A LANDSCAPE REVIEW OF THE LITERATURE FOCUSING UPON THE USE OF TECHNOLOGY TO SUPPORT PROBLEM, CASE AND PROJECT BASED LEARNING IN HIGHER EDUCATION STEM DISCIPLINES.

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ABSTRACT

A systematic approach was undertaken to locate and analyse empirical research examining the use of technology to support constructivist approaches to learning. In particular, this paper focuses upon Problem, Project and Case Based Learning and consults 56 publications which have employed technology in Science, Technology, Engineering and Mathematics within on campus higher education settings. Four databases were searched along with hand searching and, after applying relevant inclusion and exclusion criteria, 56 publications published during 2007–2021 were included in this review. In addition to systematically documenting the landscape of literature associated with this area of research, this paper offers an analysis of the contributions of the research in understanding the way in which technology affects performance, team-working and graduate skills as part of the learning process.

1 INTRODUCTION

1.1 Problem, Project and Case based constructivist approaches in STEM

The disciplines of science, technology, engineering and mathematics are collectively and more commonly referred to as STEM. Constructivist approaches such as Problem, Project and Case based learning are often employed within these disciplines and involve students working collaboratively to resolve complex, authentic and real-world problems (Hmelo-Silver, 2004; Graham, 2010; Hanney & Savin-Baden, 2013; Harmer & Stokes, 2014; Kennedy & Odell, 2014). Autonomy in learning, team work, and an active approach to sharing knowledge and understanding as part of a problem-solving process are integrated across the STEM disciplines. The tutor undertakes the role of facilitator to support students when

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engaging in carefully selected real-world challenges (Wood, 2003; De Graaf & Kolmos, 2003; Allen, Donham & Bernhardt, 2011).

Distinctions between Problem, Project and Case based learning often relate to the discipline in which they are most often located, for example, medicine and related fields such as healthcare often use the term ‘Case Based Learning’ (CBL). Cases relate to clinical practice but draw upon features of Problem Based Learning (PBL) such as problem solving in small groups. In some instances, the term CBL can be used interchangeably with PBL (Azer & Azer, 2015) with both involving the ability to collaborate and communicate as key attributes. Such attributes may, in some circumstances, be referred to as graduate skills or attributes of employability (Gunn, Bell & Kaffman, 2010).

For STEM subjects, such an approach would be relevant as the ability to solve problems as part of a team relates to the context in which many of the students will ultimately work and, as such, would be attractive to prospective employers and valued by accrediting bodies. However, there are also potential barriers to PBL-related approaches often cited as resource-related to include facilities as well as staff time (Graham, 2010; Kokotsaki et al, 2016; Harmer & Stokes, 2014; Frambach et al., 2019)..

1.2 Constructivist approaches and the use of technology

A wide range of technologies to support campus-based teaching and learning are currently available. These include, but are not restricted to interactive handsets, displays and mobile devices to support, facilitate and enhance constructivist approaches to learning (Ioannou, 2016; Wood & Shirazi, 2020); simulations, games (Vlachopoulos & Makri, 2017), augmented reality, (Ibáñez & Delgado-Kloos, 2018), computer supported collaborative learning environments, (Al-Samarraie & Saeed, 2018) and use of multimedia and video (Noetel et al., 2021).

Existing systematic reviews examine specific technologies in relation to constructivist or student centered approaches to learning for example, the use of a web-based online environment (Jurewitsch, 2012); cloud computing (Al-Samarraie & Saeed, 2018); audience response systems (Wood & Shirazi, 2020); video (Aronis, 2016; Noetel et al., 2021) or perhaps the use of a specific technology within STEM subjects, for example, augmented reality, (Ibáñez & Delgado-Kloos, 2018); digital case scenarios (Gavgani et al., 2015). There are also studies which focus upon a specific subject or discipline within the overarching portfolio of STEM, for example, Car et al., (2019) who focussed on any form of digital technology and Jin & Bridges, (2014) who examined literature focussing upon video/3D models, Interactive whiteboards/plasma screens and Learning management Systems; both within health education. . The former concluded that there was evidence that digital PBL appeared to be more effective than either traditional PBL or traditional learning in terms of students’ skill outcomes and more effective or equal to traditional PBL where

knowledge outcomes are concerned. Jin & Bridges' study found that authenticity and 'rich' opportunities for learning facilitated students' growing expertise. Technology offered structured learning and supported engagement in collaborative activities which allowed students to explain, discuss and reflect upon their understanding thereby making their thinking more explicit (2014).

