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Does Interprofessional Problem-Based Learning (iPBL) Develop Health Professional Students' Interprofessional Competences? A Systematic Review of Contexts, Mechanisms and Outcomes

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ABSTRACT

This systematic review reports the state-of-the-art and evidence supporting interprofessional problem-based learning (iPBL) as a developmental tool for interprofessional competences. A targeted search strategy deployed across seven electronic databases identified 32 studies which met inclusion criteria following independent double review. All study types were included. Aggregated results identified evidence (quantitative and/or qualitative) that iPBL promotes competences as categorised using the Interprofessional Education Collaborative (IPEC) framework, in Ethics/Values (n = 7); Roles/Responsibilities (n = 27); Interprofessional Communication (n = 19) and Teams/Teamwork (n = 21). Qualitative research dominated the literature. Limited, high-level quantitative data observed effects on students' attitudes and perceptions of interprofessional competences. Reporting of iPBL context and implementation mechanisms (e.g., trigger design) were largely absent in identified studies. Most iPBL (n = 26), was conducted in university rather than clinical settings.

Keywords: interprofessional education (IPE); interdisciplinary education; health professions education; higher education; collaborative practice; problem-based learning (PBL)

Health professionals who collaborate competently can improve patient safety, quality of care (Olson & Bialocerkowski, 2014; Zwarenstein et al., 2009) and clinical outcomes (Institute of Medicine [IOM], 2015). Growing evidence supports interprofessional education (IPE) as a strategy to improve undergraduate and graduate interprofessional attitudes and collaborative knowledge and skills (Reeves et al., 2016). However, IPE activities are often described in the context of the chosen teaching approach. In many cases, the interprofessional learning outcomes are not defined but assumed through the choice of evaluation tool used (Thistlethwaite & Moran, 2010). Reviews of IPE have focused on effectiveness and decisions about what IPE to offer students, and when or how to do so, are often made on pragmatic and logistical rather than pedagogical grounds (Thistlethwaite, 2012).

Faresjö et al. (2007) reported that the Linköping IPE model (Wilhelmsson et al., 2009)—an exemplar of how IPE and problem-based learning (PBL) can be combined effectively at curriculum level for all prelicensure healthcare students at a Faculty of Health Sciences—provided medical doctors with interprofessional competence skills and abilities in addition to profession specific medical skills. In the only review of interprofessional problem-based learning (iPBL) prior to our review reported here, Thompson (2010) included seven studies and examined the rationale for delivering IPE

through PBL. Although data were limited from the included studies, Thompson concluded that favourable evidence exists that iPBL improved attitudes towards other professional groups. However, to advance IPE evidence-based practice, context and implementation mechanisms in the delivery of specific IPE pedagogical approaches require further investigation. iPBL has been identified as a popular strategy for IPE delivery (Abu-Rish et al., 2012).

Therefore, the aim of this review is to describe the state-of-the-art delivery of iPBL by focussing on the context of delivery and implementation mechanisms for entry-level health professional students and evaluating the evidence that supports iPBL as an effective strategy for developing interprofessional competences. In other words, we want to evaluate in the literature where iPBL is delivered, how it is delivered and whether it works. The research questions for this review are as follows: a) "What contextual factors are associated with iPBL delivery for health professional students?," b) "What iPBL mechanisms warrant consideration in interprofessional education (IPE) for health professional students?," and c) "What interprofessional competences are achieved as outcomes of iPBL with health professional students?"

To provide a clear framework for data extraction and narrative synthesis of the findings, we begin by defining iPBL and presenting a conceptual framework to outline the core components of iPBL development for interprofessional competence based on the extant literature.

Defining IPE, iPBL and the Modified Kirpatrick Model of Evaluation

The operational definition of IPE adopted in this paper is the widely accepted definition of IPE and reflects the type of interactive, experiential and cooperative learning that IPE theorist D'Eon (2005) advocates for the development of interprofessional competences. The operational definition of IPE is "occasions when two or more professions learn with, from and about each other to improve collaboration and the quality of care" (Barr, 2002, p.6).

Knowledge, skills and behaviours relating to interprofessional competence are distinct from discipline specific knowledge and skills (Interprofessional Education Collaborative [IPEC], 2011). Four interprofessional competency frameworks exist (Thistlethwaite et al., 2014) which offer health educationalists a common language when setting IPE learning outcomes. The Interprofessional Education Collaborative (IPEC) of the United States (IPEC, 2011; 2016) provides one such framework which groups core interprofessional competences into four domains: 1) Values/Ethics, 2) Roles/Responsibilities, 3) Interprofessional Communication, and 4) Interprofessional Teams and Teamwork. Each competency domain contains several competency statements focused on the learning outcomes of IPE and are directed at the learner on an individual rather than team level. For example, "Communicate one's roles and responsibilities clearly to patients, families, community members, and other professionals" is the first competency statement in Domain 2, Roles/Responsibilities (IPEC, 2016, p.12). The conceptual model (Figure 1) proposed in this paper is informed by the IPEC competence domains and used to categorise and evaluate outcomes of interprofessional competences in this systematic review.

iPBL is a 'complex intervention' combining IPE and PBL components that can act either independently or interdependently (Medical Research Council, 2000). The combination of IPE and PBL in the form of iPBL has been referred to as a "marriage made in heaven" (Dahlgren, 2009, p. 448). In his paper, Dahlgren (2009) proposes that iPBL learning results from the social and cooperative processes that occur within the group. Originating in medical education, PBL is first described as learning that occurs through the process of trying to solve or manage real-life problems (Barrows, 1986). Although the PBL teaching model (knowledge acquisition versus problem-solving skills model) remains a source of controversy in the literature (Servant-Miklos, 2019), a number of published PBL reviews (Albanese & Mitchell, 1993; Colliver, 2000; Hung et al., 2019; Koh et al., 2008; Li et al., 2019; Neville, 2008; Norman & Schmidt, 1992; Strobel & van Barneveld, 2009; Vernon & Blake, 1993) report mixed and often contradictory outcomes for knowledge acquisition, problem solving, teamworking and socio-cognitive skills. However, there does appear to be consensus that the theoretical and instructional constructs of PBL are suited to the development of collaborative competences. As the use of PBL to develop interprofessional collaborative competences rather than discipline specific knowledge is the focus of this review, we adopt the operational definition of iPBL as learning which results from the process of interprofessionally and collaboratively trying to understand or manage shared clinical problems.

The modified Kirkpatrick framework (Barr et al., 2005; Reeves et al., 2015) has previously been identified as the preferred evaluation framework for IPE initiatives (Reeves et al., 2017) and consists of four levels. The first level (Level 1) focuses on students' reaction to IPE, moving to perceptions/attitudes at Level 2a, followed by knowledge/skills at Level 2b. Collaborative behaviour occurs at Level 3, with the final level focused on performance in practice (Level 4a), including benefits for the patient and the wider community (Level 4b). This hierarchical framework (Table 1) is used in our review to assess the impact of iPBL interventions on the level of interprofessional competence achieved

Level	Description
Level 1 **Reaction**	Learners' views on the learning experience and its interprofessional nature.
Level 2a **Modification of attitudes/perceptions**	Changes in reciprocal attitudes between participant groups. Changes in perception or attitude towards the value and/or use of team approaches to caring for a specific patient/client group.
Level 2b **Acquisition of knowledge and/or skills**	Including knowledge and skills linked to interprofessional collaboration.
Level 3 **Behavioural change**	Identifies individuals' transfer of interprofessional learning to their practice setting and their changed professional practice.
Level 4a **Change in organisational practice**	Wider changes in the organisation and delivery of care.
Level 4b **Benefits to patients/clients**	Improvements in health or well-being of patients, families and/or communities.

Table 1. Kirpatrick/Barr's Hierarchy of Interprofessional Education (IPE) Outcomes Framework (adapted from Reeves et al., 2015)

by health professional students. We draw on the modified Kirkpatrick model of evaluation to guide both analysis and discission of the results in relation to our research questions outlined above.

An iPBL Conceptual Framework for Entry-level Interprofessional Competence

Based on published reviews of IPE (Abu-Rish et al., 2012; Cooper et al., 2001; Lawlis et al., 2014; Reeves et al., 2016; Thistlethwaite, 2012; Thistlethwaite & Moran, 2010) and extant literature in PBL design research (Barrett & Moore 2010; Hung, 2009, 2011, 2016; Jonassen & Hung, 2008; O'Rourke et al., 2011; Stanton & McCaffrey, 2011), we developed a framework (Figure 1) to identify essential elements in designing, delivering and evaluating iPBL as a guide for health professional educators in the development of iPBL interventions. This framework was subsequently used to inform a data extraction proforma for iPBL studies identified in the review. We propose that the components presented in this framework operate in a non-linear fashion to influence and generate desired interprofessional competence outcomes. The framework considers iPBL design, implementation and evaluation in terms of context (C), mechanisms (M) and outcomes (O). Contextual factors consider where the iPBL intervention takes place: university setting; clinical setting or a joint initiative; the professional disciplines involved; the stage of learning and whether iPBL is embedded or supplementary to the curriculum; and whether students have prior exposure to clinical working and knowledge of the PBL process. Mechanisms focus on the iPBL theoretical underpinnings, design and the PBL process. These mechanisms include whether the initiative was designed specifically for IPE by an interprofessional team, the type of PBL trigger employed (e.g., diagnosis solution problems, where a patient's symptoms are presented and there is a clear goal of diagnosis, treatment and management), the PBL process or format used (including the number and duration of PBL tutorials), and facilitator training specific to PBL and/or IPE. The interprofessional learning outcomes were informed by the four domains defined by IPEC (IPEC, 2011).

Method

To identify relevant studies, a systematic search of the literature was conducted guided by the preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement (Moher et al., 2015). Meta-analysis was not considered appropriate for this body of literature because of methodological, statistical and study outcome heterogeneity; therefore, narrative synthesis was employed (Popay et al., 2006).

Search Strategy and Inclusion Criteria

The following educational and medical databases were searched from inception up to December 2019: Educational Resources Information Centre (ERIC), PsychINFO, EMBASE, PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Web of Science and the Cochrane Library. To identify additional studies, references from included papers and systematic reviews in the fields of IPE and PBL were manually checked and cross-checked. English language and human-study limits were applied where the database allowed. No limitations were applied by

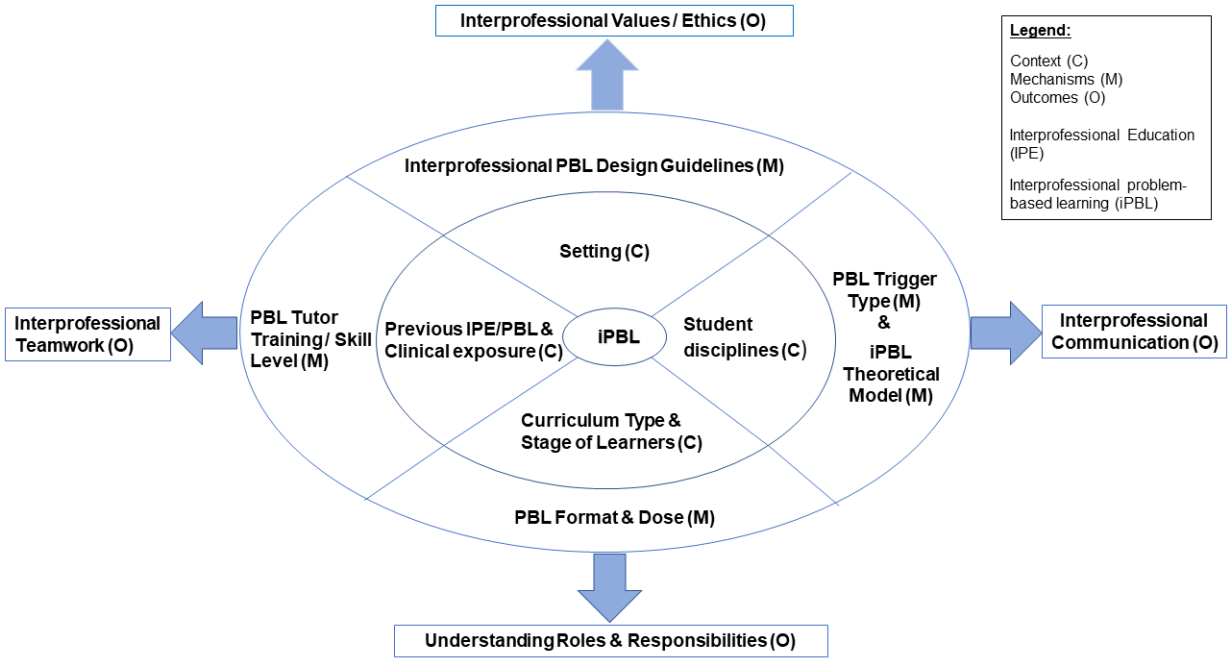

Figure 1. A Conceptual Model of Context, Mechanisms and Outcomes for Developing Interprofessional Problem-Based Learning (iPBL).

study methodology to allow for a comprehensive overview that includes students' perceptions of iPBL and its role in developing the interprofessional competences of interest. Conference abstracts without an accompanying full conference paper or other publication, non-peer reviewed reports and theses were excluded based on evidence that data presented may be inadequate or not dependable. In addition, inclusion of those documents typically results in negligible or less conservative results (Hartling et al., 2017; Scherer & Saldanha, 2019).

