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Cognitive apprenticeship in health sciences education: a qualitative review

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Abstract Cognitive apprenticeship theory emphasizes the process of making expert thinking "visible" to students and fostering the cognitive and meta-cognitive processes required for expertise. The purpose of this review was to evaluate the use of cognitive apprenticeship theory with the primary aim of understanding how and to what extent the theory has been applied to the design, implementation, and analysis of education in the health sciences. The initial search yielded 149 articles, with 45 excluded because they contained the term "cognitive apprenticeship" only in reference list. The remaining 104 articles were categorized using a theory talk coding scheme. An in depth qualitative synthesis and review was conducted for the 26 articles falling into the *major theory talk* category. Application of cognitive apprenticeship theory tended to focus on the methods dimension (e.g., coaching, mentoring, scaffolding), with some consideration for the content and sociology dimensions. Cognitive apprenticeship was applied in various disciplines (e.g., nursing, medicine, veterinary) and educational settings (e.g., clinical, simulations, online). Health sciences education researchers often used cognitive apprenticeship to inform instructional design and instrument development. Major recommendations from the literature included consideration for contextual influences, providing faculty development, and expanding application of the theory to improve instructional design and student outcomes. This body of research provides critical insight into cognitive apprenticeship theory and extends our understanding of how to develop expert thinking in health sciences students. New research directions should apply the theory into additional aspects of health sciences educational research, such as classroom learning and interprofessional education.

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Background

New technologies, innovative pedagogical strategies, redesigned clinical experiences, and transformed curricula have permeated health sciences education in recent years (Cooke et al. 2010; Doherty et al. 2015). Understanding the impact of traditional and emerging educational practices on student outcomes through systematic and rigorous educational research is imperative for fostering student development and preparing students to meet the needs of twenty-first century health care. While the use of theory is argued by many as critical to understanding learning in the health sciences, it is often absent from the literature (Clifton et al. 2007; Kaakinen and Arwood 2009). A review by Kaakinen and Arwood (2009), for example, found that only 16 out of 120 articles referenced learning or developmental theory.

Cognitive apprenticeship is one theory-based approach to teaching and learning that is gaining popularity in health sciences education (e.g., Pimmer et al. 2012). It has been used as a theoretical framework for design of learning environments (e.g., Woolley and Jarvis 2007) as well as analysis of teaching and learning practices (e.g., Saucier et al. 2012; Stalmeijer et al. 2009). While clinical education has traditionally incorporated apprenticeship learning as evidenced by the *see one, do one, teach one* maxim, cognitive apprenticeship extends the apprenticeship model beyond physical processes and observable skills to include cognitive processes and skills by making expert thinking "visible" to the learner (Collins et al. 1989). This approach makes cognitive apprenticeship highly applicable to teaching and learning the complexities of clinical thinking.

Cognitive apprenticeship defined

According to Collins et al. (1991), cognitive apprenticeship emphasizes processes employed by experts to handle complex tasks and teaching cognitive and metacognitive (as opposed to physical) skills and processes. The cognitive apprenticeship theoretical framework developed by Collins et al. (1989) operationalizes four interconnected dimensions of all learning environments: (1) *content*, which involves knowledge and thinking strategies required for expertise; (2) *method*, which outlines teaching strategies for developing expertise; (3) *sequence*, which explicates how learning tasks should be organized and presented to promote increasing complexity and diversity; and (4) *sociology*, which emphasizes the influence of situated and cooperative learning supported by students' intrinsic motivation and communication (Table 1). Applying principles of apprenticeship learning to the cognitive dimension requires *making thinking visible* and situating learning tasks in contexts that make sense to students (Collins et al. 1991).

Cognitive apprenticeship is rooted in the theories of situated learning and cognition, which view knowledge as dynamically constructed within social contexts and posit learning as a social activity that is profoundly structured by interaction with the setting (Clancey 2008; Wilson 1993). As such, knowledge is situated within the activity, context, and culture in which it is learned and applied (Brown et al. 1989). The theory of cognitive apprenticeship was introduced by Collins et al. (1989) to describe a set of approaches to teaching based on the situated learning theoretical framework with an emphasis on: (1) pedagogical strategies that experts use to teach complex tasks; and (2) cognitive and meta-

Table 1 Four dimensions of cognitive apprenticeship (Collins et al. 1989)