1.3 Context and Rationale

There is a noticeable rise in the use of blended learning within campuses across the higher education sector. The popularity of PBL and related challenges listed above, calls for a review of the research carried out to date that represents the use of technology to improve the key outcomes for which PBL is chosen. A particular focus is on campus PBL settings as STEM educators now face a high proliferation of technology in their practice. Researchers looking at the how and why technology can enable or enhance the key outcome will also benefit from this review. Rather than selecting a specific technology or subject within the STEM disciplines, this study reviews empirical research which employs digital technologies used within any STEM discipline as part of a constructivist approach to learning and teaching, for example PBL, PjBL and CBL.

2 METHODOLOGY

2.1 Research Questions

This systematic landscape review provides a comprehensive overview of empirical research which examines the use of technologies for CBL, PBL and PjBL in higher education. It focuses upon the meta-discipline of STEM and reports on the landscape of literature which, at the time of writing this paper, sought to present the way in which technology supported and enabled: team-working; the development of graduate skills and student performance in learning.

The PICO framework (Schardt, Adams, Owens, Keitz, & Fontelo, 2007), was employed where key criteria involving Population (P), Intervention (I), Comparison (C) and Outcome (O) provided a means of systematically defining our research question, search clause, inclusion and exclusion criteria in order to identify relevant literature which would allow us to answer the research questions. The population was limited to STEM disciplines in on campus Higher Education (HE) settings and the intervention involved the use of any technology in order to study its impact on the three key outcomes: team-working, graduate skills and student learning.

The following overarching and sub-research questions were developed using the PICO framework:

1. How have learning technology interventions been used to support the key outcomes related to problem, project and, case-based approaches within on campus higher education STEM settings?

    a. What technologies have been used in relation to the identified outcomes?
2. What are the characteristics of these studies?
    a. Which disciplines within STEM education have employed such approaches?
    b. What are the methodological characteristics of the studies?
3. What are the main findings of these studies?

2.2 Search and selection

In order to locate relevant articles undertaking primary research, which corresponded to the area of interest described above, a systematic search of four databases: Scopus (Sco), Education Resource Information Centre (ERIC), Web of Knowledge (WoK) and ScienceDirect (SD), was undertaken. Filters, where available, were applied in order to include articles published from January 2007 to June 2021 and which were written in English. The search was not restricted to journal articles or to those which were subject to peer review in order to ensure the returns encompassed as wide a range of sources as possible thereby reducing the risk of bias across studies (Schlosser et al., 2007). Hand searching and reference checking were undertaken after the screening of full papers had been completed, more specifically, an ancestral search of the reference lists of the 41 selected articles was conducted by the authors, who identified a further 15 articles that met the inclusion criteria.

The PICO framework, (see table 1), was also helpful in systematically defining search terms within this review.

Table 1

PICO Themes	Corresponding search term
Population: Case / *Problem / Project based*	("Problem based Learning" OR "Project based learning" OR "CDIO" OR or "case based learning")
Population: *Higher Education*	("higher education" or "university" or "graduate" or "bachelor" or "college" or “post compulsory” or “post secondary” or “third level”) AND ("engineering education" or "medical education" or “health education” or “science education” or “computing” or “mathematics”)
Intervention: *Technologies*	("technology enabl*" or "technology enhanc*" or "video*" or "collabor* technology" or "flip* class*" or "flip* learn*" or "learn* techno*" or "m learning" or “mobile learn*” or "e learning" or “electronic learn*” or "interactive whiteboards" or "forum*" or "Wiki*" or "blog*" or "MCQ*" or "vlog*" or "Network* learn*" or "scale-up" or "blended lear*" or "learning environment" or "interactive learn*" or "handheld" or "active learn*" or "active method*" or "game based" or "Gamifi*" or "Social software" or "CAL" or "Computer assisted*" or "Computer support*" or "CSCL" or "learner track*" or "social learn*" or "Web 2.0" or "authentic*" or “voting systems” or “clickers” or “audience response systems” or “interactive learning tech*” or “simulations” or “augmented reality” or “peer instruction”)
Comparator: *Any*	None.
Outcome: *Learning, Team working and graduate skills*	("perform*" or "team management*" or "achievem*" or "pretest" or "posttest" or "team develop*" or "team dynamics" or "collaborat*" or "cooperat*" or "group cohesion" or "team cohesion" or "team work*" or "self-regulated learning" or "SRL" or "team perform*" or "social dilemma*" or "conflict*" or "graduate attri*" or "graduateness" or "graduate skill*" or “soft skills” or “employ* skills” or “learning gain”)
Final search clause	Population terms AND Intervention terms AND Outcome terms.