A detailed search strategy bespoke to each database was devised based on the PICO acronym (population, intervention, comparator and outcomes), with search terms and search strings crafted in the population and intervention fields only. The review population of interest was entry-level health and social care professional students. The intervention of interest was iPBL. For inclusion in the review, papers were required to either explicitly reference PBL as their pedagogical approach or adhere to PBL principles and processes. The presence of the following essential PBL characteristics as identified by Barrows (1986), Maudsley (1999) and Schmidt (1993) were required: 1) a learner centred process that is initiated and directed by authentic problems or triggers, 2) a period of self-directed learning and 3) a minimum of two small group collaborative learning sessions facilitated by tutors. In keeping with the IPE definition, studies included in this review required the PBL intervention to consist of two or more student groups from health and social care professions, as defined by the World Health Organisation classification of health workers (World Health Organisation, 2010a). The review considered any objectively measured or self-reported interprofessional competence outcome that could be clearly categorised under one of the four IPEC domains: 1) Values/ Ethics, 2) Roles/Responsibilities, 3) Interprofessional Communication, and 4) Interprofessional Teams and Teamwork. Final search strings employed included free-text terms with the Boolean operator OR and appropriate subject indexing terms (e.g., MeSH in PubMed) related to entry-level health professional students (population), iPBL and PBL (intervention) combined with the Boolean operator AND. A sample full-search strategy is provided as supplementary information in Appendix 1. Inclusion and exclusion criteria applied during the systematic review process are summarised in Table 2.

Study Selection

Publications identified by electronic database searches were exported to bibliographical software (Endnote version X7.7) to assist with data management. Duplicate articles were identified and removed. One reviewer (DP) first screened the papers by title to remove studies that clearly did not match the inclusion criteria. Remaining papers were

Inclusion	Exclusion
1. Health and social care undergraduate or graduate entry students (pre-registration/pre-licensure), regardless of disciplines. Studies that involve qualified healthcare staff with undergraduate students as part of the intervention were included only where the interprofessional competence outcomes were reported separately for student participants.	1. Conference abstracts without accompanying full conference or other paper publication, theses, and non-peer reviewed reports.
2. Included participants must represent two or more health professions.	2. iPBL interventions that did not meet the PBL definition or PBL process as outlined. E.g., iPBL workshops that do not provide a period of self-directed, independent study to explore learning issues generated in PBL groups.
3. Available full text empirical studies published in English.	3. Other interprofessional interventions: simulation, interprofessional clinical placement models, team-based learning, and case-based learning.
4. The intervention was described as PBL and/or adhered to published PBL principles and processes (Barrows, 1986; Maudsley, 1999; Schmidt, 1993). All PBL settings were included in this review (e.g., university, clinical setting, online or blended learning), once the PBL process and learning principles were adhered to.	4. Studies that did not describe student interprofessional competence outcomes. For example, studies that describe implementation of curriculum changes, organisational barriers to iPBL or tutor iPBL skills and facilitation styles.
5. Studies that describe interprofessional competence outcomes (either qualitative or quantitative) that could be categorised under one of the four Interprofessional Education Collaborative (IPEC) competence domains.	

Table 2. Inclusion and Exclusion Criteria

then independently screened by abstract against the inclusion and exclusion criteria by two reviewers (DP & OL). An inclusive approach was taken at both these stages, whereby if it was unclear whether the paper met inclusion criteria and no clear exclusion criteria applied, it was included at the next review stage. Final screening by full manuscript review was again conducted by two independent reviewers (DP & OL). Disagreements between reviewers were resolved through discussion amongst reviewers. For instances in which no consensus was reached, an independent third party was available to arbitrate. Figure 2 details the flow chart related to study selection.

Quality Assessment

Study quality was independently appraised by two reviewers (DP & OL) using the Mixed Methods Appraisal Tool (MMAT) (Hong et al., 2018; Pluye et al., 2009). This quality assessment tool has good reliability and validity (Pace et al., 2012; Pluye et al., 2009; Souto et al., 2015) and allows concurrent appraisal of quantitative, qualitative, and mixed-methods studies, as included in this review. The MMAT contains five specific sets of criteria: 1) a qualitative set, 2) a randomised controlled set, 3) a non-randomised set, 4) an observational descriptive set and 5) a mixed-methods set. Following a set of screening questions for all study types, included studies were assessed against the MMAT criteria appropriate to the study methodology. Global quality scores were assigned, ranging from 0 stars (no criteria were met) to 5 stars (*****, all criteria were met). Appraisal of mixed-methods studies requires appraisal in three criteria sets: the qualitative set, the appropriate quantitative set and the mixed-methods set. Again, a global rating score rating from 0-5 stars is generated. Discrepancies in quality rating scores between reviewers were resolved by discussions with direct reference to the MMAT user guide (Hong et al., 2018). For cases in which consensus could not be reached, the decision was adjudicated by a third reviewer (TB). No studies were excluded based on their quality score to allow a rich body of

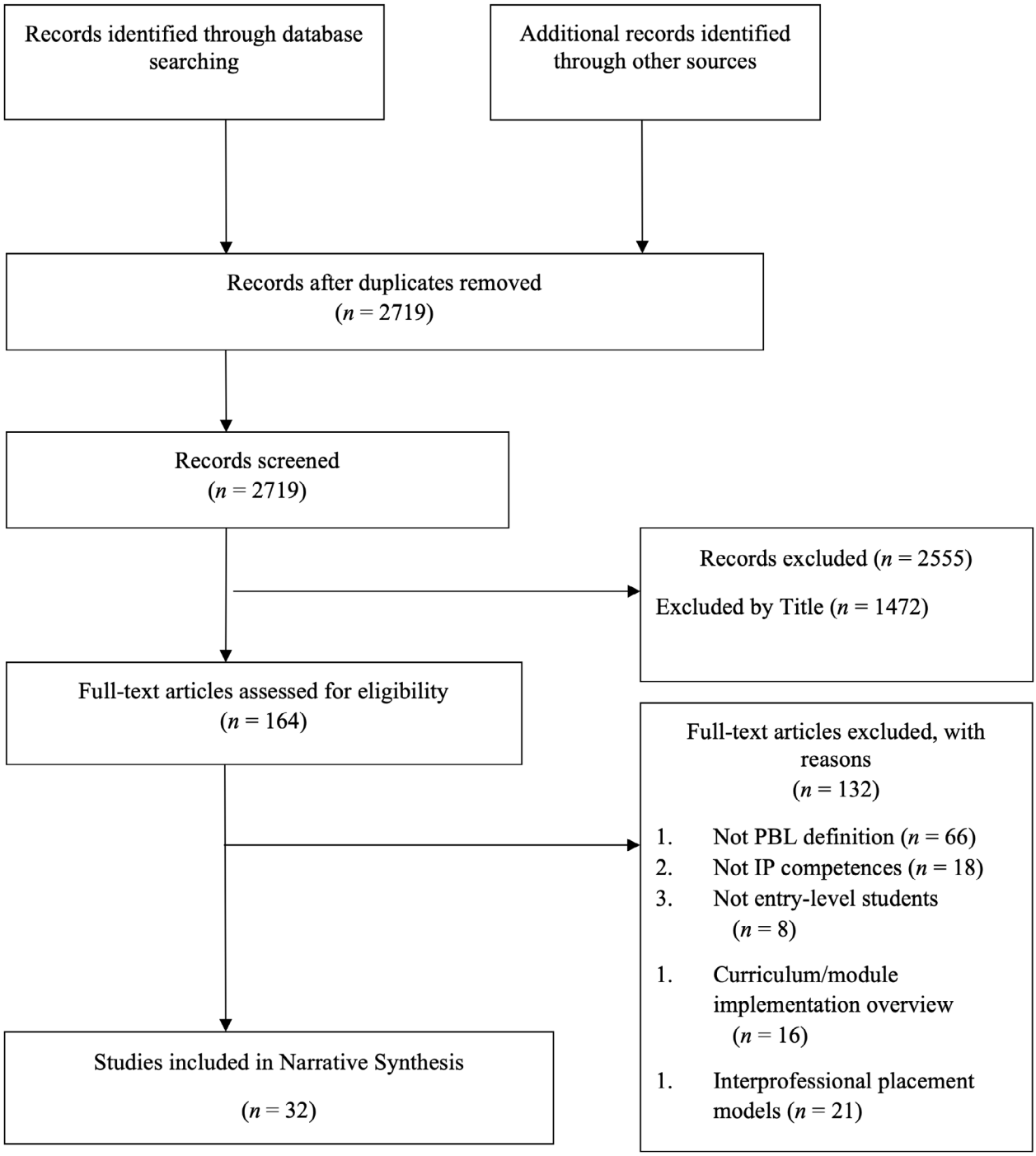

Figure 2. Study Selection Process - PRISMA Flow Diagram

data to be maintained for synthesis. The quality assessment of included studies was however a factor considered during data synthesis.

Data Extraction and Synthesis

Two authors independently extracted data relating to the following factors: research aims and theoretical perspectives; study context and population; intervention mechanisms, such as trigger type and PBL format; study design; and all reported interprofessional competence outcomes mapping to the IPEC framework (2011). A data extraction proforma is available as supplementary material in Appendix 2. During data extraction, if an article did not include information relevant to a question in the form, the extractor recorded, "Not reported." When both authors had completed their data extraction, the forms were examined, discussed, and subsequently merged to form a single data extraction table for synthesis.

The narrative synthesis that was conducted was partially guided by recommendations by Popay et al. (2006), whereby textual description, grouping and tabulation methods for preliminary synthesis were first utilised and patterns across studies were subsequently explored, using the developed iPBL framework (Figure 1). Data extracted were organised in a manner that addressed our specific research questions.

Results

Summary and Quality of Papers Identified

A total of 3,342 papers were identified through the search strategy employed. Thirty-two studies were included in the final review following screening, as represented in Figure 2. The included studies, summarised in detail in Table 3, were conducted in twelve countries: Canada (n = 7), USA (n = 6), United Kingdom (n = 7), Germany (n = 2), Japan (n = 2), Taiwan (n = 2), Australia (n = 1), Belgium (n = 1), Indonesia (n = 1), Ireland (n = 1), South Africa (n = 1) and Sweden (n = 1). Most (n = 18, 56%) utilised mixed-methods design, seven used (22%) qualitative methods only and seven (22%) quantitative methods only. Seven studies with quantitative data had a control/comparator group, none of which randomised group allocation. No quantitative data study reporting within or between group change conducted a sample size calculation to ensure adequate power for the inferential statistical tests. The mean quality rating using the MMAT tool for the included papers was 3.5 stars (sd 1.2), with scores ranging from 1 star (where one criterion was met) to 5 stars (where all criteria were met). Study limitations primarily related to sampling strategies, measurement tools and methodological reporting. Interrater quality rating agreement was 81%, with discrepancies subsequently resolved by discussion between the two independent reviewers.

