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Outcomes of inquiry-based learning in health professions education: A scoping review

Résultats de apprentissage par le questionnement dans la formation des professionnels de la santé : une revue exploratoire

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Article abstract

Background: Open inquiry-based learning (IBL) that aims to foster higher-level thinking, is defined by students formulating their own questions and learning through exploration. The present study aimed to summarize the breadth of metrics used to evaluate health professions trainees in open IBL curricula.

Methods: We conducted a scoping review to identify publications detailing trainee outcomes in open IBL initiatives in health professions education. We queried five databases and included studies which described interventions with five phases of IBL (orientation, conceptualization, investigation, conclusion, and discussion). We completed abstract and full text reviews in duplicate. Data were collated and summarized.

Results: From 3030 record, 21 studies were included in the final extraction (k = 0.94), with nine involving physician trainees and twelve involving nursing trainees. Three studies used validated data collection tools to measure student inquiry behavior, and a single study used a validated data collection tool to measure critical thinking abilities. Most studies (n = 11) reported trainee self-reported satisfaction or perceived gain of skills as the primary outcome. All four studies using validated tools reported high scores in inquiry behaviors at the end of the curriculum and results on critical thinking skills were mixed. One study collected serial data, while remaining studies collected pre-post or post-only data.

Conclusion: IBL has the potential to cultivate a climate of curiosity among health professions learners. However, studies have relied heavily on subjective outcomes. Limited studies reported standardized measures of inquiry behaviors suggest favorable results. Curriculum innovations using IBL could make use of existing tools to better understand their impact on students' inquiry-oriented skills.

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Reviews, Theoretical Papers, and Meta-Analyses

Outcomes of inquiry-based learning in health professions education: a scoping review

Résultats de apprentissage par le questionnement dans la formation des professionnels de la santé :une revue exploratoire

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Abstract

Background: Open inquiry-based learning (IBL) that aims to foster higher-level thinking, is defined by students formulating their own questions and learning through exploration. The present study aimed to summarize the breadth of metrics used to evaluate health professions trainees in open IBL curricula.

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Résumé

Contexte : L'apprentissage libre par le questionnement, qui vise à favoriser une réflexion de haut niveau, se définit par le fait que les étudiants formulent leurs propres questions et apprennent par l'exploration. La présente étude visait à faire l'inventaire des méthodes utilisées pour évaluer les étudiants des professions de la santé dans les programmes qui ont recours à l'apprentissage libre par le questionnement.

Méthodes : Nous avons effectué une étude une revue exploratoire pour recenser les publications traitant des résultats des étudiants inscrits dans des programmes de formation dans une professionde la santé qui appliquent la méthode de l'apprentissage libre par le questionnement. Nous avons interrogé cinq bases de données et inclus les études qui décrivaient des interventions portant sur cinq phases de l'apprentissage par le questionnement (orientation, conceptualisation, investigation, conclusion et discussion). Nous avons procédé à l'examen des résumés et du texte intégral par deux lecteurs indépendants. Les données ont été colligées et résumées.

Résultats : Sur 3030 documents, 21 études ont été incluses dans l'extraction finale (k=0,94), dont neuf concernaient des étudiants en médecine et douze des étudiants en sciences infirmières. Les auteurs de trois études ont utilisé des outils de collecte de données validés pour mesurer le démarchede recherche des étudiants, et ceux d'une seule étude ont employé un outil de collecte de données validé pour mesurer les capacités de réflexion critique. La plupart des études (n = 11) ont avancé comme résultat principal la satisfaction des étudiants ou l'amélioration ressentie de leurs compétences. Les quatre études réalisées à l'aide d'outils validés ont fait état de scores élevés en matière de démarche de recherche à la fin du programme, tandis que les résultats concernant les capacités de réflexion critique étaient mitigés. Dans l'une des études, les données avaient été recueillies de façon longitudinale et dans les autres, avant et après ou seulement après.

Conclusion : L'apprentissage par le questionnement a le potentiel de cultiver la curiosité chez les apprenants des professions de santé. Cependant, les études recensées se sont largement appuyés sur des critères subjectifs. Des études limitées qui présentaient des mesures standardisées de la démarche de recherche des étudiants et ont montré des résultats favorables. Pour leurs innovations pédagogiques faisant appel à l'apprentissage par le questionnement, les programmes peuvent recourir aux outils de mesure existants pour mieux comprendre l'impact de cette méthode sur l'aptitude des étudiants au questionnement.

Introduction

Health professions trainees in the 21st century have access to an unprecedented amount of open access educational resources that greatly exceeds the organizational capacity of an individual's mind.[1] In response, future practitioners must be proficient in knowledge acquisition.[2] The Carnegie Foundation for the Advancement of Teaching highlighted the need to incorporate habits of inquiry and improvement in the 2010 Call for Reform of Medical Education as a learning strategy to optimize proficiency in knowledge acquisition.[3] To meet the evolving needs of trainees and to foster greater student curiosity as the foundation for learning, inquiry-based learning (IBL) has emerged as an appealing educational strategy.

IBL focuses on learner driven acquisition of knowledge through development of inquiries, and hypothesis generation. This differs from problem-based learning in that PBL is focused on learner investigation of teacher provided problems. Comparative to problem-based learning is case based learning wherein learners are provided cases around which to target their investigation and research. Through exclusion of these other teaching methods and focusing only on open inquiry, we attempt to distinguish the specific benefits of pure trainee inquiry learning and consider how this can be incorporated in areas of health profession that involve mature learners such as post-graduate medical education and nursing education.

Educational philosopher John Dewey, a prominent education reformist in the early 20th century laid the foundation for inquiry as a central focus of science education, and Jerome Bruner pioneered the inquiry-based instruction in science curricula[4] in the 1950s. The theory behind IBL is the constructivist, learner-driven active process of knowledge acquisition. Students formulate hypotheses and make observations in order to construct their knowledge.[5] While descriptions of IBL vary widely in the literature, the framework can be divided into five general phases:[5]

1. Orientation: the topic is introduced, and the student creates a problem statement,
2. Conceptualization: the student develops an open question pertaining to the problem, and generates a hypothesis,
3. Investigation: the student explores or observes, they may even experiment, and interpret their findings,
4. Conclusion: the student reviews the problem, hypothesis, and their interpretation of the findings to consider whether their question has been answered, and,
5. Discussion: the student communicates their findings to others (external) and reflects upon successes and areas for improvement within the inquiry process (internal).

While the IBL curriculum design has evolved and taken many forms since Bruner's initial model, the core foundation of student-directed epistemic curiosity has been consistently aimed at encouraging active participation, and improving scientific literacy.[5] Studies in higher education have found that IBL can hone students' analytical and critical thinking abilities,[6] and may improve students' overall academic performance compared to a traditional lecture-based curriculum.[7]

IBL has been variably classified and subdivided in the literature. Aditomo et al. grouped IBL curricula based on assigned tasks that include: scholarly research (students formulate questions and collect empirical data to address them), simplified research (students formulate question but only perform some aspects of data collection or analysis), literature-based research (no empirical data collection), and applied research (similar to simplified, though focused on practical issues and "real-world" problems).[8]

In some cases, IBL has been considered as overlapping or else an umbrella term encompassing problem-based learning (PBL).[6] Some have sub-classified IBL based on the roles and responsibilities of teachers and students:[9]

1. Structured inquiry (e.g. PBL) – teachers provide a problem and an outline for addressing it,
2. Guided inquiry – teachers provide questions to stimulate inquiry however students are self-directed in the investigation, conclusion, and discussion, and,
3. Open inquiry – students develop questions themselves, and are self-directed in investigation, conclusion, and discussion.

While there have been apparent benefits of IBL in higher education, particularly with regards to fostering inquiry behavior, the outcomes of an IBL curriculum in health professions education are yet to be fully elucidated. In this scoping review, we examine the published literature

exploring student outcomes in inquiry-based learning curricula in health professions training. We aim to describe the extent of existing literature in this area, to characterize study designs and outcomes, and to identify gaps in the health professions' literature where future studies on IBL should focus.