Content	Types of knowledge required for expertise	
	Dimension knowledge	Subject matter specific concepts, facts, and procedures
	Heuristic strategies	Generally applicable techniques for accomplishing tasks
	Control strategies	General approaches for directing one's solution process
	Learning strategies	Knowledge about how to learn new concepts, facts, and procedures
Method	Ways to promote the development of expertise	
	Modeling	Teacher performs a task so students can observe
	Coaching	Teacher observes and facilitates while students perform a task
	Scaffolding	Teacher provides supports to help the student perform a task
	Articulation	Teacher encourages students to verbalize their knowledge and thinking
	Reflection	Teacher enable students to compare their performance with others
	Exploration	Teacher invites students to propose and solve their own problems
Sequencing	Keys to ordering learning activities	
	Increasing complexity	Meaningful tasks gradually increasing in difficulty
	Increasing diversity	Practice in a variety of situations to emphasize broad application
	Global to local skills	Focus on conceptualizing the whole task before executing the parts
Sociology	Social characteristics of learning environments	
	Situated learning	Students learn in the context of working on realistic tasks
	Communities of practice	Communication about different ways to accomplish meaningful tasks
	Intrinsic motivation	Students set personal goals to seek skills and solutions
	Cooperation	Students work together to accomplish their goals

cognitive processes and skills required for expertise. Cognitive apprenticeship was developed and proposed in response to an observed disconnect between the knowledge taught in school settings and the application of that knowledge in real world settings. The limited integration of conceptual and problem-solving skills acquired in school into the context of their intended use prompted Collins et al. (1989) to argue that school-based teaching should extend traditional apprenticeship models to support learning in the cognitive dimension.

Purpose of review

A growing body of literature provides empirical support for the theory of cognitive apprenticeship and suggests that health sciences educators are incorporating this framework into their practices in various ways. Currently, the cognitive apprenticeship literature is dispersed across various disciplines, including nursing, medicine, pharmacy, and veterinary medicine, and applied within various settings, including classrooms, clinics, and online environments. The purpose of this qualitative review was to synthesize and evaluate the use of cognitive apprenticeship theory in health sciences education research with the primary aim of understanding how and to what extent the theory of cognitive apprenticeship has been applied to education in health sciences. By synthesizing the use of cognitive apprenticeship in health sciences education, this work can extend our understanding of theories that underpin educational practice and inform pedagogy and research.

Methods

The search strategy was shaped by the goals of this qualitative review: to describe and evaluate the use of cognitive apprenticeship as a theoretical model in published health sciences education research. We conducted preliminary searches in health sciences and education databases (PubMed, CINAHL, PsychInfo and Education Full Text) using terms "cognitive apprenticeship" and some related terms, such as "scaffolding," "situated cognition," and "reflection," as well as various combinations of those terms with "cognitive apprenticeship." Comparing the results of these different searches, we observed that while including additional terms substantially increased the overall number of articles retrieved, it did not appear to capture any more relevant articles than searching for "cognitive apprenticeship" alone. Thus we concluded that using "cognitive apprenticeship" as the only search term would give us optimal balance of precision and recall.

Following our preliminary searches, we aimed to scope our review to the domain of health sciences education and achieve maximum recall (i.e., not miss any relevant articles that contain the term "cognitive apprenticeship"). After consultation with a reference librarian at the University of North Carolina Health Sciences Library, we chose a hybrid strategy of searching PubMed and CINAHL databases in combination with full-text searches through journals that publish articles on health sciences education (AAMC-GEA-MESRE Section 2014). There were no boundary dates used in the search and all article types were included (e.g., experimental studies, observational studies, qualitative studies). The searches carried out in the fall of 2014 identified a total of 149 articles. Of those, 45 contained the term "cognitive apprenticeship" only in the titles of works cited in the reference list without any discussion of cognitive apprenticeship theory in the text of the article. These were excluded from further review.

We then conducted a qualitative content analysis in two phases. In phase one, the objectives were to describe the characteristics of the articles which used the term "cognitive apprenticeship" and classify author's use and talk of cognitive apprenticeship theory. First, we classified the remaining 104 articles according to a set of characteristics such as profession and study location. Then we used a recently developed method for evaluating the text to which author's used theories in their studies as a criterion for inclusion in phase two of the review. While some researchers have proposed a checklist for assessing article's theoretical *quality* (Hean et al. 2015), we were interested in *extent* to which authors used theory. As such, we applied an adaptation of the *theory talk* coding schema from Kumasi et al. (2013) which was designed to qualitatively analyze the extent to which theory is meaningfully used in scholarly literature (Table 2). The scheme includes three categories of *theory talk*: minimal theory talk (e.g. theory is mentioned in the introduction and not revisited later); moderate theory talk (e.g. theory is discussed in a piece which does not report original research); and major theory talk (e.g. theory is employed throughout). Major theory talk is characterized by employing theory throughout, typically to inform research design and data analysis (i.e. theory application), empirically validating or testing an existing theory or instrument (i.e. theory testing), and/or building, revising, or expanding a theory to create new theory (i.e. theory generation). The coding scheme allowed us to focus our analysis on articles in which authors used cognitive apprenticeship to a greater magnitude.