All studies had clearly stated research objectives with 63% (n = 20) reporting student satisfaction with the iPBL learning process listed as the main outcome of interest. Matching Level 1 (participants' reaction) on the modified Kirkpatrick model, results presented in Table 3 indicate that students and tutors were positive about iPBL overall and highly rated the group dynamics and interprofessional aspects of this approach to learning. However, negative findings were identified which indicated the struggle and frustration associated with a new learning concept, negative group dynamic effects, interprofessional barriers and insufficient co-ordination during the iPBL process.

Contextual Factors Associated with iPBL Delivery

Table 4 provides an overview of the main contextual factors reported in the iPBL studies reviewed. The setting for iPBL was identified as important by participants in a small number of studies that highlighted students' preference for iPBL within the clinical setting with real patient triggers in line with the published literature proposing this improves learning fidelity (Dreier-Wolfgramm et al., 2018; Goelen et al., 2006; McKee et al., 2013). Despite this, the university setting was the most popular setting for delivery of iPBL interventions (n = 26, 81%), with two of these studies incorporating online iPBL (Owens et al., 2010; Solomon et al., 2010). Only two studies (6%) embedded iPBL in practice-based settings (Gjessing et al., 2014; Marshall et al., 2008), while four studies (13%) combined university and practice-based settings categorised as 'joint-led iPBL' (Dreier-Wolfgramm et al., 2018; Furber et al., 2004; Imafuku et al., 2018; Playford & Hagues, 2009). All studies reported positive interprofessional competence outcomes in at least one IPEC domain, with no pattern evident for specific outcomes, as reported, based on the setting for delivery.

Despite a diverse range of disciplines identified across the included studies (see Table 3), data presented does not facilitate identification of the ideal number of professional groups in iPBL or the optimal grouping of professions. Certain disciples were noted to dominate the iPBL literature: nursing (n = 27, 84%), medicine (n = 26, 81%), physiotherapy (n = 17, 53%) and pharmacy (n = 11, 34%). Less than a fifth of studies (19%, n = 6) included only two disciplines in their iPBL initiative, with medicine and nursing proving the most popular pairing (Chou et al., 2016; Dreier-Wolfgramm et al., 2018; Lin et al., 2013). Some caveats exist in relation to group pairings and dynamics. Differences in student perceptions of professions were evident: doctors were rated as less caring than other professions (Lindqvist et al., 2005; Hawkes et al.,

Author, Year, Country & Quality Rating	Study Design, Measurement Instruments & Data Collection	Setting, iPBL Topic & Student Participant Profile	IPEC Competence as stated Learning Outcome (Yes/No) & Competence Domain	Main Findings
Chou et al., (2016) Taiwan *****	Mixed Methods Multi-arm (uni-professional and iPBL groups) post evaluation design *Instruments & data collection* 2 x self-developed checklists: PBL process & Clinical Ethics; student self-reflections	University-based; Clinical Ethics *Participants (n=89)/ 9-10 per group* 45 Medicine (4th year); 44 Nursing (3rd year) (Uni-professional versus interprofessional group)	Yes IPEC Domain 1 Values/Ethics	**Quantitative** PBL process checklist: Statistically significant difference (p <. 001) was observed for 'engagement' element between delivery to single discipline (medicine) and interprofessional group in favour of IPE (Mann-Whitney p < .001). Ethics discussion skills checklist: A between group difference was observed (p =.049) in the Kruskal-Wallis test with the interprofessional group showing favourable performance over medicine only group. No sample size calculation reported. Statistical values not provided; effect size could not be calculated **Qualitative** Emergent themes from interprofessional group self-reflections: 1) Comparing & understanding other professions and features; 2) learning from others and making self-reflections and 3) considering communication & future collaboration in the workplace.
Curran et al., (2005) Canada ***	Mixed Methods Single-arm pre-post design *Instruments & data collection* Role Perception Checklist; Interprofessional Weekly Team Inventory; Team Skills Scale; Participation Evaluation Survey & self-developed Team Dynamics Checklist (tutors)	University-based; HIV/AIDS *Participants (n=133) / 8-10 per group* 62 Medicine (2nd year) 45 Nursing (3rd year) 26 Pharmacy (Final year)	Yes IPEC Domain 2 Roles/ Responsibilities IPEC Domain 4 Interprofessional Teams & Teamworking	**Quantitative** Interprofessional Weekly Team Inventory: Significant within group increase in weekly overall scores over 3-week period (t-test p = .000). Nursing & medicine students displayed significant changes in weeks 2 &3 of intervention (ANOVA & Scheffé post hoc analysis). Team Skills Scale: No significant difference between professions (t test p = .268) Team Dynamic Checklist: Tutors reported great variation in team meeting skills between groups. No sample size calculation reported. No t statistic reported; effect size could not be calculated. **Qualitative** Emergent themes from open questions on participation evaluation survey: 1) Knowledge of roles of other health professionals & how to collaborate with these professions in the delivery of care to HIV/AIDS patients and their families; 2) Knowledge of HIV/AIDS; 3) Group dynamics & negative impact on interprofessional collaborative process
Cusack et al., (2012) Ireland ***	Quantitative Descriptive Single-arm pre-post design *Instruments & data collection* IEPS; RIPLS	University-based; Professional Practice *Participants (n = 61)/ 10 per group* Medicine (1st year); Nursing (1st year); Physiotherapy (1st year); Radiography (1st year)	Yes IPEC Domain 2 Roles/ Responsibilities IPEC Domain 4 Interprofessional Teams & Teamworking	**Quantitative** Within group changes reported individually for each iPBL cohort that undertook the module. RIPLS: Student iPBL: Statistically significant within group change in 2 subscales post intervention via Wilcoxon Signed Rank test p < .005 (Subscales: Teamwork & Collaboration cohort 1 z =-2.67; p = .008; rc = .52; cohort 2 z =-2.73; p = .006); rc = .47), Positive Professional Identity cohort 1 z =-2.23; p =.027; rc = .52; ; cohort 2 z =-2.90; p =.004; rc =.51) Understanding of their own and others' roles cohort 2 z = -3.16; p =.002; rc = .56). IEPS: Statistically significant difference in subscale 1 (Competence & Autonomy) (Wilcoxon Signed Rank test Cohort 1 z = -2.17; p = .030; rc = .42; cohort 2 z = -2.91; p= .004; rc = .51). Subscale 3 (Perception of Actual Cooperation: cohort 2 z =-3.12; p = .002; rc = .55). No sample size calculation reported. Effect sizes: moderate effect sizes rc reported.
D'Eon et al. (2010)	Mixed Methods Single-arm pre-post design	University-based; HIV/AIDS	Yes	**Quantitative**

Table 3. Summary of Included Studies (n = 32)

Canada ***	*Instruments & data collection* Pre-post test case study questions; Self-assessment questionnaire (open & closed questions); Discipline specific focus groups (medicine & nutrition only)	*Participants (n = 777)/ 10 per group* 131 Medicine (2nd year); 10 Medicine (3rd year); 172 Nursing (4th year); 61 Physiotherapy (3rd year); 253 Pharmacy (4th year); 65 Medical Social Work (4th year); 75 Nutrition & Dietetics (3rd year); 10 Clinical Psychologists (graduate level)	IPEC Domain 2 Roles/ Responsibilities IPEC Domain 4 Interprofessional Teams & Teamworking	Statistically significant gains in student self-assessments (10-point scale) of their knowledge of other professions in all 3 years that the intervention was delivered ($p < .001$). Year 1 *mean difference* = 4.86; *sd* = 2.1; $t = 30.81$, $p < .001$; $d = 2.55$; Year 2 *mean difference* 3.89; *sd* 2.0; $t = 41.1$; $p < .001$; $d = 2.93$; Year 2 *mean difference* = 4.08; *sd*= 1.9; $t = 24.3$; $p < .001$; d= 2.43 No sample size calculation reported. Cohen's $d > 0.70$ indicating large effect size. **Qualitative** Emergent qualitative themes from focus groups: 1) Usefulness of iPBL module; 2) Enjoyment and 3) Facilitator effectiveness
Drier-Wolfgramm et al. (2018) Germany ***	Quantitative Descriptive Single-arm pre-post design *Instruments & data collection* Self-developed questionnaires	Joint-led; Community Medicine *Participants (n = 10) / 1 group of 10 for iPBL* (1st year) 5 Medical; 5 Nursing	No	**Quantitative** Descriptive statistics only used. Pre-post questionnaires focused on IPE, the roles of both professions and suitable topics for iPBL. Overall medical students evaluated the design of the course as less successful than nursing students (E.g., 4 medical students rated composition and structure as "not so good" while 4 nursing students rated the same category as "very good"). Tutor guidance was evaluated as positive overall with 9 out of 10 students rating statements as "strongly agree" or "agree". All 10 students rated mutual appreciation of the other profession as "high". Post intervention, medical students rated their ability to engage in interprofessional communication & collaboration as "good", having considered them to be "very good" pre-intervention. Pre-intervention all students reported that they knew the roles of the respective other profession well. Post intervention, all students reported an expanded and more detailed understanding of the roles. No inferential statistical tests reported.
Eccott et al. (2012) Canada ****	Mixed Methods Single-arm pre-post design *Instruments & data collection* Interprofessional Teamwork Questionnaire(adapted); Satisfaction questionnaire; Focus groups	University-based; Postnatal Care *Participants (n = 24)/ 4-5 per group* (Year: 1st-4th) 5 Medicine; 5 Nursing; 5 Pharmacy; 5 Occupational Therapy; 4 Physiotherapy	Yes IPEC Domain 4 Interprofessional Teams & Teamworking	**Quantitative** Interprofessional Teamwork Questionnaire: Significant increase in 7-point Likert scales scores in 16 questions broadly assessing students' attitudes and knowledge of interprofessional collaboration and teamwork. (*averaged mean difference* = 0.7; paired t-tests $p < .05$ in 11 out of 16 questions) 100% respondents 'strongly agreed' or 'agreed' that the module enhanced their understanding of interprofessional teamwork. No within group sample size calculation calculated; t statistic not provided. Effect size could not be calculated. **Qualitative** Emergent themes from focus groups: 1) Others' roles & perspectives; 2) iPBL process conducive to improved communication; 3) Increased confidence collaborating with other professions, a more patient-centred approach and improved practice readiness and 4) Timing/ stage of implementation for iPBL
Furber et al. (2004) UK ***	Mixed Methods Single-arm pre-post design *Instruments & data collection* Self-developed questionnaires	Joint-led (University & practice setting); Maternal & Child Health *Participants (n = 40) / 8 per group* 13 Medicine (4th year); 10 Nursing (2nd year); 17 Midwifery (3rd year)	Yes IPEC Domain 4 Interprofessional Teams & Teamworking	**Quantitative** No results of inferential statistics reported in pre/post intervention in questionnaire scores (questionnaires focused on: expectations, interprofessional attitudes & teamworking). For teamworking on a 12-72 scale; medical students improved by 2 points and nurses by 1 point. On interprofessional working using a 14–84-point scale midwifery and nursing students improved by 2 points and doctors improved by 4 points. No further data was presented. No within group sample size calculation calculated; no statistics provided. Effect size could not be calculated. **Qualitative** Themes: 1) Working in teams; 2) Sharing of knowledge skills & different perspectives and 3) trying out PBL
Gjessing et al. (2014) Sweden *****	Mixed Methods Single-arm post evaluation design & Qualitative open questions *Instruments & data collection*	Practice-based; Quality & Safety Improvements *Participants (n = 222)/ Group size not reported*	Yes IPEC Domain 4	**Quantitative** A questionnaire comprising 19 items rated on a 6-point Likert scale was used with results dichotomised to positive or negative responses for concept and implementation, learning objectives, reflection on professional roles, and perceived effects of interprofessional teamwork. Chi^2 tests examined proportional differences between programme affiliation and between gender. Both medical and male students rated

Table 3 cont. Summary of Included Studies (n = 32)