Methods

Our study followed the framework of Arksey and O'Malley[10] and the PRISMA Extension for Scoping Reviews.[11] Our preliminary research question explored the extent of published literature on IBL curricula in medical education. Our initial literature search revealed a scarcity of studies, and we iteratively refined this question after an extensive literature review to identify, characterize, and evaluate the scope of published studies IBL in health professions education and to identify remaining gaps in this area (Appendix A).

Terms and definitions

Whereas IBL has been variably defined and categorized in the literature, we adopted the pedagogical approach of Oğuz-Ünver & Arabacioğlu,[12] and Feletti[13] which differentiates "pure" IBL from PBL, wherein the former is founded on student-driven inquiry in a guided or open manner, and the latter on problem-solving through structured inquiry. For the purpose of this review, we have considered structured inquiry as being PBL, and guided- and open- inquiry as IBL. We also used the framework of Aditomo et al[8] to subclassify IBL curricula based on assigned tasks.

Inclusion and exclusion criteria

Studies were eligible for inclusion if they a) evaluated an inquiry-based learning curriculum as defined above, b) studied a population of health professionals or health professions trainees, and c) reported trainee outcomes.

We excluded studies if they described multiple curricular modalities (e.g. evaluated a program with IBL, PBL and traditional lecture-based components) without providing specific evaluation of the IBL component.

Search strategy

We searched Embase, MEDLINE through PubMed, PsycINFO, CINAHL, and ERIC for eligible peer-reviewed records published up to April 20, 2021. To ensure full capture of eligible studies, bibliographies of commentaries, reviews, and book chapters were reviewed to identify additional relevant records. We consulted a librarian in the development and refinement of the search strategy, and we iteratively refined search terms until saturation was reached. The search strategy is reported in Supplemental Digital Appendix A. All studies collected were imported into Covidence online software for screening and review.[14] There were no date or language restrictions.

Review and data abstraction

After removal of duplicate studies, two reviewers independently screened all titles and abstracts against inclusion and exclusion criteria (SV and AK). Full text review was conducted independently and in duplicate. Percent agreement and Cohen's κ statistic were calculated to evaluate interrater reliability in accordance with published guidelines.[15] All studies meeting inclusion criteria were submitted for data abstraction (SV, MY, and AK). Abstracted data points included publication date, research questions, population, study design, data collection tools and outcomes. Content was double-checked for accuracy.

Results

Study selection

A PRISMA diagram of the study selection is shown in Figure 1. Our search resulted in 3320 studies. After removal of duplicates, 2919 studies were eligible for screening. Two authors reviewed all records in duplicate with a percent agreement of 98.0% and κ statistic of 0.784 indicating substantial agreement. Twenty-one full-text records were submitted for abstraction and inclusion in the final analysis. Percent agreement for full-text review was 98% (κ = 0.939). Disagreements were resolved by discussion of rationale for inclusion or exclusion amongst the authors. The earliest record meeting inclusion criteria was from 2000.

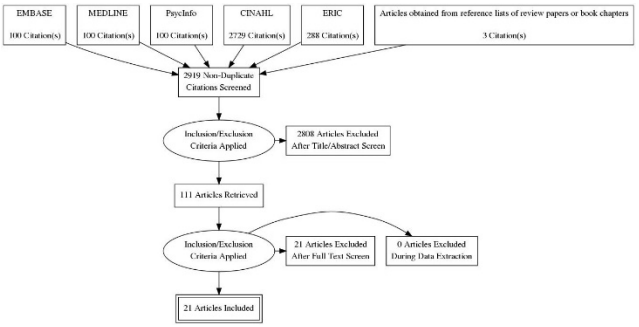

Figure 1. PRISMA diagram of study retrieval

Study design and population

Included studies are summarized in Appendix B. All 21 studies provided data on trainee outcomes, and 17 of these had this as a primary objective. Twelve studies included nursing students or licensed nurses. Nine studies included medical students, residents or fellows in their study

population. One study was done as a randomized trial; the remainder of the studies were quasi-experimental.

Data collection tools

The primary method of evaluation across the majority of the studies (*n* = 19) was via student surveys. Only four studies used a validated survey tool to assess trainee outcomes while the remaining studies used investigator-designed surveys with no clear evidence of validation and a single study did not describe the data collection tool. Only one study collected serial data, while eight studies provided both pre- and post- intervention data, and the remainder had only post intervention data (*n* = 13).

Trainee outcomes

Ten studies included some form of objective trainee outcomes however, in five of those studies, objective data included only course administrative information such as project poster presentations completed after the intervention, rather than assessments of behavior or competence. The majority of studies (*n* = 11) primarily gathered subjective, self-reported outcomes through qualitative methods (e.g. Trainee perceived confidence with IBL).

Trainee Perceptions. Subjective trainee outcomes about IBL were predominantly positive across all studies (*n* = 11). Generally, trainees felt that IBL methodology would be useful for their future career. There was a general increase in perceived skills and comfort level. Few studies (*n* = 3) reported negative subjective student outcomes. In one study that implemented an IBL curriculum (Fin et al) trainees had difficulty understanding the concept of IBL and gained only a superficial understanding with limited application to practice, based on teacher observations. Tamayo et al described greater difficulty with and interest in the course when an IBL curriculum was used[16]. Overall, there is evidence that IBL generally has a positive perception among most students but can be challenging for some to grasp.

Objective metrics. Within the few studies (*n* = 4) that used a validated data collection tool (see Table 1), outcomes of interest included quantifiable changes in behavior or analytical ability. All of these studies reported high scores in inquiry behaviors at the end of the curriculum and results on critical thinking skills were mixed. Wentland et al showed a significant increase in perceived skills in finding and re-reviewing evidence post IBL intervention.[17] Kim et al showed improved scores in all Evidence-Based Practice (EBP) activities post IBL intervention.[18] The third study by Magnusse et al used the Watson Glaser Critical Thinking Appraisal (WGCTA) tool to measure critical thinking skills, and found no difference in the mean WGCTA scores pre- and post- intervention. When separated into terciles the lowest group had a significant increase in scores while the highest group dropped with no change in the middle group. This suggested a possible benefit for trainees with the lowest baseline proficiency in critical thinking.[19] Lastly, Brondfield et al, used a modified Delphi design to create and validate survey tool to measure inquiry behaviors (e.g. justifying statements with evidence, acknowledging limitations of one's own knowledge), and demonstrated that students self-graded and faculty-graded inquiry behaviors improved significant through serial measurements over the course of an IBL curriculum.[20]

Table 1. Validated data collection tools in included studies

Study	Tool	Construct being measured
Magnussen[19] et al (2000)	WGCTA (Watson Glaser Critical Thinking Appraisal)	Critical thinking
Wentland[17] et al (2020)	DEBPQ (Developing Evidence Based Practice Questionnaire)	Inquiry knowledge and skills
Kim[18] et al (2019)	EBP Questionnaire EBP Beliefs Scale KAS-R (Kim Alliance Scale – R)	Inquiry knowledge and behaviours
Brondfield[20], S et al (2019)	Medical Student Inquiry Behavior Assessment Tool	Inquiry behaviours

Inquiry-based learning task assignments. The IBL curricula across all studies were grouped into five assigned tasks based on the Aditomo classification:[1] Fifteen used a scholarly research method, four used a simplified research method, one used literature-based inquiry and one used applied research.

All (*n* = 15) studies using a scholarly research method reported an increase in trainee confidence, and perceived improvement in skills or benefit to their future career after the IBL learning intervention. Among the four studies that used a simplified research method, all used surveys to assess trainee outcomes. Student satisfaction was favorable, use of EBP resources increased, and students gained more comfort and interest in their chosen topic. The authors also noted a number of poster presentations from participants at scientific conferences. The lone study that used applied research also used a validated outcome tool that demonstrated a significant increase in students' perceived inquiry skills.

Discussion

This review provides a summary of the use of inquiry-based learning in health profession literature. It demonstrates evidence of the potential for IBL to cultivate learner growth and promote a climate of curiosity among health professionals. Education researchers should be encouraged to investigate further the utility and benefits of IBL, the data collected in this review supports this endeavour in health profession education. With accumulation of more rigorous evidence, IBL may be incorporated into both undergraduate and post-graduate health profession courses at both individual project levels and larger course curricula levels. However, most studies rely heavily on subjective trainee outcomes, experimental research designs, and validated tools are infrequently used. Use of validated tools in future research will contribute to rigorous designs and collection of objective, reproducible data.