The original theory talk coding categories were modified for the context of the study after consensus of all members of the research team. Two members of the research team (KL & JK) conducted independent review and coding of the 104 articles based on the three

Table 2 Analytic coding categories based on theory talk continuum

Continuum of theory talk[a]	Analytical categories of theory talk	Definition of categories
Minimal	Theory dropping	A theory is discussed/mentioned (with or without citation) in the introduction or methods and not revisited later
	Theory relating	Theory is referred to in the discussion (with or without citation) to make meaning of the original research results, but the theory did not inform study design or analysis
Moderate	Theory conversation	The contribution of a particular theory to health sciences education is discussed in a piece which does not report original research
Major	Theory application	Employs theory throughout, typically to inform research design and data analysis
	Theory testing	Empirically validating or testing an existing theory or instrument
	Theory generation	Building, revising or expanding a theory to create a new theory

[a] Adapted from Kumasi et al. (2013)

categories of theory talk in the theory talk coding scheme. The initial agreement was 95 % with all differences resolved through discussion. Table 3 summarizes the characteristics of the articles reviewed. Of note, more than half of the articles (n = 56) were on the minimal end of the theory talk continuum, with 22 articles identified as moderate and 26 articles identified as major.

In phase two, we conducted a qualitative content analysis (Hsieh and Shannon 2005) in order to synthesize the use of cognitive apprenticeship theory in the health professions literature. Qualitative content analysis provided a flexible method for analyzing articles by focusing on the language and contextual meaning of the texts (Hsieh and Shannon 2005; Budd et al. 1967). Our overall approach was interpreting article content data through a systematic process of identifying themes and then coding data around these themes. Only articles coded as *major* theory talk were included for this further in-depth analysis by three members of the research team (JK, KL, JM). Moderate theory talk articles were not included in further review because they tended to be editorial or discursive in nature and did not report original research. Minor theory talk articles were not included since the lack of discourse limited our ability to determine how and to what extent the theory of cognitive apprenticeship applied to the design, implementation, and analysis of the research. Each researcher coded the major theory talk articles independently and group discussions were held to synthesize findings through inductive thematic analysis (Bearman and Dawson 2013). To understand how the theory of cognitive apprenticeship has been applied to educational research in the health sciences, the findings were organized according to four generated themes. The themes are presented as the following four questions:

Which dimensions (content, method, sequencing, sociology) of cognitive apprenticeship are emphasized in the health sciences education literature?
In what health sciences educational settings is cognitive apprenticeship applied?
How is cognitive apprenticeship used to inform health sciences teaching?
What are the major recommendations deriving from cognitive apprenticeship health sciences literature?

Table 3 Characteristics of cognitive apprenticeship articles (n = 104)

Characteristic	Categories	Number of articles (%)	Number of major theory talk articles (%)[b]
Theory talk	Major	26 (25)	26 (100)
	Moderate	22 (21)	
	Minor	56 (54)	
Profession	Medicine	61 (59)	13 (50)
	Nursing	20 (19)	6 (23)
	Interdisciplinary	8 (8)	1 (4)
	Dentistry	3 (3)	1 (4)
	Other	12 (11)	5 (19)
Journal	Medical teacher	24 (23)	6 (23)
	Academic medicine	12 (11)	4 (15)
	Medical education	11 (10)	1 (4)
	Advances in health sciences education	8 (8)	2 (8)
	Nurse education in practice	8 (8)	6 (23)
	Nurse education today	8 (8)	1 (4)
	Other	33 (32)	6 (23)
Year	1990–1994	3 (3)	0 (0)
	1995–1999	3 (3)	0 (0)
	2000–2004	8 (7)	2 (8)
	2005–2009	27 (26)	6 (23)
	2010–2014	63 (61)	18 (69)
Study location[a]	United States	27 (26)	7 (27)
	Canada	24 (23)	3 (12)
	United Kingdom	24 (23)	6 (23)
	Netherlands	21 (20)	8 (31)
	Other	17 (16)	2 (8)
Participant[a]	Students	54 (54)	16 (62)
	Educators (e.g., clinical teachers)	21 (20)	3 (12)
	Post-graduates (e.g., residents)	15 (14)	7(27)
	Practitioners	7 (6)	3 (12)
	Not applicable (e.g. editorial)	18 (17)	0 (0)
Setting	Clinical environment	54 (54)	16 (62)
	Classroom	13 (12)	0 (0)
	Online module	12 (11)	5 (19)
	Simulation	5 (4)	3 (12)
	Blended learning	2 (2)	2 (8)
	Not applicable (e.g. editorial)	18 (17)	0 (0)