2.3 Inclusion and exclusion criteria

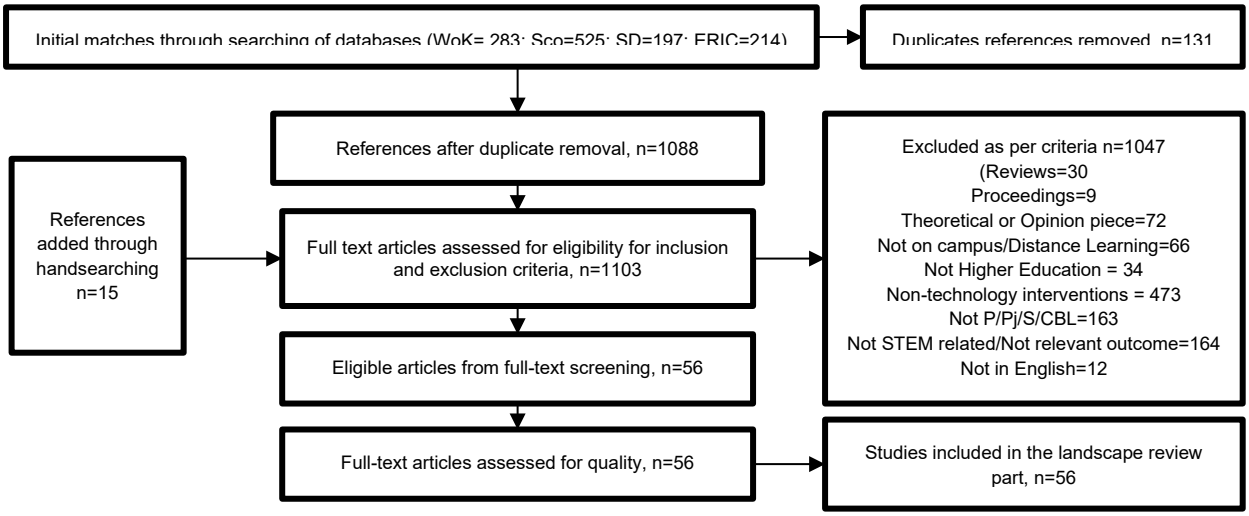
The PICO framework also helped in aligning our inclusion/exclusion criteria in a systematic way with the search terms and research questions. Table 2 shows details of the inclusion and exclusion criteria used.

Table 2

Inclusion Criteria	Exclusion Criteria
Population ● HE-STEM Explicit mention of PjBL/PBL/CBL/CDIO. ● On campus environments. **Intervention** ● Any instance where technology has been used to support the selected population and outcomes. **Outcomes** ● Team working ● Learning gain ● Graduate skills **Time Limit** ● Publications between 2007 and 2021.	● All Subjects and Outcome not as stated in the inclusion criteria ● Not on campus / Distance Learning. ● All non-HE studies. ● All studies not written in English. ● All theoretical texts/ opinion pieces. ● All proceedings ● All reviews. ● All studies published outside the defined date range. ● All Non-Project / Problem/ case-based learning studies. ● All Non-technology interventions. ● No Access.

Following the recommendations from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses, (PRISMA), (Moher et al. 2009), the landscape review of literature was undertaken through a three-stage systematic process of identifying and screening in order to arrive at the 56 papers included in this study (see figure 1).

Figure 1



During the first phase, a search resulted in 1219 results from the four selected databases. After removing the duplicates, attempts to access the full-text version were made on 1088 articles. To improve the reliability in the use of inclusion and exclusion criteria, each author and a third colleague read the titles and abstracts of 100 randomly chosen articles from the search results. Each researcher examined and assessed the articles independent of the others. A shortlist from each author was used to perform an inter-rater reliability check. The inter-rater reliability scores were calculated using Cohen's Kappa calculation to consider any chance agreements between the researchers. As there were only 100 data points, the calculation was undertaken using a spreadsheet. Scores between the three pairs of researchers were: 0.70, 0.67 and 0.93 respectively. Scores ranging from 0.61 – 0.80 represent substantial agreement and 0.81 – 0.99 as near perfect agreement

(HowToStats, nd). This allowed the authors to identify papers which needed further discussion and opportunity to refine the use and definitions of the inclusion and exclusion criteria before progressing. The researchers then discussed the differences and agreed on the papers to include before phase two.
The second phase of the review process consisted of dividing the remaining papers from the search results between the researchers who reviewed these independently. This resulted in 41 papers being shortlisted from the search results. Handsearching yielded fifteen articles that met the inclusion criteria which were added to the shortlist. In total, 56 articles were retained for the landscape review.
A shared spreadsheet was used to extract key information, namely; (1) authors, (2) year of publication, (3) type of publication, (4) Population, (5) Intervention type, (6) Comparator / Control use, (7) Outcomes (8) aim of study, (9) country, (10) HE Level, (11) demographics, (8) research design, (9) research instruments, (10) data analysis procedures, (11) length of study and (12) Main findings of study. These are discussed further in the results section.