The existing literature has a lack of validated tools and substantial reliance on subjective perception. Within this cohort of studies, the WGCTA (Watson Glaser Critical Thinking Appraisal) measured critical thinking abilities,[19] the DEBPQ (Developing Evidence Based Practice Questionnaire), EBP Questionnaire, EBP beliefs scale, and KAS-R (Kim Alliance Scale) measured inquiry knowledge and skills,[17,18] and the tool from Brondfield et al[20] measured primarily observable inquiry behaviours.[20] This tool showed validity for both self and faculty assessment of trainees, and may be used for serial measurements of inquiry behaviours.

Additional research into IBL can help with development of this learning strategy and incorporation of IBL into curricula. When researching IBL, studies may draw upon existing data collection devices used in other teaching modalities. Existing literature in has reviewed instruments used for evaluation of self-directed learning, team based learning and peer evaluation in team based learning.[21-23] Additionally, although self-evaluations can provide insight, Papinczak et al[24] demonstrated that such self-evaluations in problem-based learning is not an accurate measure of student performance.[24] Various validated assessment tools have been developed for problem based learning in medical education including checklists,[25] and objective structured clinical exams (OSCEs).[26-28] Further study into the reliability and construct validity of these tools in IBL may help to establish their use in this area, and this may reduce researchers' reliance on trainee self-evaluation as the sole outcome.

These numerous studies assessing validity of evaluation tools within specific learning methods provide a basis for educators to properly design and evaluate curricula. Such literature in the realm of inquiry-based education is important to demonstrate the utility of IBL in medical education. Additionally, in order to encourage dissemination, a repertoire of validated tools for IBL should be easily accessible to educational institutions.

The IBL literature we identified focused on experimental design that involved incorporating IBL into curricula. There was a lack of literature using non-experimental, or literature-search based designs (e.g. where no empirical data collection is required). These should be explored further as potentially more feasible and widely available modality for individual studies. Most included studies introduced IBL through a research project assignment, and while this did show variable success, this framework may be difficult for widespread use based on task complexity, and a lack of available personnel and resources.

Overall, evaluating and implementing IBL in health professions education requires the development of high quality and rigorously designed studies. This may be achieved by promoting collaborative, multicenter work, focus on validated tools aimed at higher level outcomes and use of serial measurements to evaluate interventions. In addition to education, IBL may have a role in patient care and partnership with clinical researchers who may help to assess the translational potential into clinical medicine.

Future directions for IBL research include consideration of non-experimental research designs, extrapolating tools from other teaching modalities, use of validated tools when appropriate, and collaborative multicenter work.

There are limitations of this review that must be considered. Selected articles focused on IBL-exclusive curricula only, and multimodal programs that may have included an IBL component were not encompassed in the search. It is important to consider that validated tools are typically validated for specific purposes and their use in different contexts may require re-validation. Extrapolation of tools from literature would therefore need to be done with this in consideration. Additionally, due to variability in definitions, studies that used IBL format may have been categorized under different learning strategies such as problem-based or team-based learning and therefore not included in our study. Lastly, a publication bias may result

in studies with negative results being inadequately captured.

IBL methods have been effectively used in various educational settings including health profession education. This curriculum design holds promise in fostering behavioral changes for health professions trainees' ability to nurture their own curiosity and refine their scholarly aptitudes. There is a need for further study with refined data collection methods to adequately assess the potential benefits of these curricula, and novel validated tools may help advance curriculum design in this domain.

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References

1. Wartman SA, Combs CD. Reimagining medical education in the age of AI. *AMA J Ethics* 2019;21(2):E146-52. https://doi.org/10.1001/amajethics.2019.146
2. Ellaway RH. When I say … epistemic curiosity. *Med Educ* 2014;48(2):113-4. https://doi.org/10.1111/medu.12272
4. Irby DM, Cooke M, O'Brien BC. Calls for reform of medical education by the Carnegie Foundation for the advancement of teaching: 1910 and 2010. *Acad Med* 2010;85(2):220-7. https://doi.org/10.1097/ACM.0b013e3181c88449
5. Lazonder AW, Harmsen R. Meta-analysis of inquiry-based learning: effects of guidance. *Rev. Educ. Res.* 2016;86(3):681-718. https://doi.org/10.3102/0034654315627366
6. Pedaste M, Mäeots M, Siiman LA, et al. Phases of inquiry-based learning: Definitions and the inquiry cycle. *J Educ Res Review* 2015;14:47-61. https://doi.org/10.1016/j.edurev.2015.02.003
7. Experiencing the Process of Knowledge Creation: the nature and use of inquiry-based learning in higher education; 2008.
8. Justice CR, J. Warry, W. Laruie, I. Taking an ''inquiry'' course makes a difference: a comparative analysis of student learning. *J Excell Coll Teach* 2007;18(1):57-77.
9. Aditomo A, Goodyear P, Bliuc A-M, et al. Inquiry-based learning in higher education: principal forms, educational objectives, and disciplinary variations. *Stud High Educ* 2013;38(9):1239-58. https://doi.org/10.1080/03075079.2011.616584
10. Spronken-Smith R, Walker R. Can inquiry-based learning strengthen the links between teaching and disciplinary research? *Stud High Educ* 2010;35(6):723-40. https://doi.org/10.1080/03075070903315502
11. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *Intern J Social Res Methodol* 2005;8(1):19-32. https://doi.org/10.1080/1364557032000119616
12. Tricco AC, Lillie E, Zarin W, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. *Ann Intern Med* 2018;169(7):467-73. https://doi.org/10.7326/m18-0850
13. Oğuz Ünver A, ArabacioĞlu S. Overviews on inquiry based and problem based learning methods. 2011
14. Feletti G. Inquiry based and problem based learning: how similar are these approaches to nursing and medical education? *Higher Education Research & Development* 1993;12(2):143-56. https://doi.org/10.1080/0729436930120203
15. Covidence Systematic Review Software 2021 VHI, Melbourne, Australia. *Covidence Systematic Review Software 2021,* Veritas Health Innovation, Melbourne, Australia. Available at Www.Covidence.Org.
16. McHugh ML. Interrater reliability: the kappa statistic. *Biochem Med (Zagreb)* 2012;22(3):276-82. [published Online First: 2012/10/25]
17. Tamayo G, Santibañez M, Javier Meana J. Evaluation of a pharmacology educational activity based on a research project: a randomized, controlled and blind analysis of medical students' perceptions. *Med Teach* 2005;27(1):53-60. https://doi.org/10.1080/01421590400013487
18. Wentland BA, Hinderer KA. A nursing research and evidence-based practice fellowship program in a Magnet®-designated pediatric medical center. *Appl Nurs Res* 2020;55:151287. https://doi.org/10.1016/j.apnr.2020.151287
19. Kim SC, Covington B, Benavente V, et al. Capstone projects as experiential evidence-based practice education. *J Nurse Prac* 2019;15(3):e51-e56. https://doi.org/10.1016/j.nurpra.2018.12.011
20. Magnussen L, Ishida D, Itano J. The impact of the use of inquiry-based learning as a teaching methodology on the development of critical thinking. *J Nurs Educ* 2000;39(8):360-4. https://doi.org/10.3928/0148-4834-20001101-07
21. Brondfield S, Boscardin C, Strewler G, et al. A medical student inquiry behavior assessment tool: development and validity evidence. *Acad Med* 2019;94(4):586-94. https://doi.org/10.1097/acm.0000000000002520
22. Cadorin L, Bressan V, Palese A. Instruments evaluating the self-directed learning abilities among nursing students and nurses: a systematic review of psychometric properties. *BMC Med Educ* 2017;17(1):229. https://doi.org/10.1186/s12909-017-1072-3
23. Keshmiri F, Rahmati A, Ghafarrahimi Amin A, et al. Validating and assessing the reaction of medical students toward team-based learning. *Acta Med Iran* 2016;54(12):806-11. [published Online First: 2017/01/26]
24. Yoon HB, Park WB, Myung SJ, et al. Validity and reliability assessment of a peer evaluation method in team-based learning classes. *Korean J Med Educ* 2018;30(1):23-29. https://doi.org/10.3946/kjme.2018.78
25. Papinczak T, Young L, Groves M, et al. An analysis of peer, self, and tutor assessment in problem-based learning tutorials. *Med Teach* 2007;29(5):e122-32. https://doi.org/10.1080/01421590701294323
26. Salinitri FD, Lobkovich AM, Crabtree BL, et al. Reliability and validity of a checklist to evaluate student performance in a problem-based learning group. *Am J Pharm Educ* 2019;83(8):6963. https://doi.org/10.5688/ajpe6963
27. Salinitri FD, O'Connell MB, Garwood CL, et al. An objective structured clinical examination to assess problem-based