	Self-developed questionnaire (face validity tested)	(3rd year) 51 Medicine; 118 Nursing; 53 Physiotherapy & Occupational Therapy combined	Interprofessional Teams & Teamworking	significantly lower in questionnaire change scores following the IPE initiative than other professions and female students for 1) ability to describe own interprofessional competence; 2) ability to describe own & other's professional knowledge and 3) perception of developed ability to work with other healthcare professionals (chi-square test, $p < .05$). No within group sample size calculation calculated; Chi^2 statistic not provided. Effect size could not be calculated. **Qualitative** Emergent themes from open questions: 1) Frustration & anger- usure if this intervention was a good way to develop interprofessional competence; 2) Insufficient cooperation & coordination by university & clinics. Students identified interpersonal dynamics rather than professional competences as success factor
Goelen et al. (2006) Belgium ***	Mixed Methods Multi-arm (uni-professional and iPBL groups) pre-post design *Instruments & data collection* IEPS; Student evaluation questionnaire with free text comments	University-based; Neurology patients (Parkinson's Disease & Stroke) *Participants (n = 179)/ Group size not reported* Data for: 42 Medicine (2nd year); 53 Nursing (3rd year); 54 Physiotherapy (3rd year) (89 Control Group, 90 Intervention group)	Yes IPEC Domain 4 Interprofessional Teams & Teamworking	**Quantitative** No between group comparison data were presented. Results reported indicated the intervention was associated with a significant within group change in IEPS domain 1 only (Competence & autonomy) *(mean difference* = 1.5 points: $p = .05$). No within group change in any domain of IEPS was observed in the control group. Gender differences were observed with males improving more post intervention in domain 1 (Competence & autonomy; *mean difference* = 4.1 points; $p < .05$) & 4 (Understanding the value of other professions; *mean difference* = 3.5 points; $p < .05$) of IEPS. No within or between group sample size calculation; Wilcoxon ranks statistic not provided. Effect size could not be calculated. **Qualitative** 73 out of 84 evaluation questionnaire respondents indicated their preference for real patients as opposed to other possible triggers for PBL.
Hawkes et al. (2013) UK ****	Quantitative Descriptive Single-arm pre-post design *Instruments & data collection* AHPQ	University-based; Medicines Management *Participants (n = 76)/ Group size not reported* (1st year) 33 Medicine; 15 Nursing; 28 Pharmacy	No	**Quantitative** AHPQ: focussed on 13 components that could be associated with 'caring dimension' using principle component analysis. A 3-way ANOVA assessed differences between student groups, professions and the IPL intervention, with post hoc paired t-tests for each profession. The whole group's perception of how caring each profession is improved post intervention ($p < .005$). The iPBL intervention resulted in a within group improvement in the perception of how caring a pharmacist is (*mean difference* = 5.7701; *95% CI* =3.1184 - 8.4218; t =3.47; $p < .0001$); perception of a doctor (*mean difference* = 4.8715, *95% CI* =2.8743 – 6.8686; t = 5.4; $p < .0001$) and perception of a nurse (*Mean difference* = 2.1566; *95% CI* = 0.9174-3.3957; t = 3.5; $p = .0009$) No within or between group sample size calculation reported; Within group effect sizes calculated d= 10.5; 10.1 and 4.2 for within group changes in perceptions of how caring a pharmacist, doctor and nurse is by professions respectively.
Hodges & Massey (2015) USA **	Mixed Methods Multi-arm (uni-professional and iPBL groups) *Instruments & data collection* Pre/post individual & group quiz grades, self-assessment Likert; narrative comments	University-based; Optometry/Visual Impairment *Participants (n = 94)/ 5-7 per group* Nursing & Pharmacy (Uni-professional versus interprofessional group)	No	**Quantitative** Descriptive design. No raw data presented. Authors report significant within group differences between pre/post-test quiz scores and self-assessment scores (satisfaction and perceived knowledge gained) of single-discipline or interprofessional groups observed as a result of the intervention. No within or between group sample size calculation conducted; No inferential statistics reported. Effect size could not be calculated. **Qualitative** Narrative themes: 1) Unexpected satisfaction with the learning approach; 2) Development of Positive Interprofessional Perspective. Tutor Comments: Overall positive but effect of group dynamics on learning evident
Hughes & Lucas (1997) UK	Quantitative Descriptive *Instruments & data collection*	University-based; Social structure, health & NHS *Participants (n = 174)/ Max 9 per group*	Yes IPEC Domain 4 Interprofessional	**Quantitative** Descriptive data presented only. Results highlight the following change post intervention. Multi-professional objectives 1) Respecting other team members: 97% felt this objective was met both years of

Table 3 cont. Summary of Included Studies (n = 32)

****	Student ratings of multiprofessional educational & PBL objectives; Limburg scale for tutor performance	(1st year) Physiotherapy; Prosthetics & Orthotics; Diagnostic Radiography	Teams & Teamworking	module; 2) The lowest level of agreement that objectives had been fully met was in the areas of effective communication and reflection (80%) PBL objectives: Participation (~60%) and overcoming conflict (~46%) were the PBL objectives with the lowest levels of agreement. Average self-directed learning time was 2.10 hours. Overall tutor performance was rated as either 'good' or 'very good'. No inferential statistical tests reported.
Imafuku et al. (2014) Japan *****	Qualitative *Instruments & data collection* Video recording of PBL sessions, E-portfolios	University-based; Rheumatoid Arthritis *Participants / 8-9 per group* 6 Medicine (3rd year); 3 Dentistry (3rd year); 9 Pharmaceutical Science (3rd year); 5 Nursing (2nd year); 2 Occupational Therapy (2nd year); 1 Physiotherapy (2nd year)	Yes IPEC Domain 4 Interprofessional Teams & Teamworking	**Qualitative** Emergent themes from video recordings & e-portfolios: 1) Interprofessional working and development of a care plan; 2) Perceptions of learning through iPBL and participation – mixed results 2 out of 3 groups were positive re: iPBL learning process and 3) development of professional identity through interprofessional working
Imafuku et al. (2018) Japan *****	Qualitative *Instruments & data collection* E-portfolios	Joint-led; Mixed patient presentations e.g. nutrition, heat stroke, cancer support *Participants (n = 26)/ 8-9 per group* (1st year) 5 Medicine; 4 Dentistry; 4 Pharmaceutical Science; 2 Physiotherapy; 1 Occupational Therapy	No	**Qualitative** Emergent themes from e-portfolios: 1) Teams and Teamwork with a focus on the process of team development; 2) Interpersonal Communication – importance of communication and active listening skills; 3) Roles and Responsibilities as group members and 4) Roles and Responsibilities as health professionals. Themes relating to students IPE learning trajectory: 1) Struggling in a new educational context; 2) Learning though social interactions; 3) Changing viewpoints as learners and 4) Identity formation.
L'Ecuyer et al. (2015) USA *****	Qualitative *Instruments & data collection* Critical reflection assignments	University-based; Patient safety & quality care *Participants / 13-15 per group* 88 Nursing (Accelerated prelicensure courses) (Groups = Interprofessional but only nursing data)	Yes IPEC Domain 4 Interprofessional Teams & Teamworking	**Qualitative** Emergent themes from reflective assignments: 1) Identifying attributes of good or poor teamwork in practice; 2) Articulating importance of effective communication when providing health care; 3) Understanding roles and responsibilities of other professions; 4) Expressing confidence to engage other professions in practice and 5) Connecting PBL to interprofessional practice.
Lehrer et al. (2015) USA ***	Quantitative Two-arm (iPBL & control) post evaluation design *Instruments & data collection* IEPS	University-based; Not reported *Participants (n = 97)/ 10-14 per group* (1st & 2nd year); 62 Medicine 35 Pharmacy	No	**Quantitative** Medical students (*mean score* = 97.8; *sd* = 4.8) and pharmacy students (*mean score* 76.7; *sd* =11.6) in the iPBL intervention group showed a significant difference in IEPS subscale 2 'Perceived need for cooperation' when compared to the control students for each profession (medical *mean score* = 93.5 *sd* = 7.0; $p = .006$; pharmacy *mean score* = 88.3 *sd* = 10.8; $p = .02$ respectively) Two-tailed *t*-test. Combined student responses (intervention & non-intervention groups) also showed that pharmacy students perceived a significantly higher need for 'interdependence' (IPES subscale 3) ($p = .002$) when compared to medical students. No sample size calculation reported. No *t*/statistic reported; effect size could not be calculated.
Lestari et al. (2019) Indonesia *****	Mixed Methods Single-arm post evaluation design *Instruments & data collection* Maastricht Peer-Activity Rating Scale (MPARS), Video recordings of PBL sessions, Focus groups	University-based; Reproductive health *Participants (n = 62)/ 10-15 per group* 16 Medicine (5th year); 22 Nursing (5th year); 14 Midwifery (3rd year)	Yes IPEC Domain 4 Interprofessional Teams & Teamworking	**Quantitative** MPARS: Items to measure constructive (e.g., asking questions) and collaborative activities were deemed valid (Kappa coefficient of 0.01-0.02 and $p < .05$). Kruskal-Wallis test indicated significant difference in all constructivist & collaborative scores of students across all professions ($p = .000$) following iPBL. Mann-Whitney testing between professional groups indicated significant difference in MPARS mean scores of medical students in all item scales for constructive activity and collaborative activity when compared to nursing and midwifery groups ($p < .001$). No sample size calculation reported. No H or U statistic reported; effect size could not be calculated.

Table 3 cont. Summary of Included Studies (n = 32)

				Qualitative Emergent themes from focus groups: 1) Students learned from each other professions' knowledge; 2) Asking critical questions is not always self-evident; 3) Correcting misunderstandings without causing offence; 4) Factors affecting student participation (Tutor role & Social status) and 5) Persisting professional barriers.
Lin et al. (2013) Taiwan ***	Mixed Methods Multi-arm (uni-professional and iPBL groups) post evaluation design *Instruments & data collection* Self-developed Interprofessional Communication and Collaboration Questionnaire (ICCQ) & students self-evaluation of Performance Questionnaire	University-based; Clinical ethics *Participants (n = 36)/ 6 per group* 18 Medicine (6th year); 18 Nursing (4th year) (Uni-professional versus interprofessional groups)	Yes IPEC Domain 4 Interprofessional Teams & Teamworking	**Quantitative** ICCQ: One-way ANOVA identified significant difference among the 3 different student groups (p = .0184). The mean score of the interprofessional group for interprofessional communication and collaboration (*mean* = 37.6; *sd* = 3.3) was significantly higher than the mean score of the medical only group (*mean* = 32.1; *sd* = 5.0 (Tukey-Kramer HSD test, $p < .05$). No significant difference in mean scores observed between the interprofessional & nursing only group. No statistically significant difference for student self- evaluation questionnaire between uni-professional and interprofessional groups. General student satisfaction with intervention was 79.41%. No sample size calculation reported. F statistic not reported. Effect size could not be calculated. **Qualitative** Comments identify the following themes: 1) Respect for others' perspectives; 2) Different professions may hold values or perspectives that are unique to their own profession and 3) Interprofessional groups allow more holistic view of clinical scenario.
Lindqvist et al. (2005) UK ***	Quantitative Two-arm non-randomised (iPBL & control) pre-post design *Instruments & data collection* AHPQ, Plenary & Debriefing session	University-based; Professional roles & interprofessional teamworking *Participants (n = 96)/ 5 per group where possible* 27 Medicine; 21 Nursing; 23 Occupational Therapy 19 Physiotherapy; 6 Midwifery (Control & Intervention groups)	No	**Quantitative** No statistical difference between control & intervention group for 'caring' dimension of AHPQ (repeated measures ANOVA with Huynh-Feldt adjustment – $F_{1,50} = 2.8$ $p = .099$) or for 'subservient' dimension (p = .623) following the intervention. When both scales were considered simultaneously, there was some evidence of an overall between group difference ($F_{1,50} = 2.36$; $p = .026$, MANOVA). Clear differences in students' attitudes (AHPQ) towards different health professions were seen at the start of study between all 5 professions. Doctors rated as 'less caring' than other professions & nursing rated as more 'subservient' than other professions (Tukey's post hoc analysis $p < .001$). No sample size calculation reported. F statistic reported. Effect size ω^2 could not be calculated.
Marshall et al. (2008) USA *	Mixed Methods Single-arm pre-post evaluation design *Instruments & data collection* Self-developed evaluation questionnaire. Observation by health education specialist	Practice-based; Pandemic preparation/SARS *Participants (n = 17)/ Group size not reported* 6 Medicine (1st year); 3 Nursing (2nd year); 2 Medical Social Work (year not reported); 1 Public Health (year not reported); 1 Nurse Practitioner (Qualified); 3 Medical Social Work (Qualified)	No	**Quantitative** Summary statistics provided only. Improvements seen in bioterrorism knowledge change scores following the intervention. Post evaluation questionnaire (Likert scales 1-5) provide mean scores for: 1) PBL case content and process; 2) Multidisciplinary group process and 3) Overall view of the case. Based on mean scores, the iPBL case and process was considered positive overall with a student preference for iPBL over traditional lecture to learn about topic (mean score 4.5). From a multidisciplinary aspect, mean scores indicated that the group worked cooperative rather than competitively (4.6) and with active participation by group members (4.6). No inferential statistics conducted. **Qualitative** Qualitative data from anonymised student comments reiterated similar points.
McKee et al. (2010) Canada ***	Mixed Methods Single-arm post evaluation design *Instruments & data collection* Pre/post case study questions, Satisfaction survey, semi-structured interviews	University-based; Prostate cancer/end of life care *Participants (n = 9)/ Group size not reported* Medicine, Nursing & Pharmacy	Yes IPEC Domain 4 Interprofessional Teams & Teamworking	**Quantitative** No pre-post raw data reported. Authors reports narratively that students list doctors, nurses & pharmacists as palliative team members pre intervention and include social workers, therapists and spiritual care workers post intervention. Student satisfaction (Likert scale 1-6), descriptive statistics only reported: Students rated the interprofessional and group dynamic aspects of the iPBL module most highly (8 out of 9 students scored 5 or 6 for these aspects). Explanations regarding PBL process was the least satisfying aspect of module (≤4 students gave a rating of 5 or 6) No inferential statistical tests conducted. **Qualitative**