3 RESULTS OF THE LANDSCAPING REVIEW

The 56 selected studies are summarised in table 3 below. These are largely quantitative in nature reflecting the general focus upon the effect of the interventions upon student performance. Of the studies that explicitly stated the methodology they had employed, quasi-experimental was the most frequently cited closely followed by randomised control trials. Qualitative data is sometimes employed within studies in combination with quantitative data, however, the emphasis is generally upon the quantitative with qualitative data occupying a minor role. Medicine and other health-related disciplines appear to make the most use of, and undertake research in, the use of technologies for PBL/CBL/PjBL. Alongside engineering and technology, these disciplines appear to contribute the most in terms of research publications. Interest is widespread across the globe although there is a greater concentration of publications originating from North America and Europe.

Table 3 Landscape review of the findings included in this work

Authors and date of publication	**Population, intervention, outcome**	**Methods, instruments and duration**	**Main findings**
Aparicio, F., De Buenaga, M., Rubio, M. and Hernando, A., (2012).	medical, ITS, Performance	Quantitative Case study with comparator 90 mins Test and questionnaire	‘computer tools created to facilitate and direct information searches on Internet are useful to enhancing the learning process in Health Sciences students.’
Arain, S.A., Afsar, N.A., Rohra, D.K. and Zafar, M.,(2019)	medical, video, graduate skills	Quantitative Quasi- RCT 1 semester Observations	‘The study indicates that inclusion of AV aids improved students’ engagement and classroom environment in electronic-PBL sessions, but did not improve diagnostic abilities based on the learned clinical skills’
Balslev, T., De Grave, W., Muijtjens, A.M.M., Eika, B. and Scherpbier, A.J.J.A. (2009),	medical, video, team-working	Quantitative Case study with comparator 1 session Interview	An ‘enhanced shared cognition through collaborative concept link formation’ and ‘Co-elaboration of concept formation is stimulated’

Barmaki, R., Yu, K., Pearlman, R., Shingles, R., Bork, F., Osgood, G.M. and Navab, N. (2019)	medical, augmented reality, performance	Quantitative RCT 1 semester Test and questionnaire	'time on task, painting outcomes, and level of engagement with statistically significant outcomes' 'Statistical significance was established for most measures except long term knowledge retention.'
Bridge, P., Trapp, J.V., Kastanis, L., Pack, D. and Parker, J.C (2015)	medical, virtual lab, performance and graduate skills	Mixed Cross sectional questionnaire	Greater efficiency (student time and resource access), increased understanding, enjoyable learning, increased opportunity for experimentation and team working.
Chang, S.H., Chen, M.L., Kuo, Y.K. and Shen, Y.C., (2011)	engineering, simulation and online, multiple outcomes (performance, team-working and graduate skills)	Mixed Case study no control 1 semester Questionnaire and test	Improved student conceptual understanding, design skills and allowed students to learn from one another (team working skills)
Chen, C.Y. and Teng, K.C., (2011)	engineering, collaborative system, team-working	Mixed Longitudinal 3 years Survey and interview	The use of a collaborative system introduced a macro-level meeting-oriented group process to guide collaborative work
Cole, D., Rengasamy, E., Batchelor, S., Pope, C., Riley, S. and Cunningham, A.M.,(2017)	medical, social media, team-working	Quantitative Cross sectional 1 year Survey and user metrics	Depending on a student's strategy (to use or not to use social media), students used SM to support collaborative learning
De-La-Fuente-Valentín, L., Pardo, A. and Kloos, (2013)	engineering, scripted learning, performance	Quantitative Case study no control 6 weeks Test	Reduction in staff workload, reduction in student dropout rate, sustained student effort, students valued the scaffolding despite increased workload
Ende, H.B., Lumbreras-Marquez, M.I., Farber, M.K., Fields, K.G. and Tsen, L.C., (2021)	medical, low fidelity sim, performance	Quantitative Quasi RCT 6 months Survey and test	No statistical difference between traditional approach and intervention
Eng, A.J., Namba, J.M., Box, K.W., Lane, J.R., Kim, D.Y., Davis, D.P., Doucet, J.J. and Coimbra, R., (2014)	medical, hi fidelity simulation, performance	Quantitative Case study no control 1 semester Tests, survey	Improved confidence, evidence of improved patient care linked to performance, sim environment supported students' recall and skill application
Gisondo, C.M., Weiner, G. and Stanley, K., (2021)	medicine (transport), video, performance and graduate skills	Quantitative Case study no control 30 mins to 2 months Questionnaire, pre/post test	Significant improvement in knowledge and confidence
Guariento, B., Al-Masri, N. and Rolinska, A., (2016)	engineering, blended, graduate skills and team-working	Mixed Case study no control 1 academic year Survey	Improved awareness of appropriate communication, processes of teamwork
Gurpinar, E., Zayim, N., Ozenci, C.C. and Alimoglu, M.K. (2009)	medical, web-based learning (quizzes, links, search engine), performance	Quantitative Case study with comparison 8 weeks Questionnaire, computer log files and exam results	Significant improvement in exam performance
Hannig, A., Kuth, N., Özman, M., Jonas, S. and Spreckelsen, C.,(2012)	medical, game based, performance	Quantitative Quasi RCT 4 semesters Questionnaire and	Strong collaboration inspired by the competitiveness of the gaming aspects, increased willingness to learn