learning. *Am J Pharm Educ* 2012;76(3):44. https://doi.org/10.5688/ajpe76344
28. Cömert M, Zill JM, Christalle E, et al. Assessing communication skills of medical students in objective structured clinical examinations (osce)--a systematic review of rating scales. *PLoS One* 2016;11(3):e0152717. https://doi.org/10.1371/journal.pone.0152717
29. Battistone MJ, Barker AM, Beck JP, et al. Validity evidence for two objective structured clinical examination stations to evaluate core skills of the shoulder and knee assessment. *BMC Med Educ* 2017;17(1):13. https://doi.org/10.1186/s12909-016-0850-7
30. Zhang F, Zhao L, Zeng Y, et al. A comparison of inquiry-oriented teaching and lecture-based approach in nursing ethics education. *Nurse Educ Today* 2019;79:86-91. https://doi.org/10.1016/j.nedt.2019.05.006
31. Migliore L, Chouinard H, Woodlee R. Clinical research and practice collaborative: an evidence-based nursing clinical inquiry expansion. *Mil Med* 2020;185(Suppl 2):35-42. https://doi.org/10.1093/milmed/usz447
32. Schön M, Steinestel K, Spiegelburg D, et al. Integration of Scientific Competence into Gross Anatomy Teaching Using poster presentations: feasibility and perception among medical students. *Anat Sci Educ* 2020:89-101. https://doi.org/10.1002/ase.2031
33. Crabtree E, Brennan E, Davis A, et al. Improving patient care through nursing engagement in evidence-based practice. *Worldviews Evid Based Nurs* 2016;13(2):172-5. https://doi.org/10.1111/wvn.12126
34. Durstenfeld MS, Statman S, Carney K, et al. Swimming with sharks: teaching residents value-based medicine and quality improvement through resident-pitched projects. *J Grad Med Educ* 2020;12(3):320-26. https://doi.org/10.4300/jgme-d-19-00421.1
35. Rush B, Barker JH. Involving mental health service users in nurse education through enquiry-based learning. *Nurse Educ Pract* 2006;6(5):254-60. https://doi.org/10.1016/j.nepr.2006.02.002
36. Bebb H, Pittam G. Inquiry-based learning as a 'whole-curriculum approach': the experiences of first-year nursing students. *Learning in Health and Social Care* 2004;3(3):141-53.
37. Si J. Course-based research experience of undergraduate medical students through project-based learning. *Korean J Med Educ* 2020;32(1):47-57. https://doi.org/10.3946/kjme.2020.152
38. Riner ME. Using implementation science as the core of the doctor of nursing practice inquiry project. *J Prof Nurs* 2015;31(3):200-7. https://doi.org/10.1016/j.profnurs.2014.11.002
39. Neville K, Horbatt S. Evidence-based practice: creating a spirit of inquiry to solve clinical nursing problems. *Orthop Nurs* 2008;27(6):331-7; quiz 38-9. https://doi.org/10.1097/01.NOR.0000342417.13842.cf
40. Rodríguez G, Pérez N, Núñez G, et al. Developing creative and research skills through an open and interprofessional inquiry-based learning course. *BMC Med Educ* 2019;19(1):134. https://doi.org/10.1186/s12909-019-1563-5
41. Mateo E, Sevillano E. Project-based learning methodology in the area of microbiology applied to undergraduate medical research. *FEMS Microbiol Lett* 2018;365(13) https://doi.org/10.1093/femsle/fny129
42. Frey K, Edwards F, Altman K, et al. The 'Collaborative Care' curriculum: an educational model addressing key ACGME core competencies in primary care residency training. *Med Educ* 2003;37(9):786-9. https://doi.org/10.1046/j.1365-2923.2003.01598.x
43. Lakin JR, Brannen EN, Bernacki RE, et al. A Curriculum in Quality Improvement for Interprofessional Palliative Care Trainees. *Am J Hosp Palliat Care* 2020;37(1):41-45. https://doi.org/10.1177/1049909119850794
44. Finn FL, Fensom SA, Chesser-Smyth P. Promoting learning transfer in post registration education: a collaborative approach. *Nurse Educ Pract* 2010;10(1):32-7. https://doi.org/10.1016/j.nepr.2009.03.005
45. Kenty JR. Weaving undergraduate research into practice-based experiences. *Nurse Educ* 2001;26(4):182-6. https://doi.org/10.1097/00006223-200107000-00015

Appendix A.

Search strategy

((project-based OR design-based) NEAR/3 (learn* OR teach* OR educat* OR intruct* OR course* OR curriculum* OR practic* OR study*))

OR ((inquiry OR enquiry OR inquiry-based OR enquiry-based) NEAR/3 (learn* OR teach* OR educat* OR intruct* OR course* OR curriculum* OR practic* OR study*)))

AND (medic* student* OR nurs* OR resident* OR medic* residen* OR nurs* student* OR nurs* educat* OR medic* educat* OR health profession* OR undergrad* medic* OR health occupation*)

Appendix B. Summary of Included Studies

Citation	Year	Primary Research Question	Secondary Research Question(s)	Study Design	Population	Intervention	Control (if applicable	Data collection tool(s)	Outcome(s)	Strengths	Limitations (including sources of bias)
Zhang[29] et al A comparison of inquiry-oriented teaching and lecture-based approach in nursing ethics education.	2019	Is an inquiry-oriented learning curriculum associated with greater perception of competency and positive attitudes in ethics in nursing education?	N/A	Quasi-experimental, two groups	Undergraduate nursing students in two nursing schools in China.	Inquiry-oriented teaching strategies (students required to identify ethical issues through literature review, analyze concepts, develop approaches, and discuss with group and facilitator)	Traditional lecture-based teaching (assigned reading, lecture via Powerpoint presentations)	Self-designed Likert-scale questionnaire measuring students' knowledge, attitudes, and competencies in nursing ethics delivered pre- and post-intervention to both groups. 36 items in 6 dimensions.	No difference in pre-investigation survey in any of 6 dimensions. Both groups scored significantly higher in 5/6 domains post-investigation. IBL group scored higher in post-investigation survey in ethical decision-making scale, and professional relationship scale. Lecture group scored higher in theoretical foundation of nursing ethics.	Two groups, multicentred study. Pre and post-investigation data available.	No validation data for survey. Outcomes exclusively based on student perception. IBL and traditional lecture not compared within centre. Institution may confound the results.
Migliore[30] et al Clinical Research and Practice Collaborative: An Evidence-Based Nursing Clinical Inquiry Expansion.	2020	What is the scholarly output before and after implementation of a Clinical Research and Practice Collaborative in a nurse scientist education program?	N/A	Quasi-experimental	Nurse scientists in the Air Force Medical Service.	Implementation of Clinical Research and Practice Collaborative (CRPC), an IBL curriculum in which nurse scientists ask a clinical question in a PICOT format, perform a literature search, appraise the evidence, and implement their project.	None	Not described	Number of research initiatives unchanged after implementation of IBL curriculum (n=4). Number of research publications and posters reduced from 8 to 3 and number of EBP initiatives grew from 2 to 11 and EBP publications and posters from 2 to 12.	Pre- and post-investigation data available	Small sample size. Single institution. No description of data collection tool. Descriptive analysis only.
Magnussen[19] et al The impact of the use of inquiry-based learning as a teaching methodology on	2000	Does inquiry-based learning (IBL) enhance critical-thinking ability as measured by the Watson Glaser Critical Thinking	N/A	Quasi-experimental	Nursing students at the University of Hawaii.	Inquiry-based learning curriculum wherein students were introduced to cases and had to define their own clinical questions, complete a literature review,	None	WGCTA administered in first week of school (form A) and during final semester (form B) of the program	228 students completed pre-investigation WGCTA and 257 completed the post-test (including 150 paired scores). No difference in mean WGCTA scores pre- and post-investigation.	Pre- and post-investigation data available. Validated assessment tool.	No control groups. Single institution. No ability to address confounding

