicaties van het onderzoek voor zowel IP-onderwijs als IP-onderzoek worden gepresenteerd. De sterke punten en de beperkingen van dit onderzoek worden besproken, evenals toekomstige richtingen voor onderzoek. De auteurs tonen het nut aanvan een vereenvoudigde versie van de IAM voor ondersteuning en analyse van het KC-gedrag van studenten en leveren validiteitsondersteuning voor een tool op basis van de IAM die kan worden gebruikt om lerenden formatieve feedback te geven over hun IP-interacties. Hiermee bevestigt dit werk het nut van het KC-construct in IP-klinisch onderwijs. Het onderzoek benadrukt ook het belang van informele IP-interactie op de klinische werkplek. Het geheel van het onderzoek uit dit proefschrift draagt bij aan het begrip van het ontwerpen en evalueren van IP-interventies, teneinde interactieve KC-processen die nodig zijn voor IP-samenwerking in de praktijk beter te ondersteunen.

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Curriculum Vitae

Leslie Carstensen Floren was born in the state of California in the United States and grew up in San Diego County. She attended the University of California San Diego, where she developed a passion for teaching and earned her bachelor's degree in molecular and cellular biology. Exposure to the field of molecular modeling during her last years as an undergraduate, as well as early work experience in health care, inspired her to pursue pharmacy training at the University of California San Francisco (UCSF). After completing her PharmD training, she completed a pharmacy practice residency at UCSF, followed by a fellowship in Clinical Pharmacology and Therapeutics in the laboratory of Dr. Leslie Benet. Upon completing her clinical research training, she joined the faculty at UCSF in the Department of Bioengineering and Therapeutic Sciences in the School of Pharmacy.

After three years on faculty, she made the transition to work in the pharmaceutical industry for several years, working as a Clinical Pharmacokineticist and Group Leader in Clinical Pharmacology. Driven by a desire to develop a fellowship that would be structured as a joint industry- academic partnership, Leslie had the good fortune to return to UCSF in the role of Academic Coordinator for the Department of Bioengineering and Therapeutic Sciences and to serve as the co-Director of the UCSF Clinical Pharmacology and Therapeutics Fellowship Program. Given her enthusiasm for health professions education, she sought training through the UCSF Teaching Scholars Program (TSP). Although she had years of experience designing and performing clinical research in both academic and industrial settings, participation in TSP ignited a tremendous interest in gaining expertise in health professions education research.

After completing TSP, she completed a Master's degree in health professions education in a joint program between UCSF and University of California Berkeley in Dr. Marcia Linn's research group. This experience confirmed her growing enthusiasm for education research and helped bring into focus her plan to conduct research emphasizing learning through interaction. Continuing her training, Leslie joined the UCSF–Utrecht University collaborative doctoral program in health professions education in 2015.

Leslie has held a faculty appointment at UCSF School of Pharmacy for 15 years and she is currently an Adjunct Associate Professor in the Departments of Clinical Pharmacy and Bioengineering and Therapeutic Sciences. Her career is primarily focused on health professions education and she is involved in direct teaching across the spectrum of health professions learners – including undergraduate pharmacy trainees, pharmacy residents, as well as post-graduate trainees in Clinical Pharmacology from across disciplines. She led the development and implementation of the Respiratory block in the integrated, 3-year

PharmD curriculum, for which she also serves as the course director. She is involved in education leadership and mentors students, residents, fellows and faculty on scholarly projects. She also practices as a clinical pharmacist in the UCSF Care Transitions Outreach and enjoys serving as a clinical preceptor to pharmacy trainees of all levels.

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