[a] Some articles include multiple study location or participant categories

[b] Only articles coded as using major theory talk from Kumasi et al. (2013) were included in phase two of the review (see Table 2)

We utilized direct content analysis to answer the first question and a conventional content analysis to inform the remaining questions (Hsieh and Shannon 2005). During the direct content analysis, we deductively coded articles for their use of the four cognitive apprenticeship dimensions. First, articles were coded for each dimension, and then they were coded for use of principles under a dimension. For example, articles explaining their use of the methods dimension were then coded for methods principles such as modeling, scaffolding, or articulation. Patterns were identified and extracted for use in the results section. The direct content analysis approach allowed us to focus on variables related to the existing theory of cognitive apprenticeship whereas the conventional content analysis approach we used for the remaining questions, allowed new insights to emerge. During the conventional content analysis, we first immersed ourselves in the texts and then identified categories for each question. For example, when we were searching for what settings the theory had been applied, we identified the clinical environment as a category. Thereafter, we analyzed articles grouped into categories and identified subcategories and patterns for use in the study results.

Results

Articles using *major theory talk* (n = 26) are listed in Appendix Table 5. All 26 articles were published between 1990 and 2014, with the majority published in the last 5 years (n = 18). Six countries were represented, with most articles originating from the Netherlands (n = 8), United States (n = 7), and United Kingdom (n = 6). The majority of the articles were focused on medical education (n = 14), with ten articles about medical residents and practitioners and four about medical students. The remaining articles focused on nursing or midwife education (n = 7), veterinary education (n = 3), dental education (n = 1), and pharmacy education (n = 1). The results of this review are structured by question to summarize relevant findings.

Which dimensions (content, method, sequencing, sociology) of cognitive apprenticeship are emphasized in the health sciences education literature?

While all learning environments embody the four dimensions of cognitive apprenticeship (i.e., content, method, sequencing, sociology), environments can differ in the extent to which each dimension is emphasized. This varied emphasis was clearly reflected in the studies reviewed, as described below.

Content dimension

The content dimension of cognitive apprenticeship differentiates between the concepts and procedures associated with expertise, termed *domain knowledge,* and the strategies underlying an expert's ability to effectively apply dimension knowledge for problem solving and task completion, termed *strategic knowledge* (Collins et al. 1989). Domain knowledge was emphasized in all articles and strategic knowledge was apparent in two articles: (1) Linnet et al. (2012) highlighted a variety of heuristic and learning strategies, such as conducting internet searches, consulting clinical guidelines, and patient follow up strategies designed to support clinical reasoning processes; and (2) Nothnagle et al. (2010) focused on development of self-directed learning skills, with an emphasis on metacognitive strategies.

Method dimension

Of the four dimension of cognitive apprenticeship, the method dimension was most extensively and explicitly applied in the health sciences education research reviewed. Researchers generally applied Collins et al. (1989) methods of modeling, coaching, scaffolding, articulation, reflection, and/or exploration. However, Finnerty and Collington (2013) added “fading” to the model as a separate strategy, rather than conceptualizing fading as a part of scaffolding (Woolley and Jarvis 2007). While most authors used the entire six-method model to design or redesign learning environments, varied approaches were used to operationalize these methods (Table 4).

Sequencing dimension

According to cognitive apprenticeship, learning activities should facilitate conception of the entire task before addressing specific parts of the task. In addition, students should practice simple tasks prior to completing more complex and diverse tasks (Brown et al. 1989). In this review, sequencing was often implied in the major theory articles; however, none of the articles explicitly described sequencing of learning activities or framed this dimension of teaching and learning from the cognitive apprenticeship perspective.