the development of critical thinking.		Appraisal (WGCTA)?				and discuss evidence to support, refute, and revise hypotheses in small-group discussion.			When separated into WGCTA terciles the lowest group had a significant increase in WGCTA scores while the highest group dropped, with no change in the middle group. Response rate of 84% in control and 87% in experimental group.	Large sample size.	from influence of other course and learning experience.
Tamayo[16] et al Evaluation of a pharmacology educational activity based on a research project: a randomized, controlled and blind analysis of medical students' perceptions.	2005	Do students involved in a research project-based experimental model of pharmacology education have more positive perceptions of their course experience than students in a traditional model of practical activity-based teaching?	N/A	Randomized, double-blind, controlled trial	Medical students at the University of the Basque Country in their 3rd to 5th years.	IBL curriculum Students had to identify a research issue in pharmacology, review scientific literature, generate one or more hypotheses, design and implement a study, collect and process reliable and valid data, interpret results, draw conclusions and communicate results. The overall topics were provided but students had to generate their own hypotheses and questions. Both groups had foundational lectures.	Traditional model of practical activity including laboratory and computer-assisted demonstrations of pharmacological experiments, computer-assisted bibliographic search activities and seminars. Both groups had foundational lectures.	Self-developed questionnaire assessing 18 items on a 4-point Likert-type scale. The questionnaire was delivered to students two years after the course.	No differences observed between the experimental and the control groups in any of: appropriateness of objectives, adequacy of available resources, organization, support received and enthusiasm of the teachers. IBL group reported greater difficulty and interest in the course, and greater perception of bring able to use their own initiative, more effort required, larger requirement for concern for the subject of the activity. IBL group felt their course to be more useful for their future profession and more positive perception of knowledge and skill acquisition.	Double-blinded. Randomized controlled trial. High response rate.	Data collection tool not validated. Only post-test available. No description of baseline characteristics of each group to assess success of randomization.
Wentland[17] et al A Nursing Research and	2020	What are the scholarly outcomes of individuals in a	What are participants' perceptions of	Quasi-experimental	Nurse scientist trainees in a Nursing Research and		N/A	Survey on reported scholarly	All respondents were female, and 85% were White. Response rates were 100% at time 1,	Use of a validated scale for perceived	Small sample size.

Evidence-Based Practice Fellowship Program in a Magnet®-designated pediatric medical center.		Nursing Research and Evidence-Based Practice Fellowship Program?	knowledge, skills, and barriers to finding and reviewing evidence and changing practice?		EBP Program at Connecticut Children's Hospital.			outcomes and achievements. Developing Evidence-Based Practice Questionnaire: 49-item survey evaluating knowledge and skills related to EBP, evaluated in 5 subscales: bases of practice knowledge, barriers to finding and reviewing evidence, barriers to changing practice on the basis of evidence, facilitation and support in changing practice, skills in findings and reviewing evidence. DEBPQ was sent before the intervention, at the conclusion, and one year afterwards.	55% at time 2, and 100% at time 3. 24 participants started in the fellowship program and 22 completed. Nine projects were completed. Three participants completed graduate nursing programs, one participant completed a doctorate of nursing program. Nine projects have been presented locally and/or regionally. Four projects have been presented nationally. One manuscript has been published and six others are in progress. One group received a national grant and research award. DEBPQ results showed a significant increase in perceived skills in finding and rereviewing evidence, though with a significant increase in barriers to finding and reviewing evidence as well.	skill measurements. Pre- and post-intervention assessment. High post-test response rate.	Single institution. No control.
Kim[18] et al Capstone Projects As Experiential Evidence-Based Practice Education.	2019	Does a capstone research project improve students' beliefs, knowledge, attitude, competencies, and practice of EBP before and	What are students' perceptions of educational alliance during a capstone research project?	Quasi-experimental	Students in Master of Science in Nursing-Family Nurse Practitioner program.	Students undertook a capstone project which included 3 translational research courses. Within the scope of the 3 courses students were tasked with creating a clinical question, appraising evidence,	N/A	Evidence-Based Practice Questionnaire (EBPQ) which contains 24 items in 3 scales (Practice of EBP, Attitude toward EBP, and EBP knowledge) in a	68/69 students completed both questionnaire packets (99%). EBPQ: Statistically significant improvements were seen in 4 of the 5 measures: EBP practice	High response rate. Use of validated scale for primary outcome. Pre- and post-intervention data available.	No control groups. No validation of modified KAS-R scale.

after completion?	What is the perceived effectiveness of a capstone research project in improving EBP competence? What are the predictors of Evidence-based practice after completion of a capstone research project?		synthesizing evidence, developing and completing a research project and disseminating findings.	7-point Likert format. EBP Beliefs scale has 16 items in a 5-point Likert format. Modified Kim Alliance Scale-R (KAS-R) where the original 16-item (4-point Likert scale) KAS-R was modified to replace 'provider' with 'professor' and assess the student perception on the quality of educational alliance between themselves and their supervisor. Self-designed survey on perceptions containing 13-items on a 7-ponit Likert scale, with some items adapted from EBP Competence scale. All participants completed EBPQ, EPB Beliefs and self-designed	(3.29 vs 5.50; t ¼ 10.8, P < .001), EBP knowledge (3.92 vs 5.63; t = 11.4, P < .001), EBP competence (2.18 vs 3.86; t = 16.7, P < .001), and EBP beliefs (3.66 vs 4.30; =t - 11.7, P < .001). No improvements in EBP attitude. Mean scores improved in all EBP activities on the self-designed EBP competence scale (formulate a key question, search databases, find best clinical evidence, understand research articles, appraise articles critically, synthesize research evidence, apply evidence to patient care). Educational alliance was highly correlated with perceived effectiveness of the interventions (r = 0.77, P < .001). EBP competence (b = 0.36, P ¼ .004) and effectiveness of translational research courses (b = 0.50, P = .002) were significant predictors of evidence-based practice.

							survey, along with demographics questionnaire at the start of the course. Participants also completed all scale and the KAS-R (modified) at the of their last course.			
Schön[31] et al Integration of Scientific Competence into Gross Anatomy Teaching Using Poster Presentations: Feasibility and Perception among Medical Students	2020	What are the types of posters created by students after integration of scientific work into anatomical teaching?	Does integration of scientific work into anatomical teaching result in a positive perception from students'? What are the successes and difficulties with integration of the new format in anatomical teaching?	Quasi-experimental	Second-year medical students at Ulm University.	Groups of 10 students working with one body donor in an Anatomy lab to either describe anatomical findings or create a clinical question based on their findings during dissection. Students then conduct a literature search, synthesize evidence and produce either a case report or original research study to be presented in poster format to a professional audience.	N/A	Course administrative data regarding poster number and content. Self-designed post-intervention survey of students using 6-point Likert-type scale.	76 posters were created between 2019-2020. 70/76 described pathological findings in a case report format. 6/76 developed a scientific question and collected data in the form of a research study. Posters used 1-5 references, with majority collected from Google or Google Scholar and few from any other library databases. Errors were commonly noted with citation and authorship formatting. 162/373 students completed a post-course survey (43%). Students invested 2-4 hours for poster production, and 74% perceived this as burdensome (median 4/6 +/- 1.8/6)).	Mixed Methods Design.	No control group, post-test only. Single institution. Low response rate in student survey and low volume of qualitative data subject to response bias. Survey tool was not validated.