		observation	
Harris, D.M., Ryan, K. and Rabuck, C., (2012)	medical, hi fidelity simulation, performance	Quantitative Case study with comparison One week 3 x 3 hour Pre/post-test and survey	Increased students' confidence in treatment strategy attributed to active learning involved in simulation
Hoic-Bozic, N., Mornar, V. and Boticki, I., (2008)	technology, blended learning, management system, performance	Mixed Case study no control 2 terms questionnaire	Academic achievements were better than expected, dropout rate diminished, but students felt it was time-consuming
Jesus, Â., Gomes, M.J. and Cruz, A. (2016)	pharmacy, various tools performance	Quantitative Quasi RCT 10 weeks Test	Better exam results than traditional f2f.
Jou, M., Lin, Y.T. and Tsai, H.C., (2016)	engineering, mobile app and cloud computing, performance	Quantitative Case study with comparator 1 semester questionnaire	the Mobile Learning APP provided a significant positive effect on learning performance and that most students showed favourable attitudes toward the usage of the mobile learning system
Kish, G., Cook, S.A. and Kis, G., (2013)	medical, simulation and online content, performance	Quantitative Case study with comparator 11 weeks (8 computer sessions) Exam	Significantly better anatomy curriculum student performance
Kleinert, R., Heiermann, N., Plum, P.S., Wahba, R., Chang, D.H., Maus, M., Chon, S.H., Hoelscher, A.H. and Stippel, D.L., (2015)	medical, simulation, performance	Quantitative Experimental 1 year Pre/post test and survey	Impact shown on knowledge gain- increase in declarative knowledge, students were 'enthusiastic and motivated'
Kourdioukova, E.V., Verstraete, K.L. and Valcke, M. (2011)	medical, computer supported collaborative learning scripting, multiple (performance, team working and graduate skills)	Mixed Survey and case study with comparison 3 weeks and 5 weeks survey and online interactions	Neutral to positive attitude to collaborative learning. CSCL developed students' medical vocabulary and reporting skills
LaRochelle, J.S., Durning, S.J., Pangaro, L.N., Artino, A.R., Van Der Vleuten, C. and Schuwirth, L., (2012)	medical, video, performance	Quantitative RCT 2 years test	Increased authenticity of learning resources- mid level students' performance worsened (attributed to the possibility of cognitive overload)
Lee, M.J., Nikolic, S., Vial, P.J., Ritz, C.H., Li, W. and Goldfinch, T., (2016)	engineering, video conferencing, graduate skills	Mixed Case study with comparator 2 semesters Test and questionnaire	'students became more confident and honed their presentation skills in preparation for their assessable pitches.'
Lin, J.W. and Tsai, C.W. (2016)	technology, scripting, team working	Quantitative RCT 14 weeks questionnaire	In an online PBL environment, GA has positive but temporary effects on low-SR students but positive and sustainable effects on high-SR students. In sum, an online PBL environment with GA support has different time length effects (i.e., temporary or sustainable effects) on different SR-level students.
Lu, J., Lajoie, S.P. and Wiseman, J., (2010)	medical, scripting, multiple (graduate skills, team working)	Mixed Case study no control 1 semester Observation	'..visualization and argumentation tools which supported goal setting, help seeking, time management, and planning. Students using interactive whiteboards demonstrated more adaptive problem-solving behavior than those using only traditional whiteboards. Interactive whiteboards mediated the