Table 3 cont. Summary of Included Studies (n = 32)

				Emergent themes from semi-structured interviews: 1) Personal connection and relevance to palliative care & advantage of working in a team to tackle complex and difficult problems; 2) Respect for other professionals; 3) Role dentification and 4) Patient-centred approach to care.
McKee et al. (2013) Canada ****	Quantitative Descriptive Single-arm post evaluation design *Instruments & data collection* Self-developed questionnaire	University-based; Palliative & end of life care *Participants (n = 930)/ 8-12 per group* 212 Medicine (2nd year); 81 Nursing (2nd year); 93 Nursing (Post RN); 106 Physiotherapy (2nd year); 275 Pharmacy (3rd year); 74 Medical Social Work (4th year); 88 Nutrition & Dietetics (3rd year); 1 Clinical Psychology (PhD)	Yes IPEC Domain 2 Roles/ Responsibilities	**Quantitative** Univariate ANOVA with post-hoc Tukey's test were conducted to compare differences between different years in which the intervention took place and between different programs that participated in the intervention. Statistically significant gains in knowledge about other professions in all years of study ($F_{5, 886} = 27.24$. $p < .001$) with very large effect sizes (Cohen's-d 2.67- 3.76). Examining differences between programmes identified medicine students' gains in knowledge of other professions as significantly lower than other professional student groups ($F_{5,871} = 6.46$, $p < .001$). Student Satisfaction Rating scale: 1) Usefulness of iPBL = moderate (mean 4.36/6); 2) Highly enjoyable module (5.9/6) and 3) Facilitator effectiveness also rated highly (5.19/6). No sample size calculation reported. F statistic and effect size reported.
Owens et al. (2010) UK ****	Qualitative *Instruments & data collection* Self-developed questionnaire, Focus groups(uni-discipline)	University-based: Online; Not reported *Participants (n = 59)/ 6-10 per group* (1st year) Nursing; Midwifery; Physiotherapy; Occupational Therapy; Radiography	Yes IPEC Domain 4 Interprofessional Teams & Teamworking	**Qualitative** Emergent themes from focus groups 1) Knowledge of other professions; 2) Timing of the module (i.e., establish a professional identity and gain clinical knowledge) and 3) Mode of delivery (online), processes and implications.
Playford & Hagues (2009) Australia ****	Qualitative *Instruments & data collection* Self-developed questionnaires – open-ended questions	Joint-led; Stroke Patient *Participants (n = 11)/ Group size not reported* 4 Medicine; 3 Nursing; 2 Physiotherapy; 1 Speech & Language Therapy; 1 Medical Social Work	Yes IPEC Domain 4 Interprofessional Teams & Teamworking	**Qualitative** Emergent themes from open-ended questions: 1) Moving from the benefit of many perspectives to holistic care; 2) From incidental expertise and support to sustained working together and 3) From concern about power and authority to concern about communication
Popovich et al. (2000) USA *	Qualitative *Instruments & data collection* Written reflections; self-developed peer assessments of self/team learning	University-based; Mixed patient presentations *Participants / 20 per group* (Final year on-campus) Nursing; Pharmacy; Nutrition & Dietetics; Health promotion/Education	Yes IPEC Domain 2 Roles/ Responsibilities IPEC Domain 4 Interprofessional Teams & Teamworking	**Qualitative** Emergent themes from qualitative sources: What students liked about course: 1) Professional respect; 2) Cooperation between disciplines; 3) Interpersonal skill development and communication skills. Areas for Improvement: 1) Debriefing session at end of process and 2) Trigger cases repetitive and/or not attuned to interprofessional care. Key student learning: Respecting the contributions of another discipline and developing the skills to interact with members of another profession. Also allowed an opportunity to learn 'jargon' of other disciplines. Skills learned: 1) Patience; 2) Listening skills and 3) Personal Confidence.
Reitsma et al. (2019) South Africa ***	Mixed Methods Single-arm post evaluation design *Instruments & data collection* Written reflections, Self-developed Likert questionnaire based on qualitative findings	University-based; Mixed patient case scenarios *Participants (n = 49)/ 6 per group* (3rd year) 10 Nursing; 10 Pharmacy; 7 Nutrition & Dietetics; 5 Medical Social Work; 7 Psychology; 10 Human Movement Science	Yes IPEC Domain 2 Roles/ Responsibilities IPEC Domain 4 Interprofessional Teams & Teamworking	**Quantitative** Summary statistics reported only. Likert scale results were reported as percentage of students that 'Do not agree' to 'Agree to a great extent'. 92.5% of students were unsure of their professional role at the start of the intervention. 100% of students indicated to varying degrees that they understood their professional role at the end of the intervention. No inferential statistical tests conducted. **Qualitative** Emergent themes from written reflections: 1) Understanding & developing professional identities in teams; 2) Interprofessional collaboration; 3) Interprofessional team dynamics; 4) Influence of facilitators on interprofessional teamwork; 5) Trigger effectiveness – preference for theoretical case studies over practical scenarios with overall preference for real-life scenarios and 6) Developing interprofessional competences. Students reported that competences developed during iPBL were working as a team & communication

Table 3 cont. Summary of Included Studies (n = 32)

Reynolds (2003) UK *****	Mixed Methods Single-arm post evaluation design *Instruments & data collection* PBL Attitudes Questionnaire (PBLAQ) with qualitative open-ended questions	University-based; Chronic pain *Participants (n = 157)/ 4-5 per group* (1st year) Physiotherapy; Occupational Therapy	No	**Quantitative** PBLAQ: reasonable internal consistency (Cronbach's alpha = 0.72). Summary statistics reported. Total PBLAQ scores post intervention indicate that as a group, students were positive about this approach to learning (mean 62.0, *SD* = 5.6; max score possible = 80). Independent t tests examined gender differences with reported small but significant differences ($p < .05$) in 3 attitude scores between men and women. Trust: women *mean score* = 4.3; *sd* = .8; men *mean score* = 3.9; *sd* = .9; Enjoyment of responsibility women: *mean* = 4.1; *sd* = .8; men *mean score* = 3.7; *sd* .9; Enjoyment of working with others: women *mean score* = 4.3; *sd* =0.7; men *mean* score =4.0; *sd* = 0.7. No sample size calculation conducted. No t statistic presented. Effect size could not be calculated. **Qualitative** Emergent themes form open-ended questions: 1) Depth/detail of study; 2) Working in a group/Support from others; 3) Relevant/real problem to solve; 4) Learning about multidisciplinary work/each profession's role; 5) Considering different viewpoints and 6) Active/self-directed learning.
Solomon et al. (2003) Canada ***	Mixed Methods Single-arm post evaluation design *Instruments & data collection* Reflective journals, semi-structured interviews, Students' rating of educational objectives.	University-based; HIV/Rehabilitation *Participants (n = 10)/ 5 per group* ('senior level' students) 2 Medicine; 2 Nursing; 2 Physiotherapy; 2 Occupational Therapy; 2 Medical Social Work	Yes IPEC Domain 2 Roles/ Responsibilities	**Quantitative** Summary statistics only reported. Student ratings of educational objectives were consistently high on a 1-7 Likert rating scale (lowest rating 5.87 to 7). Understanding professional roles in the rehabilitation of HIV patients scored 6.78 (*SD* 0.46) and developing skills in interprofessional communication, planning and decision making scored 6.5 (*SD* 0.53). No inferential statistical rests conducted. **Qualitative** Emergent themes from reflective journals & student interviews: 1) Factual knowledge HIV/AIDS and knowledge of the roles of other health disciplines; 2) Benefits to interprofessional learning (learning with and from each other); 3) Rehabilitation insights including understanding different professions understanding of rehabilitation; 4) Sense of confidence (knowing their own role & advocating for their profession and 5) enjoyment of experience.
Solomon et al. (2010) Canada *****	Qualitative *Instruments & data collection* Online discussion text, Focus groups & Individual semi-structured interviews, Online Likert Evaluation Questionnaire	University-based: Online; Mixed topics e.g. communication; healthcare ethics, stroke management, palliative care, rural community Aboriginal healthcare *Participants (n = 77)/ Group size not reported* (Year range 1st- 4th) 15 Medicine; 14 Nursing; 23 Occupational Therapy; 7 Physiotherapy; 5 Medical Social Work; 3 Speech & Language Therapy; 2 Nutrition & Dietetics; 1 Pharmacy; 3 Health promotion; 4 Spiritual Care	Yes IPEC Domain 2 Roles/ Responsibilities IPEC Domain 4 Interprofessional Teams & Teamworking	**Quantitative** Results of Likert student evaluation not reported. Authors describe study as qualitative with only data from online discussion text, focus groups and individual student interviews reported. **Qualitative** Emergent themes from qualitative sources: 1) Importance of communication strategies; 2) Clarifying professional roles; 3) Problem-solving together; 4) Recognising and valuing collaboration; 5) Providing information from own professional perspective; 6) Positive attitudes towards IPE and 7) Strategies to move the learning process forward (e.g., supporting comments, comfortable asking other's opinions and perspectives).
Straub et al. (2017) Germany ***	Mixed Methods Single-arm post evaluation design *Instruments & data collection* Student evaluation questionnaire (open & closed questions with free text comments), RIPLS, self-developed interprofessional self-assessment instrument (ISI)	University-based; Child protection & family services *Participants (n = 85)/ 4-7 per group* 34 Medicine (4th year); 17 Medical Social Work; 9 Psychology; 24 Educational Pedagogy; 1 Clinical Pedagogy	No	**Quantitative** iPBL module evaluation conducted over 5 consecutive terms with different evaluation instruments used during different terms. Therefore, results of RIPLS and self-developed ISI and modified ISI not reported. Student evaluation questionnaire: All iPBL courses were evaluated with a mean of 1.32 (*sd* ± .26) on a 6-point scale (1= excellent, 6=insufficient). All students voted that the course be continued in the following academic terms. Kruskal–Wallis tests for multiple comparisons between health professional student groups reported non-significant findings in each sub-domain. No sample size calculation conducted. No statistic presented. Effect size could not be calculated. **Qualitative**