				Students reported they earned competencies not only in the field of the poster's clinical (31.8%) and pathological content (24%), but also in the field of teamwork (24%) and literature search (21.7%). In contrast, 24% of respondents indicated that they did not experience gain in any of the listed competencies. Students were unsure whether or not the project was an useful addition to the dissection course (Median 4/6; ± 1.3/6), but were positive about the experience of learning new scientific skills (Median 4/6 ± 1.2/6). 31% of the students agreed to the statement that their interest in science was increased and 46.5% of the students wished to work on scientific projects more frequently during their studies 73 codes generated from qualitative survey data, majority negative (47/73), largely related to additional workload and difficulty retrieving helpful literature.

Crabtree[32] et al. Improving patient care through nursing engagement in evidence-based practice.	2016	Can an evidence-based nurse scholars course improve patient care and prepare nurses to engage in EBP?	N/A	Quasi experimental	Nursing students at the Medical University of South Carolina (MUSC).	12-week, project-based course focused on teaching theory, practice and dissemination of evidence-based practice (EBP), including how to frame clinical questions, perform literature searches, analyze and evaluate evidence and translate knowledge into clinical practice. Nurses then selected a hospital policy, applied their acquired EBP knowledge and updated the policy.	No control	Pre and post self-designed survey. Course administrative data regarding poster number.	Significant increase in confidence with critically reviewing literature (p<0.001), increase in belief that EBP is necessary for nursing practice (p = 0.052), and increased interest in improving EBP skills (p=0 .002). Increases in the use of EBP resources in clinical practice, including the Cochrane Database of Systematic Reviews (p<0.001), CINAHL (p<0.001), National Guideline Clearinghouse (p=0.049), PubMed (p = 0.005), and UpToDate (p = 0.018) Increased understanding of statistical concepts and study design methods (p<0.001). Successful completion of 15 projects related to nursing care and practice. Some nurses presented their findings at regional and national conferences.	Pre and post data available	Single institution Response rate not provided. Survey tool was not validated. No control group
Durstenfeld[33] et al. Swimming with sharks Teaching Residents Value-Based Medicine and Quality	2020	Does a project-based curriculum increase resident confidence	Does a new project-based curriculum increase the likelihood of resident participation	Quasi experimental	Internal medicine and primary care residents at the New York University	2-week curriculum 3 hours of interactive introductory Lean training, with	No control	Retrospective, pre/post survey. 1 year follow up survey.	Significant improvement in resident self-assessed knowledge, confidence levels, and comfort with QI and value learning	Pre and post data available Long term follow up data included.	Survey tool was not validated.

Improvement Through Resident-Pitched Projects	using essential QI tools and institutional data to solve systems-based value challenges?	in future quality and value projects?	school of medicine.	a focus on charter construction, process mapping, problem identification, and solution design 6 hours of in-person lectures emphasizing institutional priorities and case studies to illustrate concepts Residents engaged in exercises reviewing 3 of their own readmissions to determine contributing systems causes. During the final event, residents worked in groups to identify a process they believed to be inefficient, unsafe or of low value, designed potential solutions, presented the solutions to faculty and subsequently implemented their projects.	Self-designed 4-point Likert-type scales to self-assess knowledge, attitudes, and skills.	objectives after the curriculum Increase in residents' ability to identify unsafe or inefficient processes in the hospital (56% to 96%, P<.001, Cohen's d ¼ 0.85). Residents felt more comfortable in their abilities to use process mapping (18% to 86%; P<.001; Cohen's d ¼ 1.20) and principles of Lean management to propose solutions (16% to 64%; P<.001; Cohen's d ¼ 1.14). Residents reported being likely or highly likely to participate in quality, safety, and value projects (25% to 70%, P <.001, Cohen's d ¼ 1.08) Residents reported being likely or highly likely to suggest quality, safety, and value proposals to hospital leadership (12% to 65%; P , .001; Cohen's d ¼ 1.25). 39 /43 (91%) residents completed a 1-year follow-up Survey. Improvements were sustained at 1-year follow-up for all survey questions.	High response rate	Pre-surveys done retrospectively

								95% of residents had at least 1 poster presentation accepted to the center's internal Quality and Safety Day 44% of survey respondents reported that they were involved in QI/ VBM projects beyond their required rotations, of which 10 had resulted in presentations at national meetings prior to completion of residency training 26% of respondents were very likely to consider a career that focused on improving quality, safety, and value		
Rush[34] et al Involving mental health service users in nurse education through enquiry-based learning.	2006	Does incorporating enquiry-based learning with mental health service user involvement better prepare nurses for practice?	Does service user involvement make the EBL process more valid in allowing the service user voice to come through? Does service user involvement in education enhance the student experience?	Quasi-Experimental	Nursing students at the end of the first year of a Diploma Nursing program at the University of Nottingham.	3 days assigned for the EBL process involving discussions between students and the service user. Subsequently, students identified a topics to pursue for further, did their own research on the topic, presented to their peers, facilitator and service user. Based on information gained, students wrote action plans. Upon returning from clinical	No control	Written evaluations completed by students of their experience with EBL and service user involvement. Three specific questions provided for students to answer: 1. How does this experience of EBL compare with other modules using this approach?	26 (100%) students provided written evaluations. All students described the experience positively Sessions found to be relevant and thought provoking in providing a more rounded view of mental health issues than a traditional EBL approach. Service users provided perspective and created motivation for learners to make more of an effort.	High volume of qualitative data available.	No control group. Survey tool was not validated. No quantitative data. Subjective trainee outcomes only.

					practice, students discussed their experience with their facilitator and service user.		2.How does the involvement of a service user impact on the experience of EBL? 3.What did you like about the experience? 4. How could the experience be improved?	Students highlighted that service users provide a meaningful view-point that is readily accessible. Service users allowed students to access different perspectives, reported to be one of prime objectives of EBL. Some students identified that they would have liked more time to explore the issues raised.		
Bebb[35] et al. Inquiry-based learning as a 'whole-curriculum approach': the experiences of first-year nursing students	2004	What are the student experiences after incorporating inquiry-based learning for a first-year nursing degree?	N/A	Quasi-experimental	First year nursing students at Anglia Polytechnic University.	Students are split into groups with facilitators that remain consistent throughout their 3-year program. Students undergo a 5-stage IBL process: Exploration tutorial in which students discuss and analyze a scenario and identify learning issues to explore. Self-directed study in which students gather information through presentations, and individual study. Review tutorial in which students present their information, apply it to the scenario with	No control	Self-designed series of questionnaires. Questions included on individual modules, other program components. Content derived from approach of Stufflebeam (1983) an includes themes of context, input, process and product. Semi-structured 40-90 minute interviews with participants that were tape-recorded and transcribed.	15 students attended interviews. Identified themes: 1) Adapting to IBL Confidence improved as the course progressed. Several students reported difficulties with initial adjustment to a more student-centered learning method (some still experiencing problems a year into the course). Some students struggled with the unstructured nature of IBL and wished for more guidance 2. The IBL process in use Several groups modified the tutorial process possibly due to a desire to focus on the assignment rather than discussion within	High volume of qualitative data available. Independent coding of data by authors reducing interviewer bias.	Survey tool and semi-structured interviews not validated. No control. No quantitative data.

					their group and discuss. Consolidation tutorial in which the group develops an action plan. Plenary tutorial in which students review their learning and the group identifies further learning needs.			the group. Students learned from each other's experience within the group. 3. Taking responsibility for learning There was variation in students' reaction to the self-directed nature. There was also variability in learning resources used (relying on library texts versus knowledge of peers) 4. Working as a group. Students were almost always positive about facilitator involvement. Most groups experienced conflict at some stage. 5. Overall perception of IBL. There was agreement that IBL offered advantages. Students had increase self-confidence and felt that self-directed learning would be useful for future practice		
Si J.[36] Course-based research experience of undergraduate medical students through project-based learning	2020	Can an introductory level course-based research experience (CRE) through problem based learning be effectively and efficiently utilized for undergraduate	N/A	Quasi experimental	Second-year premedical students.	The course met twice weekly, for a 15-week semester. Students divided into nine groups of 4-5 students with one professor. In the first 5 weeks, lectures provided to students on how to conduct research. In	No control	Students given a course grade based on individual and group components. Individual scores included attendance, individual contribution, self-assessment,	Students perceived the course structure as appropriate and helpful. Students felt group work experience was positive and productive. Learner satisfaction items also earned positive responses in general.	Mix of quantitative and qualitative data collection tools.	Small sample size Single institution No control No pre-assessments.