			teacher's scaffolding by increasing class participation'
Manogaran, E., (2013)	technology, blended technologies, performance	Quantitative Quasi experimental Test and questionnaire	Decreased failure rate by approx. 50% with students performing significantly better
Martinez, M.L., Romero, G., Marquez, J.J. and Perez, J.M. (2010)	engineering, collaborative web environment, performance	Quantitative Case study with control 1 academic year Survey and final marks	'The use of a collaborative Web environment has made it possible for students to work in multidisciplinary teams' and 'enabled students to approach a problem from four different points of view'
McNamara, J., Sweetman, S., Connors, P., Lofgren, I. and Greene, G. (2020)	agriculture, mind maps and T-Charts, graduate skills	Quantitative RCT 2 weeks questionnaire	'successful at encouraging students to use more CT-DM skills when compared with the control group.' 'better at making a decision and supporting that decision with a greater number of evidence-based reasons.'
Ng, O.L., Ting, F., Lam, W.H. and Liu, M. (2020)	maths, interactive whiteboard, performance	Quantitative Quasi RCT 13 weeks test	students in the interactive group had almost twice the normalized gain of the traditional tutorial group.
Pearson, R.J., (2017)	chemistry, clickers, performance	Quantitative Longitudinal 2 years Exam score and survey	students think more deeply in-class and providing instant feedback are essential ingredients when creating an effective problem-based learning environment where students become more inquisitive learners. Combining a team-based model with clicker technology created a perfect blend, thereby allowing students to enter into peer instruction while maintaining a fun, interactive, and engaging environment in which to learn.
Peng, J., Wang, M. and Sampson, D., (2017)	engineering, various tools including visualisation, performance	Mixed Case study no comparison 1 year Survey, tests and interview	the participants made significant improvements on programming task performance and subject knowledge after completing the learning module. Their progress in programming performance was significant in all aspects (i.e., problem understanding, modular design, process design, and coding)
Peng, J., Wang, M., Sampson, D. and van Merriënboer, J.J., (2019)	technology, visualisation, performance	Quantitative Case study no control 6 weeks Test	the visualisation-based cognitive tool is more effective in improving students' programming performance and better perceived by students in terms of its support for scaffolding and articulating the complex project process.
Poulton, T., Ellaway, R.H., Round, J., Jivram, T., Kavia, S. and Hilton, S., (2014)	medical, simulation, performance	Quantitative RCT 1 semester Test	the use of Dynamic-PBL leads to better midterm learning outcomes than linear PBL (for questions related to D-PBL experiences
Prescott, W.A., Woodruff, A., Prescott, G.M., Albanese, N., Bernhardi, C. and Doloresco, F., (2016)	medical, various tools including quizzes, performance	Quantitative Case study with control 1 academic year Exam and survey	improved academic performance and was well-received by students - students enrolled in the blended-learning model scoring better on the final examination and on aspects of the clinical skills examination, and achieving a higher letter and numeric course grade (poss due to watching/rewatching the videos)
Rodrigues Da Silva, A.N., Kuri, N.P. and Casale, A., (2012)	engineering, various tools, performance	Mixed Case study with control 4 years Grades, questionnaires and assessments	increased student performance over the four years, evidence of greater knowledge and depth of understanding for PBL groups students took increasing responsibility for their own learning.
Sáiz-Manzanares, M.C., Escolar-Llamazares, M.C. and Arnaiz	medical- nursing, online interaction, multiple, (performance,	Quantitative Quasi RCT 9 weeks Test and questionnaire	Good results have been obtained in all assessment tests in the two types of blended learning. However, the type of blended learning that applied automated feedback and hypermedia resources obtained even

González, Á. (2021)	graduate skills)		better results
Sancho-Thomas, P., Fuentes-Fernández, R. and Fernández-Manjón, B. (2009)	technology, various tools, team-working	Mixed Case study with control Up to 2 years Questionnaire	Reduced drop out rate, increased pass rate, positive effect in knowledge acquisition, helped to develop team work skills
Saraç, L. and Ok, A., (2010)	medical, video, multiple (performance, graduate skills)	Quantitative Experimental with control 1 semester Test	Students performed less well than traditional approach- attributed to lack of hands-on practice and reinforcement from tutor
Saunder, L. and Berridge, E.J., (2015)	medical- nursing, simulation, graduate skills	Qualitative Case study no control 1 session Interview	Mostly focussed on design-divided student opinion opportunities to reflect on clinical practice and enhanced sense of competence but lack of realism, possible oversimplification and more student preparation were also listed
Selvi, S.T., Kaleel, D. and Chinnaiah, V., (2012)	engineering, various tools, multiple (Team working and graduate skills)	Quantitative Case study with control questionnaire	TEL enhanced PBL approach revealed increase in skills (commitment, decision-making, confidence and collaboration) 2. increased competitiveness and 3. team spirit
Spinello, E.F. and Fischbach, R., (2008)	medical, simulation, performance	Mixed Case study with control 1 year Survey and exam	reported higher levels of cognitive learning in traditional than those in the Sim group, academic performance in sim higher particularly in needs assessment and intervention planning
Splichal, J.M., Oshima, J. and Oshima, R., (2018)	technology, scripting, team working	Mixed Case study no control 13 weeks questionnaire, observation	students were likely to self-regulate themselves or co-regulate other members when they encountered socio-emotional challenges such as inactive discussions, students who produced well-organized scripts shared the perceptions of challenges and progressively worked on them and used various regulation strategies.
Sun, C. and Qi, X. (2018)	medical, simulation and scripting, performance	Quantitative Quasi RCT 1 year Test and questionnaire	Increased confidence, sense of accomplishment and individual judgement, the approach visually stimulated students' interest and enthusiasm and increased their self-confidence, pre/post test showed no significant difference between pSBL and non-PSBL
Topalli, D. and Cagiltay, N.E., (2018)	engineering, various tools, performance	Quantitative Longitudinal experimental 4 years Test	students' performance in the Senior-projects improved significantly; the game projects improve students' motivation
Tsai, M.H. and Tang, Y.C., (2017)	chemistry, various tools, graduate skills	Mixed Case study with control 1 semester Questionnaire	the experimental group was found to outperform the control group in terms of problem-solving attitudes, and the difference was statistically significant; authors suggest that lesson plan contents need to be designed based on problem-based learning theory, and reflect real-world conditions
Vivian, R., Falkner, K., Falkner, N. and Tarmazdi, H. (2016)	technology, various tools, team working	Qualitative Instrumental Case study Duration not stated Online discussions,	Most students employed content knowledge and discussed the problem- some metacognitive activities-solution focussed, rarely employed monitoring and regulation in favour of leadership and team-orientation
Weidenbusch, M., Lenzer, B., Sailer, M., Strobel, C., Kunisch, R., Kiesewetter, J., Fischer, M.R. and Zottmann, J.M., (2019)	medical, video, performance	Quantitative RCT 90 mins Test and questionnaire	CCD approach is effective and sustainable approach for clinical reasoning. Higher efficacy of more interactive formats can be attributed to positive effects of collaborative learning.
Whelan, J.J., Spencer, J.F. and	medical, simulation,	Mixed Quasi experimental design	1) student understanding of interprofessional practice in relation to quality of patient care increased 2)