Table 3 cont. Summary of Included Studies (n = 32)

				Emergent themes from open questions and free text comments: 1) Learning from other professions (both methods and knowledge acquisition) and 2) Interprofessional-competency-acquirement. Aspects of interprofessional-competency-acquirement include the importance of IPCP, avoidance of stereotypes, interprofessional communication, roles and expertise.
Wakefield et al. (2003) UK *	Mixed Methods Double-arm (iPBL students and Tutors) pre-post design *Instruments & data collection* Self-developed questionnaires with closed & open-ended questions	University-based; Labour, birth & new baby care *Participants (n = 40)/ 8 per group* 13 Medicine (4th year); 10 Nursing (2nd year); 17 Midwifery (3rd year)	Yes IPEC Domain 4 Interprofessional Teams & Teamworking	**Quantitative** No quantitative data reported in the paper. **Qualitative** Emergent themes identified from open questions: 1) Working in teams; 2) Sharing knowledge, skills and perspectives on care and 3) Learning to interact in a multiprofessional group
Wellmon et al. (2016) USA *****	Mixed Methods Double-arm (iPBL & control) pre-post design *Instruments & data collection* IEPS, RIPLS, Attitudes Towards Healthcare Teams Scale (ATHCTS), Discipline specific focus groups	University-based; Multiple Sclerosis patient *Participants (n = 38)/ Group size not reported)* Nursing; Physiotherapy; Medical Social Work; Clinical Psychology (19 Intervention group; 19 Control Group)	Yes IPEC Domain 4 Interprofessional Teams & Teamworking	**Quantitative** IEPS, RIPLS and ATHCTS between and within group differences for the intervention were explored using 2-way ANOVA with repeated measures. Statistically significant interactions were identified using Tukey-Kramer HSD test (alpha set at $p < .05$). IEPS: Following the intervention no statistical difference between groups was identified. Statistically significant within group increase in 3 subscales (Competency & Autonomy mean within group change: 9.2; $p < .05$; Perceived Need for Cooperation mean within group change: 9.2; $p < .05$; Perception of actual Cooperation mean within group change: 8.1 $p < .05$) reported. RIPLS: No statistical differences between or within groups were identified. ATHCTS: Following intervention, the IPE group scored significantly higher than control group on team value (mean difference between group change scores =3.5; $p = .003$) and team efficiency (mean difference between group change scores =1.1; $p = .048$) subscales. Within group statistical difference pre/post intervention on the same subscales reported in the interprofessional group (mean within group change: 5.9; $p = .025$ & mean within group change: 2.4; $p = .017$ respectively). No sample size calculation was conducted. Inferential statistics not reported. Effect size could not be calculated. **Qualitative** Emergent themes from focus groups: 1) Valuing input of multiple perspectives and 2) Putting it all together (i.e., collaborative patient-centred care).

AHPQ: Attitudes to Health Professionals Questionnaire; Attitudes Towards Healthcare Teams Scale (ATHCTS); ICCQ: Interprofessional Communication and Collaboration Questionnaire; IEPS: Interdisciplinary Education Perception Scale; IPE: Interprofessional Education; RIPLS: Readiness for Interprofessional Learning Scale

Table 3 cont. Summary of Included Studies (n = 32)

2013) and nurses were rated as more subservient (Lindqvist et al., 2005). Lestari et al. (2019) identified social status as a barrier to iPBL participation. Careful facilitation of group dynamics in iPBL is required in this context as these aspects received the most negative commentary in the qualitative findings (Curran et al., 2005; Gjessing et al., 2014; Hodges & Massey, 2015).

No consistency was detected across included studies in the timing of iPBL delivery for entry-level students. Seven studies (22%) focused their iPBL on students during the first year of their programme (Cusack et al., 2012; Dreier-Wolfgramm et al., 2018; Hawkes et al., 2013; Hughes & Lucas, 1997; Imafuku et al., 2018; Owens et al., 2010; Reynolds et al., 2003). Six studies (19%) did not specify the stage of learning, while two targeted senior-level students approaching the end of their programme (Solomon et al., 2003; Popovich et al., 2000). Whether students included in the iPBL process had previous clinical exposure or experienced other IPE opportunities was poorly reported across studies. As all studies reported positive interprofessional outcomes from their iPBL interventions, little can be inferred from these findings in relation to optimal timing of delivery. However, one study reminds us that matching the problem trigger appropriately to the stage of learning warrants more consideration than the timing. In that study, an iPBL initiative delivered in the first year for nursing, midwifery, physiotherapy, occupational therapy and radiography students identified the need to establish a professional identity and some clinical knowledge prior to engaging with their iPBL (Owens et al., 2010).

Description of iPBL Contexts (*n* = 32)

Category	Number	%
1. Setting		
University-based	24	75
University-based Online	2	6.25
Practice-based	2	6.25
Joint-led	4	12.5
2. Disciplines Involved		
Two professions only	6	18.75
Three professions	7	21.87
Four or more professions	19	59.37
3. Stage of Learning		
First year students only	7	21.87
Students at varying stages of learning	19	59.37
Student stage of learning not reported	6	18.75

Table 4. Contextual Factors in iPBL Delivery

iPBL Implementation Mechanisms

Use of theory to justify iPBL as a viable teaching method for interprofessional competence development and its use in informing the development and evaluation of iPBL offerings was limited in the studies identified. A quarter of studies (n = 8) cited an explicit theoretical grounding for how iPBL works. Constructivist learning theory—focusing on how learners construct new knowledge and understanding based on previous learning—was most frequently cited (Cusack et al., 2012; Hodges & Massey, 2015; Solomon et al., 2010). Aligned theories of social constructivism, cooperative learning and experiential learning were less frequently cited (D'Eon et al., 2010; McKee et al., 2013). Intergroup contact theory—in which interactions between different professional groups is central to helping students explore, clarify and improve professional relations—is from the field of social-psychology and was proposed by both Hawkes et al. (2015) and Lindqvist et al. (2005). Few papers addressed the role of theory in the success of their iPBL intervention. However, self-determination theory for positive professional identity development (Cusack et al., 2012), socio-cultural dynamics to create communities of practice (Eccott et al., 2012), situated learning to develop professional identity and to promote collaborative skills (Imafuku et al., 2014) were referenced specifically in the papers included in this review.

Table 5 provides an overview of the implementation mechanisms extrapolated from the included studies. Students' evaluation of the iPBL process across the included studies identified trigger design as a critical factor that can either positively or negatively contribute to learning outcomes (Lindqvist et al., 2005; Marshall et al., 2008; McKee et al., 2013; Reitsma et al., 2019). Students requested realistic trigger scenarios that ensure all disciplines included in the group can easily identify their respective roles (Lindqvist et al., 2005), that triggers are cognisant of the stage of the learners and do not contain language that is too technical (McKee et al., 2013), and that cases presented (e.g., in the context of pandemic preparedness) address broader psychosocial and population/public health perspectives (Marshall et al., 2008). The students also identified that triggers which lack critical information when developed limit the opportunity for true interprofessional collaboration (Reitsma et al., 2019).

While a variety of healthcare related topics for the iPBL triggers were employed in the identified studies (Table 3), over a quarter (28%, n = 9) provided no detail of the design process of their iPBL trigger(s). Only one paper (Cusack et al., 2012) reported using published PBL trigger-design guidelines to inform the development of the iPBL materials and included an interdisciplinary design group constituted by academics, clinicians, students, and librarians in line with

these published guidelines. In four studies (13%), the learning stimulus (problem triggers) were generated from real patients (n = 2, 6%) or a clinical site visit (n = 2, 6%). No further information was provided about whether patients were provided with additional training or guidance in advance of their inclusion in iPBL sessions. One paper reported using previously published cases in peer-reviewed journals or cases from an affiliated medical centre (Lehrer et al., 2015). The remaining studies utilised an interprofessional faculty design team, reinforced in some cases by use of clinical guidelines, clinicians, PBL experts, IPE experts or with patient representation. Only one study formally evaluated the quality of their iPBL triggers, identifying that the presented problems contributed to superficial learning rather than the deeper exploration of concepts and anticipated learning materials (Hughes & Lucas, 1997).

Different PBL models are noted to impact learning outcomes (Barrows, 1986; Schmidt, 1993). Based on the data presented in this review, it is not possible to comment on an optimal iPBL model as no papers identified in this review categorised their iPBL approaches using a published PBL taxonomy. The PBL practice utilised to guide tutorials was described in seven papers (22%), with the 7-step or 7-jump process the most frequently cited (Dreier-Wolfgramm et al., 2018; Goelen et al., 2006; Hughes & Lucas, 1997; Imafuku et al., 2018; Lestari et al., 2019), followed by the Manchester 8 step process (Wakefield et al., 2003) and the traditional PBL process (McKee et al., 2013). The minimum amount of time students spent engaged in iPBL small group sessions was three hours. The number of PBL sessions ranged from 2-10 sessions (where reported) or for the duration of an academic semester.

Another key consideration in iPBL implementation is the type of problem used to generate the desired learning outcomes. Jonassen (2011) provides a typology of problems and describes how each type of problem engages different cognitive, affective and conative (i.e., the learner's connection between knowledge, emotion and an intentional planned action) skills. When the studies identified in this review were evaluated by problem type, insufficient reporting of the trigger type and/or failure to provide the trigger/s used made data from across the studies included in this review difficult to synthesise and interpret by typology. Triggers were presented in a patient-case format in the majority of papers (n = 21, 66%) and where studies provided sufficient trigger details, diagnosis solution problems were the main problem type utilised (n = 14, 44%).

iPBL group sizes varied across included studies, from interprofessional pairs of students for patient assessments (Dreier-Wolfgramm et al., 2018; Wellmon et al., 2017) to groups of up to 15 students (L'Ecuyer et al., 2015) for each group. On average, group size reported in the included studies was 8-10 participants per group. Only 34% of included studies (n = 11) provided details of the tutor training provided for the facilitation of iPBL sessions, with only one paper (Reitsma et al., 2019) reporting tutors were trained specifically in IPE facilitation skills. Five studies (16%) reported 'experienced or expert' tutors facilitated iPBL sessions.

Description of iPBL Mechanisms (*n = 32*)		
Category	**Number**	**%**
1. iPBL Trigger Design		
Published iPBL Design Guidelines	1	3.12
Interprofessional Faculty	9	28.12
Interprofessional Design Team (Faculty +/- Clinicians, Teaching & Learning Faculty, Patient representation)	7	21.87
Students involved in design process	1	3.12
Patients as the learning trigger	4	12.5
Not Reported	9	28.12
2. PBL Model Employed		
7 Step/Jump Model	5	15.62
Other	2	6.25
Not Reported / Unclear	25	78.12
3. Problem Type Employed		
Diagnosis Solution Problem	14	43.75
Other (e.g. Design/Trouble-shooting problem triggers)	6	18.75
Not Reported/Unclear	12	37.5
4. iPBL Group Size		
≤ 5 particiapnts per group	5	15.62
≥ 5 ≤ 15 participants per group	22	68.75
≥ 15 participants per group	0	0
Not Reported / Unclear	5	15.62
5. Facilitator Training		
Provided	11	34.37
Specific IPE facilitation reported	1	3.12
Experienced / Expert Facilitators reported	5	15.62
Not Reported / Unclear	16	50
6. Duration of iPBL		
2 sessions only	4	12.5
2-10 sessions	17	53.12
1 semester	7	21.87
Not Reported / Unclear	4	12.5

Table 5. iPBL Implementation Mechanisms

Interprofessional Competence Outcomes of iPBL for Health Professional Students

Evidence from studies included in this review supports development of competences in all four of the IPEC (2011) core interprofessional competence domains through iPBL, as summarised in Table 3. Twenty-three papers (72%) detailed an a priori interprofessional competence as learning outcomes. These related to domains of Roles/Responsibilities (n = 8; 25%), Values/Ethics (n = 1; 3%) and Teams and Teamwork (n = 21; 66%). No paper identified in this review reported competence in interprofessional communication as a desired learning outcome following iPBL. Results as mapped to the interprofessional competence domains defined by IPEC (2011) are reported below.