Table 4 Examples of the cognitive apprenticeship methods seen in this review

Method	Example[a]
Modeling	Observation of experts, both skills and attributes Externalizing mental processes in text or oral explanations Modeled in person, 3D animations or video footage
Coaching	Individualized feedback Expert observes student demonstrate a skill Replay of a video-taped student performance Checklists for trainers and learners Formative assessments
Scaffolding	Individualized support from experts Conceptual models, algorithms Hints, reminders, access to resources, informal chatting Simulations, scenarios
Articulation	Summative assessments Socratic questioning, assessment questions Students explain rationale
Reflection	Post-hoc reflection of performance Informal or formal discussions with colleagues or peers Portfolios, online forums, journals, online prompts, video footage of performance Comparison with expert performance Encouragement by mentors
Exploration	Self-directed learning in related content areas Encouragement to explore and form own learning goals Stimulate students to ask more questions

[a] Examples taken from: DeBourgh (2001), Durak et al. (2006), Feinstein and Yager (2013), Finnerty and Collington (2013), Kalet et al. (2007), Kilistoff et al. (2013), Nothnagle et al. (2010), Weeks et al. (2013d), Woolley and Jarvis (2007), Wright (2000)

Sociology dimension

The sociology dimension of cognitive apprenticeship outlines the following ideal social characteristics of a learning environment: situated learning; communities of practice; intrinsic motivation; and cooperation. All four of these social characteristics were apparent in this review. Situated learning, for example, was largely represented by the use of realistic tasks and settings (e.g., clinical practice settings). In the absence of real-world settings, educators simulated realistic tasks such as a dental carving technique (Kilistoff et al. 2013) and medication dosage calculations (Weeks et al. 2013a, b, c, d). DeBourgh (2001) used community of practice principles to create an online discussion board that provided opportunities to share ideas and strategies for practice, clarify understanding of content, and find peer support. Intrinsic motivation was strongly emphasized by Nothnagle et al. (2010), who focused on goalsetting as an integral part of developing self-directed learning skills. The fourth ideal characteristic, cooperation, was mentioned by Woolley and Jarvis (2007) in designing a workshop with small group collaborative learning.

In what health sciences educational settings is cognitive apprenticeship applied?

Researchers have applied the concept of cognitive apprenticeship across a range of educational settings, including clinical environments (n = 16), online learning modules (n = 5), simulations (n = 3), and blended courses (n = 2). Given the importance of engaging students in real world healthcare practice and the varied approaches to clinical rotations in the health sciences, the focus on clinical experiences is not surprising. Researchers examined how students learn in the clinical environment from broad perspectives (e.g., experiences in hospitals) to specialty-specific perspectives (e.g. experiences in pediatric practice) and in multiple disciplines (e.g. medicine, veterinary, midwifery). In addition, the scope of the clinical studies reflects student learning and development at various points across and beyond a curriculum. Examples include analysis of early exposure to the inpatient setting on medical students' professional development (Dyrbye et al. 2007), mentored coaching for 2nd and 3rd year midwife students (Finnerty and Collington 2013), and an evaluation of teaching and supervision received by veterinary students in clinical experiences (Boerboom et al. 2011). Researchers have also applied the theory of cognitive apprenticeship to better understand clinical learning in post-graduates, including medical residency programs (George et al. 2013; Linnet et al. 2012; Saucier et al. 2012) and doctor-to-doctor consultations (Pimmer et al. 2012).

Online learning included work by Weeks et al. (2013d), who published a series of papers discussing the use of cognitive apprenticeship to design an online medication dosage calculation module for nursing students while Wright (2000) described the development and evaluation of an internet-based independent-study module to teach pharmacists drug information skills. Simulated learning environments included a clinical practice suite of two simulation wards to teach clinical nursing skills (Woolley and Jarvis 2007), an exercise with manikins to teach medical students basic life support skills (Durak et al. 2006), and a simulation dental clinic to teach dental students a step by step carving technique (Kilistoff et al. 2013).

To accommodate the fast paced and time pressed environment of the clinical setting, Kalet et al. (2007) described the use of cognitive apprenticeship theory to design and implement blended learning environments that provided learning activities coinciding with clinical rotations. The Web Initiative for Surgical Education (WISE-MD) was a theory-driven technology-based approach to surgical education that provided tacit knowledge about the collective values and communication strategies for medicine and fostered cognitive and metacognitive strategies that guide decision-making process (Kalet et al. 2007). Similarly, DeBourgh (2001) used scaffolding to design and incorporate WebCourse technology into a clinical nursing course, resulting in clinical skill and knowledge refinement.

How is cognitive apprenticeship used to inform health sciences teaching?

Cognitive apprenticeship theory was developed, in part, to help instructors make their expert thinking visible to students. As such, this theory can inform any aspect of the educational environment that influences what and how students learn. In this review, two primary elements of teaching were described and studied in the context of cognitive apprenticeship: instructional design and instrument development.