Rooney, K., (2008)	team working	2 years Survey and focus group	Broadened student understanding og professional roles-theirs in relation to others 3) interactivity and authenticity of CNL scenarios well-received. Some not keen on role play but overall the experience contributed to collaborative and team-working skills
Williams, C., Familusi, O.O., Ziemba, J., Lee, D., Mittal, S., Mucksavage, P., Smith, A. and Kovell, R.C. (2020)	medical, various tools (synchronous and asynchronous online), multiple (performance and graduate Skills)	Mixed Case study no control 4 weeks Questionnaire	course significantly increases students' scores in: self-perceived urologic knowledge, confidence in naming urologic conditions, comfort with performing urologic evaluations, and confidence placing consults for urologic conditions (P <.05).
Woltering, V., Herrler, A., Spitzer, K. and Spreckelsen, C., (2009)	medical, various tools, multiple (performance and team working)	Mixed Case study with control 3 years Questionnaire	The students described the blended PBL as ''realistic'', ''descriptive'' and ''very practical'' supporting memorisation and motivation of the students; flexibility the students emphasized the flexibility that was offered by the program, so that they were able to meet when they wanted to and to reconnect to the information after the first meeting; the use of a video was well-received For the tutors; no difference was perceived by tutors
WUa, C.P. and YONG, H.J (2013)	technology, various tools, simulation, web-based resources, performance	Quant Quasi RCT Over 1 month Test	PBL group performed better than the traditional PBL group- authors suggest the worked example simulation of an expert's reasoning process with reasons given for decisions made helped students understand the process and to apply this to similar problems
Yaniawati, R.P., Kartasasmita, B.G. and Saputra, J. (2019)	medical, various tools, online assisted, performance	Mixed RCT 7 sessions Test	The study showed positive impact of PBL and eLearning on Math skills / performance and on SRL to be statistically significant.
Yoon, B.Y., Choi, I., Choi, S., Kim, T.H., Roh, H., Rhee, B.D. and Lee, J.T., (2016)	medical, video, graduate skills	Quantitative Case study with control 2 weeks Questionnaire	Standardised patients v video cases- SP more authentic and offer the most gains in terms of student learning (interaction, communication, attitudes and motivation to learn). SP more expensive and resource-heavy than video.
Zhao, J., Pan, S., Dong, Y., Ge, Q., Chen, J. and Dai, L., (2013)	medical, video multiple (performance and team working)	Quantitative Self-controlled randomised crossover 2 days Pre/post -test/assessments	SBL and CBL can improve theory knowledge, practical ability and teamwork. Results suggest that a mix of SBL and CBL is effective, which has implications for course costs and feasibility of training.
Zhao, X. and Cong, L., (2019)	medical- nursing, scripting and wearable technology, graduate skills	Quantitative RCT (no within group comparison) Questionnaire	Intervention group had better scores in most of the preparedness and performance feedback. Group also made significantly better total score than "Conventional training" Group

4 DISCUSSION AND CONCLUSION

There seems to be a wide distribution of research papers although these are concentrated across European countries, North America and Australia. An inclusive approach was undertaken to allow non-peer reviewed, conference papers and book chapters in addition to peer reviewed journal articles. However, language will have limited the distribution of papers which involve only those written in English and is an unavoidable limitation of this study.