Domain 1: Values/Ethics (including respect for other professions/perspectives)

Seven papers (22%) reported a study outcome that mapped to the domain of Values/Ethics. Three of these papers reported qualitative findings of increased respect for other professions and professional perspectives (Lin et al., 2013; McKee et al., 2010; Popovich et al., 2010). Of the four studies reporting quantitative findings, two used a validated outcome measure, that of the Attitudes to Health Professionals Questionnaire (AHPQ) (Hawkes et al., 2013; Lindqvist et al., 2005), mapping to level 2a (perceptions/ attitudes) of the modified Kirkpatrick model of educational outcomes for IPE. The highest level of evidence, by means of a control trial, is provided by Lindqvist et al. (2005), who identified no significant differences between the control and iPBL groups for either the 'caring' or 'subservient' domains of the AHPQ. In contrast, a single-arm trial revealed that within group change demonstrated statistically significant improvements in perceptions of how caring other professions appeared following iPBL (Hawkes et al., 2013).

Domain 2: Roles/Responsibilities

Understanding one's own and other disciplines' roles and responsibilities (Level 2b [knowledge and/or skills] on the modified Kirkpatrick model of educational outcomes for IPE) was the interprofessional competence most reported across studies (n = 27 studies, 84%) even though only eight studies set out with an explicit goal in this domain. Results were largely through qualitative exploration with 22 studies reporting themes in this domain. Positive findings relating to the development of a professional identity, understanding roles and responsibilities of other professions and the avoidance of stereotypes were evident. Of the 12 studies that reported quantitative findings, four used validated measures, designed to assess attitudes and perceptions as mapped to Level 2a of the modified Kirkpatrick model for IPE. Two controlled trials, providing the highest level of evidence, report non-significant results in this competence domain between iPBL and control groups using the Readiness for Interprofessional Learning Scale (RIPLS) (Wellmon et al., 2016) and the Interdisciplinary Education Perception Scale (IEPS) (Lehrer et al., 2015; Wellmon et al., 2016). Effect size was not reported and could not be calculated with data presented. In single-arm studies, conflicting results are presented in two studies for within group change in this domain using the RIPLS positive professional identity subscale (Cusack et al., 2012; Straub et al., 2017). In contrast, Cusack et al. (2012) report a moderate within group effect size. One positive change in professional competency and autonomy, as measured by the IEPS, was reported—again with a moderate effect size (Cusack et al., 2012). Early signals of gender- and profession-specific aspects in iPBL were identified by Gjessing et al. (2014) following implementation of an iPBL module comprising five professions. Both medical and male students had significantly fewer positive changes in their ability to describe their own and others' professional roles when compared to the other student professional groups examined.

Domain 3: Interprofessional Communication

Outcomes relating to the domain of Interprofessional Communication were reported in 19 (59%) of the included studies, drawn primarily (n = 15) from qualitative data. Students identified that the iPBL process improved communication (including listening skills) and highlighted the need for effective communication in healthcare delivery (including sharing knowledge, skills and perspectives on patient care) and the need for correcting misunderstanding without causing offence. These outcomes map to Level 2b (knowledge and/or skills) of the modified Kirkpatrick model of educational outcomes for IPE. Notably, Lestari et al. (2019) identified that students particularly recognise that additional discursive skills may need to be developed first to enhance learning through iPBL. This need was confirmed through video analysis of their iPBL tutorial sessions which confirmed students had difficulty posing critical questions and developing their argument. Students also tended to avoid conflict and largely relied on the tutor's questions to develop a concept as a group. Seven studies reported quantitative outcomes for communication but failed to use validated measures. Lin et al. (2013), who reported criterion validity for their self-developed Interprofessional Communication and Collaboration Questionnaire (ICCQ), noted statistically significant differences between iPBL and uni-professional groups in their self-evaluated interprofessional

communication and collaboration ability and attitudes, in favour of the iPBL group. An associated effect size could not be calculated in relation to this result.

Domain 4: Interprofessional Teams and Teamworking

Teamwork/collaboration, the primary a priori interprofessional competence goal stated by 20 identified studies, was reported as an outcome in 21 studies (66%). Results map to both Level 2a (attitudes/perceptions) and Level 2b (collaborative knowledge and/or skills) in the modified Kirkpatrick model of educational outcomes for IPE. Qualitative themes relating to this domain were reported in 13 studies, with the importance of working in interprofessional teams for holistic patient-centred care emerging as the predominant theme. Increased confidence in professional collaboration, the process of team development, recognition of the attributes of good and bad teamworking and interprofessional team dynamics were further highlighted. It is important to note that this domain also generated the most negative dialogue in relation to constructive collaboration (Gjessing et al., 2014; Hodges & Massey, 2015; Lestari et al., 2019). Results highlighting in some cases that students' perception of a hierarchy between health professional groups can hamper teamwork and iPBL participation, and in others that student engagement and learning was related to the dynamic between the iPBL group participants and that the benefits accrued in teams and teamworking may be more related to interpersonal dynamics than interprofessional ones.

Of the quantitative studies that addressed this domain, four used validated outcome measures, namely the Attitudes Towards Health Professionals Questionnaire (AHPQ) (Hawkes et al., 2013; Lindqvist et al., 2005), the Attitudes Towards Healthcare Teams Scale (ATHCTS) (Wellmon et al., 2016), RIPLS (Cusack et al., 2012; Wellmon et al., 2016) and the IEPS (Cusack et al., 2012; Lehrer et al., 2015, Wellmon et al., 2016). Wellmon et al. (2016) and Lehrer et al. (2015) provide the highest level of evidence in support of iPBL for developing team-based competences in comparison to a control group who received no interprofessional learning. Significant between group differences in change scores in the ATHCTS subscales team value and team efficiency were observed (Lehrer et al., 2015) and the IEPS subscales of perceived need for cooperation and perceptions of actual cooperation (Lehrer et al., 2015). Within group change in team-working subscales following iPBL was similarly reported (Cusack et al. 2012; Lehrer er al., 2015), with Cusack et al. (2012) reporting a moderate effect size and Hawkes et al. (2013) reporting a large within group effect size in the global AHPQ score. These results lend additional weight of evidence in this domain.

Discussion

Five key findings emerged from this systematic review and are discussed here. First, findings support iPBL as an effective pedagogical approach to promote the development of interprofessional competences during entry-level health professional education, notably those of understanding professional roles and responsibilities and interprofessional teamwork. However, poor reporting of iPBL interventions identified in this review currently make problematic the effective comparisons between context, implementation mechanisms and achievement of interprofessional competence.

Second, this review provides evidence in support of the effectiveness of iPBL in the development of interprofessional competences across all four IPEC domains of Values/Ethics, Roles/Responsibilities, Interprofessional Communication and Interprofessional Teams, and Teamwork. When results were summarised using the modified Kirkpatrick model of educational outcomes for IPE, evidence showed that students developed at both Level 2a (attitudes and perceptions) and Level 2b (knowledge and/or skills) when mapped to interprofessional competences. However, the overall evidence from the included studies fails to determine whether identified effects were maintained over time or provide confirmation that students' future interprofessional collaborative work changes as a result of the intervention. In other words, the review does not provide evidence of Kirkpatrick's final levels of practice—in this case, the transfer of learning to clinical practice (Level 3 and Level 4a) and health outcomes (Level 4b) after full time education. While measurement of learning at all levels of the modified Kirkpatrick model is ultimately required, several tools currently under development (Archibald et al., 2014; Curran et al., 2011; Iverson et al., 2018) measure IPE outcomes at the skills and behaviours levels (Level 2b and Level 3). When incorporated into future research, these tools may provide a more useful evaluation of interprofessional competence attainment by learners following iPBL. Furthermore, future quantitative research should include larger sample sizes that are powered to detect true change, particularly where a comparator group is employed, and that use standardised measurement instruments to facilitate a more robust analysis of interprofessional competence outcomes achieved with iPBL across studies. In addition, our findings point to the need to report detailed statistical results and effect sizes to facilitate a better comparison across studies.

Third, the findings indicate that context is important in developing and implementing iPBL. Based on these findings, we propose that interprofessional education should take place in clinical settings, where students will ultimately practice, and that considering context in this way may better

Included Papers & Quality Rating	IPEC Competency Domains (2016)			
	1. Values/Ethics	**2. Roles/ Responsibilities**	**3. Interprofessional Communication**	**4. Teams & Teamwork**
Chou et al., (2016) *****	Quantitative evidence- observer checklist **(↑)** Interprofessional group for ethics discussion skills versus medicine only group **(↔)** Mutual respect/Interaction	Qualitative evidence (+)	Quantitative evidence - observer checklist **(↑)** Qualitative evidence (+)	
Curran et al., (2005) ***		Quantitative evidence- Student role perception checklist **(↑)** Qualitative evidence (+)		Quantitative evidence - Team Inventory **(↑)** & Team skills list **(↔)**
Cusack et al., (2012) ***		Quantitative evidence- RIPLS **(↑)** & IEPS **(↑)**		Quantitative evidence- RIPLs **(↑)** & IEPS **(↑)**
D'Eon et al., (2010) ***		Quantitative evidence-pre/post test scores **(↑)** & student self-assessments **(↑)**		
Drier-Wolfgramm et al., (2018) ***		Quantitative evidence (+)	Quantitative evidence – Likert rating scale (+) nursing students; (-) medical students	
Eccott et al., (2012) ****		Qualitative evidence (+)	Qualitative evidence (+)	Quantitative evidence- Interprofessional Teamwork Questionnaire **(↑)**
Furber et al., (2004) ***		Qualitative evidence (+)	Qualitative evidence (+)	Quantitative evidence-self-developed Likert questionnaire **(↔)** Qualitative evidence (+)
Gjessing et al., (2014) *****		Quantitative evidence- self-developed Likert questionnaire (↔) Nursing; (↔) Physiotherapy/Occupational therapy; (↓) medicine Qualitative evidence (+)		Quantitative evidence- self-developed Likert questionnaire (↔) Nursing; (↔) Physiotherapy/Occupational therapy; (↓) medicine Qualitative evidence (+)
Goelen et al., (2006) ***		Quantitative evidence IEPS (↑) Qualitative evidence (+)		
Hawkes et al., (2013) ****	Quantitative evidence-AHPQ (↑)			
Hodges & Massey, (2015) **		Qualitative evidence-student/tutor data (+)		Qualitative evidence -Tutor Data (-) for team dynamics & participation
Hughes & Lucas, (1997) ****	Quantitative evidence- % objectives met (+)	Quantitative evidence - % objectives met (+)	Quantitative evidence - % objectives met (+)	Quantitative evidence - % objectives met (+)
Imafuku et al., (2014) *****		Qualitative evidence (+)	Qualitative evidence (+)	Qualitative evidence (+)
Imafuku et al., (2018) *****		Qualitative evidence (+)	Qualitative evidence (+)	Qualitative evidence (+)
L'Ecuyer et al., (2015) *****		Qualitative evidence (+)	Qualitative evidence (+)	Qualitative evidence (+)
Lehrer et al., (2015) ***				Quantitative evidence- IEPS **(↑)**

Table 6. Interprofessional Competence Outcomes Reported Following Interprofessional Problem-Based Learning Interventions.