		research experiences?				the second part of the course, students define a research question and conducted their own research to develop answers. Research proposals and final reports presented to the class. Feedback provided by professors and classmates.		peer-assessment. Group scores included presentation skills, research proposal and research report. Survey comprising 15 items of both 5-point Likert scale and open-ended questions. Included questions about course structure, group work, learner's satisfaction, open-ended questions. Items of group work and learner satisfaction developed based on learner perception utilized by Si and the learner satisfaction survey utilized by Shin and Chan. Their Cronbach's α were 0.93 and 0.86, respectively	Mean value of the research skill scores of each group was 19.11/ 27 and the mean value of each research skill score was 2.12/3 Overall, active learning and motivation of students was increased. Many students indicated that the development of research skills was the most beneficial aspect of the course Students had difficulties in understanding scientific journals, selecting research topics, finding relevant journals, understanding journals in English, conducting an experiment, and writing a report. They also had difficulties in with effectively presenting data.		Survey tool was not validated.
Brondfield[20] et al A Medical Student Inquiry	2019	Can an assessment tool be used to articulate and guide medical	N/A	Quasi experimental	First year medical students at The University of California,	A longitudinal, core inquiry curriculum is a part of the school of medicine. It entails weekly small	No control	Modified Delphi survey in which participants rated the	77% response rate for the two-round modified Delphi survey	Use of a validated scale Large sample size	No control group.

Behavior Assessment Tool: Development and Validity Evidence	student development of essential inquiry behaviors?	San Francisco (UCSF) School of Medicine	groups with 8-9 students and a faculty facilitator. Students choose their own learning objectives, seek evidence from the primary literature to justify explanations, critically evaluate their own and peers' explanations, and collaborate in their small groups. To assess students' inquiry development in this course, an inquiry behavior assessment tool was developed. The development involved two phases (Messicks validity framework). In phase one inquiry behaviors were identified and categorized, followed by a modified two-round Delphi study (including modified Delphi survey) to generate consensus on the most salient inquiry behaviors. Students and faculty rated the importance of the inquiry behaviors and provided suggestions. One-way analysis of variance (ANOVA) used to compared faculty and student ratings.	importance of the selected candidate inquiry behaviors, done twice.	The five behaviors that met the inclusion threshold were: select relevant questions to pursue; justify explanations with evidence; critically evaluate his/her explanation in light of alternative possibilities; allow for the possibility that his/her own knowledge may not be completely correct; and collaborate well with peers. The remaining 35 behaviors were dropped. ANOVA demonstrated no significant differences between faculty and student ratings and effect sizes were mostly small. 1/5 behaviors had a moderate effect size (select relevant questions to pursue, d = 0.78). Behaviors that were close to but did not reach the CVI threshold for inclusion also had small effect sizes, indicating strong agreement between faculty and students. Qualitative feedback was obtained from 18 faculty facilitators from the pilot. This included support for the small number of items and use of a 3-point scale. Based on feedback, the tool's	High response rate Subjective and objective data for trainee outcomes provided.

					Additional validity evidence was gathered by distributing the tool to a pilot inquiry small group and feedback was obtained through a free-response survey, open ended email and focus group. Inquiry tool was modified based on the feedback. Final tool was implemented in 2016-2017as both a faculty assessment of students and student self-assessment. 67 facilitators and 152 students used the tool. Students who did not meet expectations on the tool reviewed written facilitator feedback.			rating scales and associated descriptors were simplified. Two (1.3%) of 152 students did not meet expectations based on faculty scores. Both students subsequently met expectations in the following quarter Student paired t test, we found no statistically significant difference between faculty and student scores on most items at most time points, indicating evidence of interrater reliability During implementation, faculty and student scores increased on most items, indicating skills development over time.		
Riner, M[37] Using Implementation on Science as the Core of the Doctor of Nursing Practice Inquiry Project.	2015	Will using implementation science to develop an inquiry project allow DNP graduates to obtain sufficient experience with advanced literature searching, identifying evidence for an intervention,	N/A	Quasi experimental	Students in the doctor of nursing practice program (students who have a nursing masters degree).	Students partook in an inquiry project in which they identified a problem from their clinical agency, conducted a literature review, synthesized the evidence and developed a plan to address the problem. In the second part of the course, students develop a	N/A	Self-designed alumni survey	Five papers published from first cohort, one student selected for poster presentation at the Midwest Nursing Research Society, two presented at peer-reviewed national presentations. Survey indicated that alumni of the course believe they developed valuable nursing science knowledge and	Data from across 3 years available.	No quantitative or qualitative data from survey provided. Survey tool not validated. No response rate

		implementing, evaluating and disseminating the findings to adequately meet the needs of clinical agency partners for practice improvement?			detailed plan through 4 modules for implementation of their project.			advanced as clinical practice leaders		
Neville[38] et al Evidence-based practice: creating a spirit of inquiry to solve clinical nursing problems.	2008	How can evidence based practice best be used for clinical issues identified in professional nursing practice settings? .	What are the levels of evidence available in the conduct of evidence-based literature search activities? What are the barriers in conduct of EBP? What is the perception regarding using EBP in clinical decision making amongst professional nurses?	Quasi-experimental	10 professional nurses pursuing their RN-BSN degrees.	Professional nurses participated in an EBP project through an independent nursing practicum. Initially seminars were provided to discuss EBP including the history, misconceptions, steps. Nurses posed a PICO based on identified uncertainties. Reference librarians provided guidance in online search strategies. 5 different examples of PICO questions, evidence search and implementation of findings were provided.	N/A	None	After initial session of the project, nurses gained confidence and competence in search techniques, nurses reported that implementation of an EBP project is challenging but stimulating and that they gained confidence in knowing they could use research in their practice 5 PICO questions and implementation described: 1) Anti-pyretic recommendation for fever management. Literature review and implementation of policy to recommend avoiding alternating acetaminophen and ibuprofen for school aged-children. 2) Students noted high incidence of MSK injuries in a long-term residential facility. Conducted research around effectiveness of mechanical lifting devices and brought back to their units.	Specific examples provided of inquiry learning and implementation in clinical settings.	No quantitative data. No survey tool used to assess effectiveness of intervention. Small sample size. No control group.

								3) Difference in infection rate with use of gauze and paper versus transparent polyurethane dressing. Literature review suggested choice should depend on patient preference and cost, this was brought back to the institution. 4) Effectiveness of PTCA vs TT for STEMI, literature review showed clear benefit of PTCA. Learner gained scientific knowledge and ability to better communicate with patients. 5) Use of acupuncture for treating asthma in adults. Literature review demonstrated lack of clinical trial in this.		
Rodriguez[39] et al Developing creative and research skills through an open and interprofessional inquiry-based learning course.	2019	Can IBL enhance the development of research and creativity skills in undergraduate health science students?	What is the impact of a creativity workshop focusing on IBL?	Quasi-experimental	Students in the bachelor of human biology and bachelor of medicine programs.	10-week IBL course in which students are assigned to groups and develop a research question based on a broad problem in biomedicine provided to them. Students developed a hypothesis and suggested methods to obtain an answer. Tutors were present to guide students through the process. Students in the 2014 and later cohorts also took part in a creativity workshop to help develop creative skills in the	Students from the 2011-2014 cohorts who did not take part in the creativity workshop associated with the course.	Questionnaire completed by students about their development of research skills and creative thinking, and about the creativity workshop.	Ratings for the course were high for all items, there was no significant difference between the two cohorts that did and did not perform the creativity workshop. The strongest correlations were between cooperative work and inquiry process (r=0.69), research skills and inquiry process (r=0.66) and research skills and creativity (r=0.64) Satisfaction and usefulness of the course were rated highly (higher in human biology than	Quantitative and qualitative data. Subjective and objective trainee outcomes. High number of students included over 5 academic years. Pre and post data for creativity workshop.	No control group for IBL learning No pre and post data available for IBL learning. Survey tool based on trainee perceptions. Survey tool not validated.