Of the papers included in the final 56, there were variations in quality with some providing relevant theoretical frameworks allowing the author(s) to critically analyse

the data collected. In many instances, the findings indicated that the technology had affected some change but this was largely unexplored with some problematic terms such as ‘motivation’ remaining unexplored. In some instances, studies did not articulate the research design or offer detail regarding the intervention which made it difficult to evaluate the quality of the research and its overall contribution to knowledge. Given the use of technology is often seen as innovative and that the range of technologies used is always increasing, the limited number of qualitative or mixed methods studies is certainly a gap in this body of literature. Recognising that there are strengths and limitations in each approach, it would be beneficial to address this imbalance in order to gain greater insight into the way in which interventions using technologies might support student learning and skills development. There were also instances where research was described as mixed methods in its approach but involved limited qualitative data with, for example, a single open question in a questionnaire.

In terms of efficiency, the use of technologies relieved pressures on physical resources such as specialised rooms and equipment and offered opportunities to hone skills and reinforce knowledge and understanding through repetition. There were also advantages in being able to experience events which would not otherwise be possible, for example where it would have been too expensive or unforgiving and offer no opportunity for trial and error; involve challenging logistics in order to bring relevant people together at specific points in terms of time and location or to replay, pause and review content. Student motivation and engagement were also often cited in addition to commitment to their studies. This may not necessarily result in increased efficiency should students commit more time to undertaking the tasks, however, there are arguments that suggest that students might engage more and be more likely to retain what they have learnt and that on campus sessions are able to focus upon exploring and extending learning. Greater flexibility existed where continued access to content, peer discussion and tutor support beyond the campus setting was possible. Individually or used in combination, such interventions provided rich, interactive and extended opportunities to support collaboration during PBL.

Although there were advantages in engaging students beyond the on-campus setting and in providing greater flexibility in terms of access to people and learning resources, this also raised questions regarding the use of staff time. Their involvement in the development of well-designed and appropriate resources and in the support of small groups as part of PBL approaches would need to be considered although in some instances, technology reduced staff time by encouraging greater student autonomy and offering automatic feedback on student activity to the tutors. In addition to staff time there were also some concerns regarding the expense associated with technological resources and the necessary infrastructure which might include staff and student development in addition to technical support. Beyond the use of the technologies, the approach to learning including the ability to

collaborate and work as part of a team would also need to be considered to avoid inefficiency through unresolved conflict.

The development of team working was integral to some of the research projects including technology supported frameworks and scripting which sought to address what might be viewed as ‘soft skills’ such as project planning, negotiation, collaboration, leadership and team management. Rather than allow students to find their own way in terms of teamwork, such studies guided the students’ learning experience and the outcome was, in most instances, positive and encouraged greater awareness when communicating with others. Automated feedback not only allowed for safe experimentation of ideas but also provided prompts which invited students to reflect individually and collectively upon their learning.

In addition to the cognitive, there were gains in the affective domain where enthusiasm, confidence and enjoyment in the learning provided a stronger impetus for team working. Conversely, where unresolved conflict had been reported in some studies, working relationships had fractured and progress in learning had been slowed or had stalled. This largely hinged upon the ability of individuals within the group to employ appropriate skills to communicate effectively, in order to cooperate in the mediation and resolution of disagreement. In some instances, the technology itself was viewed as a potential distraction to learning with students more closely involved with resolving issues or interacting with the resource than committed to the PBL task.

Inclusivity was given less attention than either efficiency or team effectiveness, however, there were instances where students, by virtue of working with peers from other countries, had gained a sense of cross-cultural awareness. There were also reports of increased sensitivity towards others as part of team-working and the use of visualisation to support the process of scaffolding. Most often, the sense that students were able to regulate their own pace of learning was viewed as a positive contribution and a means of providing a structure and framework to support the intricacies of team working as part of a constructivist approach to learning. This appeared to be more effective in the first year of an undergraduate programme where students were gaining awareness of and developing relevant skills for successful team-working alongside the subject knowledge associated with the relevant discipline.

In addition to addressing the imbalance in terms of qualitative, mixed methods and quantitative research approaches, recommendations for further research would include exploration of the design and implementation of technologies which support inclusivity and provide reasonable adjustments to allow all students to participate. Current studies are also restricted to some STEM disciplines and tend to focus more upon student performance. Future research might be extended to provide greater

representation from across the portfolio of disciplines in, for example, mathematics and the sciences.

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