First, cognitive apprenticeship has been commonly used to design or redesign educational programs, curricula, and experiences for students and teachers. Learning activities described in this review included a learning coach (Nothnagle et al. 2010; George et al. 2012, 2013), skill workshop (Linnet et al. 2012; Feinstein and Yager 2013), apprenticeship models (Durak et al. 2006), simulated patient cases (DeBourgh 2001), simulated skill performance (Kilistoff et al. 2013), and self-directed online modules (Kalet et al. 2007; Weeks et al. 2013a; Wright 2000). Learning activities were often redesigned in the clinical environment by improving either the quality or quantity of cognitive apprenticeship methods (e.g. modeling, coaching). For example, in a simulated clinical environment, instructors followed a process of first *modeling* through taped DVDs, then *coaching* students through filmed student performance, providing individual *scaffolds* in conversations, having students *articulate* their rationale for decisions, asking students to *reflect* on their performance, and finally, stimulating students to *explore* other situations to apply their new skills (Woolley and Jarvis 2007). Educational designs based on cognitive apprenticeship theory led to student satisfaction (Kalet et al. 2007; DeBourgh 2001; Durak et al. 2006; Feinstein and Yager 2013; Wright 2000), student perceptions of learning and attitudes (Linnet et al. 2012; George et al. 2012), and increased learning outcomes (Kilistoff et al. 2013; George et al. 2012, 2013). Kalet et al. (2007) cognitive apprenticeship informed design had mixed results on different measures of clinical reasoning as well as no difference in student's grades or certain exam scores. Limited differences in learning outcomes were also seen with Durak and colleagues' design.

Second, cognitive apprenticeship has been used to develop assessment instruments. A research program at Maastricht University applied the six methods of cognitive apprenticeship to the development and testing of the Maastricht Clinical Teaching Questionnaire (MCTQ), a questionnaire used by students to evaluate clinical teachers (Stalmeijer et al. 2008). Confirmatory factor analysis yielded five factors correlated with student's overall judgment of the clinical instructor: modeling, coaching, articulation, exploration, and learning environment (Stalmeijer et al. 2010). In a subsequent study, 17 experienced clinical teachers agreed that this five factor model fit the teaching activities in student clerkships (Stalmeijer et al. 2013). Boerboom advanced the MCTQ as a valid and reliable tool in veterinary clinical teaching (Boerboom et al. 2011a) and as a clinical veterinary teacher professional development tool (Boerboom et al. 2011b). The work of Boerboom et al. (2012) further supported the validity of the MCTQ by demonstrating between-student and between-teacher differences.

What are the major recommendations deriving from cognitive apprenticeship health sciences education literature?

The practical applicability of the cognitive apprenticeship model was affected by a number of factors, such as workloads, institution size and scope, and learner roles (Pimmer et al. 2012). For example in applying the cognitive apprenticeship model to clinical teaching, researchers advocated having students focus on patients with longer lengths of stay (Linnet et al. 2012), and ensuring adequate teacher capacity (Feinstein and Yager 2013). Saucier et al. (2012) noted the time constraints associated with investing in a learner's development within the clinical environment while Stalmeijer et al. (2009) found that students only experienced more advanced cognitive apprenticeship methods (e.g., scaffolding, reflection, and exploration) on longer rotations. Although Linnet et al. (2012) described cognitive apprenticeship methods as feasible for encounters as short as 9-min, others noted the challenges of the clinical environment and proposed developing complementary blended learning or simulation activities for full operationalization of cognitive apprenticeship models (Kalet et al. 2007). As a result, researchers generally recommended that consideration be given to student, teacher, and institutional factors and resources that can impact the incorporation of cognitive apprenticeship into practice.

Authors frequently advocated formal training for faculty and clinical teachers as a strategy for providing more efficient, effective, and meaningful apprenticeship experiences (Finnerty and Collington 2013; Nothnagle et al. 2010; Saucier et al. 2012). In this review, some studies implemented training in cognitive apprenticeship as a part of or the entire focus of their study (Boerboom et al. 2011b; Linnet et al. 2012). A number of apprenticeship competencies were identified as deficient in some teachers, including feedback skills and reflection implementation (Stalmeijer et al. 2009). Students also identified lack of teaching skills and teacher commitment as significant barriers to learning (Stalmeijer et al. 2009).

Cognitive apprenticeship was advanced as flexible and translatable in rapidly changing healthcare and educational settings and endorsed as a useful approach to the design, implementation, and evaluation of educational practices in the health sciences. Learners (Durak et al. 2006; Wright 2000), faculty (Stalmeijer et al. 2013) and patients (Feinstein and Yager 2013) were satisfied with teaching and learning models derived from cognitive apprenticeship. Cognitive apprenticeship was effective in the development of learner knowledge, skills (Woolley and Jarvis 2007), and attitudes (Nothnagle et al. 2010) while providing a framework for feedback to clinical teachers (Stalmeijer et al. 2008) and insights into the clinical learning environment (Dyrbye et al. 2007). Table 4 provides several concrete examples of cognitive apprenticeship applied widely to teaching.