Lestari et al., (2019) *****		Qualitative evidence (+)	Qualitative evidence- student data (+) asking critical questions; tutor/student data (-) re: enhanced discussion skills required	Quantitative evidence - MPARS peer rating scale **(↑)** Qualitative evidence (-) for hierarchy within groups
Lin et al., (2013) ***	Qualitative evidence (+)		Quantitative evidence- ICCQ self-developed questionnaire **(↑)**	Quantitative evidence- ICCQ self-developed questionnaire **(↑)**
Lindqvist et al., (2005) ***	Quantitative evidence- AHPQ **(↔)**			
Marshall et al., (2008) *			Quantitative evidence- self-developed Likert questionnaire (+) Qualitative evidence (+)	Quantitative evidence- self-developed Likert questionnaire (+) Qualitative evidence (+)
McKee et al., (2010) ***	Qualitative evidence (+)		Qualitative evidence (+)	
McKee et al., (2013) ****		Quantitative evidence- self-developed questionnaire (↑) Qualitative evidence (+)		
Owens et al., (2010) ****		Qualitative evidence (-) nil improvements reported by students	Qualitative evidence (+)	Qualitative evidence (+)
Playford et al., (2009) ****		Qualitative evidence (+)	Qualitative evidence (+)	Qualitative evidence (+)
Popovich et al., (2000) *	Qualitative evidence (+)	Qualitative evidence (+)	Qualitative evidence (+)	
Reitsma et al., (2019) ***		Quantitative evidence- self-developed Likert questionnaire (+) Qualitative evidence (+)	Quantitative evidence- self-developed Likert questionnaire (+) Qualitative evidence (+)	Quantitative evidence- self-developed Likert questionnaire (+) Qualitative evidence (+)
Reynolds, (2003) *****		Qualitative evidence (+)		
Solomon et al., (2003) ***		Quantitative evidence- students' rating of objectives (+) Qualitative evidence (+)	Quantitative evidence- students' rating of objectives (+)	
Solomon et al., (2010) *****		Qualitative evidence (+)	Qualitative evidence (+)	Qualitative evidence (+)
Straub et al., (2017) ***		Quantitative evidence- RIPLS **(↔)** Qualitative evidence (+)	Qualitative evidence (+)	Quantitative evidence- RIPLS **(↔)**
Wakefield et al., (2003) *		Qualitative evidence (+)		Qualitative evidence (+)
Wellmon et al., (2016) *****		Quantitative evidence - IEPS **(↔)** & RIPLS **(↔)** Qualitative evidence (+)		Quantitative evidence- ATHCTS **(↑)** IEPS **(↑)** & RIPLS **(↔)**

Key: (↑) Statistically significant improvement in scores; (↓) Statistically significant reduction in scores; (↔) Nil statistically significant changes identified; (+) Positive themes/aspects reported; (-) negative themes/aspects reported

Legend: AHPQ: Attitudes to Health Professionals Questionnaire; Attitudes Towards Healthcare Teams Scale (ATHCTS); ICCQ: Interprofessional Communication and Collaboration Questionnaire; IEPS: Interdisciplinary Education Perception Scale; MPARS: Maastricht Peer Assessment Rating Scale; RIPLS: Readiness for Interprofessional Learning Scale

Table 6 cont. Interprofessional Competence Outcomes Reported Following Interprofessional Problem-Based Learning Interventions.

facilitate the transfer of developed interprofessional competences to clinical placement and onward into future health-professional work settings. Evidence of phased iPBL starting with triggers to develop professional identity early within health professional programmes, moving through collaborative problems and transitioning into real-life and 'interprofessional training wards' is lacking. Further longitudinal studies along the model presented by Linköping University in Sweden (Pelling et al., 2011; Wilhelmsson et al., 2009) are required to help identify longer-term results but also to detect where transitions in learning outcomes are best implemented as students' progress through their programme towards becoming autonomous practitioners. As students' develop their interprofessional competences, these should be reflected in interprofessional learning outcomes that achieve professional behaviours, transferred to the practice setting.

The fourth major outcome of this review was an identification of a gap in evidence around the type of trigger that would lead to optimal iPBL for developing desired interprofessional competences. 'Diagnosis solution problems' are the prominent trigger type employed within medical education (Gijbels et al., 2005; Hung et al., 2008). This review highlights that this problem type is preferentially employed by iPBL studies. These types of problems have been considered to be moderately ill-structured and relatively complex because of various interpretations and multiple possibilities of symptom causes (Jonnassen & Hung, 2008) which often exceed learners' cognitive abilities, especially in the early stages of their curriculum in which clinical experience is limited. Therefore, it is important that more attention and special reference is paid to the design and implementation mechanisms of iPBL. These should focus on the stage of the learners, the desired learning outcome(s) for interprofessional competence(s) development and the desired level of educational outcomes for IPE (modified Kirkpatrick framework). We propose that both knowledge acquisition and problem-solving PBL models can generate targeted interprofessional competences, if appropriately designed and evaluated.

Finally, issues associated with the sustainability of IPE initiatives are well-documented in the literature and include timetabling of different health-professional curricula, a lack of specially trained facilitators, and limited resources, such as sufficient room availability (Homeyer et al., 2018; Oandasan & Reeves, 2005; Thistlethwaite & Nisbit, 2007). Forty-one percent of iPBL initiatives in primary studies identified in this review were relatively small pilot studies and appear to be undertaken mainly by proponents of IPE which highlight concerns in relation to sustainability of iPBL. A notable shift towards the increased use of technology to facilitate collaboration within the healthcare setting (Jones et al., 2014) and IPE delivery (Curran et al., 2015) is reported in the literature, with penetration now identified in the iPBL field in this current review (Owens et al., 2010; Solomon et al., 2010). Promising results for the feasibility of an online iPBL platform and for learner satisfaction with this medium were reported by both studies in this review. In particular, Owens et al. (2010) demonstrated successful delivery of online iPBL to 334 students from five different professions, providing encouraging evidence to iPBL educators that online delivery may help overcome some of the barriers previously identified with traditional face-to-face IPE. On this basis, we argue that future work should examine the relative merits and potential of online iPBL initiatives, both in terms of sustainability and quality of interprofessional competence learning outcomes. Much remains unknown about how learners construct knowledge in an online environment (Casimiro et al., 2009), and this research direction is particularly warranted given its capacity to overcome timetabling issues across multiple curricula. and in the context of the recent rapid transition to online teaching and learning and health-service delivery via online technologies.

Limitations

Several limitations were identified in this review. First, the inclusion of quantitative, qualitative, and mixed-method study designs, while providing a wide lens through which to view current iPBL practice, also provides a methodological challenge in synthesis (Dixon-Woods et al., 2005; Popay et al., 2006). Future exploration of iPBL mechanisms and context-dependent factors through realist synthesis is warranted to obtain a more holistic understanding of the complexity of iPBL interventions and their influence on interprofessional competence development (Wong et al., 2013).

Second, the scope of this review was determined by our pre-specified iPBL operational definition and process criteria, which means pedagogical interventions such as case-based learning, team-based simulation and one-off iPBL style interventions such as workshops were excluded. Other researchers may argue for the inclusion of such studies in future reviews as the definition and comparable understanding of what is and is not considered PBL remains a contentious issue (Charlin et al., 1998). Our review stipulated that iPBL required two or more health-professional student groups to work together, thereby excluding papers examining the benefits of health-professional students learning with, from, and about other disciplines, such as engineering (Geist et al., 2019) and education (Wilson et al., 2016). Many merits to learning occur in these settings, including the use of novel trigger types (e.g., design triggers [Geist et al., 2019]), which may provide more possibilities for the development of interprofessional competence that were not explored in this

review. Finally, we applied an English language publication limit in our search strategy and acknowledge that relevant materials published in other languages may exist.

Conclusion

This systematic review makes valuable contributions to iPBL theory, research and practice. The main contribution to theory of this paper provides a research-informed and useable conceptual framework (Figure 1) for iPBL practitioners to plan, implement and evaluate iPBL initiatives in order to develop interprofessional competence. This review highlights the importance of context and implementation mechanisms that health-professional educators, especially those new to iPBL, need to investigate and adapt for their own IPE practice.

The evidence synthesised in this review identifies iPBL as an appropriate pedagogical approach to promote interprofessional competences. A wide range of iPBL interventions were included in the review. Evaluations of iPBL were biased towards learners' attitudes and perceptions of interprofessional competences—in particular, knowledge of professional roles and team working attitudes. Finally, our review also highlighted that few iPBL initiatives took place in the clinical setting, which may partly explain why a direct effect between students' interprofessional competence development and change in professional practice and health outcomes were not identified.

Authors Contributions

All authors (DP, TB & OL) contributed to the conceptual design of this systematic review and in the development of the targeted search strategy. DP conducted the electronic search and screened all articles by title. All authors contributed to the review process. DP & OL extracted data and conducted the quality appraisal of included studies. All authors have previous experience or training in systematic review methodology. All authors contributed to the preparation of the manuscript and have agreed to the final content.

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Appendix 1

Sample search strategy for identification of papers for the review

Search Strategy (PubMed)
Population: Health and Social Care Undergraduate Students
S1. Students, Health Occupations [MeSH]
S2. Health Occupations/education [MeSH]
S3. Medical education [MeSH]
S4. Allied health occupations [MeSH]
S5. Health adj3care student* [ti.ab.kw]
S6. Health profession* student* [ti.ab.kw]
S7. Health profession* education [ti.ab.kw]
S8. Health science education
S8. Health adj3care profession* education [ti.ab.kw]
S9. "Health and social care student*" [ti.ab.kw]
S10. S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S7 OR S8 PR S9
S11. Education, Medical, Undergraduate [MeSH]
S12. Undergraduate [ti.ab]
S13. "Graduate entry" [ti.ab]
S14. ("Entry Level" OR Entry-level) [ti.ab]
S15. (Pre-qualification OR Prequalification) [ti.ab]
S16. (Pre-licensure OR prelicensure) [ti.ab]
S17. (Pre-registration OR preregistration) [ti.ab]
Student.
S18. S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17
S19. S10 AND S18
Intervention: Interprofessional Problem-based Learning
S20. Interprofessional relations [MeSH]
S21. (Interprofessional OR Inter-profession$) [ti.ab.kw]
S22. (Interdisciplin$ OR Inter-disciplinary OR Interdisciplinary) [ti.ab.kw]
S23. (Interoccupational OR inter-occupational) [ti.ab.kw]
S24. (Multidisciplinary OR Multi-disciplinary) [ti.ab.kw]
"Interprofessional education" OR Inter-professional education OR IPE
"Interprofessional learning" OR IPL
Interdisciplinary education OR interdisciplinary learning
S25. S20 OR S21 OR S22 OR S23 OR S24
S26. Problem-based learning [MeSH]
S27. ("Problem based learning" OR PBL) [ti.ab.kw]
S28. ("Problem-orientated learning" OR POL) [ti.ab.kw]
S29. "Active learning" [ti.ab.kw]
S30. "Self-directed learning" [ti.ab.kw]
S31. S26 OR S27 OR S28 OR S29 OR S30
S32. S25 AND S31
Population AND Intervention
S33. S19 AND S32

Appendix 2

Data extraction tool that was designed and used to extract data from included studies in this systematic review

Headings for Data Extraction Proforma
1. Included papers – Full reference 2. Quality rating against MMAT Criteria 3. Setting a) University-based b) Practice-based c) Online d) Joint-led (i.e., University & clinical setting combined) 4. Country of study 5. Study design 6. Subject area/Clinical topic of iPBL intervention 7. Underpinning Theoretical perspective of iPBL a) rationale for study design b) rationale for iPBL outcomes 8. Interprofessional Competences stated as study objectives Use IPEC domains to categorise: 1) Values & Ethics; 2) Roles and Responsibilities; 3) Interprofessional communication; 4) Interprofessional Teams & Teamwork 9. Study Population Population subgroups if applicable 10. Previous learner IPE/PBL exposure 11. Students previous clinical exposure/level of clinical experience 12. Stage of Learning 13.Core versus elective versus supplementary curriculum for learners 14. Tutor/Facilitator training 15. Tutor Profile 16. PBL/Trigger design process 17. PBL model employed – e.g., Barrow's Taxonomy (1986) 18. Problem/Trigger Type employed – e.g., Jonassen's Typology (2000) Diagnosis solution problems Design problems Dilemmas Troubleshooting problems Strategic performance problems 19. PBL Learning Format a) number of participants per group b) number of PBL tutorials c) Length of time (hours) engaged in PBL tutorials d) Defined process / guide provided (e.g., 7-step method) 20. Data collection methods 21. Data evaluation methods 22. Specific evaluation tools related to interprofessional competence 23. Results a) Qualitative results b) Qualitative data supported with participant quotes c) Quantitative results d) Specific interprofessional competence quantitative data