					context of the course.			medical students). 7.96 vs. 6.77 for satisfaction, $p = 1.38 \times 10^{-4}$, and 7.98 vs. 6.51 for usefulness, $p = 2.94 \times 10^{-6}$. Final overall grades were very high, tutors and evaluators qualified projects as very good. There was a significant difference in final grade between students who did and did not take the creativity workshop.		
Mateo[40] et al Project-based learning methodology in the area of microbiology applied to undergraduate medical research.	2018	Does implementing project-based learning help medical students acquire deeper knowledge research?	N/A	Quasi-experimental	Third year medical students at the University of Basque Country.	Students in groups presented with a scenario from which they extracted learning objectives and identified steps to develop their research. Students searched various sources related to their learning objectives individually then shared with the group. Each group developed an original research idea in the area of medical-microbiology and presented/discussed with other groups. Students wrote a project funding proposal, carried out the experiments and collected results. Results were presented in poster	N/A	Satisfaction survey completed by students. Survey consisted on five sections. First section for general assessment of the methodology. Second section included question about how students thought this methodology had helped them learning the subject compared to the traditional methodology. Third section included a question to assess the help offered by the teachers. Fourth section to assess if students would change	Total of 44 projects carried out, total of 173 students took part. Satisfaction survey completed by students was overall favorable. All students agreed this method was no less helpful than the traditional method in achieving learning objectives. Majority of students would choose this method over the traditional one. Projects were scored 80% by teachers and 20% by students. Overall final scores were good with marks higher than 7 out of 10.	Objective, quantitative measurements obtained for trainee outcome.	Response rate of satisfaction survey not provided Detailed objective scoring of projects not provided. No control group. No pre and post intervention data Survey tool not validated.

					and oral presentation format, and a final report was written about the project.		anything about the methodology and if they would choose this methodology in the future. Finally, the fifth section included 14 items to score from 1 to 4.		
Frey[41] et al The 'Collaborative Care' curriculum: an educational model addressing key ACGME core competencies in primary care residency training.	2003	Does implementing a disease management practice guideline, using a team-based project provide residents with practical experience in improving patient care?	Does a team-based project in implementing disease management practice guidelines equip family physician in training with skills necessary to organize chronic illness care in their future practice?	Quasi-experimental	Third year family medicine residents.	A yearlong senior (third year) resident class project in which one evidence based clinical guideline is designed, implemented and evaluated. The resident class conducted a literature search and review for existing guideline on a chosen disease or condition, and presented their guideline to faculty mentors. The entire department then received training in the use of the guideline.	N/A	Self-designed survey completed by residents to indicated confidence level for different aspects of the project (from very confident to no confidence in knowledge and/or skills in the area) Locating and critically evaluating research evidence, applying conclusions about evidence to an individual or patient group, determining effect of a positive or negative test result on the probability that a patient has a	2 years of curriculum, 12 residents participated (6/year) Highest confidence was reported in the ability to develop and adapt practice guidelines based on evaluation of evidence from relevant clinical studies. Lowest confidence reported in ability to analyze quality outcomes data, institute change based on the analysis and evaluate impact of these changes. Comments indicated a marked change in attitude about the project from start to end (ultimately viewed as a worthwhile educational experience)	Quantitative outcome measurement (scores of confidence) provided.	No control group Small population, only two years No validated outcome tool No quantitative results from survey provided. No response rate provided

		particular condition, weighing costs vs probable yield of a particular diagnostic procedure in managing a patient with a specific condition, comparing costs and probably benefits of treatment plans. Developing management plans for a panel of patients with a specific chronic condition that address patient satisfaction and treatment effectiveness. Developing and adapting practice guidelines based on evaluation of evidence from relevant clinical studies. Analyzing quality outcome data, instating change based on analysis and evaluating impact of changes as part of a QI project. Delegating responsibility

							and sharing authority with allied health in order to assure productive teamwork.			
Lakin[42] et al A Curriculum in Quality Improvement for Interprofessional Palliative Care Trainees.	2020	Does a 4-month IBL style curriculum help learners develop a basic understanding of QI?	N/A	Quasi experimental	Palliative care fellows.	Curriculum entails 4 sessions Session 1: didactic lecture on basics of QI followed by fellows creating problem statements and aims, and brainstorming possible projects. Session 2: lecture about key tools for QI followed by fellows exploring further details of the project. Fellows expected to subsequently use a QI tool to collect data. Session 3 and 4: Groups present their project and data and receive a lecture on presentation of results and data analysis tools. In the fourth session fellows present final projects and data.	N/A	Fellows completed a curriculum evaluation tool that uses a 5-point Likert scale on their perceptions and skills sets surrounding QI before and after the course, their opinions on the course and its relevance to their clinical practice.	Course has been ongoing for 13 years, facilitated 28 team-based QI projects. 36 trainees (80%) completed the retrospective evaluation tool. Average score of 4.49 (out of 5) for effectiveness of teaching method, and average score of 4.11 for clinical usefulness of the course. Marked increase in self-reported ability and confidence in using language of QI (2.57 to 3.88). Overall increase in all evaluated measure in pre-and post-scores. Most significant improvement was in learners' ability and confidence to plan, implement and present a QI project	High response rate. Pre and post intervention data available.	No control group No objective trainee outcome measurements Curriculum evaluation tool not validated.
Finn[43] et al Promoting learning transfer in post registration education: a	2010	Does a new post registration degree program focused on learning transfer,	N/A	Quasi experimental	Registered nurses or midwifes in Ireland enrolled in a post-registration	The curriculum consisted of lecturer-facilitated classes and student enquiry sessions on alternate weeks. An enquiry group presentation and	Student questionnaires, observation of EBL presentations and clinical supervisor and manager	99 students partook in the first semester, and 75% of them completed the questionnaire. 87% of students strongly	High response rate. Objective trainee outcome measurements used.	No control group. Survey tool not validated No quantitative

collaborative approach.		practice based and enquiry-based learning create more engagement of participants and provide more transfer of learning to clinical practice?			degree program.	practice-based project report were the two main assessment methods. Students conducted a literature review on an element of nursing practice that requires development then made recommendations for practice, and lead the implementation of the best practice initiative and evaluated the process. Students were required to meet with their managers and clinical supervisors regularly to discuss practice development needs and seek approval for proposed projects.	feedback used as outcome measures.	agreed/agreed that learning through enquiry is beneficial, 91% agreed that they were able to link their learning to practice, 77% strongly agreed/agreed that the in-class discussions were beneficial. Of the 8 groups, some had difficulty understanding the concept of EBL, 2 groups demonstrated only superficial learning with limited application to practice based on observations and reflections from course lecturers. Overall there was a mix of positive and negative qualitative feedback from students. Feedback from clinical supervisors and nurse managers were all positive.		objective measurements of trainee outcomes.
Kenty[44] JR Weaving undergraduate research into practice-based experiences	2001	Can a collaborative learning project allow students to understand the importance of and be better prepared for evidence-based practice?	How can students research knowledge and attitudes towards research increase?	Quasi experimental	Nursing students enrolled in a research course at a university in the USA.	Implementation of a collaborative learning project (CLP) in which students worked independently and collaboratively in a health practice group. During the first month each group worked to identify a practice problem on their respective	Survey at the beginning and end of the project in which students were asked to rate their knowledge of research concepts.	28 students enrolled in the class Overall, research knowledge generally increased significantly after pared t test (t=-0.38, df=19, p=.705). Students attitudes towards research were more positive at the end but the increase was not significant after paired t test.	Pre and post quantitative data available.	No control group No objective outcome measurements. Small sample size Survey tool not validated.

	clinical units with faculty assistance. Each student independently searched the nursing literature and with faculty assistance chose one nursing innovation research report that could be applied to their practice setting. Each student reformulated the general research question using their innovation. Each student then implemented their innovation and presented and critiqued their findings.	