Discussion

A growing body of health sciences education literature draws from the theory of cognitive apprenticeship. In the 26 articles that employed major theory talk with cognitive apprenticeship, authors often extracted the six strategies of the method dimension, with some consideration for the content and sociology dimensions, and the rare articulation of the sequencing dimension. This research encompassed broad populations and settings with significant attention to medical training in clinical settings. Researchers primarily used cognitive apprenticeship theory to design instruction or develop instruments and noted the importance of educator development and local effects when applying the theory to learning environments.

To date, the majority of cognitive apprenticeship literature in the health sciences encompasses only moderate or minimal theory talk. While articles with minimal and moderate theory talk can play a valuable role in shaping our thinking and practice, their results risk becoming isolated from purposeful strands of research. Using theory to shape educational research can more fully elucidate the complex and subtle aspects of the empirical investigation, overcome the deficiency of empiricism (i.e., recordings of individual facts with no apparatus of generalization), provide more effective organization of findings, and foster systematic inquiry and problem solving (Suppes 1974). As such, utilizing cognitive apprenticeship beyond minor or moderate theory talk in the design and dissemination of research could both strengthen this body of work and improve our understanding of how to develop expert thinking in health science students.

There is a strong theoretical justification that students will more effectively develop expertise if educators apply cognitive apprenticeship as a complete set of integrated concepts (Collins et al. 1989), yet most research in this review carved out one dimension and its sub-dimensions for study. Authors rarely mentioned the sequencing domain despite its importance as a differentiator between cognitive apprenticeship and traditional apprenticeship. In cognitive apprenticeship, tasks are sequenced to meet the demands of learning whereas, in traditional apprenticeship, tasks are sequenced to meet the needs of the workplace. Along the same lines, there was limited discussion of the sociology dimension even though clinical environments, for example, naturally reflect cognitive apprenticeship sociology principles such as situated learning. Instructors and researchers may benefit from further exploration of domains absent in the literature (e.g. sequencing). Since the four dimensions of cognitive apprenticeship are present in every learning environment (Collins et al. 1989), this body of research should give consideration to principles in all four dimensions, as the principles in methods, sequencing, content and sociology dimensions are likely to impact a student's development of professional expertise.

New research directions should consider the theory's relevance for additional aspects of health sciences educational research. The accumulation of research in the clinical environment suggests that cognitive apprenticeship theory is useful for informing clinical teaching, however, other settings are notably absent. Given that Collins et al. (1989) originally described cognitive apprenticeship for classroom learning, the lack of research in classroom design and outcomes is somewhat surprising. Opportunities may also exist in interprofessional education research given that the theory displays flexibility across health science disciplines. Also, cognitive apprenticeship may strengthen other aspects of educational training where traditional apprenticeship takes place, such as student advising, extracurricular activities, and student research training.

Future research in cognitive apprenticeship could also help refine the theory for specific learning environments. For example, Stalmeijer et al. (2013) started with all six methods of cognitive apprenticeship in their clinical teacher evaluation, but their final model only included four methods (coaching, modeling, articulation, and exploration). As a result, they have developed a local theory of cognitive apprenticeship which is specific to evaluating clinical teachers through a written student survey. This increased specificity may be especially useful for teachers and researchers interested in clinical teaching evaluation. As cognitive apprenticeship spreads to new settings, researchers should refine the theory to specific contexts. Then faculty and preceptors would be able to design more informed learning environments and evaluations.

Since health science educators typically lack formal training on effective ways to model, coach, scaffold and then have the student reflect on, articulate, and explore what they are learning, educators might benefit from development in cognitive development theory. Only two studies in our review (Boerboom et al. 2011b; Linnet et al. 2012) described faculty development efforts in cognitive apprenticeship theory despite several authors advocating for more faculty development in cognitive apprenticeship skills. Educators may lack the knowledge and skills necessary to select content purposefully, order the learning activities, and utilize the social elements of the environment for most effective expertise development in the learners. Since cognitive apprenticeship appears particularly well-suited for health professions education, we believe a critical first step is engaging faculty and clinical teachers in conversations about this theory, thereby fostering their understanding of its potential value in enhancing student learning as well as their ability to more effectively incorporate key design principles in their teaching and mentoring of students.

While this review provides insight into the application of cognitive apprenticeship to health science education, there were several limitations. First, the review did not assess the level of rigor of the studies' methodology. Our aim was to assess what level of theory talk was used (Kumasi et al. 2013) and *how* researchers applied cognitive apprenticeship. Therefore readers should assess the rigor of each study's methodology before accepting each author's conclusions. Second, the databases and journals included in our search although comprehensive in coverage of health sciences education were domain-specific. Consequently, it is possible that our review missed some relevant articles published in general education or other disciplinary journals. Finally, the review was focused on cognitive apprenticeship framework as defined by Collins et al. 1989 and articles were only included if they contained the term "cognitive apprenticeship" in the text. This approach may have excluded articles that used elements of cognitive apprenticeship theory without explicitly naming the theoretical framework. Terms of related learning theories and frameworks, such as communities of practice (Lave and Wenger 2002) or situated learning (Brown et al. 1989) did not meet criteria for inclusion. Likewise, the scope for this review did not include works that focused on the specific concepts (e.g., reflection), that the cognitive apprenticeship framework encompasses, but can be treated by researchers as self-standing concepts (e.g., Mann et al. 2009).

Despite these limitations, the specificity of review scope enabled us to focus on depth of analysis and explore multiple facets of the application of cognitive apprenticeship theory in health sciences education. Unlike reviews that assess methodological rigor, this study incorporated the extent to which researchers used theory, a critical aspect of educational research (Suppes 1974). A growing body of literature highlights the importance of theoretical frameworks and the extent to which publications explicate theoretical frameworks, including the work of Hean et al. (2015). The theory talk coding scheme developed by Kumasi et al. (2013) enabled us to evaluate the extent to which theory was used in a pragmatic manner and may be useful in shaping future reviews. Likewise, our content analysis approach produced rich and meaningful explanations of the current use of cognitive apprenticeship theory in the health sciences education literature.

Conclusion

Cognitive apprenticeship theory provides a framework for developing expertise in health sciences students. As seen in these studies, a number of researchers have successfully translated cognitive apprenticeship principles to health science learning environments in an effort to prepare students for the rapidly changing healthcare needs of society. Expanding our application of cognitive apprenticeship and providing faculty development in this area may further improve development of professional expertise. New research directions should apply the theory into additional aspects of health sciences educational research, including classroom learning and interprofessional education.

Appendix

See Table 5.

Table 5 Articles included in phase two of this review

Source	Profession	Study location	Setting	Participants
Boerboom et al. (2011a)	Veterinary	Netherlands	Clinical environment	Students
Boerboom et al. (2011b)	Veterinary	Netherlands	Clinical environment	Faculty
Boerboom et al. (2012)	Veterinary	Netherlands	Clinical environment	Students
DeBourgh (2001)	Nursing	United States	Blended	Students
Durak et al. (2006)	Medicine	Netherlands	Simulation	Students
Dyrbye et al. (2007)	Medicine	United States	Clinical environment	Students
Feinstein and Yager (2013)	Medicine	United States	Clinical environment	Residents
Finnerty and Collington (2013)	Midwife	United Kingdom	Clinical environment	Students
George et al. (2012)	Medicine	United States	Clinical environment	Residents
George et al. (2013)	Medicine	United States	Clinical environment	Residents
Kalet et al. (2007)	Medicine	United States	Blended	Residents
Kilistoff et al. (2013)	Dentistry	Canada	Simulation	Students
Linnet et al. (2012)	Medicine	Denmark	Clinical environment	Students, residents, practitioners
Nothnagle et al. (2010)	Medicine	United States	Clinical environment	Residents
Pimmer et al. (2012)	Medicine	Switzerland	Clinical environment	Practitioners
Saucier et al. (2012)	Medicine	Canada	Clinical environment	Residents, faculty, staff
Stalmeijer et al. (2008)	Medicine	Netherlands	Clinical environment	Students, faculty
Stalmeijer et al. (2009)	Medicine	Netherlands	Clinical environment	Students
Stalmeijer et al. (2010)	Medicine	Netherlands	Clinical environment	Students
Stalmeijer et al. (2013)	Interdisciplinary	Netherlands	Clinical environment	Faculty
Weeks et al. (2013a)	Nursing	United Kingdom	Online module	Students
Weeks et al. (2013b)	Nursing	United Kingdom	Online module	Students

Table 5 continued

Source	Profession	Study location	Setting	Participants
Weeks et al. (2013c)	Nursing	United Kingdom	Online module	Students
Weeks et al. (2013d)	Nursing	United Kingdom	Online module	Students
Woolley and Jarvis (2007)	Nursing	United Kingdom	Simulation	Students
Wright (2000)	Pharmacy	Canada	Online module	Practitioners

All dates and article types were included in the search. The articles were reviewed if they were coded as using major theory talk

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